Faculty of Electronics and Computer Technology and Engineering

DEVELOPMENT OF IOT BASED HEART RATE MONITORING SYSTEM USING MICROCONTROLLER

ABDUL HAKIM BIN MUSTAFA

Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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ABDUL HAKIM BIN MUSTAFA

A project report submitted
in partial fulfillment of the requirements for the degree of
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DEDICATION

I extend my heartfelt thanks to my wonderful mother, Rohana binti Hassan and father, Mustafa bin Mahmod for their constant love and support that propelled me through the completion of this project. Your belief in me has been my driving force, and I'm grateful for the encouragement you've provided. A special appreciation goes to my respected Supervisor, Ts. Dr. Hafez bin Sarkawi for the guidance and support throughout the project. Your mentorship has been instrumental in my success, and I'm thankful for the opportunities you've given me to grow and learn. This achievement is a result of the collective support from my family and supervisor, and I'm truly grateful.

ABSTRACT

Cardiovascular diseases are the leading cause of mortality around the world. According to statistics recorded by the World Health Organization (WHO) heart diseases claim 17.9 million lives each year. More than 80% cardiovascular diseases deaths due to heart attacks and strokes, and more than 30% of these deaths occur prematurely in people under 70 years of age. Body health monitoring is very important to us to make sure our body health condition and to take precautions to overcome unexpected health problems. The Heart Rate Monitoring system is developed using IoT-based technology and consists of a heart rate sensor, a microcontroller, and an IoT module. This project is designed to provide real-time monitoring of heart rates which is useful in medical application with an objective of detecting the heartbeat of the patient to monitor the risk of heart attack and as the regular checkup. The system is also cost-effective, as it uses low-cost sensors and microcontrollers. The IoT module ensures that the data is transmitted securely and reliably, making it accessible to healthcare professionals. The end goal of this project is to design some solution that provides real-time monitoring of heart rates. The system has applications in both medical and non-medical fields, its cost-effectiveness makes it accessible to a wider audience.

ABSTRAK

Penyakit kardiovaskular adalah punca utama kematian di seluruh dunia. Menurut statistik Pertubuhan Kesihatan Sedunia (WHO) penyakit jantung meragut 17.9 juta nyawa setiap tahun. Lebih daripada 80% kematian penyakit kardiovaskular akibat serangan jantung dan strok, dan lebih daripada 30% daripada kematian ini berlaku secara pramatang pada orang di bawah umur 70 tahun. Pemantauan kesihatan adalah penting bagi memastikan keadaan kesihatan kita dan mengambil langkah awal untuk mengatasi masalah kesihatan yang tidak dijangka. Sistem Pemantauan Kadar Jantung dibangunkan menggunakan teknologi berasaskan IoT dan terdiri daripada penderia denyutan jantung, mikropengawal dan modul IoT. Projek ini direka untuk menyediakan pemantauan masa nyata kadar jantung yang berguna dalam aplikasi perubatan dengan objektif untuk mengesan degupan jantung pesakit untuk memantau risiko serangan jantung dan juga sebagai pemeriksaan biasa. Sistem ini menjimatkan kos, dengan menggunakan sensor dan mikropengawal kos rendah. Modul IoT memastikan bahawa data dihantar dengan selamat dan boleh dipercayai, menjadikannya boleh diakses oleh profesional penjagaan kesihatan. Matlamat akhir projek ini adalah untuk mereka bentuk beberapa penyelesaian yang menyediakan pemantauan kadar jantung masa nyata. Sistem ini mempunyai aplikasi dalam kedua-dua bidang perubatan dan bukan perubatan, keberkesanan kosnya menjadikannya boleh diakses dengan lebih luas.

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First and foremost, I would like to express my gratitude to my supervisor, Ts. Dr. Hafez bin Sarkawi for their precious guidance, words of wisdom and patient throughout this project.

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My highest appreciation goes to my family members for their love and prayer during the period of my study. An honourable mention also goes to father for all the motivation and understanding. And to mother thanks for constant love and support that propelled me through the completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 Background

A heart attack, also known as a myocardial infarction, is a serious and sometimes deadly disease that occurs when the blood supply to a section of the heart is cut off, most often by a blood clot in the blood artery. Due to the obstruction, the heart muscle is deprived of oxygen and nutrients, which may result in injury or even death. Atherosclerosis, or the accumulation of plaque in the arteries supplying blood to the heart, is the most frequent reason for a heart attack. This plaque may eventually restrict the arteries over time since it is composed of fat, cholesterol, and other harmful substances. Eventually, a plaque fragment may rupture, causing the development of a blood clot that obstructs blood flow to the heart. High blood pressure, high cholesterol, diabetes, smoking, obesity, inactivity, and a family history of heart disease are additional risk factors for a heart attack. The risk of a heart attack rises with age, and men are more likely than women to experience one. Heart attack symptoms might vary from person to person, but they frequently include chest pain or discomfort, shortness of breath, nausea, vomiting, sweating, and lightheadedness.

According to the World Health Organization's (WHO) most recent statistics, heart disease is the top cause of mortality worldwide, accounting for 17.9 million fatalities in 2019, or around 1 in 3 deaths. The burden of heart disease is significantly increased by heart attacks (myocardial infarction). Some encouraging trends in lowering the mortality rate from heart attacks have emerged in recent years. Nevertheless, low- and middle-income nations continue to bear a disproportionately large share of the burden of heart disease and heart attacks. Smoking, high blood pressure, high cholesterol, and diabetes are risk factors for heart attacks that are widespread around the world. By making changes to your lifestyle and managing these risk factors early on, it is possible to prevent heart attacks. Early heart attack therapy is essential to increase survival and lower the chance of long-term consequences. The use of drugs to dissolve blood clots, angioplasty to unblock blocked arteries, or bypass surgery to redirect blood around a blocked artery are all possible forms of treatment. Overall, there is still more to be done to reduce the burden of heart disease and heart attacks around the world, including better access to medical services and prevention methods.

1.2 Addressing Human Health Through Heart Rate Monitoring Project

A heart rate monitoring project might impact human health in several ways. By monitoring heart rate, individuals can track their fitness levels, optimize exercise intensity, and ensure they are working out within their target heart rate zones. This information allows for more effective and efficient workouts, promoting cardiovascular health and overall fitness. Additionally, heart rate monitoring can help detect abnormal heart rhythms or irregularities, enabling early detection and intervention for potential cardiac issues. For individuals managing chronic conditions or recovering from cardiovascular events, continuous heart rate monitoring provides valuable data for healthcare professionals to personalize treatment plans and monitor progress. Overall, a heart rate monitoring project empowers individuals to take charge of their health, make informed decisions, and improve their overall well-being.

1.3 Problem Statement

The problem addressed by the heart rate monitoring system with alert using IoT is the need for an efficient and reliable system to monitor the heart rate of people, especially those with heart problems. Heart disease is one of the leading causes of death worldwide, and early detection and intervention can save lives. Traditional heart rate monitoring systems require the user to be physically present, making it difficult to monitor people remotely. In addition, traditional systems do not have alert systems in place, which can lead to delayed interventions and possible fatalities. The heart rate monitoring system with alert using IoT addresses these issues by providing a remote and efficient way to monitor the heart rate of people and trigger alerts in case of abnormal readings. The system is easy to use, cost-effective, and can be deployed in various settings, making it accessible to a wide range of people.

1.4 Project Objective

The objective of this project is as following:

i. To develop a system where able to continuously monitor the heart rate of the user in real-time using IoT.

ii. To analyze the heart rate data to identify any abnormalities or irregularities in the heart rate pattern.

iii. To trigger alert to notify the user or a healthcare provider if the system detects any abnormality or irregularity in the heart rate pattern.

1.5 Scope of Project

The scope of this project is as following:

i. Designing and developing the hardware components of the system, including the pulse sensor module, and ESP32 ESP WROOM 32.

ii. Programming the microcontroller (ESP32 ESP WROOM 32) to process the data from the pulse sensor and trigger alerts in case of abnormal readings.

iii. Developing the cloud architecture for the system, including the database and server infrastructure required to store and process the data.

iv. Testing the system to ensure that it meets the required specifications, including accuracy, reliability, and performance. It also involves validating the system in real-world settings to ensure that it is effective in detecting and alerting abnormal heart rate readings.

v. Deploying the system in focusing the use for patients who are bedridden at home. It also involves providing maintenance and support to ensure that the system operates effectively over time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Heart is a vital part for every living thing. The heart works as a pump to move blood that carries nutrients and oxygen throughout the body. Depending on how hard the body is working, the pace at which the heart beats will change. By detecting the voltage created by the beating of the heart, its rate can be easily observed and used for several heath purposes. Your heart beats as blood-carrying cell waste out of your muscles and oxygen-rich blood into them. During workout routines, the heart rate provides a useful indication of how well your health is being improved. [11]

2.2 Understanding Heart Rate Monitoring in the literature

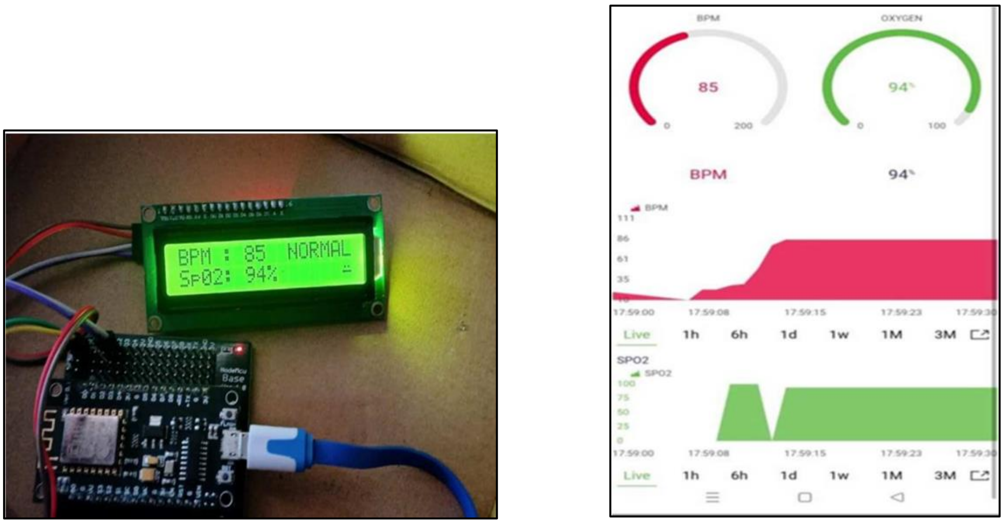
Heart rate monitoring is a method used to measure and record the number of heart beats per minute in an individual. It plays a crucial role in health monitoring and related research. Measuring heart rate provides valuable insights into an individual's cardiovascular health and overall well-being.[20] By tracking changes in heart rate over time, researchers and healthcare professionals can assess exercise tolerance, stress levels, recovery after physical activity, and even detect potential abnormalities or conditions. In this chapter, we aim to explore the various methodologies and devices used for heart rate monitoring, examine the different applications in both clinical and non-clinical settings, and analyze the relationship between heart rate and various health outcomes.

2.3 Development Internet of Things (IoT) in Healthcare System

Internet of Things (IoT) is the growing technology in the internet environment in conjunction with the real time connected objects. It is popular across a wide range of industry sectors and has long-term effects on patient physiological data monitoring, administration, and therapeutic services. [19] With machine to machine (M2M) technology, hospitals can automate processes to ensure the highest levels of treatment. By employing technology instead of a human healthcare professional, it is possible to respond more quickly in an emergency case. For example, if a patient's vital signs are below normal, an M2M-connected life support device might automatically deliver oxygen and further treatment until a medical expert arrived.[17]

2.4 Known Previous Methods of IoT based Heart Rate Monitoring System

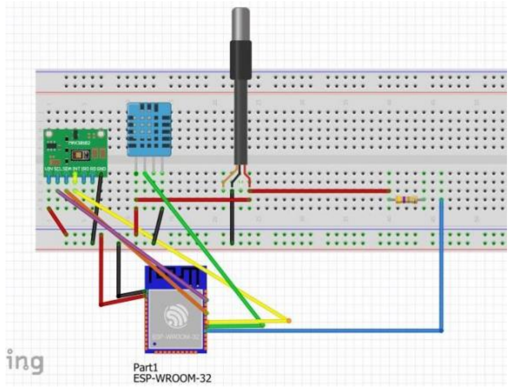
Several techniques have been proposed in the past about the heart rate monitoring system. In a recent study, Noorhayati Mohamed Noor *et al.*, [5] proposed the IoT based heart rate monitoring system implementation and analysis by using 32-bit RISC Xtensa LX106 microcontroller, NodeMCU ESP8266, Pulse Oximeter (POX) Sensor, and Blynk application. Pulse Oximeter (POX) Sensor is used to measure a patient's heart rate. The microcontroller will gather the measured data and transmit it to the Blynk application for user or health care monitoring display. Figure 2.10 shows the hardware setup of the proposed system and the user monitoring display. However, like any sensor, the POX sensor may have limitations and variations in accuracy. It is essential to calibrate the sensor properly and account for any sensor-specific biases or inaccuracies that could impact the reliability of the measurements.



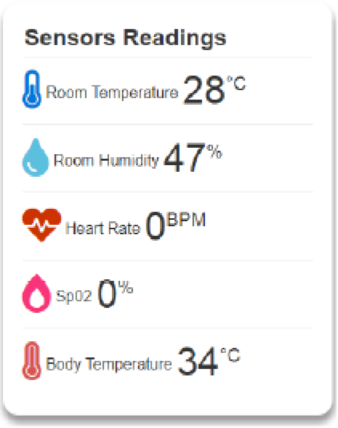
(a) Hardware setup (b) Blynk application

Figure 2.1: Heart monitoring system using Xtensa LX106 and Blynk app [5]

In another study, Muhammad Irsyad Abdullah *et al.*, [1] proposed the Covid-19 Patient Health Monitoring System using IoT where the system have three section which are input, processor, and output. For the input for this system using three type of sensor which are biosensor module (MAX30100), body temperature sensor (DS18B20) and humidity sensor (DHT11). For the processor section using ESP32 Arduino that will be linked using Arduino IDE. The output section comprises of ESP32 webserver that compiles all data and transmits it to the smartphone or PC. Figure 2.11 shows the circuit diagram and the result in the webserver for the proposed system. However, the accuracy and calibration of the sensors are crucial for obtaining reliable health measurements. Each sensor may have its limitations and variations in accuracy. Moreover, environmental factors and signal interference can impact the sensor readings.



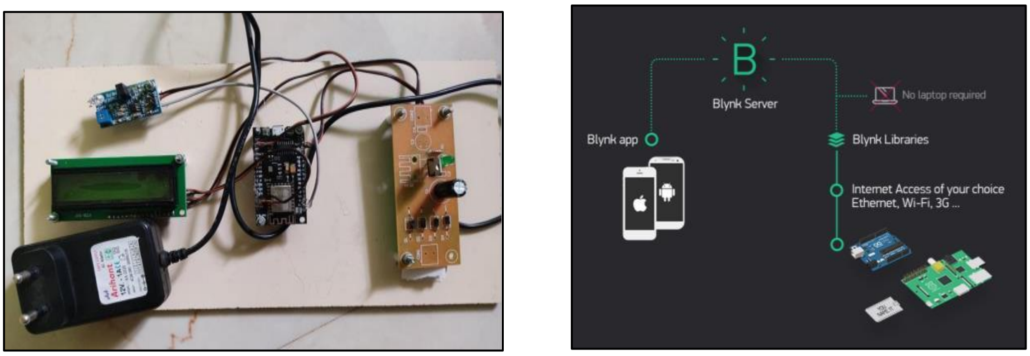
(a) Circuit diagram



(b) Webserver

Figure 2.2: Covid-19 Heart monitoring system using biosensor MAX30100, temperature sensor DS18B20 and huminity sensor DHT11 [1]

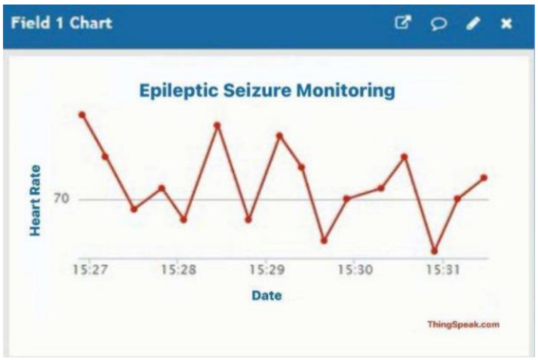
Elsewhere, Harshavardan K *et al.*, [7][9] proposed the heart rate monitoring system by using microcontroller, heartbeat sensor, ESP8266 Wi-Fi module, LCD display and receiver module (Blynk app). The heartbeat sensor has light to measure the heart rate and the light will be reflected according to the amount of blood in the capillaries. The data is transmitted to the microcontroller and the data will show on the LCD display. Then received data is sent to the receiver using IoT (Blynk app). The data that is shown on the Blynk app can be used by health care to continuously read the patient's health status. Figure 2.12 shows the hardware setup of the proposed system and the Blynk app. However, this proposed system may have an accuracy problem where the heartbeat sensor plays a crucial role in obtaining reliable measurement. Moreover, the microcontroller is responsible for processing the data and extracting the heart rate information. The accuracy and reliability of the heart rate calculation depends on the signal processing algorithms implemented in the microcontroller.



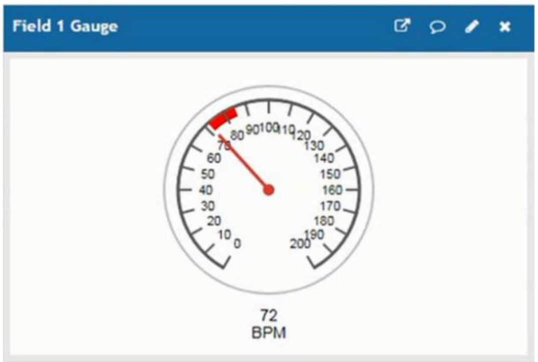
(a) System Hardware (b) Blynk App

Figure 2.3: Heart monitoring system using heartbeat sensor and ESP8266 module [7]

Meanwhile, Manar M. Edris *et al.*, [2] proposed the IoT based Monitoring System for Detection of Epileptic Seizure by Heart Rate Variation by using Pulse sensor, NodeMCU Wi-Fi module, I2C module for LCD display and ThingSpeak platform. The pulse sensor will read the heartbeat and convert data to signals. The collected signals will be sent to the microcontroller for processing and the data will be transmitted by the Wi-Fi module via internet to the ThingSpeak platform for analysis and visualization of the heart rate. Figure 2.13 shows the epileptic seizure and BPM visualization of the proposed system using the ThingSpeak platform. However, this system cannot add a limit value for heart changes as heart rate values are affected by many factors such as extreme happiness, fear, or external factors like sport etc.



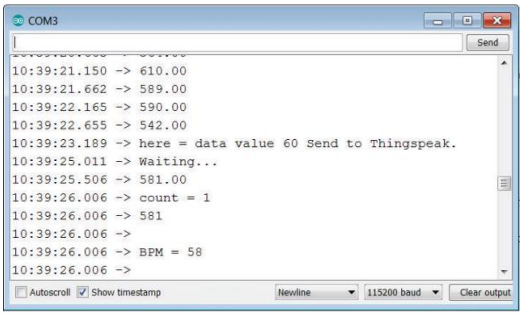
(a) Epileptics Seizure



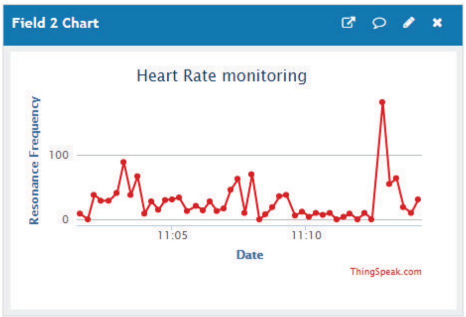
(b) BPM

Figure 2.4: Monitoring system for detection Epileptic Seizure using NodeMCU. Wi-Fi module and ThingSpeak platform [2]

In another study, Charushila Patil *et al*., [3] proposed Heart Monitoring using Pulse Rate sensor, Piezoelectric sensor and NodeMCU module. The proposed system is focused on monitoring system with the help of IoT. The pulse sensor is used to collect heartbeat reading by mounted the sensor on the patient's body and the resonance frequency is calculated using a piezoelectric sensor. NodeMCU module is used to capture and process the data and send it to the cloud for storage and analysis. Figure 2.14 shows the output from the Arduino IDE for pulse rate data and the chart from ThingSpeak for piezoelectric sensor data. However, the proposed model can suffer from accuracy issues where the pulse rate sensor and the piezoelectric sensor may provide inaccurate readings due to factors such as sensor placement, movements, or interference from other electrical signals.



(a) Pulse rate sensor output



(b) Piezoelectric sensor output

Figure 2.5: Heart monitoring using Pulse rate sensor and Piezoelectric sensor [3]

Elsewhere, Steffi Das *et al.*, [4] proposed the wearable smart heart monitoring by using Arduino Nano, Wi-Fi module, and three type of sensor which are heartbeat sensor, body temperature sensor, blood oxygen sensor. This proposed model is based on the current wireless communications, which give the user minimal power and maximum flexibility. While the user is leading a normal life, the implanted heart rate, pulse oxygen, and temperature sensor continuously gather the information. The smartphone will evaluate the data after receiving it over a low-power Bluetooth connection. Figure 2.15 shows the system architecture for the proposed system. However, wearable devices rely on batteries as their power source. Power consumption is a crucial factor as it impacts the operational duration of the device. Power-efficient designs, optimized data transmission protocols, and sensor activation strategies need to be implemented to prolong battery life and ensure continuous monitoring without frequent battery replacements or recharging.

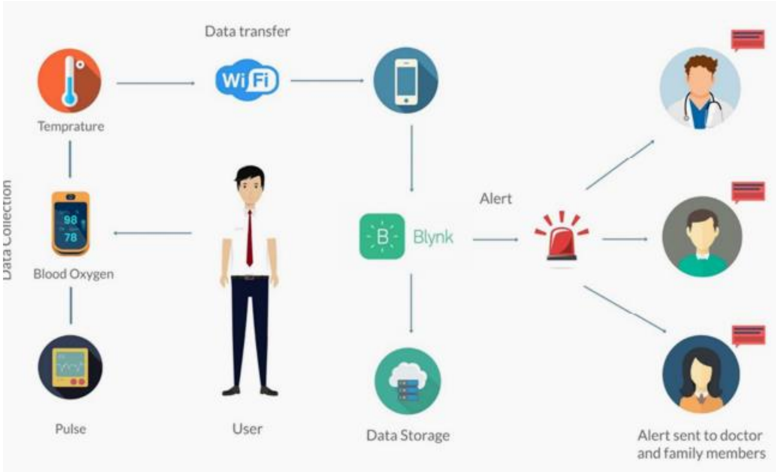
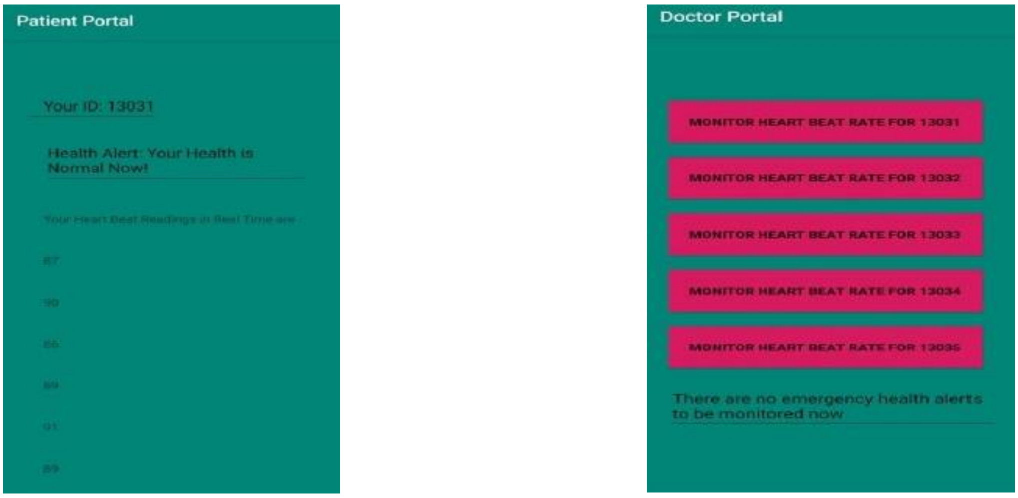


Figure 2.6: System Architecture of proposed model [4]

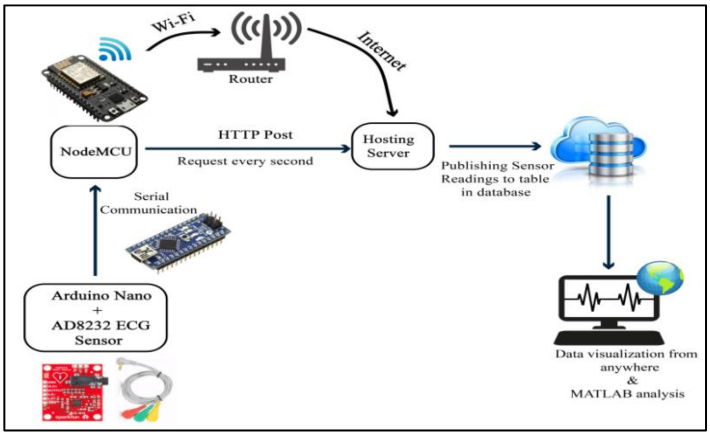
Meanwhile, Syedd Karimunnisa *et al.*, [6][8][12] proposed the advance patient's heart rate monitoring system using Cloud based Android system. The proposed system has three main components which are heart rate sensor, Arduino UNO and ESP8266 Wi-Fi module. The heartbeat data from the pulse sensor is monitored continuously by the medical practitioners and the alert must be sent to the medical professionals and to the patient guardian when there is any kind of emergency occurring. Figure 2.16 shows the alert display on the patient portal and the doctor's portal for the proposed system. However, the proposed system can be dependent on the internet connection since the heart rate data is being transmitted to and processed in the cloud, any disruption can lead to delays or even loss of data transmission. Moreover, the proposed functionality heavily depends on the availability and reliability of the cloud infrastructure. If the cloud servers experience downtime or technical issues, it can disrupt the system service.



(a) Patient Portal (b) Doctor Portal

Figure 2.7: Cloud based Android system [6]

Sumaya Akter *et al.*, [10] proposed the IoT based Real Time Cardiac State monitoring system using Arduino Nano, NodeMCU, AD8232 ECG sensor and MATLAB app. ECG signal id is detected by placing the three electrodes to left hand, right hand, and right leg. Arduino nano interfaced with AD8232 ECG sensor for processing the data. The data from Arduino nano and transmitted directly to IoT cloud using NodeMCU development board. Figure 2.17 shows the proposed architecture of the system. However, the Arduino Nano and NodeMCU are relatively small and low-power microcontroller boards. They have limited computational capabilities and memory compared to more advanced microcontrollers. This limitation may restrict the complexity of the algorithms and calculations that can be performed on the device itself, potentially affecting the accuracy and real-time processing of the cardiac state data. Moreover, Arduino Nano and NodeMCU are designed for prototyping and small-scale applications. If the system needs to be scaled up to handle a large number of patients or incorporate additional features, such as advanced analytics or multiple sensor inputs, these microcontrollers may not provide sufficient processing power or memory capacity.



Proposed Architecture of IoT based ECG monitoring system.

Figure 2.8: System architecture of proposed system [10]

In another study, Rama Reddy Rajanna *et al.*, [13] proposed an IoT Wi-Fi connected sensor for real time heart rate variability monitoring using MSP430 microcontroller, CC3100 Wi-Fi module and AD8232 ECG sensor. The ECG peak detection algorithms implemented on MCU calculate the heart rate, beat-per-minute and IBI metrics. The jsonified payload from PubNub channels was published to freeboard.io subscription. The real-time freeboard.io dashboard was set up to visualize and share the data from different channels. The threshold peak detection method is simple to implement and exhibits good accuracy. A quite complex moving average algorithm performs well in detection of IBI but introduces delay due to multiple filtering process. Figure 2.18 shows the freeboard.io visualization for heart rate, BPM and IBI variability of proposed system. However, the MSP430 microcontroller, CC3100 Wi-Fi module, and AD8232 ECG sensor all require power to function. This can result in higher power consumption, especially if the sensor is continuously monitoring and transmitting data. Managing power consumption efficiently can be a challenge, particularly if the device needs to operate on battery power or for extended periods without recharging.

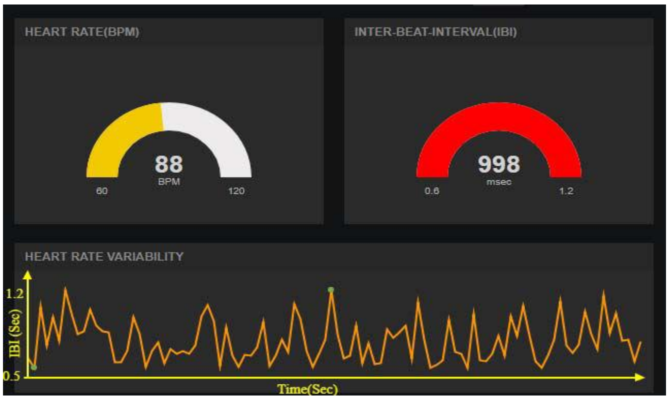
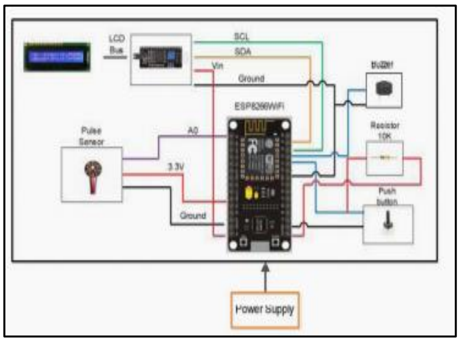
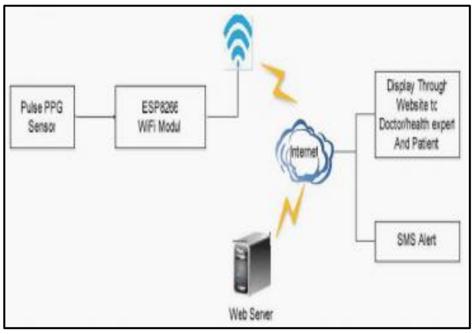


Figure 2.9: Freeboard.io visualization of heart rate, BPM and IBI variability [13]

Elsewhere, Muhammad Irmansyah *et al.*,[14] proposed low-cost heart rate portable device for risk patient with IoT and warning system using pulse sensor, and ESP8266 Wi-Fi module. The ESP8266 module has the function to communicate the web server gateway and pulse sensor. The pulse sensor is used to detect heart rate and convert it to Bit per Minute (BPM) and save the data to the database server using TCP IP communication. If a patient's heart rate is below 60 BPM and above 100 BPM, the warning system will send notification information via short message service (SMS) to doctor or patient's family. Figure 2.19 shows the pulse sensor connection with ESP8266 and system architecture of proposed system. However, pulse sensors typically used in low-cost heart rate devices, may not provide the same level of accuracy as medical-grade devices. They can be affected by various factors such as motion artifacts, ambient light, and skin conditions, leading to less reliable heart rate measurements. Inaccurate or inconsistent readings can impact the effectiveness of risk assessment and timely warnings.



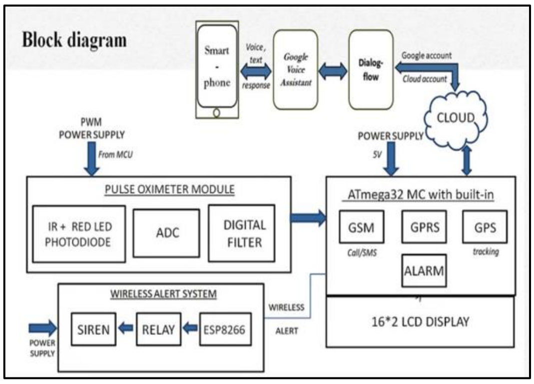
(a) Pulse sensor with ESP8266 module

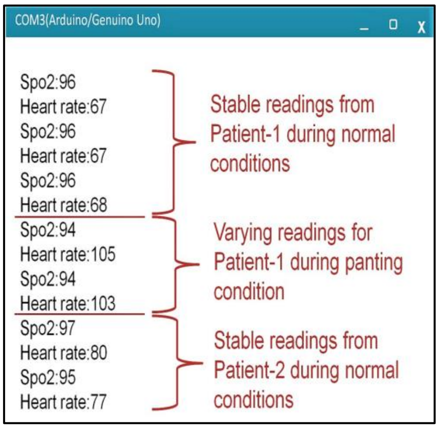


(b) System Architecture

Figure 2.10: Circuit diagram and system architecture of proposed system [14]

Meanwhile, Dhanurdhar Murali *et al.*, [15][21] proposed the pulse oximetry and IoT based cardiac monitoring integrated alert system using microcontroller ATmega32, Pulse Oximeter, I2C serial communication, GSM/GPRS module and MAX30100. Pulse oximeters gives the measure of the content of the oxygen that is being carried by the hemoglobin in the blood. The measured data will be processed by the microcontroller ATmega32, and the system output has two parts where the first one will be displayed on the LCD 16x2, and the second will be transmitted to the cloud to professional healthcare monitor. Figure 2.20 shows the block diagram and sample result at various condition for the proposed system. However, the proposed system has its limitations such as on its reliability. The reliability of the system is crucial when it comes to cardiac monitoring. Any failure or malfunction in the hardware or software components can lead to inaccurate readings or the inability to send timely alerts.

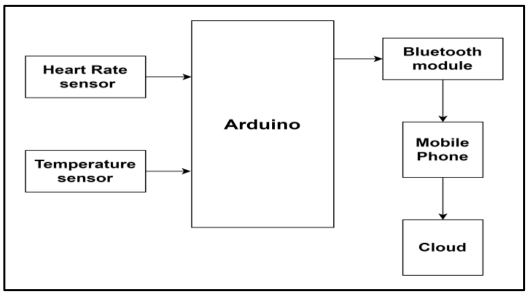


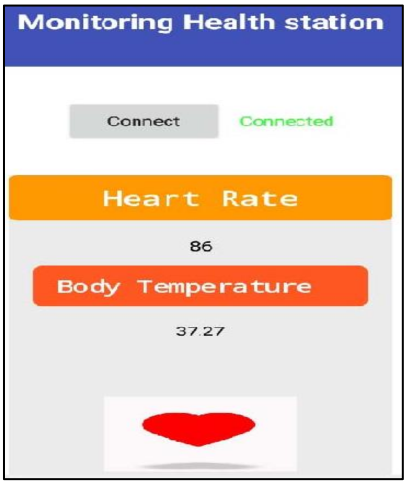


(a) Proposed system block diagram (b)Tested result for various conditions

Figure 2.11: Cardiac Monitoring Intefrated Alert System block diagram and tested result [15]

Eman Abed- Alkareem Karajah *et al*., [24] proposed online monitoring health station using Arduino mobile connected to cloud service by using Arduino UNO, Heart rate sensor, body temperature sensor and HC-05 bluetooth module. Heart rate sensors measure the heartbeat per minute using reflected light IR LED and detector using photo detector. Arduino UNO processes the data from the heart rate sensor and body temperature sensor then sends the measured data to “Heart Monitor” android application using bluetooth module HC-05. Figure 2.21 shows the block diagram and sample result on “Heart Monitor” application. However, the HC-05 Bluetooth module enables communication between the Arduino and a mobile device, but it has a limited range, typically up to a few meters. If the user moves beyond the range, the connection can be lost, disrupting real-time monitoring. Moreover, Arduino UNO and the associated sensors are designed for prototyping and small-scale applications. Scaling up the system to handle many users or integrating with other devices or platforms may pose challenges in terms of scalability and interoperability.





(a) Proposed Block Diagram (b) "Heart Monitor" Application

Figure 2.12**:** Proposed System Block Diagram and sample result

All the above studies show that there are many methods that have been developed to improve the current heart rate monitoring system in accordance with demands and technological advancement. Therefore, in our project, the aim is to develop heart rate monitoring system with IoT based for enable remote and continuous monitoring bedridden patient's cardiac health. All of the studies which have been thoroughly discussed above are summarized in Table 2.3.

Table 2.1: Summary of the previously proposed technique

Author	Proposed Method	Advantage	Disadvantage
Noorhayati Mohamed Noor *et al.*[5]	IoT Based Heart Rate Monitoring System Implementation and Analysis	i. Allow for continuous and real-time monitoring ii. Long-term data collection and analysis.	i. Pulse oximeter (POX) sensor limitation and variations accuracy
Muhammad Irsyad Abdullah *et al.* [1]	Covid-19 Patient Health Monitoring using IoT	i. Help in the early detection of symptoms ii. DS18B20 body temperature sensor allows for accurate and continuous monitoring body temperature	i. Sensor limitation and variations accuracy ii. Environment interference
Harshavardan K *et al.* [7]	Heart Rate Monitoring using IoT	i. Allow for continuous and real-time monitoring ii. Healthcare provider can access the heart rate data remotely from any location.	i. Requires large power consumption ii. Environment interference and distance can influence connection
Manar M. Edris *et al.* [2]	IoT based Monitoring System for Detection of Epileptic Seizure by Heart Rate Variation	i. Early detection and timely intervention. ii. Integration with healthcare systems	i. Heart rate variation alone not be sufficient to accurately detect epileptic seizures. ii. Variability in heart rate pattern can be influenced by various factors.

Table 2.1: Summary of the previously proposed technique (Continued)

Author	Proposed Method	Advantage	Disadvantage
Charushila Patil *et al.* [3]	Heart (Pulse Rate) Monitoring using Pulse Rate Sensor, Piezo Electric Sensor and NodeMCU	i. Comprehensive heart monitoring ii. Provide real-time monitoring and alert iii. Remote accessibility	i. Sensor limitation and variations accuracy ii. Limited diagnostic capability
Steffi Das *et al.* [4]	Wearable Smart Heart Monitor using IoT	i. Provide real-time monitoring ii. Portability and convenience	i. Sensor limitations to provide accurate readings in intense movement ii. Rely on batteries for power
Syedd Karimunnisa *et al.* [6]	Advanced patient's Heart Rate monitoring system usingCloud based Android system	i. Provide real-time monitoring and alert ii. Remote accessibility iii. Continuous data recording and analysis	i. Lack of data privacy and security ii. Sensor limitation and variations accuracy
Mst. Sumaya Akter *et al.* [10]	Development of IoT based Real Time Cardiac State Monitoring System	i. Enable real-time monitoring of the patient's cardiac state ii. Allow healthcare provider to access cardiac data remotely iii. Continuous data recording and analysis	i. Accuracy and reliability limitation of ECG sensor ii. Signal interference and noise iii. Requires large power consumption

Table 2.1: Summary of the previously proposed technique (Continued)

Author	Proposed Method	Advantage	Disadvantage
Rama Reddy Rajanna *et al.* [13]	An IoT Wi-Fi Connected Sensor For Real Time Heart Rate Variability Monitoring	i. Provide real-time monitoring ii. Enable seamless wireless connectivity iii. Remote accessibility	i. Requires large power consumption ii. Accuracy and reliability limitation of ECG sensor iii. Signal interference and noise
Muhammad Irmansyah *et al.* [14]	Low Cost Heart Rate Portable Device for Risk Patient with IoT and Warning System	i. Provide early detection and intervention ii. Cost-effective solution iii. Designed portability and convenience	i. Low cost pulse sensor provide low accuracy of measurement ii. May generate false alarms that will triggering unnecessary anxiety and inconvenience
Dhanurdhar Murali *et al.* [15]	Pulse Oximetry and IoT based Cardiac Monitoring Integrated Alert System	i. Provide real-time monitoring ii. Healthcare provider can access the heart rate data remotely from any location. iii. Provide early detection and intervention	i. Low accuracy of measurement ii. Unreliable connectivity iii. Requires large power consumption
Eman Abed- Alkareem Karajah *et al.* [24]	Online Monitoring Health Station using Arduino Mobile Connected to Cloud Service	i. Provide real-time monitoring ii. Remote accessibility iii. Improve patient care and safety	i. Unreliable connectivity ii. Limited mobility iii. Limited customization and scalability

2.5 Summary

IoT-based heart rate monitoring systems have emerged as a promising approach to monitor and manage individuals' cardiovascular health in a non-invasive and real-time manner. Further, the previous techniques employed in such systems highlight their key features, advantages, and limitations. However, their accuracy and reliability can be influenced by factors like motion artifacts and sensor placement. Based on our observation, the limitation of the existing techniques is not able provide large power consumption and sensor limitations to provide accurate readings. Due to this, users have difficulty getting an accurate heart rate reading to monitor their heart condition continuously.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The development of an IoT-based Heart Rate Monitoring System for bedridden patients represents a targeted effort to address the challenges associated with continuous healthcare monitoring in this specific context. Emphasizing precision in heart rate measurements, the system places a priority on patient comfort and minimal interference, recognizing the unique constraints of limited mobility. Striking a crucial balance between accuracy, comfort, and energy efficiency, the system employs an ESP32 microcontroller, heart rate sensor, and web server for real-time data transmission. The optimization of power consumption aims to extend device operation without frequent battery replacements, while robust security measures ensure the confidentiality of patient data. Ultimately, this integrated approach seeks to enhance healthcare delivery by providing accurate monitoring, prioritizing patient comfort, and facilitating timely interventions in a secure and efficient manner.

3.2 Selecting and Evaluating Tools for a Sustainable Development

In designing and developing an IoT-based heart rate monitoring system, it is important to carefully select and evaluate the tools and technologies that will be used to collect and analyze data. This includes conducting a comprehensive analysis of available hardware components, such as sensors and microcontrollers, to identify those that offer accurate heart rate measurement and energy efficiency. Evaluation criteria such as power consumption, reliability, and compatibility with communication protocols are considered to ensure long-term viability. Additionally, the selection of software platforms and cloud services is assessed based on factors like data security, real-time monitoring capabilities, and scalability. The methodology aims to carefully choose tools that support sustainable development, providing an efficient and reliable IoT-based heart rate monitoring system.

3.3 Overview of the System Flowchart

Figure 3.1 shows the flowchart represents a process aimed at continuously monitoring heart rate in real-time using IoT. The process starts by checking for an available IP address. If fail to detect any IP address, it loops back to restart, while if IP address detected it will continuously display of the patient's heart rhythm. Concurrently, the flowchart assesses the status of the start button, if it is not pressed, the display of the heart rhythm persists, and in the event of the button being pressed, the system proceeds to read and showcase the patient's heart rate in beats per minute (BPM).

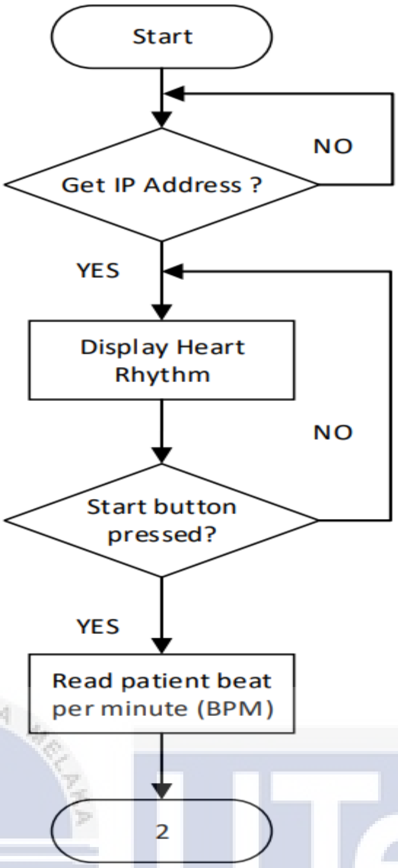


Figure 3.1: Continuous monitoring heart rate in real-time using IoT.

Figure 3.2 shows the flowchart outlines a process with the objective of analyzing heart rate data to identify any abnormal patterns. This flowchart starts with a web interface process, followed by a decision point to retrieve beats per minute (BPM) data from an ESP32 device. If the data retrieval is unsuccessful, the flowchart checks the IP address and restarts the system as needed. When BPM data is successfully obtained from the ESP32, the system proceeds to display the patient's heart rate. Simultaneously, it records the patient's heart rate in BPM, providing a streamlined process for interfacing, monitoring, and recording the patient's cardiac activity.

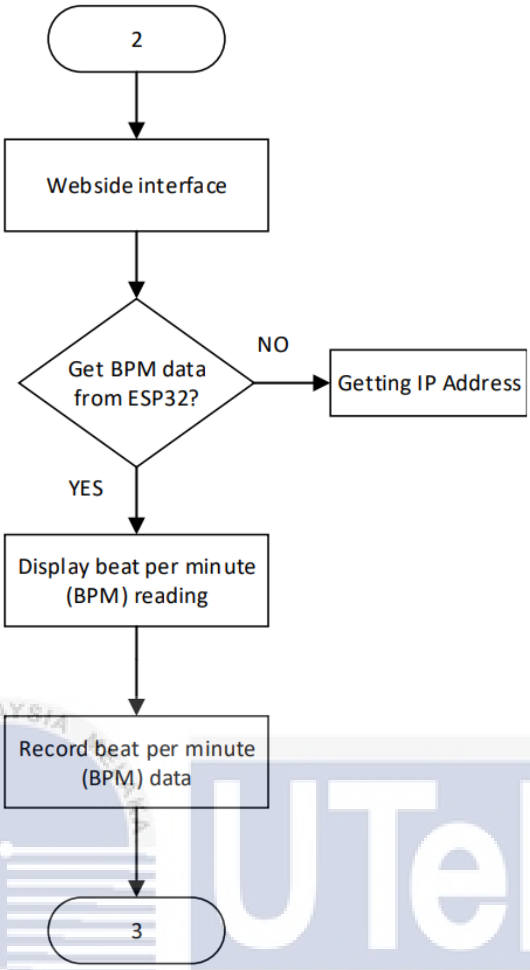


Figure 3.2: Analyzing heart rate data to record and identify.

Figure 3.3 illustrates a flowchart representing a process designed to activate an alert mechanism upon detecting abnormalities. The process start by assessing the availability of an IP address. Once obtained, the system proceeds to display the heart rhythm. By press the start button, the heart rate reading process will started. A subsequent decision point evaluates whether the resting heart rate deviates below 60 BPM or surpasses 100 BPM, triggering an alert in the event of such conditions.

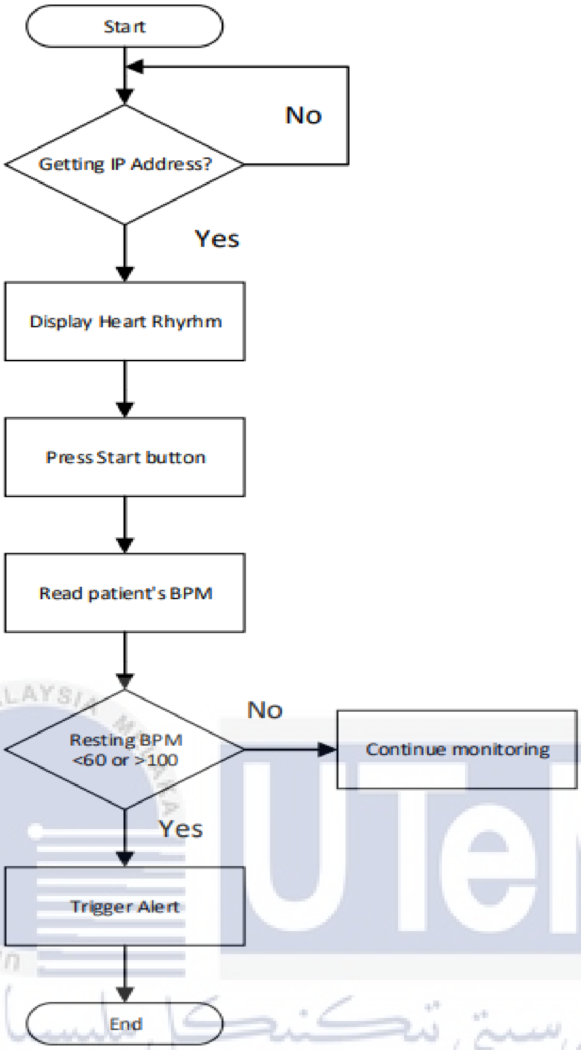


Figure 3.3: Alert trigger system.

3.4 Overview of the System Block Diagram

Figure 3.4 shows the block diagram for the proposed system. In this system block diagram, the power supply provides the necessary electrical energy to all the components. The pulse sensor acts as input devices, measuring the user's heart rate respectively. The NodeMCU ESP32 microcontroller serves as the central processing unit, receiving data from sensors. It processes the data and controls the output devices. The OLED 128x64 display shows real-time heart rhythm and heartbeat per minute (BPM) readings to the user. At the same time, ESP32 collect the data from sensor and transmit the data to the web server. The web server acts as the cloud-based storage and analysis platform, where the healthcare can monitor and analyze the heart rhythm remotely. Figure 3.4 shows the proposed block diagram.

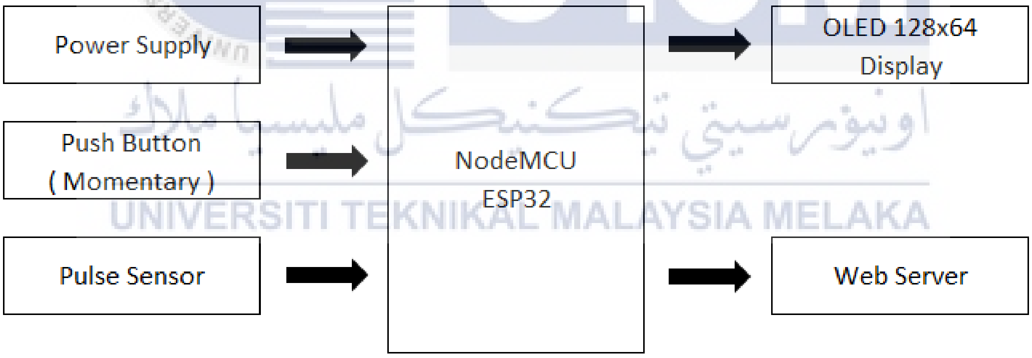


Figure 3.4: Proposed system block diagram

3.5 System Architecture

Figure 3.5 shows the system architecture for the proposed system. The IoT-based heart rate monitoring system architecture consists of several components to ensure accurate heart rate measurement, real-time display, and cloud-based healthcare monitoring. The system incorporates a pulse sensor, ESP32 ESP WROOM 32, and OLED 128x62 display. The system begins with the patient, who wears a Pulse Sensor capable of measuring the heart rate in beats per minute (BPM). The Pulse Sensor captures physiological data associated with blood volume changes, offering a reliable metric for assessing the patient's cardiovascular health.

The acquired data is then transmitted to an ESP32 microcontroller, specifically the ESP-WROOM 32 model, renowned for its processing capabilities and built-in Wi-Fi features. Within the ESP32, the processed data results in two significant outputs. Firstly, the microcontroller generates a local display output, showcasing the real-time BPM reading. This local display provides immediate feedback for the patient or healthcare professionals, facilitating quick assessment of the current heart rate.

Simultaneously, the ESP32 generates a second output aimed at remote healthcare monitoring. This output involves transmitting the BPM reading to a web server, which serves as a centralized repository for collecting and recording the transmitted data. The web server plays a crucial role in organizing and securely storing the information, establishing a comprehensive historical record of the patient's heart rate over time.

Finally, the recorded data on the web server becomes accessible to healthcare professionals, forming the basis for continuous monitoring and analysis. The healthcare monitor can review historical trends in the patient's heart rate, enabling timely interventions or adjustments in treatment plans as necessary. This system architecture ensures seamless integration of data acquisition, local display, remote transmission, and centralized storage, contributing to an effective and user-friendly IoT-based Heart Rate Monitoring System. The utilization of a microcontroller and IoT technologies enhances the system's efficiency, making it a valuable tool for continuous and remote cardiac health monitoring.

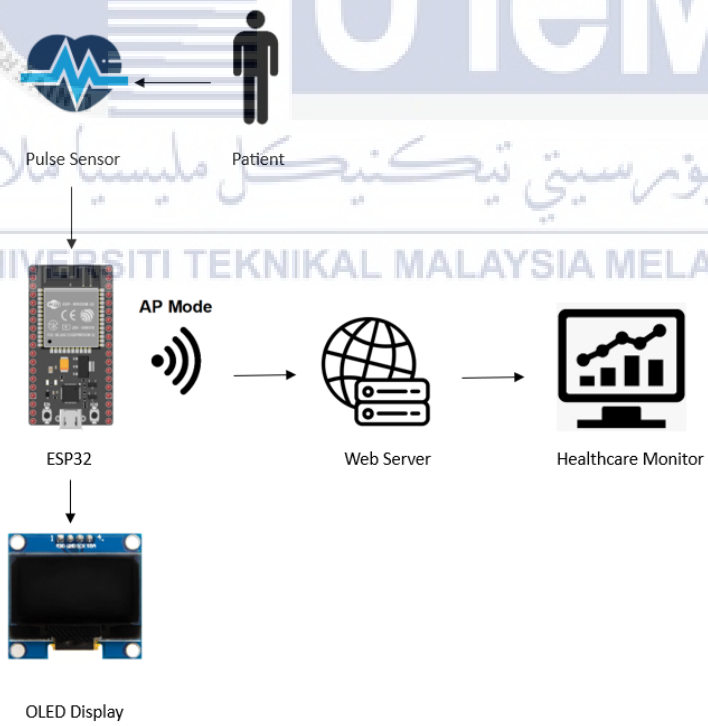


Figure 3.5: Proposed system architecture

3.6 Overview Equipment

3.6.1 ESP32 ESP-WROOM-32

The ESP32 ESP-WROOM-32 plays a vital role in an IoT-based Heart Rate Monitoring System, offering a dual-core processor for efficient real-time data processing. Its integrated Wi-Fi capabilities enable seamless wireless communication, facilitating remote monitoring. With versatile GPIO pins and ADC support, the ESP32 allows straightforward interfacing with heart rate sensors, enhancing system adaptability. The module's low power consumption is critical for energy-efficient, prolonged device operation. Overall, the ESP32 ESP-WROOM-32 provides a professional-grade solution for developing sophisticated and connected Heart Rate Monitoring Systems in the IoT domain. Figure 3.7 shows the ESP32 ESP-WROOM-32.

Figure 3.6: ESP32 ESP-WROOM-32

3.6.2 Pulse Sensor

The pulse sensor plays a crucial role in capturing and measuring the user's heart rate. The pulse sensor typically consists of a photodetector and an LED placed on the fingertip. The LED emits light into the fingertip, and the photodetector measures the amount of light that passes through the blood vessels. As blood pulses through the vessels, it absorbs more light, causing variations in the detected light intensity. These variations are then converted into electrical signals that correspond to the user's heartbeat.

In this proposed project, the pulse sensor acts as the primary sensor responsible for collecting real-time heart rate data. The ESP32 microcontroller processes this data and communicates with the OLED display to visually present the heart rate information. The pulse sensor serves as a vital component in the system, allowing for accurate and continuous monitoring of the user's heart rate in a convenient and IoT-enabled manner. The Figure 3.8 shows the pulse sensor that used for this proposed project.

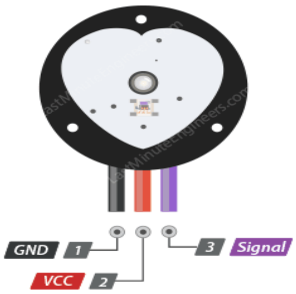


Figure 3.7: Pulse sensor

3.6.3 OLED Display 128x64

The OLED display serves as the visual interface for presenting the heart rate data. The 128x64 resolution indicates that the display has 128 columns and 64 rows of pixels, providing a compact yet informative screen. The primary function of the OLED display in this project is to showcase real-time heart rate information to the user.

Once the ESP32 processes the heart rate data obtained from the pulse sensor, it sends the processed information to the OLED display for presentation. The OLED technology used in the display allows for each pixel to emit light individually, providing high contrast and sharp visibility. The OLED display can show not only the current heart rate but also additional relevant information, such as a graphical representation of the heart rate trend, time, or any other data deemed important for the user. Figure 3.9 shows the OLED 128x64 display that used for this project.

Figure 3.8: OLED display 128x64

3.7 Limitation of Proposed Methodology

The proposed system limitations, including potential inaccuracies in heart rate measurements due to motion artifacts or sensor misplacement. Wireless communication reliability may be affected by environmental interference, leading to data transmission issues. The 128x64 OLED screen's limited size may hinder the presentation of comprehensive information, and the system's power consumption, especially with an active display, could impact battery life, necessitating careful power management for prolonged usage. Addressing these limitations is crucial for ensuring the accuracy, reliability, and user-friendliness of the system.

3.8 Summary

The proposed IoT-based Heart Rate Monitoring System employs the ESP32 ESP-WROOM-32 microcontroller, a Pulse Sensor, and an OLED 128x64 display to create a comprehensive monitoring solution. The Pulse Sensor facilitates real-time heart rate measurements, while the ESP32 processes the data and manages wireless communication for IoT connectivity. The system provides immediate feedback by displaying heart rate information on the compact OLED 128x64 display. However, potential limitations include accuracy concerns with the Pulse Sensor due to motion artifacts, processing constraints on the ESP32 for concurrent tasks, and limitations in information presentation on the small OLED display. Optimizing sensor calibration, algorithm efficiency, and power management strategies is crucial to enhancing the system's accuracy, responsiveness, and overall reliability in continuous heart rate monitoring applications.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

The IoT-based Heart Rate Monitoring System, using components such as the ESP32 WROOM microcontroller, OLED display, pulse sensor, and web server, yields valuable results and analysis for effective healthcare monitoring. By utilizing this system, real-time heart rate data is displayed on the OLED screen, providing immediate feedback to the user. Simultaneously, the system securely transmits this data to a web server, where it is stored for comprehensive record-keeping. The analysis of the collected data enables healthcare professionals to identify trends, irregularities, or anomalies in the patient's heart rate over time. This information is crucial for making informed decisions regarding the patient's cardiovascular health, allowing for timely interventions or adjustments to treatment plans. The integration of IoT technologies ensures seamless communication between the microcontroller, display, and web server, making the system a reliable and user-friendly tool for continuous heart rate monitoring and analysis.

4.2 Hardware and Software Integration

This project involves an IoT Heart Rate Monitoring System using ESP32, Pulse Sensor, and OLED 128x64 display. It starts by displaying "Heart Monitoring System" on the OLED screen, indicating system initiation. After setting up the server and obtaining the IP address, the system transitions to an ECG display for real-time monitoring of the heart's electrical signals. Upon pressing a button, it calculates and displays the Heartbeat Per Minute (BPM) with a 3-second delay for accuracy. For IoT output, the system reads the IP address (set as 192.168.1.1) and connects to a web server interface for remote monitoring. The interface displays ECG and BPM, with a start button triggering BPM computation and display on the user's device after a deliberate 3-second delay. This integrated IoT solution combines microcontroller tech, pulse sensing, and web interfaces for efficient real-time monitoring and healthcare data management. The hardware setup is shown in Figure 4.1.

Figure 4.1: Hardware prototype and web server interface

4.2.1 Electrocardiogram (ECG) Rhythm Measurement

The ECG rhythm utilizes standardized time intervals on the paper, where each small square corresponds to 0.04 seconds, five small squares make one large square (0.2 seconds), and five large squares represent a total of 1 second. This allows healthcare professionals to easily analyze the timing and duration of cardiac cycle phases, aiding in the identification of heart rhythm abnormalities for diagnostic decisions. Figure 4.2 shows the ECG rhythm.

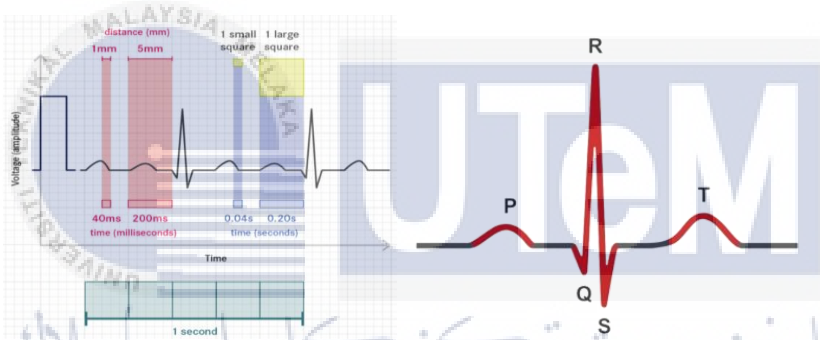


Figure 4.2: Electrocardiogram (ECG) rhythm

A regular rhythm denotes a predictable pattern of heartbeats, guided by the natural pacemaker (SA node). The consistent time intervals between heartbeats indicate a normal electrical pathway, ensuring the heart follows its standard sequence of impulses for chamber contraction and relaxation. Figure 4.3 shows the regular rhythm.

Figure 4.3: Regular Rhythm

In cases where the heart rhythm is fast, and the consecutive R waves are closely spaced. By identifying two consecutive R waves and counting the number of small squares between them, one can determine the time elapsed for these heartbeats. Dividing 1500 by the count of small squares between the R waves allows for an accurate calculation of the person's heart rate. Figure 4.4 shows the fast rhythm.

Figure 4.4: Fast Rhythm

Irregular heart rhythms pose a challenge when estimating heart rate as the beats are erratic and unevenly spaced on an electrocardiogram (ECG). The simple method involves counting the number of R waves over a 10-second period and then multiplying that count by 6. This calculation provides the average beats per minute (bpm) for a rhythm strip, offering a more accurate representation of the heart rate in irregular rhythms. Figure 4.5 shows the fast rhythm.

Figure 4.5: Irregular Rhythm

4.2.2 Heartrate Reading per Minutes (BPM)

Table 4.1 presents data on heart rate measurements in beats per minute (BPM) corresponding to normal resting conditions and the associated range of readings during moderate exercise, categorized by age from 24 to 60 years.

Table 4.1: Normal heart rate measurements data

<table>
<tr><th>Age</th><th>Normal Resting Heart Rate (BPM)</th><th>Moderate Exercise Heart Rate (BPM)</th></tr>
<tr><td>24</td><td rowspan="10">60 – 100</td><td>125 – 149</td></tr>
<tr><td>28</td><td>123 – 146</td></tr>
<tr><td>32</td><td>120 – 143</td></tr>
<tr><td>36</td><td>118 – 140</td></tr>
<tr><td>40</td><td>115 – 137</td></tr>
<tr><td>44</td><td>113 – 134</td></tr>
<tr><td>48</td><td>110 – 131</td></tr>
<tr><td>52</td><td>108 – 128</td></tr>
<tr><td>56</td><td>105 – 125</td></tr>
<tr><td>60</td><td>102 – 122</td></tr>
</table>

4.3 Measurement Result

The outcomes derived from the analysis of measurement readings across various individuals, organized by age categories, indicate the suitability of the proposed heart rate monitoring system for practical use.

4.3.1 Sample Measurement 1

The data archived on the web server demonstrates consistent measurement readings for both resting and exercise conditions in the case of the initial patient, aged 22. Although the recorded data at minute 1 during resting conditions reveals a reading of 108 BPM, exceeding the normal range of 60 - 100, it is attributed to noise interference. The recorded data shows on the Table 4.2.

Table 4.2: Resting and exercise reading for patient (22 years old)

Time	BPM
0:00:00	0
0:00:10	102
0:00:20	96
0:00:30	90
0:00:40	96
0:00:50	102
0:01:00	108
0:01:10	84
0:01:20	96
0:01:30	96
0:01:40	96
0:01:50	96

Resting

Time	BPM
0:00:00	0
0:00:10	112
0:00:20	130
0:00:30	130
0:00:40	124
0:00:50	136
0:01:00	136
0:01:10	140
0:01:20	155
0:01:30	155
0:01:40	142

Exercise

Utilizing the recorded data of beats per minute (BPM) from the webserver interface for a 22-year-old patient, healthcare professionals can visually analyze the information presented in the form of a graph. This graphical representation facilitates the identification of any anomalies in the readings that may pose a threat to the individual's health, allowing for timely intervention and preventative measures. Figure 4.6 and Figure 4.7 shows the resting and exercise data in graft.

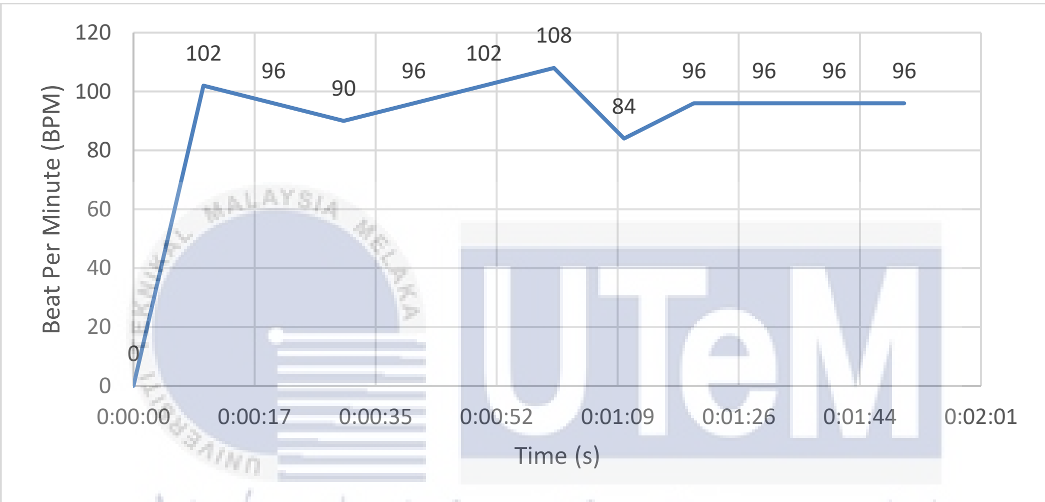


Figure 4.6: Resting condition

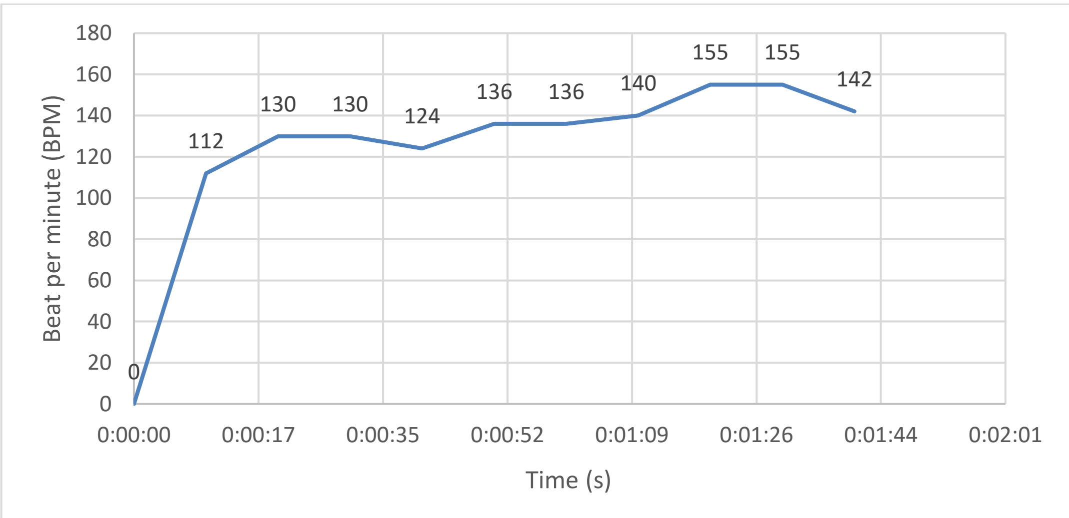


Figure 4.7: Exercise condition

4.3.2 Sample Measurement 2

The data recorded on the webserver demonstrates consistent measurement readings for both conditions for the case of patient, aged 26. During resting conditions, despite an elevated reading of 102 at minute 2, exceeding the normal range of 60 - 100, it is attributed to noise interference rather than indicating an underlying issue. The recorded data shows on the Table 4.3.

Table 4.3: Resting and exercise reading for patient (26 years old)

Time	BPM
0:00:00	0
0:00:10	74
0:00:20	84
0:00:30	90
0:00:40	90
0:00:50	108
0:01:00	89
0:01:10	68
0:01:20	68
0:01:30	80
0:01:40	86

Resting

Time	BPM
0:00:00	0
0:00:10	110
0:00:20	141
0:00:30	141
0:00:40	150
0:00:50	132
0:01:00	132
0:01:10	132
0:01:20	126
0:01:30	138
0:01:40	138

Exercise

Utilizing the recorded data of beats per minute (BPM) accessible through the webserver interface for a 26-year-old patient, healthcare professionals can analyze the information through a graphical representation. This visual presentation facilitates the identification of any anomalies in the readings that may pose a threat to the patient's health, enabling timely intervention and preventative measures. Figure 4.8 and Figure 4.9 shows the resting and exercise data in graft.

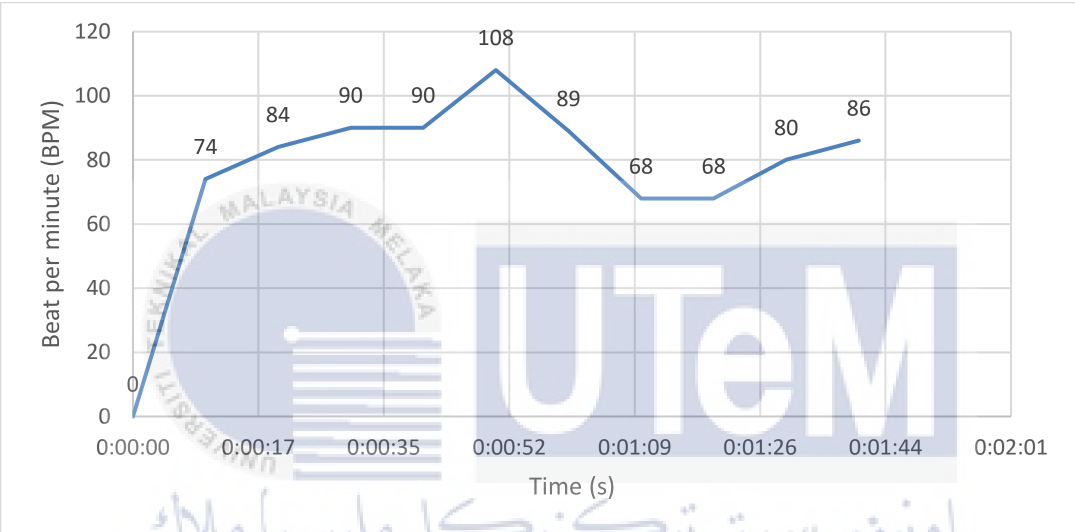


Figure 4.8: Resting condition

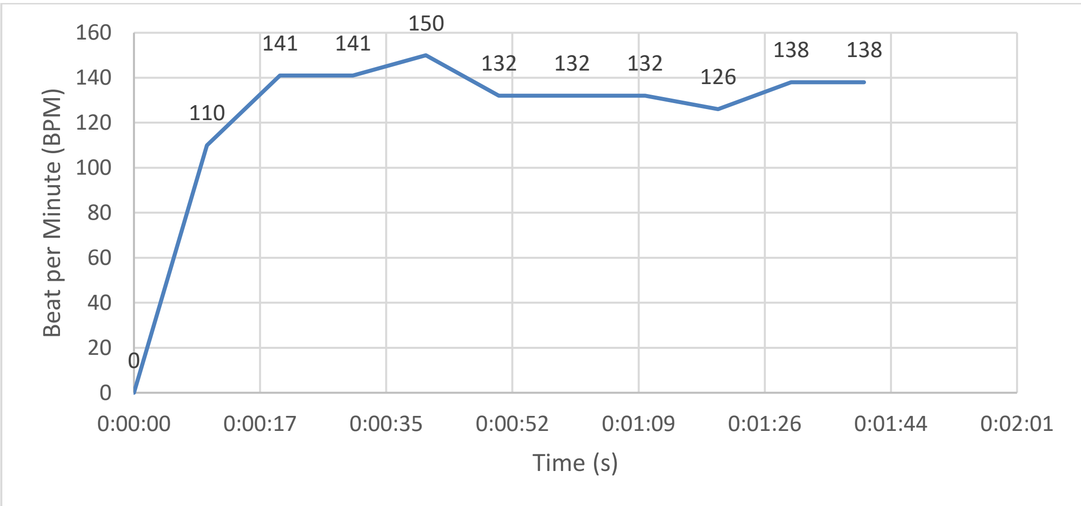


Figure 4.9: Exercise condition

4.3.3 Sample Measurement 3

The data retrieved from the webserver indicates consistent measurement readings for a 30-year-old patient, demonstrating stability in both resting and exercising conditions, with values remaining within the normal range of 60 - 100 BPM for resting and 120 - 143 BPM for exercising. An isolated instance occurred at minute 1.10 where the resting reading temporarily exceeded the specified range, attributable to potential inaccuracies in measurement positioning and environmental noise.The recorded data shows on the Table 4.4.

Table 4.4: Resting and exercise reading for patient (30 years old)

Time	BPM
0:00:00	0
0:00:10	92
0:00:20	92
0:00:30	87
0:00:40	90
0:00:50	90
0:01:00	96
0:01:10	111
0:01:20	98
0:01:30	98
0:01:40	84

Resting

Time	BPM
0:00:00	0
0:00:10	150
0:00:20	141
0:00:30	141
0:00:40	132
0:00:50	132
0:01:00	124
0:01:10	115
0:01:20	115
0:01:30	122
0:01:40	142

Exercise

Utilizing the beat per minute (BPM) data captured through the webserver interface for a 30-year-old patient, healthcare professionals can assess the patient's physiological information through a graphical representation. This graphical depiction facilitates the identification of any irregularities in the readings, enabling proactive measures for early intervention to mitigate potential health threats. Figure 4.10 and Figure 4.11 shows the resting and exercise data in graft.

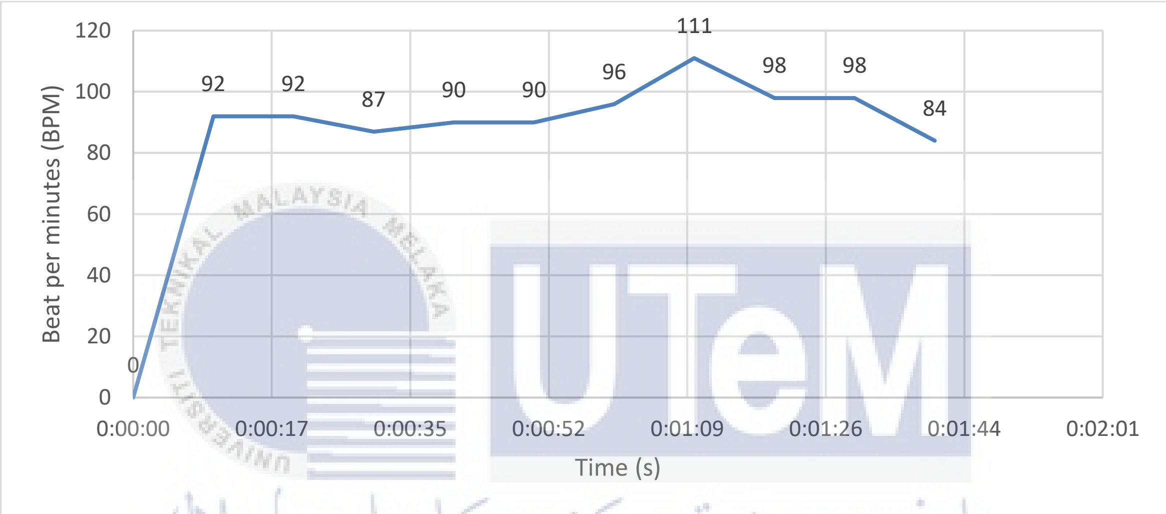


Figure 4.10: Resting condition

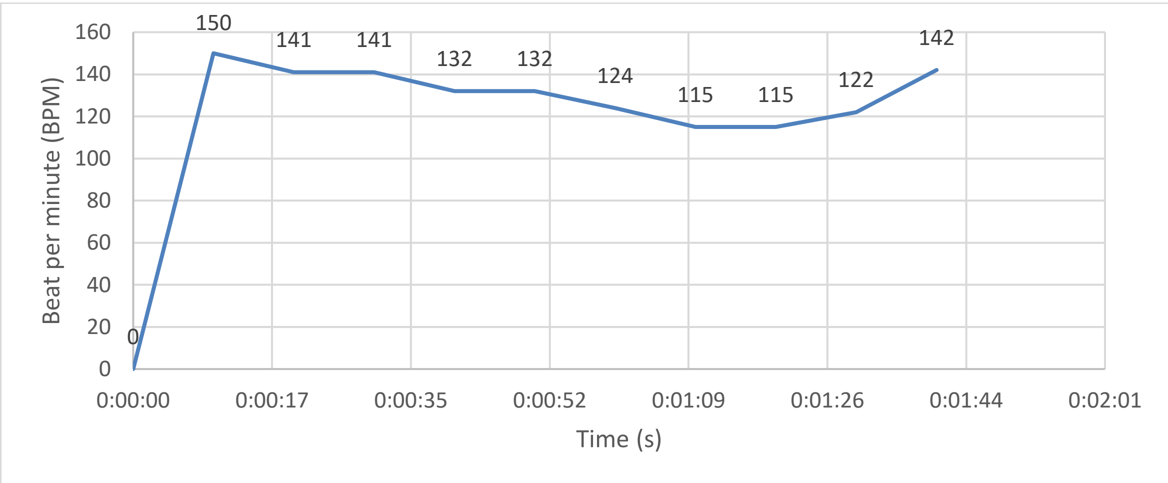


Figure 4.11: Exercise condition

4.3.4 Sample Measurement 4

Table 4.5 shows the recorded BPM data for a patient aged 55 years. Analysis of the recorded data during the resting condition indicates that all readings fall within the established normal range of 60 to 100 beats per minute (BPM), with no discernible abnormalities observed. In the exercise condition, the recorded dataset shows a stable range of readings. The slight increase aligns consistently with anticipated variations commonly noted during physical activities.

Table 4.5: Resting and exercise reading for patient (55 years old)

Time	BPM
0:00:00	0
0:00:10	68
0:00:20	72
0:00:30	70
0:00:40	74
0:00:50	69
0:01:00	71
0:01:10	73
0:01:20	67
0:01:30	75
0:01:40	66

Resting

Time	BPM
0:00:00	0
0:00:10	120
0:00:20	125
0:00:30	118
0:00:40	122
0:00:50	130
0:01:00	123
0:01:10	128
0:01:20	115
0:01:30	126
0:01:40	121

Exercise

Utilizing the recorded data of beats per minute (BPM) from the webserver interface, health professionals can analyze the information through a graphical representation. This visual depiction facilitates the identification of potential abnormalities in the patient's readings, enabling timely intervention for preventive measures to safeguard the individual's health. Figure 4.12 and Figure 4.13 shows the resting and exercise data in graft for 55-year-old patient.

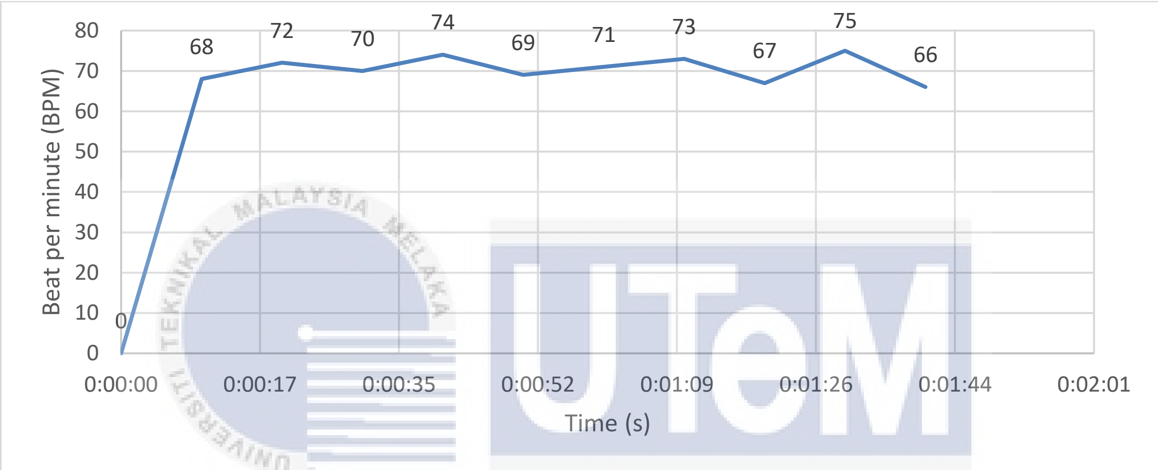


Figure 4.12: Resting condition

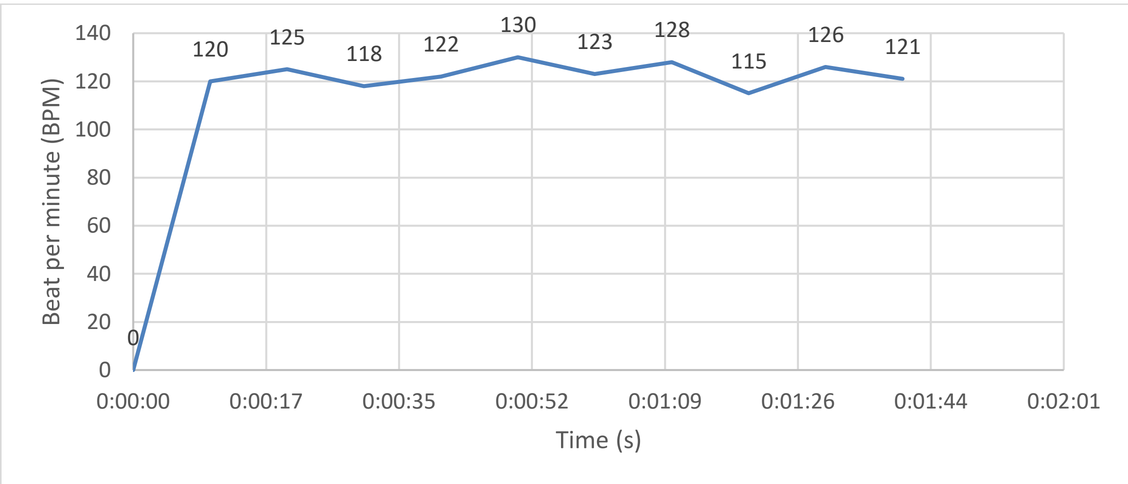


Figure 4.13: Exercise condition

4.3.5 Sample Measurement 5

Table 4.6 systematically records the beats per minute (BPM) data for a patient aged 60. An analysis of the data related to the resting condition reveals that all recorded readings consistently fall within the clinically accepted normal range of 60 - 100 BPM. This finding underscores the absence of any abnormalities in the resting heart rate measurements for the specified patient. In the exercise condition, the recorded data in shows a stable range of beats per minute (BPM) readings. While a slight increase at minute 1, it is consistent with typical variations observed during physical activities such as jogging.

Table 4.6: Resting and exercise reading for patient (60 years old)

Time	BPM
0:00:00	0
0:00:10	68
0:00:20	70
0:00:30	72
0:00:40	67
0:00:50	71
0:01:00	69
0:01:10	73
0:01:20	66
0:01:30	74
0:01:40	68

Resting

Time	BPM
0:00:00	0
0:00:10	120
0:00:20	125
0:00:30	118
0:00:40	122
0:00:50	130
0:01:00	123
0:01:10	128
0:01:20	115
0:01:30	126
0:01:40	121

Exercise

Utilizing the recorded data of beats per minute (BPM) accessible through the webserver interface, health professionals can visually analyze the patient's physiological information through a graph. This graphical representation facilitates the identification of any anomalies in the readings that may pose a potential threat to the individual's health. This comprehensive analysis enables early intervention strategies to be implemented, thereby enhancing the prospects for preventive healthcare measures. Figure 4.14 and Figure 4.15 shows the resting and exercise data in graft for 55-year-old patient.

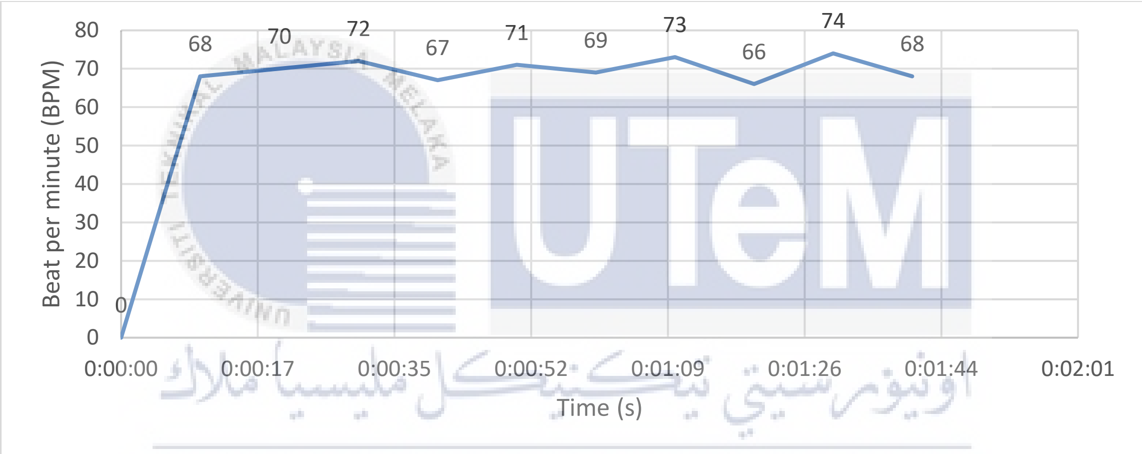


Figure 4.14: Resting condition

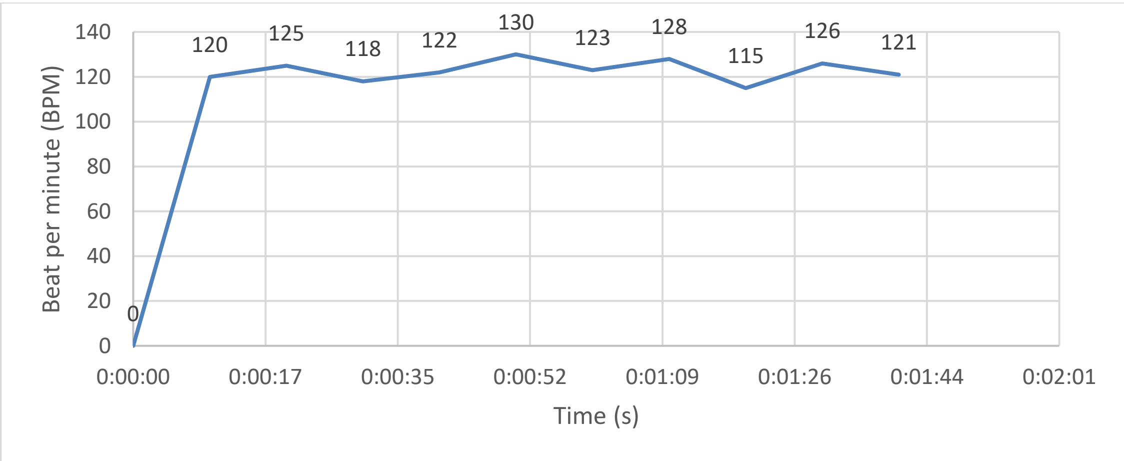


Figure 4.15: Exercise condition

4.4 Summary

The results and analysis of the IoT-based Heart Rate Monitoring System using the ESP32 WROOM microcontroller, OLED display, pulse sensor, and web server project successfully implemented a reliable heart rate monitoring solution. The system collected and recorded five heart rate samples, demonstrating consistency in measurements. The recorded data was stored on a web server, enabling in-depth analysis and visualization of heart rate patterns. The results indicated the system's ability to provide accurate and real-time heart rate information. The analysis revealed valuable insights into cardiovascular health, allowing users to monitor trends and identify potential anomalies. The project showcases a robust combination of IoT technology, microcontroller capabilities, and web-based data management for effective heart rate monitoring and analysis.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The IoT-based Heart Rate Monitoring System has reached a significant milestone in achieving its primary objectives, illustrating a seamless integration of cutting-edge technologies. The incorporation of the ESP32 microcontroller, heart rate sensor, and web server has resulted in a robust system capable of real-time heart rate monitoring. The emphasis on accuracy, reliability, and user comfort addresses the specific challenges encountered by bedridden patients, underscoring the system's commitment to providing effective healthcare solutions. The inclusion of sophisticated data analysis algorithms stands out as a pivotal feature, allowing for the prompt identification of abnormalities in heart rate patterns. This not only provides healthcare professionals with actionable insights but also establishes the system as an advanced tool for proactive health management. The success of this project not only sets a foundation for elevating patient care through continuous heart rate monitoring but also positions the system as a model for convenient and non-intrusive healthcare technology implementation.

5.2 Potential for Commercialization

The IoT-based Heart Rate Monitoring System not only represents a groundbreaking technological advancement but also holds substantial promise for commercialization within the healthcare technology market. Its user-centric design, characterized by the integration of the ESP32 microcontroller, heart rate sensor, and web server, positions the system as a versatile and user-friendly solution. The accurate monitoring capabilities and sophisticated data analysis features make it particularly suitable for adoption in diverse healthcare settings, including hospitals, care facilities, and home healthcare scenarios. The scalability and compatibility inherent in the system's architecture enhances its adaptability to varying healthcare environments, presenting an attractive proposition for widespread commercial deployment.

Furthermore, the system's potential for strategic partnerships with healthcare device manufacturers or service providers opens avenues for collaboration that could significantly amplify its commercial viability. By forging partnerships, the system could benefit from synergies that enhance its market reach, customer support infrastructure, and integration with existing healthcare ecosystems. This collaborative approach aligns with industry trends and positions the IoT-based Heart Rate Monitoring System as a comprehensive and effective solution with the potential to contribute positively to the evolving landscape of healthcare technology.

5.3 Future Works

For future improvements, the heart rate monitoring system could be enhanced as follows:

i. Integration with Health Platforms: Explore connecting the system to existing health platforms and electronic health records for easier data sharing and collaboration in healthcare networks.

ii. Remote Monitoring Features: Upgrade the system to allow healthcare professionals to monitor heart rate data remotely, enhancing accessibility and facilitating geographical flexibility.

iii. Machine Learning Algorithms: Research and implement machine learning algorithms to improve the system's ability to detect subtle patterns in heart rate data, potentially enabling more accurate predictions.

iv. Mobile Application Development: Create a mobile app for users to access heart rate data, receive notifications, and engage with personalized health insights, encouraging active involvement in their healthcare.

v. Clinical Trials and Validation: Conduct thorough clinical trials to evaluate the system's performance across various healthcare scenarios, ensuring compliance with medical standards.

vi. Battery Efficiency Improvements: Explore advanced techniques and components to optimize battery consumption, extending the system's operational lifespan and reducing the need for frequent battery replacement.

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APPENDICES A

Gantt Chart PSM 1

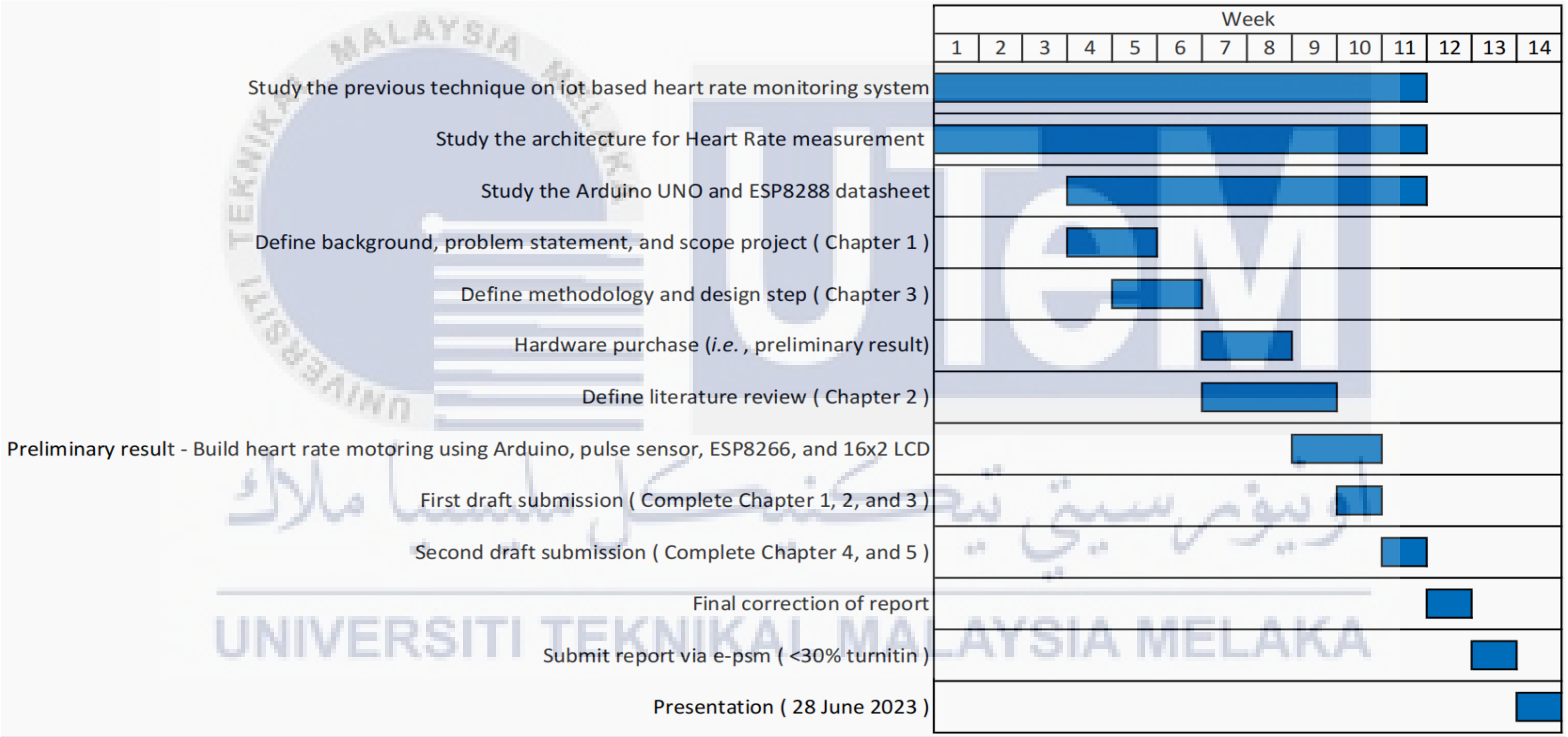

Figure xx : Timeline for Project Sarjana Muda I.

Gantt Chart PSM II

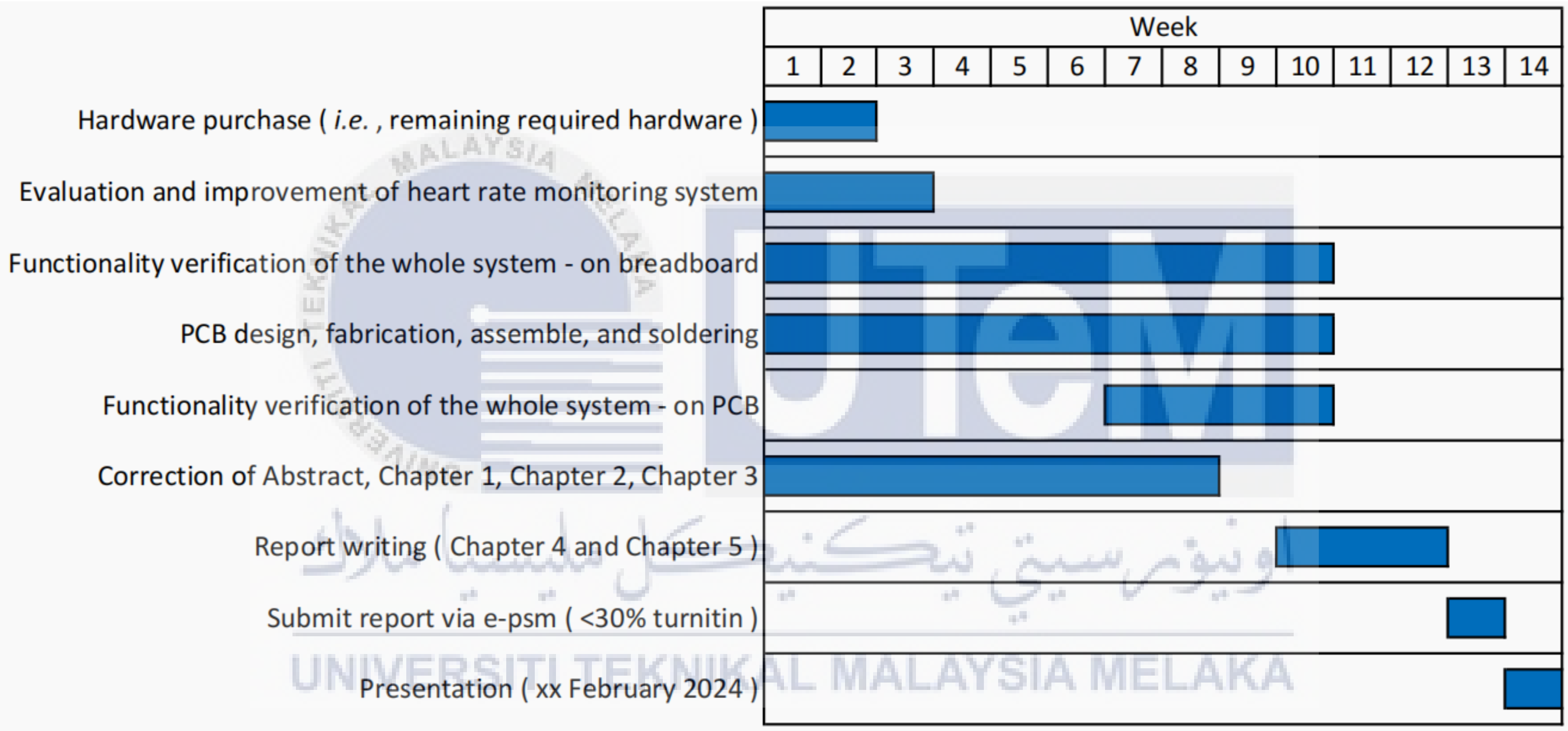

Figure xx : Timeline for Project Sarjana Muda II

APPENDICES B

Proposed Program

```
#include <Wire.h>

#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#include <AsyncTCP.h>

#include <ESPAsyncWebServer.h>

#include <Arduino_JSON.h>

#include "PageIndex.h"

#define PulseSensor_PIN 36

#define LED_PIN        23

#define Button_PIN     32

#define SCREEN_WIDTH 128

#define SCREEN_HEIGHT 64

#define OLED_RESET    -1

Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);


const char* ssid = "????";

const char* password = "????";
```

```
IPAddress local_ip(192,168,1,1);

IPAddress gateway(192,168,1,1);

IPAddress subnet(255,255,255,0);


unsigned long previousMillisGetHB = 0;

unsigned long previousMillisResultHB = 0;


const long intervalGetHB = 35;

const long intervalResultHB = 1000;


int timer_Get_BPM = 0;

int PulseSensorSignal;

int UpperThreshold = 520;

int LowerThreshold = 500;

int cntHB = 0;

boolean ThresholdStat = true;

int BPMval = 0;


int x=0;

int y=0;

int lastx=0;

int lasty=0;
```

```
bool get_BPM = false;
byte tSecond = 0;
byte tMinute = 0;
byte tHour   = 0;

char tTime[10];
const unsigned char Heart_Icon [] PROGMEM = {
  0x00, 0x00, 0x18, 0x30, 0x3c, 0x78, 0x7e, 0xfc, 0xff, 0xfe, 0xff, 0xfe, 0xee, 0xee, 0xd5,
0x56,
  0x7b, 0xbc, 0x3f, 0xf8, 0x1f, 0xf0, 0x0f, 0xe0, 0x07, 0xc0, 0x03, 0x80, 0x01, 0x00, 0x00,
0x00
};
const char* PARAM_INPUT_1 = "BTN_Start_Get_BPM";
String BTN_Start_Get_BPM = "";
JSONVar JSON_All_Data;
AsyncWebServer server(80);

AsyncEventSource events("/events");

void GetHeartRate() {
  unsigned long currentMillisGetHB = millis();
```

```
if (currentMillisGetHB - previousMillisGetHB >= intervalGetHB) {
  previousMillisGetHB = currentMillisGetHB;

  PulseSensorSignal = analogRead(PulseSensor_PIN);

  if (PulseSensorSignal > UpperThreshold && ThresholdStat == true) {
    if (get_BPM == true) cntHB++;
    ThresholdStat = false;
    digitalWrite(LED_PIN,HIGH);
  }
  if (PulseSensorSignal < LowerThreshold) {
    ThresholdStat = true;
    digitalWrite(LED_PIN,LOW);
  }
  DrawGraph();

  JSON_All_Data["heartbeat_Signal"] = PulseSensorSignal;
  JSON_All_Data["BPM_TimeStamp"] = tTime;
  JSON_All_Data["BPM_Val"] = BPMval;
  JSON_All_Data["BPM_State"] = get_BPM;
  String JSON_All_Data_Send = JSON.stringify(JSON_All_Data);
```

```
  events.send(JSON_All_Data_Send.c_str(), "allDataJSON" , millis());
}
unsigned long currentMillisResultHB = millis();


if (currentMillisResultHB - previousMillisResultHB >= intervalResultHB) {
  previousMillisResultHB = currentMillisResultHB;


  if (get_BPM == true) {
    timer_Get_BPM++;
    if (timer_Get_BPM > 10) {
      timer_Get_BPM = 1;
      tSecond += 10;
      if (tSecond >= 60) {
        tSecond = 0;
        tMinute += 1;
      }
      if (tMinute >= 60) {
        tMinute = 0;
        tHour += 1;
      }
      sprintf(tTime, "%02d:%02d:%02d",  tHour, tMinute, tSecond);
      BPMval = cntHB * 6;
```

```
        Serial.print("BPM : ");
        Serial.println(BPMval);


        display.fillRect(20, 48, 108, 18, BLACK);
        display.drawBitmap(0, 47, Heart_Icon, 16, 16, WHITE);
        display.drawLine(0, 43, 127, 43, WHITE);
        display.setTextSize(2);
        display.setTextColor(WHITE);
        display.setCursor(20, 48);
        display.print(": ");
        display.print(BPMval);
        display.setCursor(92, 48);
        display.print("BPM");
        display.display();


        cntHB = 0;
      }
    }
  }
}
  if (x > 127) {
    display.fillRect(0, 0, 128, 42, BLACK);
```

```
    x = 0;
    lastx = 0;
  }
  int ySignal = PulseSensorSignal;
  if (ySignal > 850) ySignal = 850;
  if (ySignal < 350) ySignal = 350;


  int ySignalMap = map(ySignal, 350, 850, 0, 40);
  y = 40 - ySignalMap;


  display.writeLine(lastx,lasty,x,y,WHITE);
  display.display();
  lastx = x;
  lasty = y;
  x++;
}
void setup() {
  Serial.begin(115200);
  Serial.println();
  delay(2000);
  analogReadResolution(10);
  pinMode(LED_PIN,OUTPUT);
```

```
  pinMode(Button_PIN, INPUT_PULLUP);

  sprintf(tTime, "%02d:%02d:%02d",  tHour, tMinute, tSecond);


  if(!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {

    Serial.println(F("SSD1306 allocation failed"));

    for(;;);

  }

  display.clearDisplay();

  display.setTextColor(WHITE);

  display.setTextSize(2);

  display.setCursor(7, 0);

  display.print("HEART");

  display.setCursor(7, 20);

  display.print("MONITORING");

  display.setCursor(17, 40);

  display.print("SYSTEM");

  display.display();

  delay(2000);


Serial.println();

Serial.println("-------------");

Serial.println("WIFI mode : AP");
```

```
WiFi.mode(WIFI_AP);
Serial.println("-------------");
delay(100);

Serial.println();
Serial.println("-------------");
Serial.println("Setting up ESP32 to be an Access Point.");
WiFi.softAP(ssid, password);
delay(1000);
Serial.println("Setting up ESP32 softAPConfig.");
WiFi.softAPConfig(local_ip, gateway, subnet);
Serial.println("-------------");
delay(500);

  display.clearDisplay();
  display.setTextColor(WHITE);
  display.setTextSize(1);
  display.setCursor(0, 0);
  display.print("Setting Up Servers...");
  display.display();
  delay(1000);
```

```
Serial.println();
Serial.println("Setting Up the Main Page on the Server.");
server.on("/", HTTP_GET, [](AsyncWebServerRequest * request) {
  request->send_P(200, "text/html", MAIN_page);
});
Serial.println();
Serial.println("Setting up event sources on the Server.");
events.onConnect([](AsyncEventSourceClient * client) {
  if (client->lastId()) {
    Serial.printf("Client reconnected! Last message ID that it got is: %u¥n", client-
>lastId());
  }
  client->send("hello!", NULL, millis(), 10000);
});
server.on("/BTN_Comd", HTTP_GET, [] (AsyncWebServerRequest * request) {

  if (request->hasParam(PARAM_INPUT_1)) {
    BTN_Start_Get_BPM = request->getParam(PARAM_INPUT_1)->value();

    Serial.println();
    Serial.print("BTN_Start_Get_BPM : ");
    Serial.println(BTN_Start_Get_BPM);
```

```
  }
  else {
    BTN_Start_Get_BPM = "No message";
    Serial.println();
    Serial.print("BTN_Start_Get_BPM : ");
    Serial.println(BTN_Start_Get_BPM);
  }
  request->send(200, "text/plain", "OK");
});
Serial.println();
Serial.println("Adding event sources on the Server.");
server.addHandler(&events);
Serial.println();
Serial.println("Starting the Server.");
server.begin();


display.clearDisplay();
display.setTextColor(WHITE);
display.setTextSize(1);
display.setCursor(0, 0);
display.print("Setting Up");
display.setCursor(0, 10);
```

```
  display.print("Server Completed.");
  display.display();
  delay(1000);

Serial.println();
Serial.println("------------");
Serial.print("SSID name : ");
Serial.println(ssid);
Serial.print("IP address : ");
Serial.println(WiFi.softAPIP());
Serial.println();
Serial.println("Connect your computer or mobile Wifi to the SSID above.");
Serial.println("Visit the IP Address above in your browser to open the main page.");
Serial.println("------------");
Serial.println();

display.clearDisplay();
display.setTextColor(WHITE);
display.setTextSize(1);
display.setCursor(0, 0);
display.print("ESP32 IP address :");
display.setCursor(0, 10);
```

```
display.print(WiFi.softAPIP());
display.display();
delay(3000);
  display.clearDisplay();
  display.drawLine(0, 43, 127, 43, WHITE); //--> drawLine(x1, y1, x2, y2, color)
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(10, 48); //--> (x position, y position)
  display.print("HeartBeat");
  display.display();
}
void loop() {
  if (digitalRead(Button_PIN) == LOW || BTN_Start_Get_BPM == "START" ||
BTN_Start_Get_BPM == "STOP") {
    delay(100);

    BTN_Start_Get_BPM = "";
    cntHB = 0;
    BPMval = 0;
    x = 0;
    y = 0;
    lastx = 0;
```

```
lasty = 0;

tSecond = 0;

tMinute = 0;

tHour   = 0;


sprintf(tTime, "%02d:%02d:%02d",  tHour, tMinute, tSecond);

get_BPM = !get_BPM;


if (get_BPM == true) {

  display.clearDisplay();

  display.setTextColor(WHITE);

  display.setTextSize(1);

  display.setCursor(14, 0);

  display.print("Start Getting BPM");

  display.setTextSize(3);


  for (byte i = 3; i > 0; i--) {

    display.setTextColor(WHITE);

    display.setCursor(50, 20);

    display.print(i);

    display.display();

    delay(1000);
```

```
    display.setTextColor(BLACK);
    display.setCursor(50, 20);
    display.print(i);
    display.display();
  }
  display.clearDisplay();
  display.drawBitmap(0, 47, Heart_Icon, 16, 16, WHITE);
  display.drawLine(0, 43, 127, 43, WHITE);
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(20, 48);
  display.print(": 0 ");
  display.setCursor(92, 48);
  display.print("BPM");
  display.display();
}
else {
  display.clearDisplay();
  display.setTextColor(WHITE);
  display.setTextSize(2);
  display.setCursor(42, 25);
  display.print("STOP");
```

```
      display.display();
      delay(1000);
      display.clearDisplay();
      display.drawLine(0, 43, 127, 43, WHITE);
      display.setTextSize(2);
      display.setTextColor(WHITE);
      display.setCursor(10, 48);
      display.print("HeartBeat");
      display.display();
    }
  }
  GetHeartRate();
}
```