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HEALTHCARE MONITORING SYSTEMS USING LORAWAN TECHNOLOGY

Mohamad Shazwan bin Aziz

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HEALTHCARE MONITORING SYSTEMS USING LORAWAN TECHNOLOGY

Healthcare Monitoring Systems Using Lorawan Technology

MOHAMAD SHAZWAN BIN AZIZ

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ABSTRACT

In this era of globalization, the Internet requires a network solution that can support these criteria of Things (IoT) vision, which calls for a rising number of interconnected sensor nodes. Additionally, crucial components of IoT include other difficulties, including latency, range coverage, and bandwidth. As a result, it considers the enormous volume of expected nodes connected to the Internet. The LoRaWAN (Low Power WAN Protocol for Internet of Things), a data-link layer with long-range, low power, and low bit rate emerged as a possible option for IoT in which end-devices use LoRa to interact with gateways over a single hop, is a promising alternative. This paper will focus on developing a healthcare monitoring system using LoRaWAN technologies that are able to measure heart rate and oxygen level with a broader range in real-time data transmission. This thesis will focus on the distance between Hotspot and LoRaWAN, where a comparison is made between both technologies. The outcome of this thesis is that LoRaWAN can detect heart rate (BPM) and oxygen saturation (SpO2) more comprehensive, 2.36km, compared to Hotspots, 15m from CAE Lab 1. The main issue during this project is that the current device is incompatible with The Things Network (TTN) and takes a lot of time to connect to the LoRa gateway. Furthermore, weather and buildings also affected the range of both technologies.

ABSTRAK

Pada era globalisasi ini, Internet memerlukan penyelesaian rangkaian yang boleh menyokong Internet Pelbagai Benda (IPB), yang memerlukan peningkatan bilangan nod sensor yang saling berkaitan. Selain itu, komponen penting IPB termasuk kesukaran lain, kependaman, liputan julat, dan lebar jalur. Akibatnya, ia menganggap jumlah besar nod yang dijangka disambungkan ke Internet. LoRaWAN (Protokol WAN Kuasa Rendaah untuk Internet Pelbagai Benda), lapisan pautan data dengan jarak jauh, kuasa rendah, dan kadar bit rendah muncul sebagai pilihan yang mungkin untuk IPB di mana peranti akhir menggunakan LoRa untuk berinteraksi dengan lawing laluan memalui hop tunggal, adalah alternatif yang menjanjikan. Kertas kerja ini akan menumpukan pada membangunkan system pemantauan penjagaan kesihatan menggunakan teknologi LoRaWAN yang mampu mengukur kadar denyutan jantung dan paras oksigen dengan julat yang lebih luas dalam penghantaran data masa nyata. Tesis ini akan memberi tumpuan kepada jarak antara Hotspot dan LoRaWAN, di mana perbandingan dibuat antara kedua-dua teknologi. Hasil daripada tesis ini ialah LoRaWAN dapat mengesan kadar denyutan jantung (BPM) dan ketepuan oksigen (SpO2) dengan lebih komprehensif, 2.36km, berbanding Hotspot, 15m dari CAE Lab 1. Isu utama semasa projek ini ialah peranti semasa tidak serasi dengan The Things Network (TTN) dan mengambil banyak masa untuk menyambung ke get laluan LoRa. Tambahan pula, cuaca dan bangunan turut mempengaruhi julat kedua-dua teknologi

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LIST OF ABBREVIATIONS

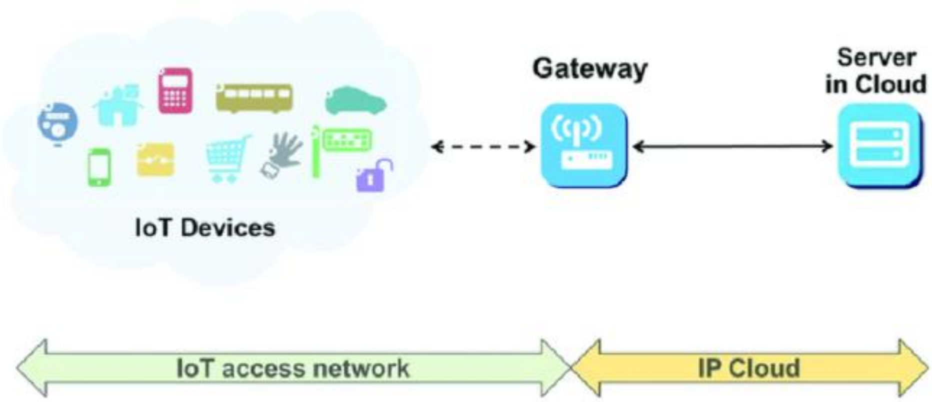
HMS	-	Healthcare Monitoring System
LoRaWAN	-	Long Range Wide Area Network
LoRa	-	Long Range
IoT	-	Internet of Things
LPWAN	-	Low-Power Wide Area Network
FYP	-	Final Year Project
I2C	-	Inter-Integrated Circuit
GPS	-	Global Positioning System
LCD	-	Liquid Crystal Display
BPM	-	Beats per Minute
SpO2	-	Oxygen Saturation

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Internet of Things (IoT) is an ideal concept for embedding sensors, actuators, and processors in various things that compute and communicate via the internet. The benefits of IoT in healthcare include life-saving telemedicine, remote diagnosis, patient monitoring, and therapy [1-2]. The IoT is an architectural framework that enables data interchange and integration between the real world and computer systems using the current communications framework. Therefore, many products, such as smartphones, laptops, healthcare devices, and other electronic devices, are designed around the IoT concept throughout the year. Based on [3], *healthcare* is defined as improving health through diagnosing, treating, and preventing diseases by health professionals such as doctors, dentists, and other medical practitioners. **Figure 1.1** show a general scheme of IoT architecture and a real-time patient monitoring system.



1Figure 1.1: General architecture of IoT [4-5].

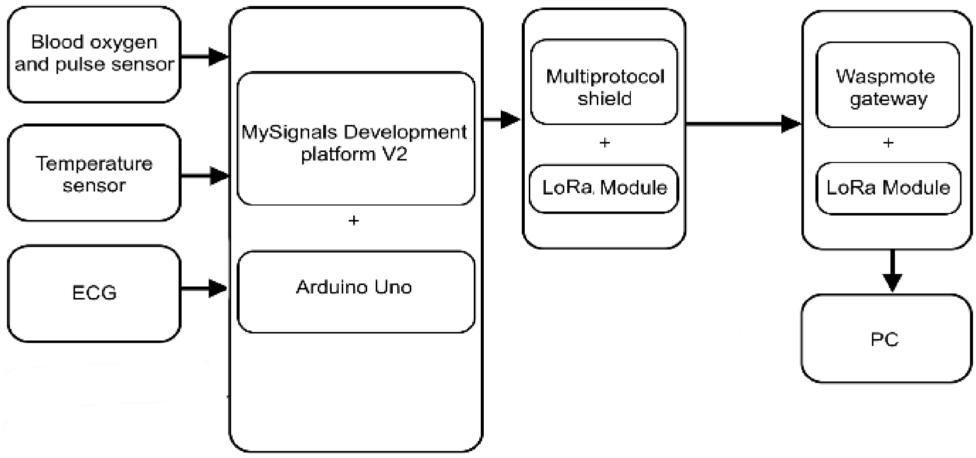
Multiple physical-layer networks are consolidated into a single converged network in an IoT access network, which overcomes these concerns. Furthermore, a single network can make enrolling IoT sensors and devices easier, create universal security protocols, and unify IoT endpoint administration and policymaking. In a nutshell, an IoT access network enables businesses to reap the benefits of IoT use cases more rapidly [6]. For example, the IoT is at the centre of today's IoT access control, also known as smart door locking system applications.

Each key, clamp access controller, scanner, and other associated device is assigned an IP address used for communication throughout this system. This intelligent equipment is generally connected to their centralised management software or mobile application in a single building through wireless networks [7]. These apps may be set up to operate various locks and controllers automatically or manually. Security alerts and notifications can also be set up to get real-time updates from mobile apps.

A IoT network is an extensive network that facilitates IoT devices and systems. The architecture, platforms, and storage necessary for real-time computing and processes are included in this category. An IoT cloud also consists of the services and standards required to connect, manage, and secure various IoT hardware and software. IoT clouds provide a cost-effective, flexible, and scalable method for organisations with limited resources for offering the structure and service required to allow IoT technologies devices and systems [8]. IoT clouds providing:

- On-demand,
- Low-price hyper-scale,
- It made it possible for companies to use the IoT's enormous potential without needing to create the necessary services and infrastructure from scratch.

RFID (Radio-frequency identification), utility computing, wireless communication systems, and LPWAN technologies such as NB-IoT and LoRa are promising for large-scale IoT application development [9]. They aid in improving device internet connectivity and the efficiency with which IoT apps work. LoRa is a spread spectrum modulation technique that evolved from chirp spread spectrum (CSS) technologies because of the need for more bandwidth while transmitting a signal [10]. LoRa's modulation approach makes it resilient to channel noise such as data and information.



2Figure 1.2: Block diagram of HMS with LoRa Communication Technology [9].

Figure 1.2 illustrates the HMS development process; biomedical sensors are coupled to MySignals and the Arduino Microcontroller to gather health information. The authors [9] stated that acquired data is subsequently sent to the personal computer through the LoRa module as well as gateway. Wi-Fi, Bluetooth 4.0 and Zigbee are well-known wireless technologies for Local Area Networks (LAN) and are all well-established protocols in both. These wireless technologies have dominated the IoT market due to their popularity and simple protocol. However, there is a disadvantage or difficulty with that technology in IoT which is the transmission range [10-11].

In addition, the HMS not only provides patients with seamless healthcare in a comfortable home environment while reducing medical treatment costs, but it also allows limited hospital resources to be utilised for persons in need of emergency care.

1.2 Problem Statement

The existing HMS cannot provide real-time patient health updates and is limited by the patient's distance from the hospital. According to [10], [12-13], the authors conducted an indoor positioning test using Wi-Fi and LoRa technologies, respectively. The Wi-Fi-based locating system in [12] has a coverage area of only 2 metres. In comparison, the work in [13] can accomplish a maximum coverage area of 200 metres and a placement precision of 28.8 metres. Both authors demonstrate the limitations of Wi-Fi technology in locating systems as compared to LoRa technology. The solution will be more expensive to implement if Wi-Fi or Bluetooth technology is used to establish a long-range communication network that requires an additional range extender. This drives the development of numerous LPWAN technologies, such as LoRa, to meet these requirements.

Still, the current approach is inefficient in terms of collecting measures from patients and is not cost-effective. LoRa Technology's low power, low cost, and consistent performance make it perfect for vital, intelligent healthcare applications [14]. Moreover, IoT solutions based on LoRa sensors and gateways can continuously monitor high-risk patients or systems, guaranteeing that the health and safety of patients and systems are never jeopardised.

1.3 Research Objectives

There are two main objectives in this research which includes;

1. To construct a low-cost HMS that can work in wide-ranging distance by using LoRaWAN technology that can:

   i. Measure the heart rate and oxygen level.

   ii. Real-time data transmission.

   iii. Display the information collected by sensors.

2. To develop a mobile app (Blynk) that connected to the health monitoring system.

1.4 Project Significance

In this research, a newly developed health monitoring system that can transmit more extended range up to **2 km suburban** and give real-time health reports whenever and wherever construction is taking place.

1.5 Thesis Outline

The thesis report is organised into five sections: introduction, literature review, methodology, results and discussion, and conclusion. The first chapter will go through the research's background, research problem, research objective, and project significance.

The research literature review is explained in Chapter 2. It all starts with a health monitoring system in the background. The current authors' proposed strategy for health monitoring systems and their application will be discussed next. Next, the basic concept of vital human signals, such as pulse rate and oxygen levels, will be presented. LPWAN technologies such as LoRa, LoRaWAN with their classes were also introduced. Finally, this chapter will go over the comparison in LPWAN systems briefly.

In Chapter 3, the author will choose which model to create the system, the Waterfall model, Spiral Model, and Prototyping Model. Then, research approach is detailed using a conceptual framework, and design requirements. This chapter also covers how and what sort of hardware will be connected and the software that will be utilised in the design.

Chapter 4 presents the prototype results of the HMS device between Hotspots and LoRaWAN. The results will be presented based on distance measurement. Besides, the constraint of GPS will be analysed. Finally, the comparison between Hotspots and LoRaWAN will be explained in detail.

Chapter 5 focuses more on the summary of the research. The suggestion and recommendations for future research are also stated.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

A basic explanation of the health monitoring system (HMS) is provided in this chapter. Contemporary authors' proposed approach for HMSs will next be explained, along with the application. Next, the fundamental notion of vital human signs, including pulse rate and oxygen levels, will be discussed. Then there were LPWAN technologies like LoRa, SigFox, Fiber-Optics, WI-SUN, NB-IoT, DASH7, and SNOW. Finally, this chapter will provide a brief explanation of cost estimation and comparison among LPWAN systems.

2.2 Human Health Monitoring System

2.2.1 Overview

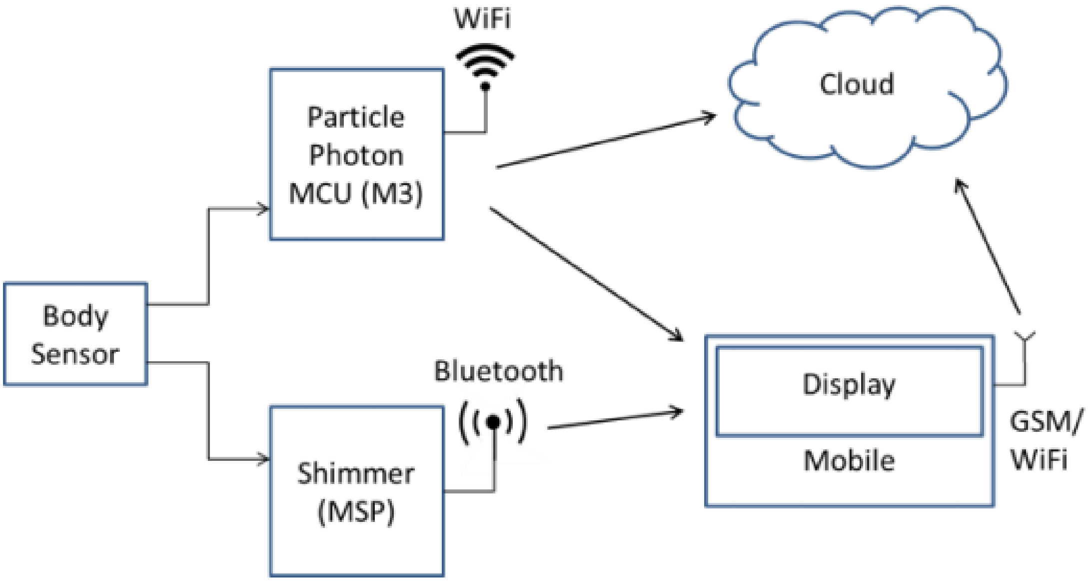
A HMS measures the vital indicators of the human body regularly. Health monitoring is critical because it provides medical practitioners with the information, they need to analyse a patient's status and diagnose the problem they are experiencing. However, today, the HMS is built fast because it cannot provide real-time health updates and is constrained by distance. This project aims to create a functioning prototype of a wireless HMS that can update health information regardless of time or location.

The phrase "health monitoring" refers to tracking a wide range of physiological indicators. One of these signals is heart rate, which is linked to the state of the body's circulatory system. Recently, heart rate monitoring has been accessible from manufacturers using an onboard or wearable heart rate sensor. Although heart rate monitoring is usually utilised for individual usage, especially in sports, it may also be used as part of a warning system for persons at risk while participating in physical activity and for the elderly [15].

2.2.2 Current Health Monitoring Systems

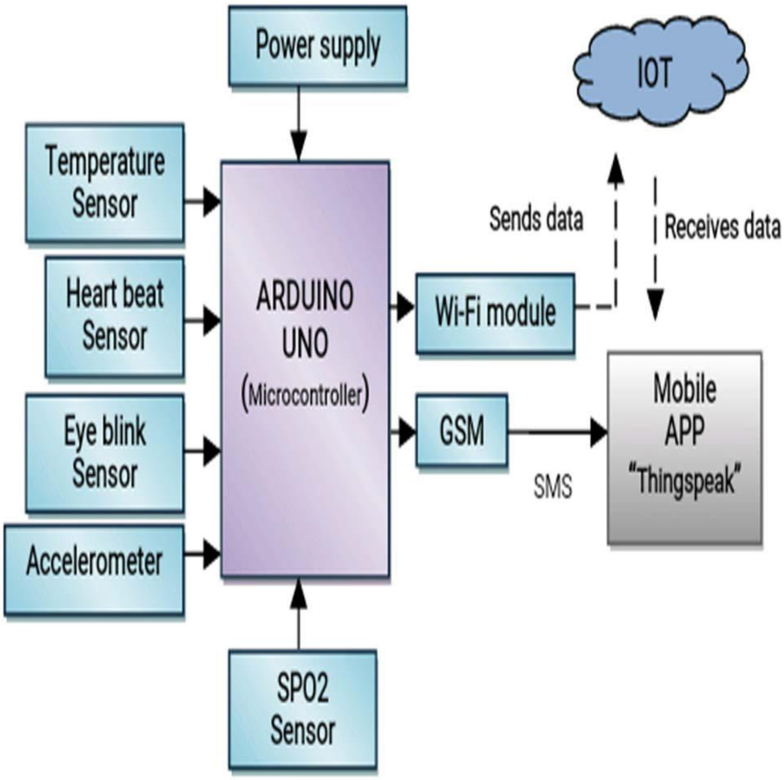
P. Jangra and M. Gupta [16] demonstrated an IoT-based intelligent healthcare monitoring system that uses biological signals to provide real-time patient surveillance. Biosensor-based data gathering, and aggregation utilities benefit from the proposed multi-layered structure. In high-stress conditions, it also leads to creating a real-time, efficient decision-making system. Moreover, before transmitting data to the edge node, this strategy may compress data perceived by sensors, lowering the amount of power required by the sensor device to provide the sensed data. After then, an intelligent node, which may be a smartphone, a laptop, or a tablet, will get this minimally processed data. The remaining processing is finished here, and the obtained data is then delivered through the internet to medical personnel and doctors. A mobile app might be developed to make the edge node more intelligent and smarter. The proposed design is simulated using LABVIEW software.

Meanwhile, an EPIC sensor system detects Heart Rate (HR) and Respiration Rate (RR) before delivering the data over Wi-Fi connectivity to mobile platforms or the cloud, according to Hegde et al. [17]. When combined with a proper analogue pre-processing board, all body sensors can be sampled using a low-power microcontroller. Instead, as indicated in **Figure 2.1**, a shimmer approach may be used to test the sensor; it transfers data to a smartphone at a shorter distance through Bluetooth. Consequently, the shimmer device has the benefit of allowing the output to be pre-filtered 3D orientation and synchronised with the sensor data. Furthermore, the receiving device can take many forms, and data may be taken and transmitted immediately to the cloud through Wi-Fi; the transmitted data is saved and processed further in the cloud. The smartphone enables real-time or offline data editing and exhibits on the phone screen.



3Figure 2.1: Internet of Things Monitoring Network [17]

Tamilselvi et al. [18] proposed technique was created utilising the ThingSpeak IoT technology as shown in **Figure 2.2**. In this system, the Eyeblink and SPO2 sensors are also employed to monitor the coma patients' eye blink and oxygen saturation percentages. All the sensors in the proposed architecture and their output values are used to monitor the health of coma patients. These sensors have been utilised in IoT to transmit medical data via the ESP8266 Wi-Fi module, and the patient's data may be saved, analysed, and shown as graphs. Additionally, it may be seen via a mobile application.



4Figure 2.2: Health Monitoring System by using mobile app Thingspeak [18]

V. Yeri and D. C. Shubhangi [19] also proposed an almost similar system from [18]. The main difference is that sensors such as pulse, temperature, and SpO2 sensors are used in the proposed framework. The system monitors patient health by measuring data in real-time and displaying them on the LCD and cloud. The Wi-Fi module sends the sensor data to the cloud. A warning message is provided to the mobile application if the sensor data is not within the allowed range.

Shubham et al. [20] developed a method in which various medical equipment, such as sensors and online or mobile-based apps, are used to provide world-class medical care to patients even if they live in remote areas without access to emergency clinics. For example, RASPBERRY PI is used to monitor the patient's heart rate and blood pressure and communicate this information to their family members and doctor, keeping them up to speed on any medical emergencies that may arise. The data is then scrutinised, and chronic problems or other ailments, such as respiratory failures in the preliminary stages, are identified using data mining techniques for better decision making.

Shaown et al. [21] presented an ECG sensor network that would gather physiological data from the body's surface and wirelessly send it to the IoT cloud Amplification, filtering, and other signal processing techniques enhance the ECG signals. As a result, sensor-collected ECG data is wirelessly transmitted to the IoT cloud. The limitation of Bluetooth and ZigBee communication ranges and the usage of Wi-Fi in the authors' suggested system is a shortcoming of this proposed technique.

All the authors stated above did not consider an extended coverage area when using all the current health monitoring devices and instead evaluated within narrow geographical and indoor zones. Existing IoT-based healthcare challenges, such as high-cost 3G/4G communication lines, data privacy, and a lack of knowledge about monitored health metrics, are now a source of worry. There have been several deployments and suggestions to address these problems. In developing a better healthcare monitoring system, energy efficiency, portability, dependability, ease of use, and cheap cost with high functionality should all be factored in. By combining medical sensors, cloud, and gateways, LoRa is proven to tackle all these concerns.

2.3 Vital Signs of the Human Being

Medical professionals take the most fundamental of human biological processes called vital signs. These vital indicators are crucial because deviations from the typical threshold or present situation indicate malfunctioning biological processes. Likewise, by frequent updates on vital sign measurements, a pattern may be established to determine if a patient is improving or deteriorating.

These assessments may appear basic, yet they foreshadow a future ailment or symptom that the patient would experience. The five vital signs measured are respiration rate, pulse rate, blood pressure, body temperature, and oxygen levels. However, this research, only two vital signs are considered:

2.3.1 Pulse Rate

The heart is amongst the most critical systems in the human body. Healthy persons have a pulse rate of 60 to 100 beats per minute [22]. As blood is pumped, the blood artery expands to meet the increased pressure, then contracts as the pressure falls to avoid blood backflow. The pulse rate is when an artery expands and contracts to assess vital indicators. The pulse rate is significant because it reveals if the heart is pumping at an average threshold.

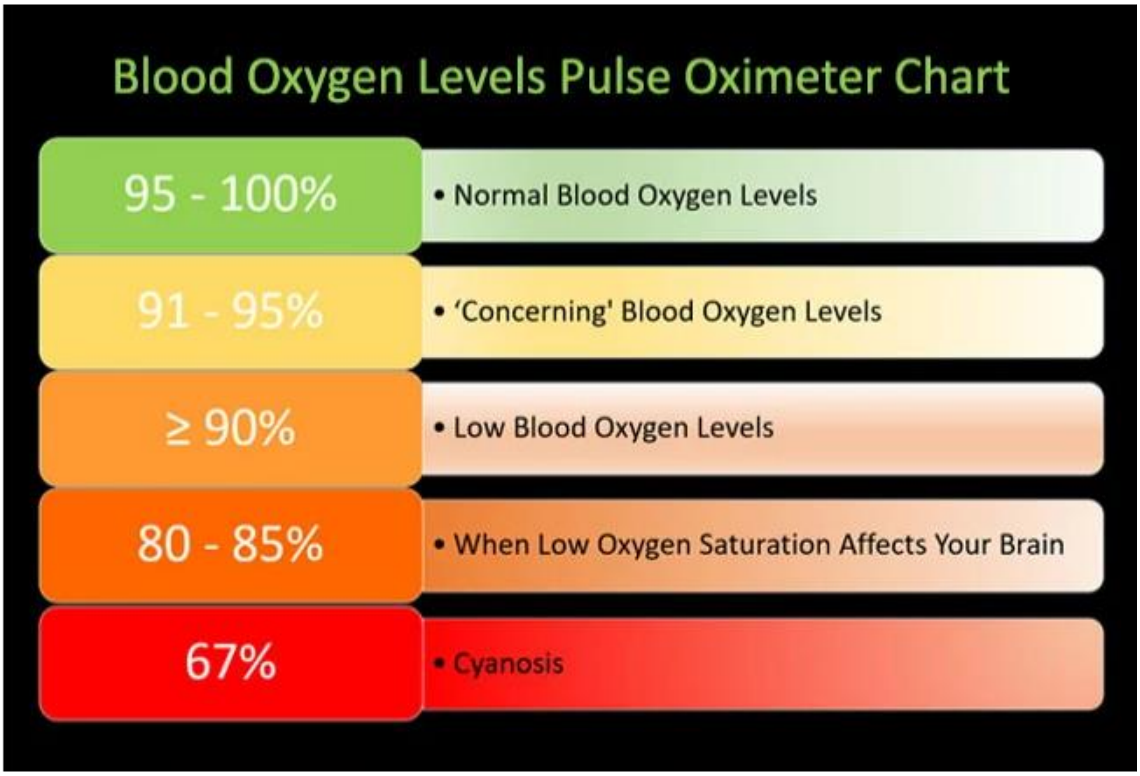
An erratic or non-existent pulse rate might signal that the heart isn't beating in an emergency, preventing oxygenated blood from reaching the body. Patients may die because of this if it is not addressed. Aside from that, a continuously fast heart rate (tachycardia) or a slow resting heart rate (bradycardia) might be signs of impending difficulties that can be discovered using pulse rate trending. However, it should be mentioned that the typical pulse rate changes depending on the stage of human development. The discrepancy is seen in the **Table 2.1** below:

1Table 2.1: Age Range for Average BPM [23]

Age Range	**Heart Rate (beats per min)**
New-born	100 - 160
0 - 5 months	90 - 150
6 - 12 months	80 - 140
1 - 3 years	80 - 130
3 - 5 years	80 - 120
6 - 10 years	70 - 100
11 - 14 years	60 - 105
>15 years	60 - 100

2.3.2 Oxygen Level

The amount of oxygen in a person's blood (also known as blood oxygen saturation) is called the blood oxygen level [24]. This is because our bodies require a specific amount of oxygen to function correctly. When breathing (inhaling), oxygen enters the body through the nose or mouth and travels through the lungs before entering the bloodstream. The oxygen then travels to every cell in the body via the bloodstream. Cells will release carbon dioxide after utilising oxygen. The carbon dioxide is then returned to the lungs by the bloodstream, where it is exhaled (breathed out) through the mouth or nose.



5Figure 2.3: Oxygen Level Chart

Figure 2.3 demonstrates how oxygen levels are calculated based on how much oxygen saturates a person's blood. According to [24 – 27], a normal oxygen level is usually 95% or higher. However, some people with chronic lung disease or sleep apnea can have normal levels of around 90%. The **SpO2** reading on a pulse oximeter shows the percentage of oxygen in someone's blood.

Two vital indications that will be evaluated in the project are heart rate and oxygen level. The system's goal is to create a wireless HMS that can track these two vital indicators.

2.4 LPWAN Technologies

2.4.1 Overview

The LPWAN is a viable alternative for IoT and HMS applications requiring long-range and low-power connectivity. LPWANs, or resource-limited networks, are defined by their long battery life operation, expanded coverage, high capacity, and low device and implementation costs [28].

In addition, the way assets and processes are remotely monitored and controlled is being redefined by LPWAN. It's intended for IoT telemetry applications that regularly communicate small amounts of data.

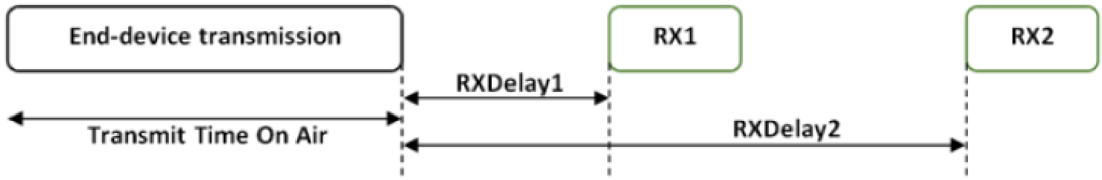
2.4.2 LoRaWAN and LoRa

LoRa is a physical layer technology based on the chirped spread spectrum (CSS) technique that operates on unlicensed sub-GHz industrial, technical, and clinical (ISM) channels. [28]. LoRa CSS modulations provide accurate bidirectional communication. The resultant signal is low in noise, extremely resistant to interference, and difficult to identify or disrupt. [11]. Meanwhile, the LoRa Alliance, a membership group, has created LoRaWAN, a wireless technique based on ISM for long-range, low-power, low-data-rate applications.

The LoRa network is designed in a star-of-stars architecture, with a gateway node relaying messages among end-devices and a central connecting server. LoRa defines three distinct classes of end-devices (Class A, Class B, and Class C) to serve the numerous applications with varying requirements. These classes provide a trade-off between downlink communication, latencies, and energy efficiency [14].

2.4.3 Class A (bi-directional end-devices)

Depending on the application, Class A end-devices offer bi-directional communications with two brief downlinks after each uplink transmission receive slot. This class is the most inadequate power end-device system for IoT applications requiring short downlink communication only after sending an uplink message [11], [29]. Any other time, downlink transmission will have to wait until the end device's following uplink message, as shown in **Figure 2.4**.



6Figure 2.4: Class A LoRaWAN bidirectional communication [11]

2.4.4 Class B (with scheduled receive slots)

Allow additional receive windows to extend the Class A random receive window at predetermined periods. The gateway node sends a time-synchronization signal to end devices, letting the server know when they listen.

2.4.5 Class C (with maximal receive slots)

Receiving windows on end devices are virtually always open. This class consumes a lot of energy and is designed for IoT applications involving constant energy power supplies.

2.4.6 SigFox

Based on [30], it is a proprietary LPWAN system that employs Ultra-Narrowband (UNB) modulation. UNB provides effective spectrum usage, which leads to increased network capacity and lower power usage.

In Europe, SigFox uses duty-cycled transmission at per cent 1. In comparison to other LPWA systems, SigFox has a low data rate [28]. SigFox only supports 140 12-byte messages per day, with each transmission requiring three seconds. Moreover, SigFox sends the communication numerous times to ensure dependability, resulting in considerable energy usage.

2.4.7 NB-IoT (Narrowband Internet of Things)

NB-IoT [31] is a LPWAN system that uses only a tiny percentage of the potential spectrum. It can accommodate up to 50 thousand devices per cell and requires at least 180 kHz of bandwidth to communicate.

It may be used as a self-contained carrier with more than 180 kHz of the accessible spectrum, inside an LTE physical resource block, or within an LTE carrier [32]. By not mapping signals to the resources consumed by LTE transmissions, NB-IoT preserves the orthogonality of LTE signals.

2.4.8 Fiber-Optics

Fibre-optics [33], which is well established in linking substations and control centres, initially met the need to provide enough data across oceanic distances to sustain the Internet. They are the product of significant technical improvements in fibre attenuation and laser technology, such as the GaAs laser [32].

It works by sending light pulses through specific glass fibres to send data. For example, the infrared wavelength employed over the visible red might be 850, 1300, or 1500 nm. A transmitter generates an optical signal, which is then sent through the fibre. The signal is reflected into the fibre due to 100% internal reflection and remains confined. This is the cause of the low attenuation measured, which can be as low as 0.2 dB/km in the 1.55 m spectral bands.

2.4.9 WI-SUN (Wireless Smart Ubiquitous Network)

The IPv6 sub-GHz mesh technology for innovative urban and utility applications is called WI-SUN [34]. Wi-SUN makes it possible for wireless mesh networks to be interoperable, multi-service, and secure, providing Smart Ubiquitous Networks to service providers, utilities, municipal governments, governments, and other enterprises. Wi-SUN can also be used for large-scale outdoor IoT communication systems in several applications, including line-powered and rechargeable battery-powered nodes.

The Wi-SUN Alliance has approved the Wi-SUN hardware from Silicon Labs, a worldwide industry organisation dedicated to uninterrupted LPWAN connectivity. Internet protocols (IP) and APIs are the foundation of Wi-SUN, allowing developers to create new features for current infrastructure platforms. Wi-SUN is a scalable wireless infrastructure solution that enables the development of smart cities and simplifies wireless infrastructure for commercial applications with long-range capabilities, high data speed, and IPv6 compatibility.

2.4.10 DASH7 Alliance Protocol (D7A)

DASH7 [35] is a non-profit mutually beneficial trade organisation formed to promote the protocol standard's existence and continued development. D7A is an Open Standard for bidirectional, sub-GHz medium-range wireless communication designed for ultra-low sensor-actuator applications using private networks. It is also an ISO 18000-7 standard for Active RFID that works in the sub-GHz ISM bands.

The protocol description is open source and does not require any patents or licences to be used. Also, its local synchronisation and novel addressing function upgrade hundreds of sensors simultaneously, dramatically lowering upgrading time.

2.4.11 SNOW

SNOW [28] is a new asynchronous LPWAN technique that can overcome the scaling restrictions of conventional LPWAN systems. The topology of SNOW is a star network. The nodes are linked to the base station and contrarywise. The base station employs a broad channel divided into orthogonal subcarriers of identical spectrum width.

SNOW is a unique physical layer architecture that overcomes the scalability restrictions of conventional LPWAN solutions. Not just that, its scalability grows in tandem with the accessibility of the TV spectrum.

2.5 Research Gap

Table 2.2 shows the comparison between LoRa and other available communication technologies, and LoRa shows that it has a high communication range with a lower data rate, making it the optimum choice for IoT-based HMS. Besides, its standard provides flawless compatibility between IoT products. Not only that, but other cost elements to consider include spectrum (licencing), deployment, and end-device prices. **Table 2.3** illustrates that LoRaWAN has a cost advantage over Sigfox and NB-IoT in terms of deployment.

2Table 2.2: Comparison of LPWAN Technologies

Network Technologies	**Topology**	**Modulation**	**Frequency Band**	**Range**
LoRa [9], [14]	Star	CSS	860 to 1020 MHz	Urban: 15 km Rural: 20 km
SigFox [11]	Star	BPSK	862 to 928 MHz	Urban: 10 km Rural: 40 km
Fiber-Optics [12], [32]	Star, Ring, Bus and Tree	NRZ format	Not applicable (wired)	AON: 10 km EPON: 20 km
WI-SUN [28], [32]	Mesh	FSK	Japan: 902 to 928 MHz Europe: 863 to 876 MHz	~5 km
NB-IoT [11 - 12]	Tree	QPSK, OFDMA (UL), SC-FDMA (DL)	B85: Uplink Band: 698 to 716 MHZ Downlink Band: 728 to 746 MHz	Urban: 1 km Rural: 10 km
DASH7 [28]	Star, Mesh and Tree	GFSK	433.05 to 434.79 MHz	0 to 5 km
SNOW [36]	Star	BPSK	547 to 553 MHz	5 km

3Table 2.3: Cost Estimation for LPWAN Technologies [9]

LPWAN Technologies	Spectrum Cost (RM)	Deployment Cost (RM)	End-device Cost (RM)
LoRa	Free	>4721.46 / Base Station	14.16 to 23.61
SigFox	Free	>18885.84 / Base Station	<9.44
NB-IoT	>2360.73M / MHz	>70821.91 / Base Station	>94.43

In conclusion, the LoRaWAN architecture is relatively simple to integrate into IoT infrastructure. LoRaWAN applications are also economically possible due to deployment on frequencies that do not require a licence and low-cost base stations. Not just that, the cheap cost of LoRaWAN IoT devices allows them to function for years on a single battery, lowering device maintenance expenses.

Chapter 3

METHODOLOGY

3.1 Overview

The approach for developing this system is proposed in this chapter, and the types of hardware and software employed. Aside from that, the basic process and flowchart of the system configuration were also shown to comprehend the project's goal and purpose better. The intended notion is merely the first step in carrying out the project. A few tweaks might be made to the system to improve it further with fresh ideas and development. This chapter demonstrates how and what sort of hardware will be linked, followed by the type of software used in the project. The study's progress will be demonstrated using a flowchart and Gantt Chart. The flowchart and Gantt Chart is presented in **APPENDIX B** section.

3.2 Introduction to Design Methodology

For this project, LoRaWAN technology is used to create a healthcare monitoring system that contains the following features: minimising physical mobility indoors, improving distance limiting, and developing a user-friendly application. Therefore, it is critical to use the proper design process to create a high level of functionality. The system development technique is a framework for planning, structuring, and controlling the development of an information system. When a designer decides which model to create the system, the Waterfall model, Spiral Model, and Prototyping Model are the standard's three primary System Development Methodologies [29-30].

Therefore, three models have been reviewed to select the appropriate model for this project: the Waterfall model, the Spiral Model, and the Prototyping model. The following criteria define the significance of Design Methodology in system design:

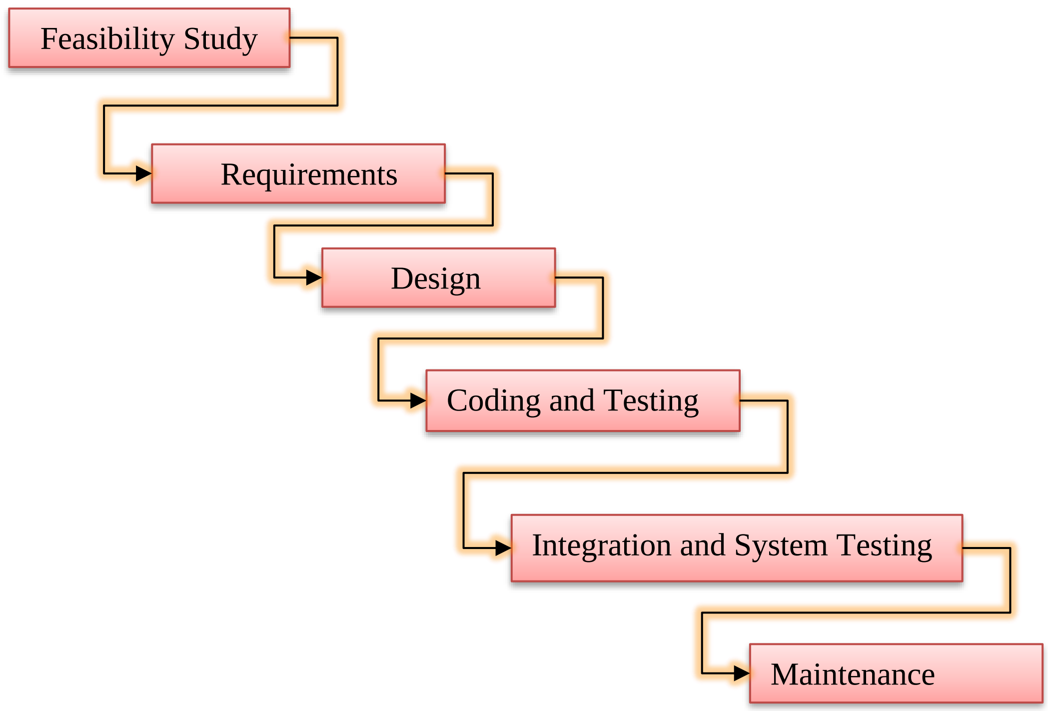
i. Can estimate the cost of a system's design,
ii. Reliable, accurate in terms of functioning, and capable of providing a high-quality product,
iii. Function correctly without substantial errors,
iv. Capable of avoiding supplying a defective system to the customer.

Next, the basic software and hardware needed in this project will be discussed. Besides that, the prototyping model will be chosen to implement in this project.

3.2.1 Waterfall Model

A waterfall model is a prominent system development life cycle model in software engineering. The waterfall model represents an inflexible and linear development technique. The classic waterfall model divides the life cycle into stages. This paradigm assumes that one phase can begin after completing the preceding phase [39]. Consequently, the waterfall model may view the development process as a sequential flow.

In a nutshell, this model is appropriate for this project since, as the development progresses, it works well for smaller projects with well-defined criteria. Not only that, but each model phase is adequately delineated, and the process, activities, and outcomes are thoroughly recorded. Therefore, the waterfall model will be used to achieve project objectives. **Figure 3.1** shows the waterfall model.

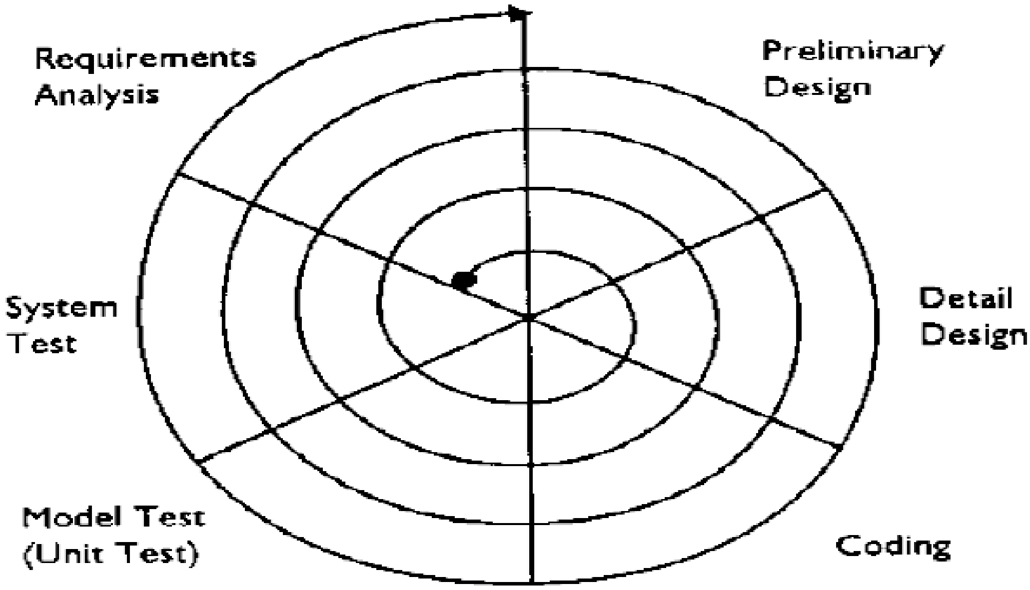


7Figure 3.1: Waterfall Model

3.2.2 Spiral Model

The spiral model, often known as the spiral lifecycle model, is one of the most prominent Software Development Life Cycle models, focusing on early risk reduction and project risk identification [40]. It seems to be a spiral with multiple loops in **Figure 3.2**. The exact number of spiral loops is unknown and varies between projects. However, each spiral loop is a stage in the software development process. Consequently, the project leader may alter the precise number of phases necessary to develop the product associated with the project risks.

This spiral model is not suitable for healthcare monitoring projects because the spiral model is focused on expensive, larger, and complex projects. In contrast, this project targets simple, cheaper, and reliable designs.

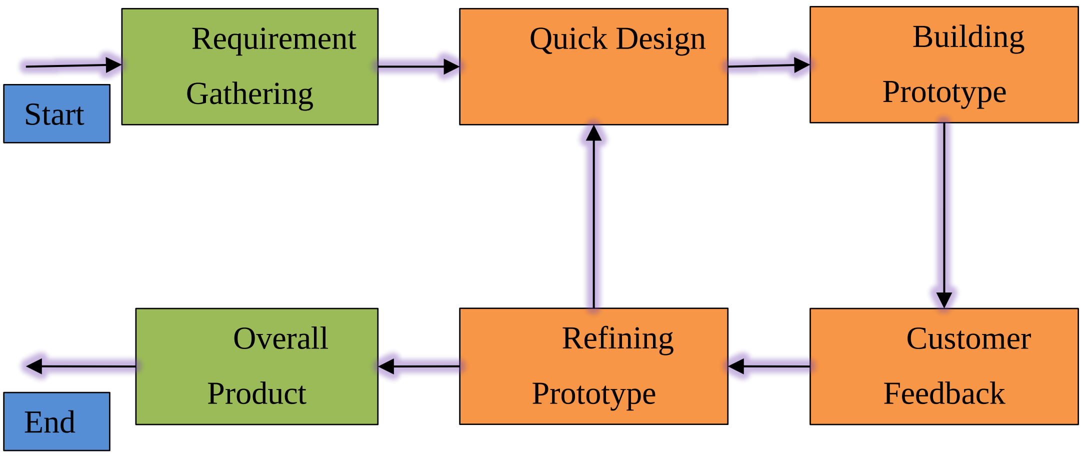


8Figure 3.2: Spiral Method

3.2.3 Prototyping Model

The prototyping model, which creates the system based on already known requirements, is one of the most often used Software Development Life Cycle Models (SDLC models) [41]. Prototyping is appropriate for systems that lack an established system or a manual procedure for establishing conditions. The prototype is an early rendition of the final design. In this method, a prototype of the eventual product is developed, analysed, and enhanced based on customer feedback until a final appropriate prototype is reached, which serves as the groundwork for building the product. Because not all criteria are known in-depth, the prototyping method is not suitable in this HMS design.

This approach has inadequate documentation as a by-product of constantly changing customer needs, time and money consuming and having too much fluctuation in the circumstances each time the customer reviews the prototype. The prototyping model is visualized in **Figure 3.3.**



9Figure 3.3: Prototyping Method

3.3 Hardware and Software

The hardware that will be used in this project includes Cytron Maker Uno/Arduino Uno R3, Dragino LoRa BEE GPS Shield 915MHz, Dragino LoRa Shield v1.1 915MHz, LoRa Gateway, Antennas, NodeMCU ESP8266, Cytron Shield-ESP-WiFi Rev 2.0, Jumper Wires, Breadboard and Oximeter MAX30100 as shown in **Figure 3.4, Figure 3.5, Figure 3.6, Figure 3.7, Figure 3.8, Figure 3.9, Figure 3.10, Figure 3.11, Figure 3.12, Figure 3.13,** and **Figure 3.14** respectively. To interface with the hardware, Arduino IDE - A Software which can interact with Arduino board and Blynk application was needed as shown in **Figure 3.15** and **Figure 3.16.**

3.3.1 LoRa Gateway

10Figure 3.4: LoRa Gateway-LG01

Figure 3.4 shows a LoRa Gateway. Basically, a gateway is an actual box or exterior sheathing containing the technology and software needed to connect IoT devices to the cloud. A gateway serves as a hub for IoT applications to dump information that has been identified and links that information to distant networks. A similar device to a gateway is a Wi-Fi router. It has a LoRa concentrator that enables it to gather RF signals sent by LoRaWAN devices and transform them into a signal compatible with a server, similar to Wi-Fi, to relay data to the cloud.

Although gateways are frequently placed in overlapped groups, a LoRaWAN gateway may serve many groups of devices simultaneously. Devices will broadcast their signals as RF packages, picked up by any gateway in range, with the most robust machine link transmitting the message to the server. The presence of numerous gateways strengthens a network's resilience if one of them fails. Additionally, when a gateway picks up an RF signal, it is transformed to a format that allows for quicker transmission rates.

The data transfer rate of LoRa, 50Kb/s, is sufficient for device-to-device or device-to-gateway information exchange [14], [29]. Still, it would indicate a severe bottleneck when attempting to deliver hundreds of messages to the cloud – and the need for a well-designed gateway to enable higher levels of information transmission from the gateway to the server. For speed, connectivity between a gateway and the cloud is generally placed through ethernet, although LTE and Wi-Fi are also viable options in outdoor areas.

3.3.2 LoRa Shield and LoRa GPS Shield

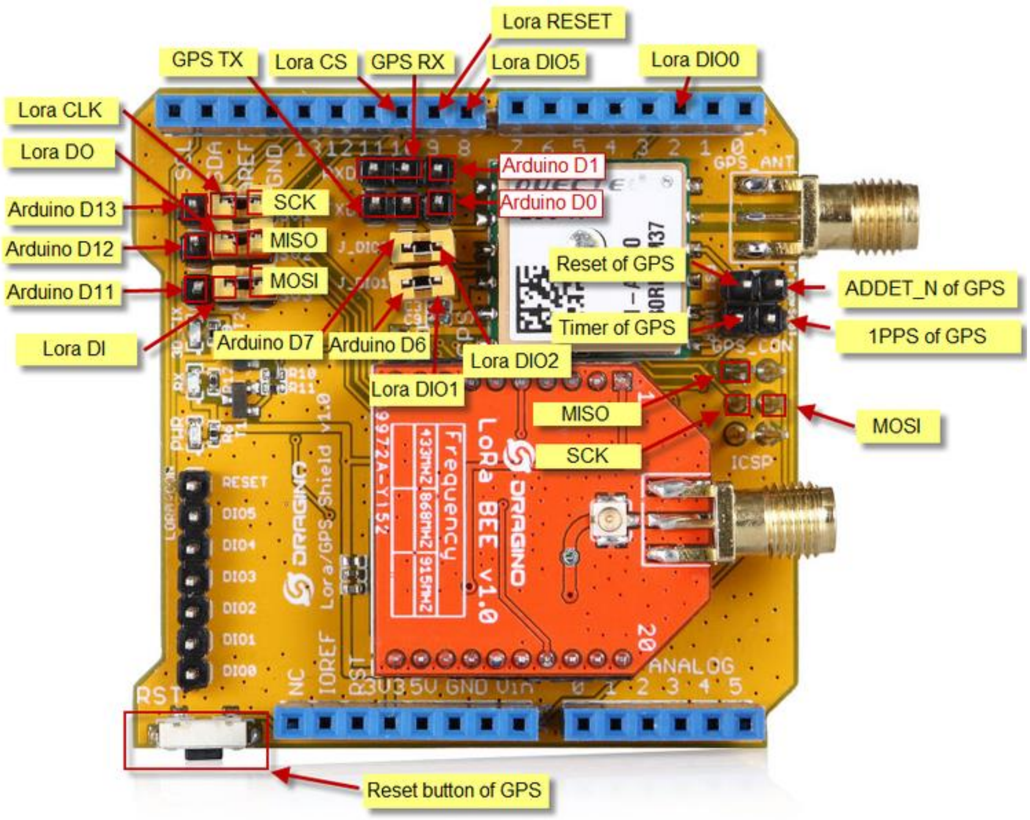
11Figure 3.5: LoRa Shield, LoRa GPS Shield and Arduino R3 Uno

Figure 3.5 shows the LoRa shield, LoRa GPS Shield and Arduino Uno. Based on the figure, the Dragino LoRa GPS Shield is an Arduino-based LoRa-GPS expansion board. This product is meant for individuals who want to create LoRa-GPS applications. The LoRa-GPS Shield is divided into the LoRa-GPS Shield motherboard and the Lora BEE [14].

The LoRa component, the LoRa-GPS Shield, is built around an SX1276 or SX1278 transceiver. LoRa-GPS Shield transceivers employ the LoRa long-range modem, which provides ultra-long range spread spectrum communication and strong noise resistance while consuming the slightest amount of power. Furthermore, compared to conventional modulation techniques, LoRa offers considerable benefits in blockage and selective, resolving the customary design trade-off between distance, interfering resistance, and energy usage.

In terms of GPS, the incorporated L80 GPS is intended for systems that have a GPS attached to the Arduino through serial ports, such as timed applications or generic applications involving GPS information. This GPS module can generate trajectories independently using ephemeris data saved in inbuilt flash storage. The shield can instantly establish its position, even at low-power indoor signal levels.

The Lora/GPS Shield's AlwaysLocate technology has allowed it to change the on/off balance localization accuracy and energy consumption based on ambient and motion circumstances [14]. The GPS also has an automatic antenna switching feature. It can toggle between an internal patch antenna and an external active antenna. What's more, it maintains its place during the changeover procedure. **Figure 3.6** shows the GPS Shield pin:



12Figure 3.6: Pin Definition of LoRa GPS Shield [14]

3.3.3 Antenna

13Figure 3.7: Antenna

Figure 4.7 shows the antennae that will be use in this project. This GPS module has a 15x15x4 antenna array. The GPS module will automatically transition between both the patch and external antennas. The GPS module's RF component is temperature sensitive. There are three types of antennae which are:

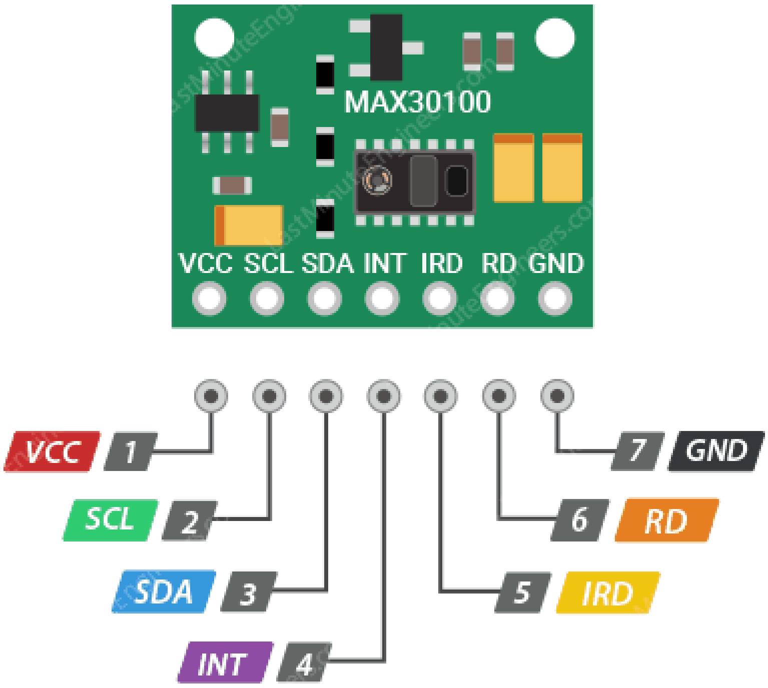
a) SMA antenna cables: The SMA cable could be used with an adapter to link the LoRA antenna to the flattened antenna cable. Another length should be used with an adapter to connect to a Helium Miner-Hotspot.
b) Antenna mounting equipment: The external antenna will need to be securely mounted at a height.
c) Antenna weatherproofing equipment: The antenna's lifetime will be increased by utilising appropriate weatherproofing, such as Coax-Seal, to seal and protect the antenna connections visible outdoors.

3.3.4 NEO-6M GPS Tracking

14Figure 3.8: Neo-6M GPS Tracking

Figure 3.7 shows the standalone receiver is used to collect the geographical coordinates of the real-time location of the shuttle bus with a 50-channel u-blox 6 position engine. The engine is competent in massive frequency space searches and can find the satellites immediately. Even in the most challenging environments, this receiver gives excellent navigation performance.

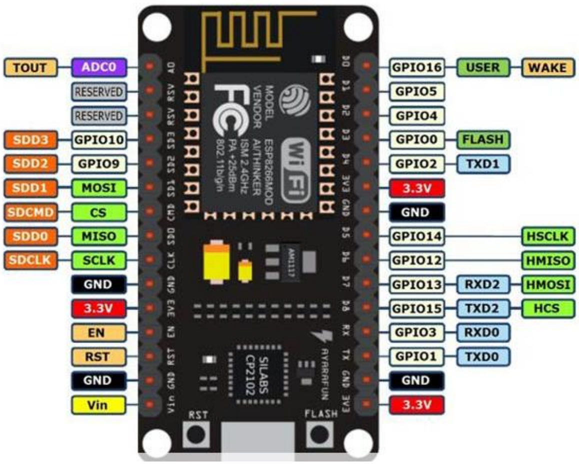
3.3.5 Oximeter MAX 30100



15Figure 3.9: Oximeter MAX 30100

As seen in **Figure 3.9**, the MAX30100 is integrated pulse oximetry (SpO2) and heart rate (BPM) system. It has two LEDs, a photodetector, better optics, and low-noise analogue signal processing to detect SpO2 and BPM values [42].

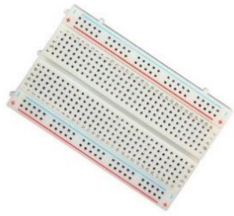
3.3.6 NodeMCU ESP8266



16Figure 3.10: NodeMCU ESP8266

NodeMCU ESP8266 as shown in **Figure 3.10** contains CPU, RAM, Wi-Fi integration, Bluetooth, existing operational system, and SDK. The built-in Wi-Fi and Bluetooth meets the demands of the project system for efficient power usage, a small design and adequate performance making it ideals for Internet of Things (IoT) projects. It can be powered using a Micro USB jack or an external supply pin. Moreover, the NodeMCU ESP8266 can be programmed with Arduino IDE with a very minimum requirement.

3.3.7 Breadboard



17Figure 3.11: Breadboard

A breadboard as shown in **Figure 3.11** is used to connect electrical components to test the circuit before soldering. For this project, the breadboard is used as a base for the whole components.

3.3.8 Jumper Wires

18Figure 3.12: Jumper Wires

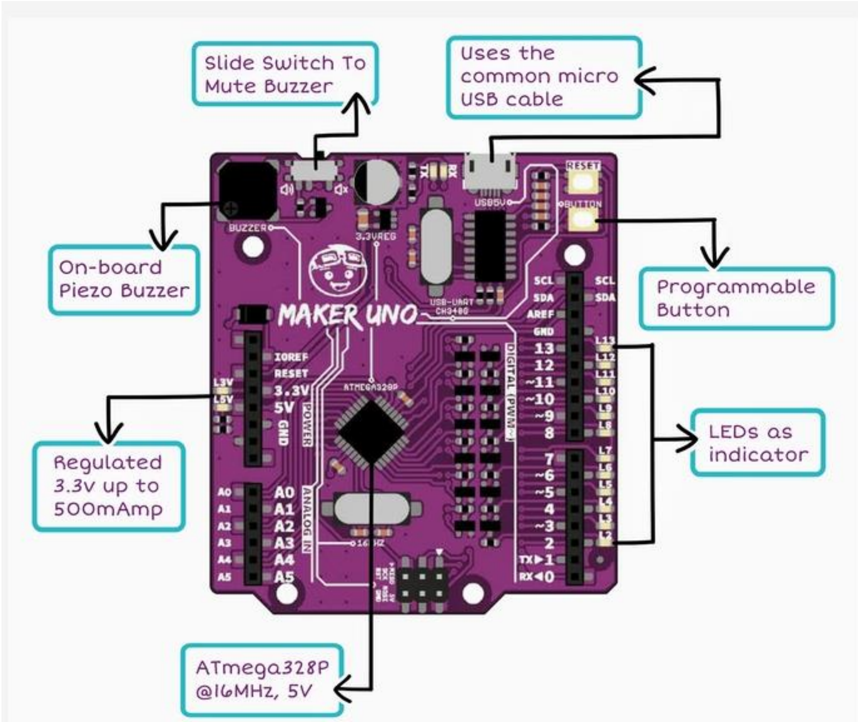
Jumper wires as shown in **Figure 3.12** are used to connect each component and are frequently used with breadboards to make it easy to change the route of the circuits

3.3.9 Cytron Uno and Cytron Shield-ESP-WiFi Rev 2.0

19Figure 3.13: Cytron Shield-ESP-WiFi Rev 2.0

As depicted in **Figure 3.13**, an ESP WiFi shield will be plugged in and used by Arduino users. A WiFi connection to the Arduino board is provided via the WROOM-02 module, which is preassembled with the shield. The shield can be stacked onto the Arduino UNO, Maker UNO, or any other compatible Arduino main board without further soldering or wiring required [43]. Then, using jumpers, choose the pins for serial transmission, and the hardware connection is complete.

Furthermore, the shield itself is not restricted to AT commands; most of the IO has been broken out, allowing for direct WROOM-02 module programming. This feature may be useful for adding custom AT commands or flashing custom firmware on the ESP8266, especially as it uses the UART pin selectors [43].



20Figure 3.14: Cytron Maker Uno

Arduino is an open-source hardware and software firm, initiative, and user community developing and producing single-board microcontrollers and microcontroller kits for creating digital devices. Building projects can be more straightforward with the Maker UNO, an Arduino-compatible board, as shown in **Figure 3.14**. With 12 integrated LEDs, a built-in buzzer, and button, coding and electronics are made simple and accessible [44 - 45].

3.3.10 Arduino IDE

21Figure 3.15: Arduino IDE [46]

The Arduino Uno R3 is a board with a microcontroller built on a detachable (DIP) dual-inline-package ATmega328 AVR microprocessor. The logo of this Arduino Uno R3 is shown in **Figure 3.15**. It features 20 digital input/output pins, of which six can be used as PWM outputs, and six can be used as analogue inputs. It may be programmed using the Arduino computer software [46]. The Arduino has an extensive support network, making it simple to get embedded electronics. It is the third and most recent version.

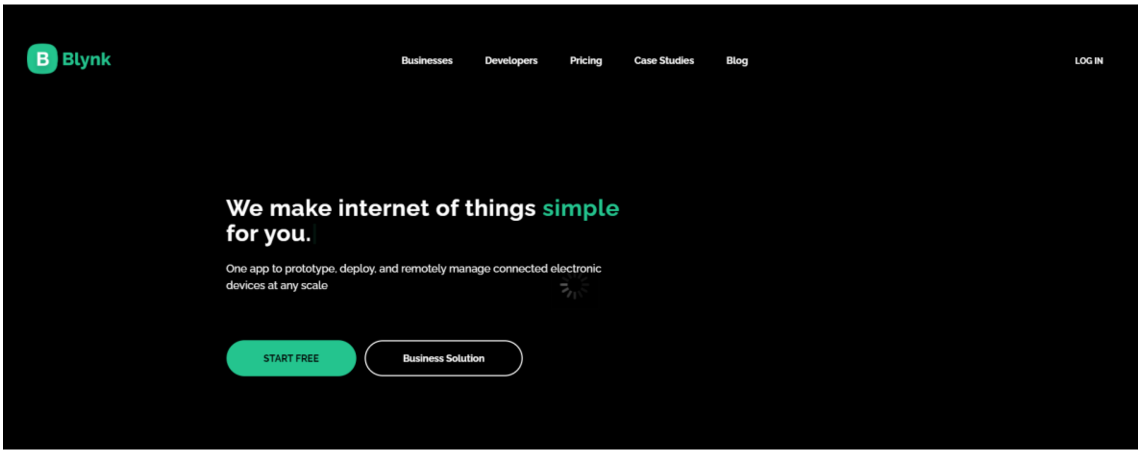
To get started, connect the Arduino Uno to a computer through a USB wire or power it via an AC-to-DC converter or battery. Arduino serves as the system's brain, processing sensor input. Arduino is an open-source hardware platform that may be used to develop projects worldwide. It includes an ATMEGA microcontroller, which analyses data and ensures the effective operation of the IoT system. And because the Arduino can be programmed 'n' times, you may create various IoT projects by modifying a basic code.

3.3.11 Blynk – IoT Platform Application

22Figure 3.16: Blynk IoT Platform Application

Blynk, **Figure 3.16** is a smartphone application that is available on Android and iOS platforms. It allows users to build interfaces for monitoring and controlling the hardware projects from a smartphone.

3.3.12 Blynk Server

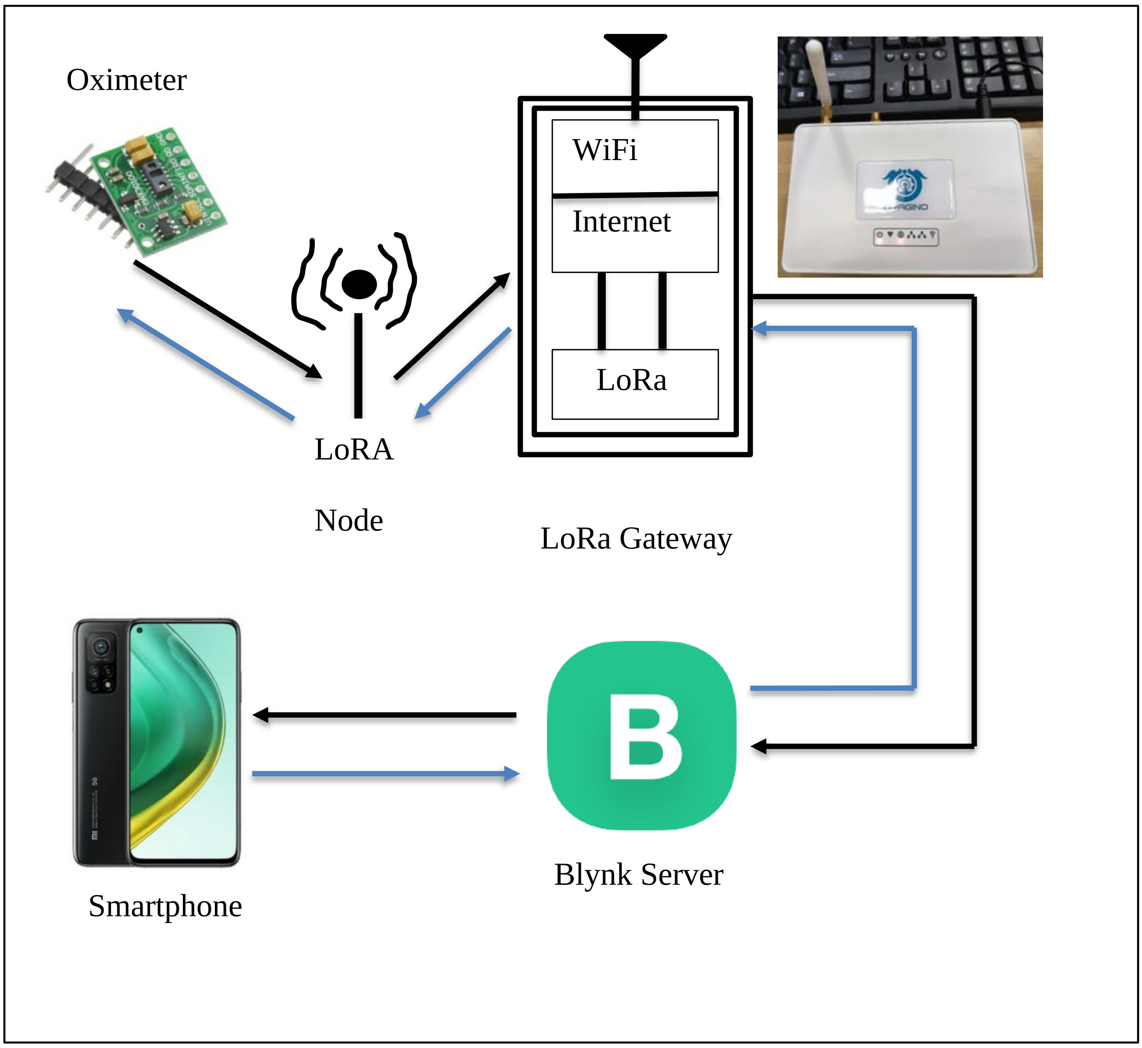


23Figure 3.17: Blynk Server

Figure 3.17 is the open-source cloud storage manages the database from the communications between the NodeMCU component and the Blynk application.

3.4 HMS Proposed Method

The author has selected a few bases to start building the prototype LoRaWAN system for the project. In short, the components chosen to match the system that the author desired to develop. The system under development is depicted in **Figure 3.16**:



24Figure 3.18: HMS block diagram

Figure 3.18 above shows the overall system block diagram of the HMS using LoRaWAN technology. Oximeter consisting of LoRa transmitter will transmit the information to LoRa chip at the gateway using LoRa wireless frequency.

Once the gateway has all the information needed from LoRa transmitters, the information gets collected to LoRa then transferred to the Internet. From the Internet, it goes to the Blynk Server.

From a smartphone, internet connectivity in the devices can retrieve the data and see all the values of the sensors on the devices. It works the other way around, where sensors can be controlled by using a smartphone.

3.5 Summary

The main idea for this chapter is to propose the method of designing this project and explain the workflow of this system. As shown in the previous section, the components that are crucial for this system consist of hardware and software. This section also states that proper System Development Methodologies is chosen by planned accordingly based on the framework for planning, structuring, and controlling. Based on the planning to design the prototype, the component selected to construct it had been confirmed. There are many available ways to choose, but this prototype was much more straightforward for LPWAN and required a lower cost to build.

Chapter 4

RESULTS AND DISCUSSION

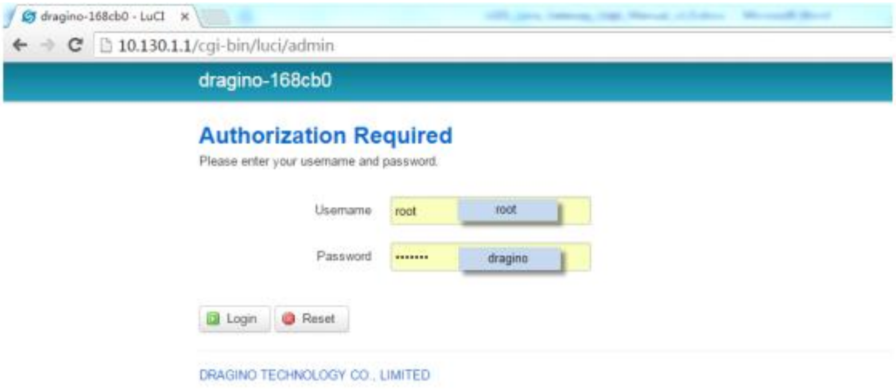
4.1 Overview

This chapter will illustrate the prototype's performance and the discussion that needs to be improved in the future. The final product operates as it should be, with minor adjustments needed to be carried out. The capability of this system is analysed in this chapter to prove that we had achieved the objective and solved the problem stated initially. Figures are included to verify that the system performs well as planned and show the part of a minor problem that occurred while conducting this project. The advantages and disadvantages were also included so others may analyse it to be used based on their project. Several limitations are achieved in this system but may be further improved with proper steps. Thus, allowing others to use this part of the report as an indicator or reference for their newly developed design.

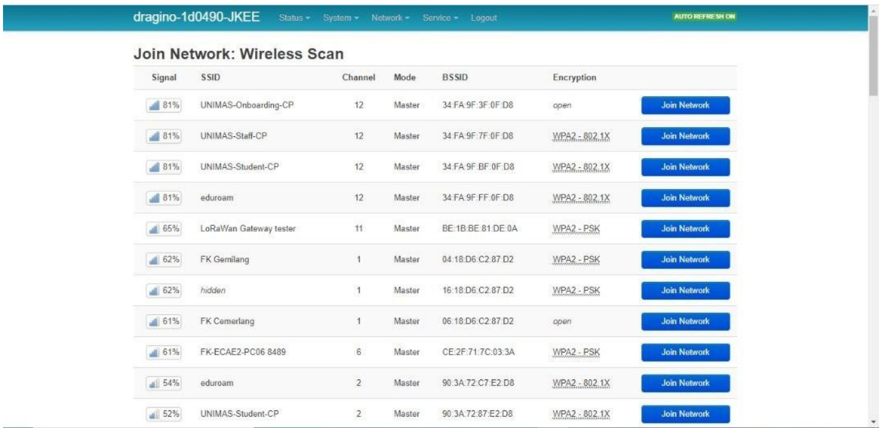
4.2 HMS Implementation

4.2.1 Set Up LoRaWAN Gateway

By default, the LG01 has a WiFi AP configuration. After joining the LG01's WiFi network, users can access and customise the device. A WiFi network called dragino 1d0490@CAE JKEE will be secured during the LG01's boot process. With the password PO210500225, users can connect their computer to this WiFi network. An IP address of 10.32.108.19 will be assigned to the computer. On the computer, launch the browser and enter 10.32.108.19. Users will see the LG01 login screen as depicted in **Figures 4** and **Figure 4.1**.



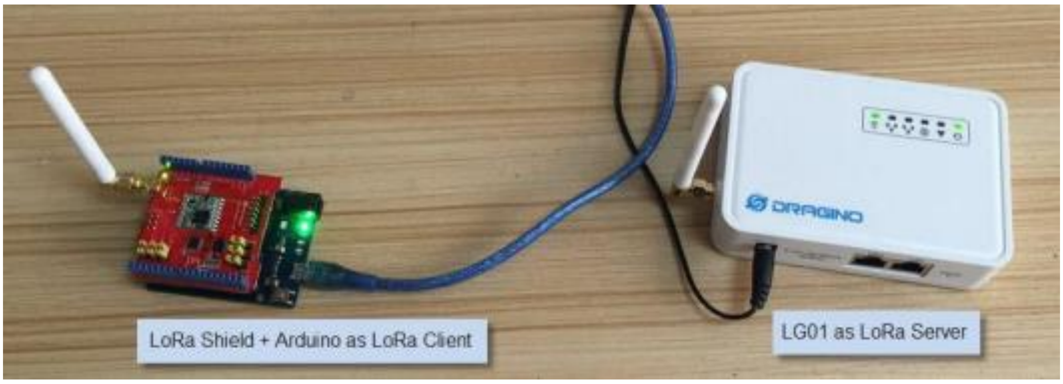
25Figure 4: LG01 Interface



26Figure 4.1: Network available in LG01

The MCU (microcontroller) M328P communicates with the LoRa Radio part and Dragino Linux module [47]. In addition, the Arduino IDE programming tool and C-based programming language are used to programme the MCU.

4.2.2 Connecting HMS device and GPS device to LoRa gateway



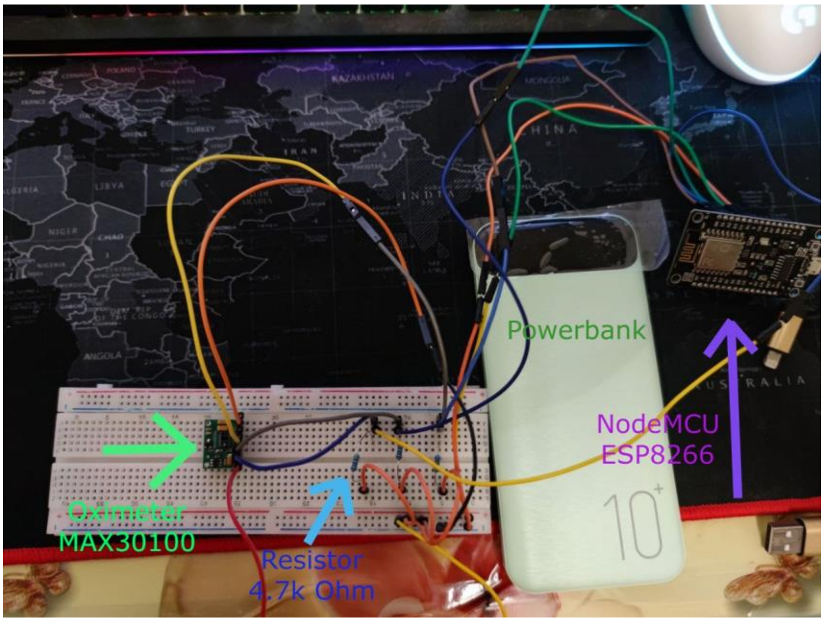
27Figure 4.2: Connecting HMS Device to LoRa Gateway

After installing all the libraries, including Blynk, Oximeter and LoRa, that are needed for this project, the device will be connected, as shown in **Figure 4.2**, via coding in Arduino IDE (refer to **APPENDIX A**, Code for Client, and Code for Server) in terms of client and server. The device will be the LoRa Client meanwhile, the LoRa gateway (LG01) will be the server.

4.2.3 Hardware and Software Construction

<u>**HMS Devices**</u>

i. NodeMCU ESP8266
ii. Oximeter
iii. 4.7k Resistor
iv. Breadboard
v. Jumper wires
vi. Powerbank



28Figure 4.3: HMS Device

Figure 4.3 shows the final product of the HMS device that will be connected to Hotspots and LoRaWAN for distance testing. The main problem of Oximeter MAX 30100 is that the 4.7kΩ pullup resistors in the sensor are connected to the 1.8V supply. Since it has a lower logic level than the NodeMCU 3.3V logic board, it will not be detected on the I2C bus. Therefore, after removing all the 4.7k pullup resistors from the board, the external pullup resistor 4.7k will be attached to the SCL, SDA, and INT signal lines to resolve this issue.

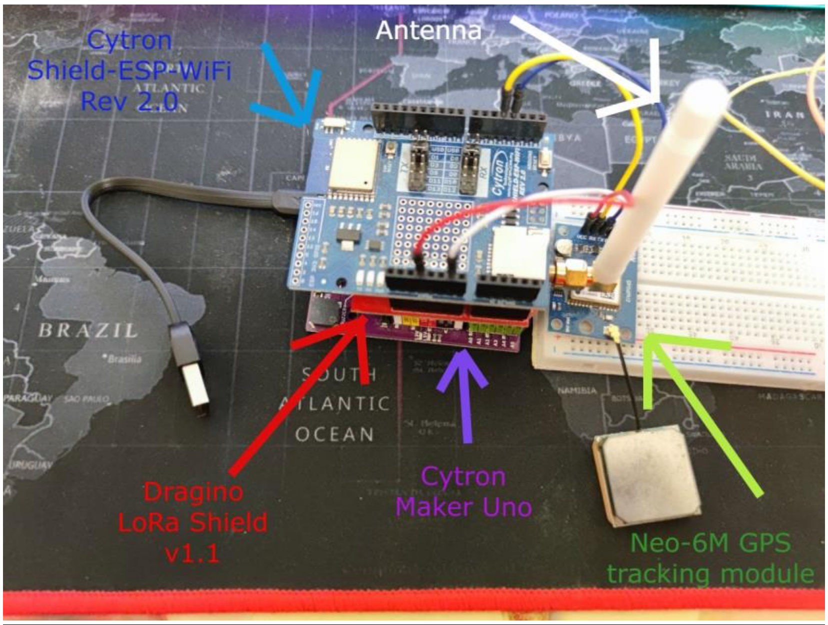
```
#include <Wire.h>
#define BLYNK_TEMPLATE_ID "TMPLScaBY7NO"
#define BLYNK_DEVICE_NAME "HMS Using LoRaWAN Technology"
#define BLYNK_AUTH_TOKEN "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ"
#include "MAX30100_PulseOximeter.h"
#define BLYNK_PRINT Serial
#include <Blynk.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

#include "Wire.h"
#include "Adafruit_GFX.h"
#define REPORTING_PERIOD_MS 1000

char auth[] = "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ";   // Auth Token in the Blynk App.
char ssid[] = "dragino-1d0490@CAE_JKEE";            // WiFi credentials.
char pass[] = "PO210500225";                        // WiFi Password

// Connections : SCL PIN - D1 , SDA PIN - D2 , INT PIN - D0
PulseOximeter pox;
```

29Figure 4.4: Connecting HMS device to Blynk

Figure 4.4 above shows the coding where the HMS device is connected to Blynk using LoRaWAN. A complete coding for both LoRaWAN and Hotspots can refer to **APPENDIX A**, Coding for LoRaWAN and Coding for Hotspots.

GPS Tracker

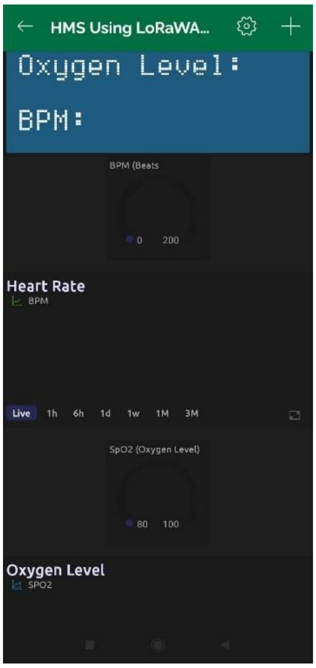
i. Neo-6M GPS tracking module
ii. Cytron Maker Uno
iii. Cytron Shield-ESP-WiFi Rev 2.0
iv. Dragino LoRa Shield v1.1
v. Breadboard
vi. Jumper wires
vii. Laptop/Computer



30Figure 4.4: GPS Tracking Device

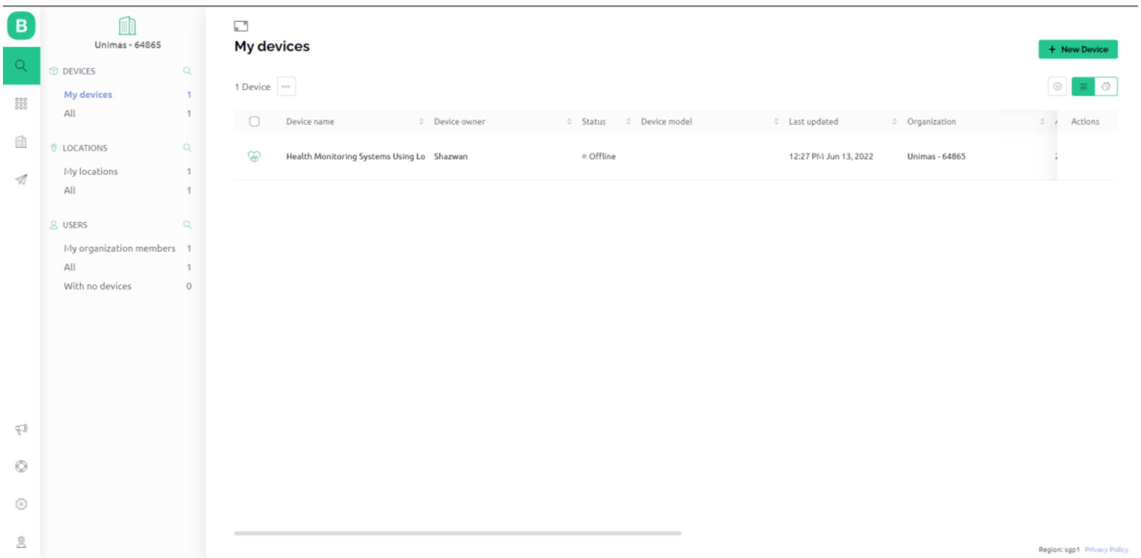
The complete GPS tracking device is visualized in **Figure 4.4**. This device will provide the coordinate results for the HMS device that will be tested in various places in terms of longitude and latitude.

4.2.4 Blynk Construction



31Figure 4.5: Overall HMS Interface

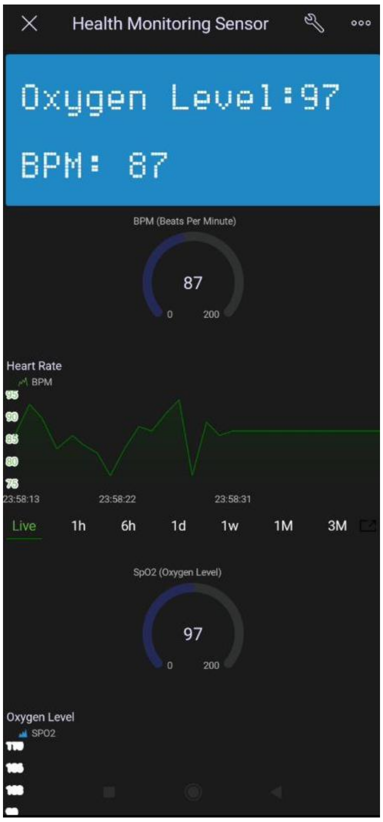
Figure 4.5 shows the overall HMS interface that has been constructed using the Blynk console for DataStream, template, and firmware, as shown in **Figure 4.6** below. Blynk app in the smartphone then include the LCD, Gauge and Super Chart for monitoring the value of BPM and SpO2.



32Figure 4.6: Blynk Dashboard

4.3 Results of HMS

4.3.1 BPM and SpO_2



33Figure 4.7: BPM and SpO2 Result in Blynk App

Both lights are shone at the fingertip or earlobe to trigger the HMS device (Oximeter). The Blynk app on the smartphone, as seen in **Figure 4.7**, will display heart rate (BPM) and oxygen level (SpO2) values. This test will be conducted several times at various places such as CAE Lab 1, Outside CAE Lab 1, FENG Parking Lot etc., to check the extent to which LoRaWAN and Hotspots can detect BPM and SpO2 values until the system is unreadable or unstable. The central location or pinpoint for measuring distances is in CAE Lab 1.

34Figure 4.8: Outside CAE Lab 1 (5m)

35Figure 4.9: Outside CAE Lab 1 (10m)

Figure 4.8 and **Figure 4.9** above show the early prototype locations that have been carried out for both LoRaWAN and Hotspots.

4.3.2 Table of comparison between Hotspots and LoRaWAN

4Table 2.4: LoRaWAN Distance Testing

Places	Distance (m)	Latitude	Longitude	BPM (Beats Per Minute)	SpO_2 (Oxygen Level)
CAE Lab 1	0	1.468188	110.428183	80	96
Outside CAE Lab 1	5	1.468185	110.428139	85	95
Outside CAE Lab 1	10	1.468207	110.428100	90	96
Outside CAE Lab 1	15	1.468234	110.428055	86	96
FENG Parking Lot	20	1.468260	110.428018	89	95
FENG Parking Lot	80	1.467903	110.427517	87	96
PlayLab GC “Parking Lot”	150	1.467814	110.429484	79	96
Student Pavilion	235	1.468336	110.430296	89	97
Dahlia College B3 Parking Lot	610	1.473533	110.429389	87	96
Dewan PITAS	838	1.470306	110.435420	86	95

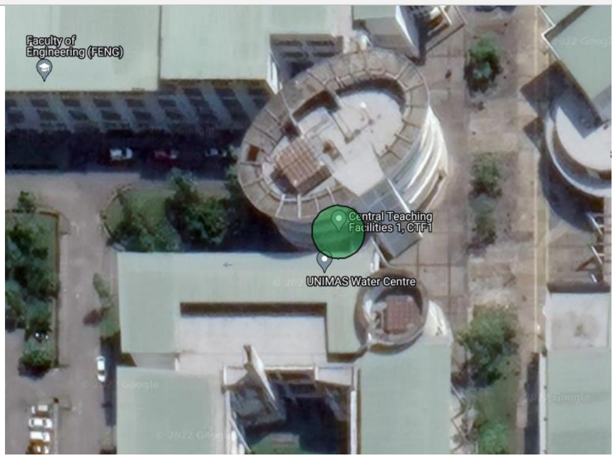
Kafe Kolej Tun Ahmad Zaidi	920	1.465470	110.436005	89	95
Indoor Badminton Court	1180	1.461121	110.436068	92	96
Shell	1980	1.457162	110.442154	101	92
Aiman Mall Parking Lot	2360	1.455130	110.444913	27	80

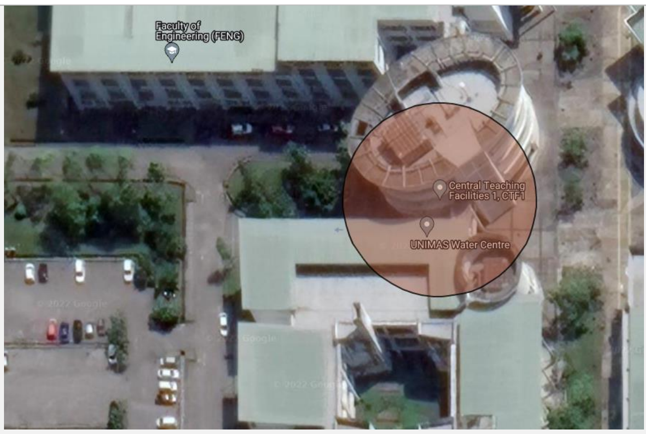
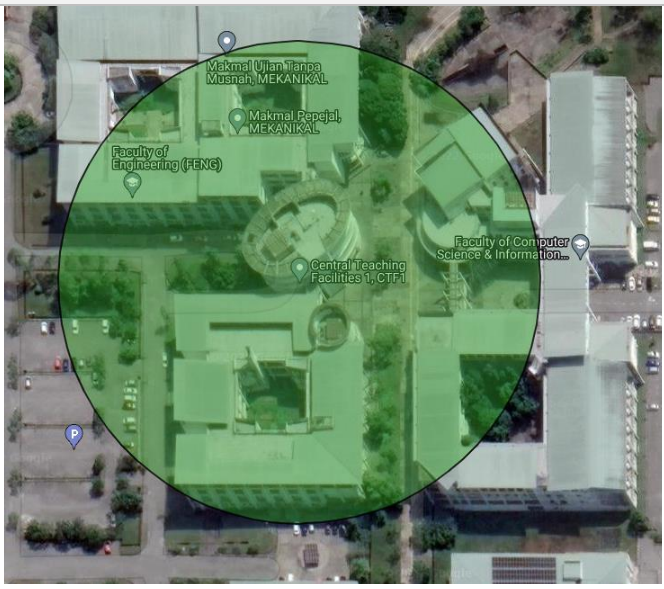
5Table 2.5: Hotspots Distance Testing

Places	Distance (m)	Latitude	Longitude	BPM (Beats Per Minute)	SpO_2 (Oxygen Level)
CAE Lab 1	0	1.468188	110.428183	85	96
Outside CAE Lab 1	5	1.468185	110.428139	87	96
Outside CAE Lab 1	10	1.468207	110.428100	85	95
Outside CAE Lab 1	15	1.468234	110.428055	194	100
FENG Parking Lot	20	1.468260	110.428018	-	-
FENG Parking Lot	80	1.467903	110.427517	-	-

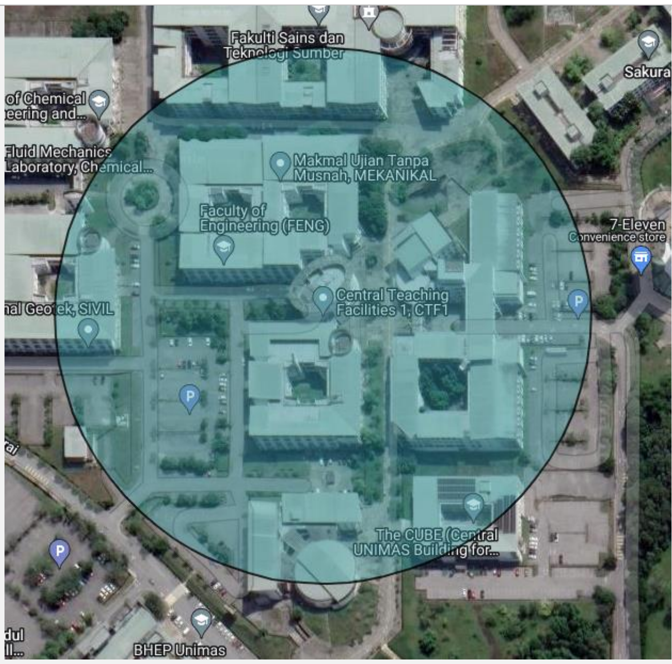
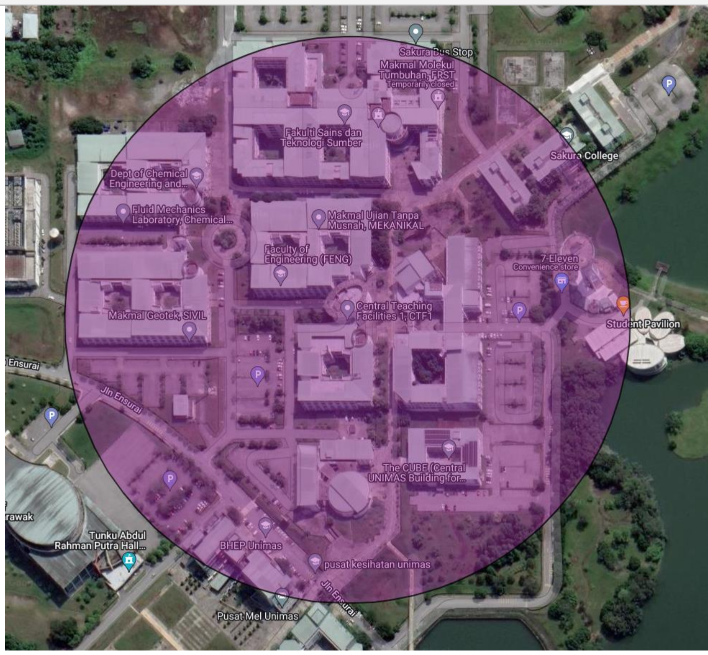
4.3.3 Geographical Distance

6Table 2.6: Distance from CAE Lab 1

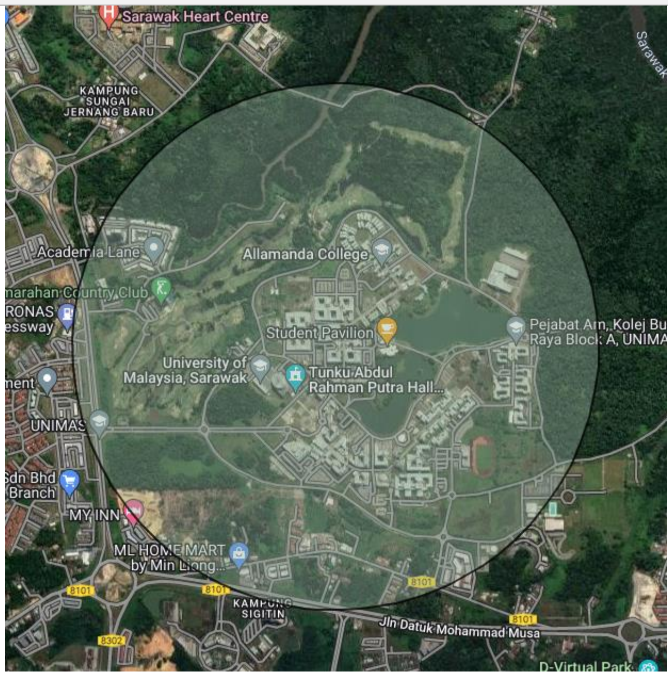
Places (Distance)	Geographical Map
CAE Lab 1 (0m)	
Outside CAE Lab 1 (5m)	
Outside CAE Lab 1 (10m)	

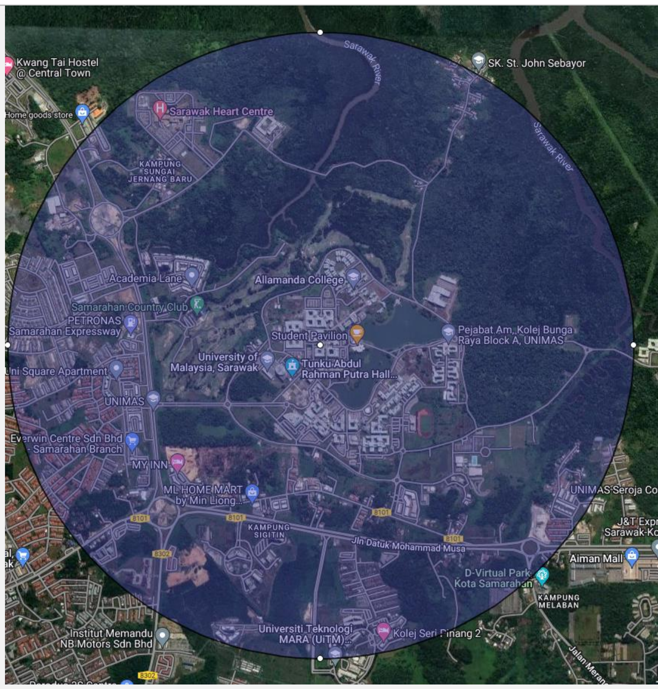
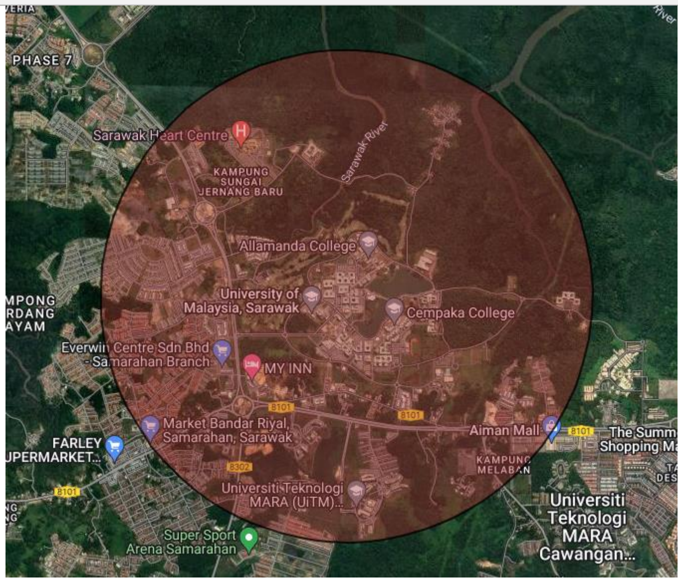
Outside CAE Lab 1 (15m)	
FENG Parking Lot (20m)	
FENG Parking Lot (80m)	

<table>
<tr>
<td>PlayLab GC “Parking Lot”

(150m)</td>
<td>
</td>
</tr>
<tr>
<td>Student Pavilion (235m)</td>
<td>
</td>
</tr>
</table>

<table>
<tr>
<td>Dahlia College
B3 Parking Lot
(610m)</td>
<td>
</td>
</tr>
<tr>
<td>Dewan PITAS
(838m)</td>
<td>
</td>
</tr>
</table>

Kafe Kolej Tun Ahmad Zaidi (920m)	
Indoor Badminton Court (1.18 km)	

Shell (1.98 km)	
Aiman Mall Parking Lot (2.36 km)	

4.4 Analysis and discussion

4.4.1 GPS Tracking

While GPS includes modern technology that benefits users, the system does have certain common issues. For example, GPS frequently takes time to access the network because of poor weather conditions that prevent it from transmitting and receiving signals from satellites. Furthermore, barriers such as tall buildings or other structures that hide the view of the sky cause a multipath error to the GPS receiver's receiving signal.

As a result, inaccurate latitude and longitude values may be provided to the server, and the location is displayed on the Google map. It also needs to place in open spaces such as FENG Parking Lot in **Figure 4.10** to get better results. Since the GPS tracking module is used offline, the value of longitude and latitude is manually placed in the Google Maps to get geographical map results, with takes a lot of time to sort one by one.

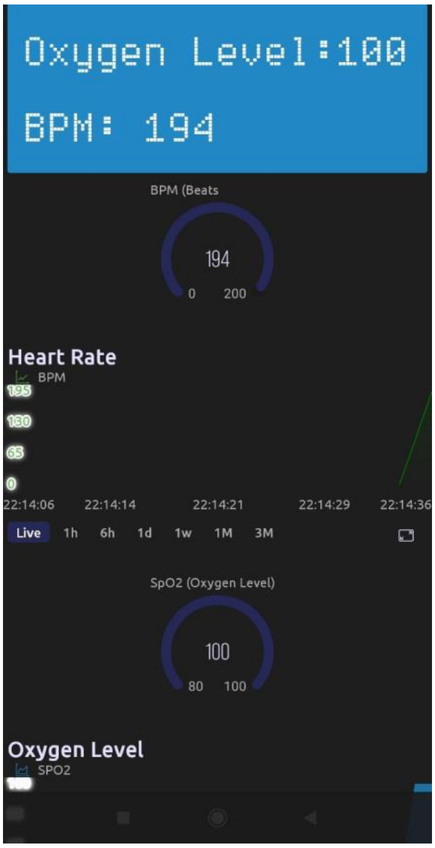
4.4.2 Distance comparison (Hotspots Vs LoRaWAN)

Table 2.4 shows the LoRaWAN distance testing; meanwhile, **Table 2.5** shows the Hotspots distance testing. In **Table 2.5**, BPM and SpO2 become unstable and give a non-standard value at Outside CAE Lab 1 (15m). A standard value of BPM and SpO2 can be referred to in **Table 2.1** and **Figure 2.3**. This is due to the signals that must travel across walls and lab equipment. Although the smartphone cannot emit a strong signal, hotspots may pick up a much weaker signal.

36Figure 4.10: FENG Parking Lot (20m)

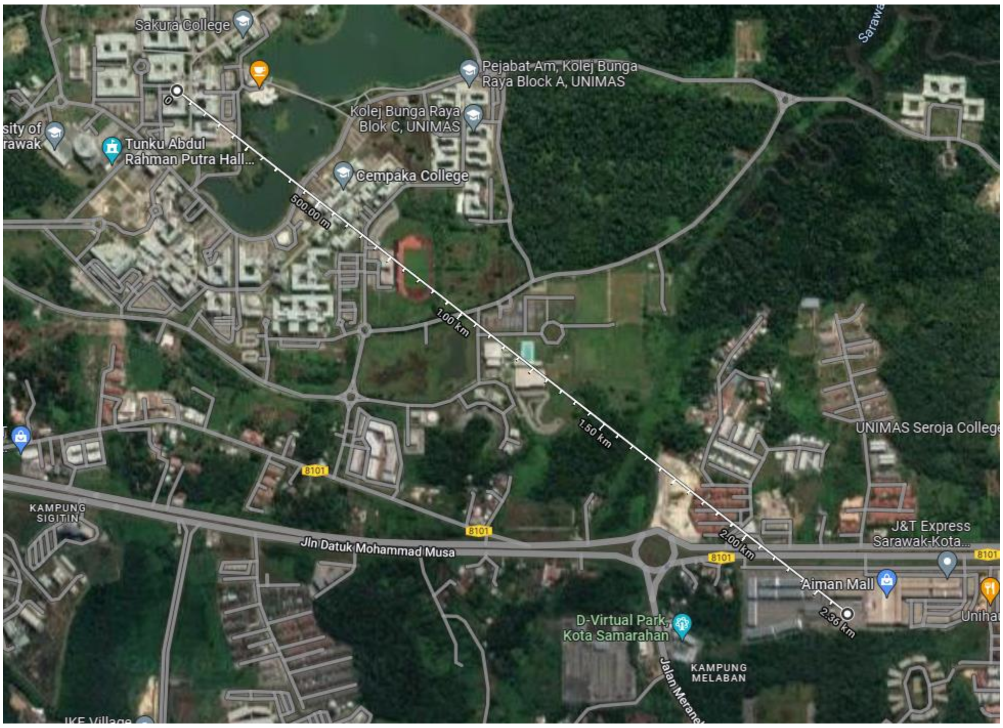
At 20 meters around FENG Parking Lot, as shown in **Figure 4.10**, the value for both BPM and SpO2 is undetectable because the HMS device is disconnected from the hotspots. It is expected because the range of Hotspots is limited, around 30 feet or +-10 meters [48]. The maximum distance depends on the transmitter and receiver, and all obstructions significantly impact the wireless transmission.

37Figure 4.11: Maximum Range of Hotspots

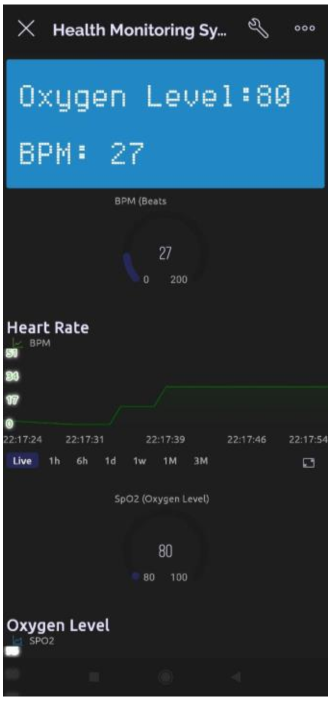


38Figure 4.12: Hotspots at 15m from CAE Lab 1

39Figure 4.13: Aiman Mall Parking Lot (2.36km)



40Figure 4.14: Maximum Range of LoRaWAN



41Figure 4.15: LoRa at 2.36 km from CAE Lab 1

Figure 4.11 and **Figure 12** show the maximum range of hotspots that can detect the value of BPM and SpO2 in the Blynk app. Meanwhile, **Figure 4.14** and **Figure 4.15** illustrates the maximum range of LoRaWAN that can detect approximately 2.36 km.

In contrast with hotspots, LoRa distance testing has been conducted in 14 places, as indicated in **Table 2.4**. At Shell (1.98 km), the HMS device starts to malfunction, and the BPM and SpO2 readings provide out-of-the-range results. Going further to Aiman Mall Parking Lot (2.36 km), as shown in **Figure 4.13**, the device is still able to detect the value of BPM and SpO2 although it is very unstable and imprecise, as shown in **Figure 4.14**.

Table 2.6 displays the geographical maps that have been conducted from a pinpoint CAE Lab 1 to Aiman Mall Parking Lot (2.46 km). A hotspot can connect to the Internet through a wireless Local Area Network (WLAN) managed by a router connected to an Internet service provider. On the contrary, LoRaWAN controls communication between end-node devices and network gateways while wirelessly connecting devices to the Internet.

4.5 Summary

This chapter summarized the entire outcome of the prototype developed in this project. The analysis was conducted by comparing the distance measured between Hotspots and LoRaWAN from the central point CAE Lab 1. The limitations of GPS are also being discussed in this chapter. The findings and review will proceed to the conclusion and recommendation in the next chapter.

Chapter 5

CONCLUSIONS

5.1 Overview

In this chapter, the overall summary of this thesis will be presented. The summary of this chapter will be important for the outcome of this study. In addition, it will discuss the implication of the project for another engineer as a based design to either start a new or develop this prototype with a different approach. Other than that, future recommendation is also included in this chapter.

5.2 Summary

This project consists of five chapters, including the conclusion of the last chapter. The main purpose of this study was to construct a low-cost HMS that can work at wide-ranging distances using LoRaWAN technology that can display the information collected by sensors, real-time data transmission and measure the heart rate (BPM) and oxygen level (SpO2). Not just that, it also needs to develop a mobile app, Blynk, that is connected to the HMS.

Based on the results, Hotspots can detect the value of BPM and SpO2 at maximum range of 15 meter from CAE Lab 1 (0m) to Outside CAE Lab 1 (15m). Meanwhile, LoRaWAN can detect the value of BPM and SpO2 at maximum range of 2.36km from CAE Lab 1 (0m) to Aiman Mall Parking Lot (2.36km). The HMS device when connected to both technologies will unstable when it reaches its maximum range. The comparison of two different wireless communications have been discussed in term of distance.

Finally, it has been proved that HMS device that connected to LoRaWAN (2.36 km) have wider range compared to Hotspots (15m). There are many available options to choose, but this prototype was much more straightforward for LPWAN and required a lower cost to build.

5.3 Recommendations

This designated prototype takes a lot of time to connect to the LoRa gateway. Therefore, it is better to use devices compatible with TTN (The Things Network), such as Arduino MKR 30100, TTU (The Things Uno), Yabby Edge, etc., then connect it to TTN Gateway.

Next, a future LoRaWAN base station to organize a data transmission network via radio channel for stable connection and reduce interruption when sending or receiving data from a long distance is above 3 km.

Lastly, it also can be used for future projects such as smart home automation, smart gardening, smart traffic lights, better GPS tracking device, etc., based on LoRaWAN technology.

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JKEE: IEEE Style

APPENDIX A

Coding for GPS Server:

```
#include <SPI.h>
#include <SoftwareSerial.h>
#include <RH_RF95.h>
// Singleton instance of the radio driver
RH_RF95 rf95;
//RH_RF95 rf95(5, 2); // Rocket Scream Mini Ultra Pro with the RFM95W
//RH_RF95 rf95(8, 3); // Adafruit Feather M0 with RFM95

// Need this on Arduino Zero with SerialUSB port (eg RocketScream Mini Ultra Pro)
//#define Serial SerialUSB
// Choose two Arduino pins to use for software serial
int RXPin = 2;
int TXPin = 3;

//Default baud of NEO-6M is 9600
int GPSBaud = 9600;

// Create a software serial port called "gpsSerial"
SoftwareSerial gpsSerial(RXPin, TXPin);

void setup()
{
  Serial.begin(9600);
  while (!Serial) ; // Wait for serial port to be available
```

```
if (!rf95.init())
  Serial.println("init failed");
// Defaults after init are 434.0MHz, 13dBm, Bw = 125 kHz, Cr = 4/5, Sf = 128chips/symbol, CRC on
//  driver.setTxPower(14, true);
// Start the software serial port at the GPS's default baud
gpsSerial.begin(GPSBaud);
}

void loop() {
 rf95.waitPacketSent();
  uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
 uint8_t len = sizeof(buf);
if (rf95.waitAvailableTimeout(3000))
 {
   // Should be a reply message for us now
   if (rf95.recv(buf, &len))
   {
     Serial.print("got reply: ");
     Serial.println((char*)buf);
   }
   else
   {
     Serial.println("recv failed");
   }
 }
```

```
  else
  {
    Serial.println("No reply, is rf95_server running?");
  }
  delay(400);

  // Displays information when new sentence is available.
  while (gpsSerial.available() > 0)
    Serial.write(gpsSerial.read());

  // Send a reply
      Serial.println("Sending to rf95_server");
  rf95.send(data, sizeof(data));
}
```

Coding for Client:

```
#include <SPI.h>
#include <RH_RF95.h>

// Singleton instance of the radio driver
RH_RF95 rf95;
//RH_RF95 rf95(5, 2); // Rocket Scream Mini Ultra Pro with the RFM95W
//RH_RF95 rf95(8, 3); // Adafruit Feather M0 with RFM95

// Need this on Arduino Zero with SerialUSB port (eg RocketScream Mini Ultra Pro)
//#define Serial SerialUSB

void setup()
{
  Serial.begin(9600);
  while (!Serial) ; // Wait for serial port to be available
  if (!rf95.init())
    Serial.println("init failed");
  // Defaults after init are 434.0MHz, 13dBm, Bw = 125 kHz, Cr = 4/5, Sf = 128chips/symbol, CRC on
  //  driver.setTxPower(14, true);
}

void loop()
{
  Serial.println("Sending to rf95_server");
```

```
// Send a message to rf95_server
uint8_t data[] = "Patient Body Temperature? ";
rf95.send(data, sizeof(data));

rf95.waitPacketSent();
// Now wait for a reply
uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
uint8_t len = sizeof(buf);

if (rf95.waitAvailableTimeout(3000))
{
  // Should be a reply message for us now
  if (rf95.recv(buf, &len))
  {
    Serial.print("got reply: ");
    Serial.println((char*)buf);
  }
  else
  {
    Serial.println("recv failed");
  }
}
else
{
  Serial.println("No reply, is rf95_server running?");
}
```

```
  delay(400);
}
```

Coding for HMS device (LoRaWAN):

```
#include <Wire.h>

#define BLYNK_TEMPLATE_ID "TMPLScaBY7NO"

#define BLYNK_DEVICE_NAME "HMS Using LoRaWAN Technology"

#define BLYNK_AUTH_TOKEN "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ"

#include "MAX30100_PulseOximeter.h"

#define BLYNK_PRINT Serial

#include <Blynk.h>

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>


#include "Wire.h"

#include "Adafruit_GFX.h"

#define REPORTING_PERIOD_MS 1000


char auth[] = "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ";    // Auth Token in the Blynk App.

char ssid[] = "dragino-1d0490@CAE_JKEE";            // WiFi credentials.

char pass[] = "PO210500225";                        // WiFi Password


// Connections : SCL PIN - D1 , SDA PIN - D2 , INT PIN - D0

PulseOximeter pox;


float BPM, SpO2;

uint32_t tsLastReport = 0;
```

```
void onBeatDetected()
{
  Serial.println("Beat Detected!");

}

void setup()
{
  Serial.begin(115200);

  pinMode(16, OUTPUT);
  Blynk.begin(auth, ssid, pass);

  Serial.print("Initializing Pulse Oximeter..");

  if (!pox.begin())
  {
     Serial.println("FAILED");

     for(;;);
  }
  else
  {

     Serial.println("SUCCESS");
```

```
    pox.setOnBeatDetectedCallback(onBeatDetected);
  }



}

void loop()
{
  pox.update();
  Blynk.run();

  BPM = pox.getHeartRate();
  SpO2 = pox.getSpO2();
  if (millis() - tsLastReport > REPORTING_PERIOD_MS)
  {
    Serial.print("Heart rate:");
    Serial.print(BPM);
    Serial.print(" bpm / SpO2:");
    Serial.print(SpO2);
    Serial.println(" %");

    Blynk.virtualWrite(V7, BPM);
    Blynk.virtualWrite(V8, SpO2);

    tsLastReport = millis();
  }
```

}

Coding for HMS device (Hotspots):

```
#include <Wire.h>
#define BLYNK_TEMPLATE_ID "TMPLScaBY7NO"
#define BLYNK_DEVICE_NAME "HMS Using LoRaWAN Technology"
#define BLYNK_AUTH_TOKEN "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ"
#include "MAX30100_PulseOximeter.h"
#define BLYNK_PRINT Serial
#include <Blynk.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

#include "Wire.h"
#include "Adafruit_GFX.h"
#define REPORTING_PERIOD_MS 1000

char auth[] = "gmjd-jV8137_oQMs1HBf_12ZgX65YSMZ";    // Auth Token in the Blynk App.
char ssid[] = "Test";            // WiFi credentials.
char pass[] = "12344321";                    // WiFi Password

// Connections : SCL PIN - D1 , SDA PIN - D2 , INT PIN - D0
PulseOximeter pox;

float BPM, SpO2;
uint32_t tsLastReport = 0;
```

```
void onBeatDetected()
{
  Serial.println("Beat Detected!");

}

void setup()
{
  Serial.begin(115200);

  pinMode(16, OUTPUT);
  Blynk.begin(auth, ssid, pass);

  Serial.print("Initializing Pulse Oximeter..");

  if (!pox.begin())
  {
     Serial.println("FAILED");

     for(;;);
  }
  else
  {

     Serial.println("SUCCESS");
```

```
        pox.setOnBeatDetectedCallback(onBeatDetected);
    }



}

void loop()
{
    pox.update();
    Blynk.run();

    BPM = pox.getHeartRate();
    SpO2 = pox.getSpO2();
     if (millis() - tsLastReport > REPORTING_PERIOD_MS)
    {
        Serial.print("Heart rate:");
        Serial.print(BPM);
        Serial.print(" bpm / SpO2:");
        Serial.print(SpO2);
        Serial.println(" %");

        Blynk.virtualWrite(V7, BPM);
        Blynk.virtualWrite(V8, SpO2);

        tsLastReport = millis();
    }
```

```
}
```

APPENDIX B

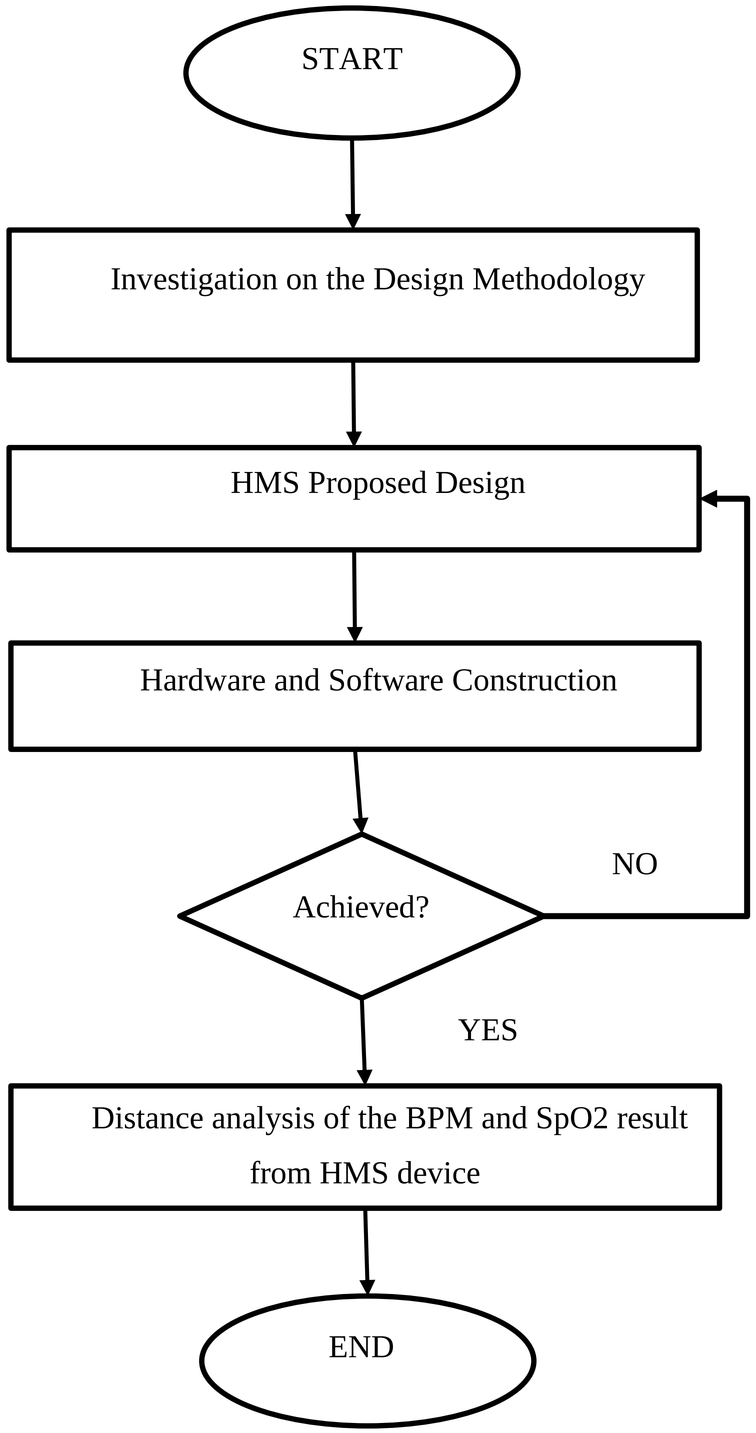

Figure 1: Flowchart of Study

Table 1: Gantt Chart during FYP 1

TASK/ WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review														
Investigation on Design Methodology														
Investigation on LoRaWAN Technology														
HMS Proposed Design														
Report writing, FYP 1 Presentation and submission														

Table 2: Gantt Chart during FYP 2

TASK/ WEEK	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Investigation on LoRaWAN Technology														
HMS Proposed Design														
Buying Hardware Devices														
Testing HMS Device														
Report writing, FYP 2 Presentation and submission														