DEVELOPMENT OF CAR GARAGE ALARM SYSTEM USING LORA AND MOBILE APP

SITI SARAH BINTI NAZARRUDDIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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THIS REPORT IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Disahkan oleh:

MOHD KHANAPIAH BIN NOR
Pensyarah
Fakulti Teknologi Dan Kejuruteraan Elektronik Dan Komputer (FTKEK)
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All praise to the almighty. With his blessing, a project report for my degree has been carried out and completed. With the completion of this report, I hope that more studies can be done, and this project can be developed to benefit mankind. I also hope that this study can be understood easily and is useful for future reference. Firstly, I would like to send this heartfelt appreciation to my parents who have been supporting and motivating me every single day. I also wish to thank my supervisor, Mr. Mohd Khanapiah Bin Nor for providing study materials and guidance throughout the process of making this project successful. Not to forget, my friends who helped and fought through this challenge together. I cannot quantify my love for you all. May Allah bless everyone. In my last say, I hope this final year project will provide more ideas and guidance for work in this field in the future.

ABSTRACT

In an era where security and connectivity converge, the development of innovative solutions to safeguard valuable assets such as vehicles becomes paramount. This thesis presents the design and implementation of a Car Garage Alarm System utilizing LoRa (Long Range) technology coupled with a mobile application interface. The system aims to provide robust security features for car garages, enhancing protection against unauthorized access and potential theft incidents.The project begins with a comprehensive exploration of existing literature, delving into topics including car security systems, wireless communication technologies, and mobile application development. Leveraging insights from this review, the methodology section outlines the systematic approach employed in designing and implementing the alarm system. This includes the selection of hardware components, the configuration of LoRa communication protocols, and the development of the mobile application interface.Through rigorous testing and evaluation, the efficacy and reliability of the Car Garage Alarm System are assessed, with a focus on its ability to detect intrusions, send timely alerts, and provide user-friendly control features via the mobile app. The results demonstrate the system's capability to enhance the security posture of car garages while offering convenient remote monitoring and management functionalities.In the discussion section, the implications of the project's findings are analyzed, addressing both its contributions to the field of automotive security and its potential for further advancements and real-world applications.

ABSTRAK

Dalam era di mana keselamatan dan ketersambungan yang terkumpul, pembangunan penyelesaian inovatif untuk melindungi aset berharga seperti kenderaan menjadi yang terpenting. Tesis ini membentangkan reka bentuk dan pelaksanaan Sistem Penggera Garaj Kereta menggunakan teknologi LoRa (Jarak Jauh) ditambah dengan antara muka aplikasi mudah alih. Sistem ini bertujuan untuk menyediakan ciri keselamatan yang teguh untuk garaj kereta, meningkatkan perlindungan terhadap akses tanpa kebenaran dan kemungkinan kejadian kecurian. Projek ini bermula dengan penerokaan komprehensif kesusasteraan sedia ada, menyelidiki topik termasuk sistem keselamatan kereta, teknologi komunikasi tanpa wayar dan pembangunan aplikasi mudah alih. Memanfaatkan pandangan daripada ulasan ini, bahagian metodologi menggariskan pendekatan sistematik yang digunakan dalam mereka bentuk dan melaksanakan sistem penggera. Ini termasuk pemilihan komponen perkakasan, konfigurasi protokol komunikasi LoRa dan pembangunan antara muka aplikasi mudah alih. Melalui ujian dan penilaian yang ketat, keberkesanan dan kebolehpercayaan Sistem Penggera Garaj Kereta dinilai, dengan tumpuan pada keupayaannya untuk mengesan pencerobohan, menghantar makluman tepat pada masanya dan menyediakan ciri kawalan mesra pengguna melalui apl mudah alih. Hasilnya menunjukkan keupayaan sistem untuk meningkatkan postur keselamatan garaj kereta sambil menawarkan fungsi pemantauan dan pengurusan jauh yang mudah. Dalam bahagian perbincangan, implikasi penemuan projek dianalisis, menangani kedua-dua sumbangannya kepada bidang keselamatan automotif dan potensinya. untuk kemajuan selanjutnya dan aplikasi dunia nyata.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Mohd Khanapiah Bin Nor for his precious guidance, words of wisdom and patient throughout this project.

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My highest appreciation goes to my parents, and family members for their love and prayer during the period of my study. An honorable mention also goes to my supervisor for all the motivation and understanding provided throughout the project's development and thanks for invaluable assistance in troubleshooting technical challenges and offering insightful perspectives.

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CHAPTER 1

INTRODUCTION

1.1 Background

Vehicle theft is a growing concern, especially in garage environments where traditional alarm systems may fall short. LoRa technology offers a solution with its long-range wireless communication capabilities, making it suitable for remote garages. Meanwhile, the widespread use of smartphones has changed how we interact with security systems, allowing for easy control via mobile apps. Combining LoRa with a mobile app interface could provide an effective and convenient way to monitor and secure car garages. This project aims to develop such a system to address the limitations of existing solutions and improve overall security for parked vehicles.

Current research in automotive security emphasizes the importance of real-time monitoring and rapid response mechanisms to deter theft and minimize damage. However, existing solutions often rely on wired connections or short-range wireless protocols, limiting their effectiveness in remote or expansive garage settings. LoRa technology, characterized by its long-range communication capabilities and low power consumption, offers a promising alternative by enabling wireless connectivity over extended distances without the need for frequent battery replacements.

1.2 Addressing Engineering and Societal Impact Through LoRa Based Communication and Alarm Systems

The project uses LoRa (Long Range) technology to enable long-range, low-power wireless communication, which is required for the effective operation of IoT applications such as a garage alarm system. The engineering aspects include addressing complex challenges such as integrating hardware (sensors and LoRa modules) with software (mobile app and backend server), ensuring system reliability, improving security measures, and achieving energy efficiency in order to create a dependable and strong alarm system. From a societal standpoint, this technology improves vehicle security by providing real-time notifications and remote monitoring capabilities, allowing car owners to better secure their assets.

It includes to the wider smart city infrastructure by incorporating IoT technologies that enhance quality of life through greater safety and convenience. The anticipated reduction in automobile theft and vandalism might result in considerable economic advantages, such as cheaper insurance premiums and repair expenses. However, the concept raises significant privacy and data security issues. Collecting and transferring data regarding garage activities requires strong security measures to guarantee user data is safeguarded and the system complies with applicable data protection requirements. Ethical factors, such as the safe management of personal information and compliance with privacy regulations, are critical to sustaining society confidence and acceptance. Furthermore, emphasizing energy-efficient technologies promotes environmental sustainability by reducing the system's ecological imprint.

1.3 Problem Statement

The primary problem statement for this project is to enhance the security of car garages by developing an effective alarm system that can detect and alert owners of any intrusion attempts or unauthorized access. This causes break-ins, which is the vehicles and other important stuff would be stolen. It also aims at providing enormous convenience through remote monitoring and control with a mobile app that will enable the user to control the alarm system with the use of the telephone, despite one's current location. Furthermore, the project aims to overcome the restrictions of traditional alarm systems, such as issues in connectivity, constraints of range, and inefficiencies in power, hence using LoRa technologies have the characteristic of being long-distance and low power, so the connection between the garage's alarm and the user's mobile app will surely be reliable and effective.

1.4 Project Objectives

There are two objectives which is aimed to be achieved upon completion of this study which are to:

a) **Design and Develop a Car Garage Alarm System**: The primary objective of this projecy is to design and develop a robust car garage alarm system utilizing LoRa technology and a mobile application interface. This involves conceptualizing the system architecture, selecting appropriate hardware components, configuring LoRa communication protocols, and implementing a user-friendly mobile app interface for remote monitoring and control.

b) **Evaluate the Effectiveness and Usability of the Alarm System:** The secondary objective is to assess the effectiveness and usability of the developed alarm system through rigorous testing and evaluation. This includes conducting simulated intrusion scenarios to evaluate the system's detection and alerting capabilities, measuring the system's response time and reliability, and gathering user feedback to assess the mobile app's usability and overall user experience.

c) **Design a Reliable and Efficient Power Management System**: This refers to relevant power sources, like long-life batteries and rechargeable power banks should be applied to supply the power input at the transmitter and receiver parts if it demands continuous operation. With a strong power management system, reliability of the car garage alarm system can be maintained, with minimum downtime caused by problems related to power and, thereby, relieving the maintenance of very frequent battery or power bank replacement.

1.5 Scope of Project

Scope of work explains the workflow of the project. It is divided into three stages which are Definition and Research, Development of Hardware and Software, and Testing:-

Stage 1: Definition and Research

- Do research related to project topic.
- Understanding objective and goal of the topic.
- Choose suitable application to design the alarm system.

Stage 2: Development of Hardware and Software

- Design the circuitry to integrate the selected components considering factors such as power supply, sensor connections, and communication interfaces.
- Develop the software that runs on the microcontroller(s) to control the components, magnetic reed sensor also managing the communication via LoRa and mobile app.

Stage 3: Testing

- Perform comprehensive hardware testing of all components including sensors, LoRa communication module, and power systems.
- Conduct software testing to verify proper functioning of the microcontroller programming and mobile app.
- Execute integration testing to ensure all components work together seamlessly.
- Validate communication reliability between the alarm system, LoRa network, and mobile application.
- Document any bugs or issues and implement necessary fixes.
- Perform real-world testing scenarios to verify system reliability and response time.
- Conduct final system validation to ensure all project objectives are met

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The development of advanced security systems for car garages has become increasingly important in mitigating the risks of vehicle theft and vandalism. Traditional security measures, such as alarm systems and surveillance cameras, often fall short in providing comprehensive protection, particularly in remote or unattended garage environments. In response to these challenges, there has been growing interest in leveraging wireless communication technologies and mobile applications to enhance car garage security.

This literature review aims to explore existing research and scholarship in several key areas relevant to the project "Development of Car Garage Alarm System Using LoRa and Mobile App." Specifically, it examines the literature on car garage security systems, wireless communication technologies, mobile application development, integration of hardware and software, user experience design, and practical applications in security contexts. By synthesizing and analyzing this body of literature, this review seeks to identify current trends, best practices, and areas of innovation in car garage security technology.

2.2 Addressing Global Disasters Through LoRa Based Communication and Alarm Systems

The increasing frequency and severity of global disasters, such as natural calamities, pandemics, and man-made crises, emphasize the critical need for robust and reliable communication systems. Traditional communication networks are often vulnerable to disruptions during disasters, leaving affected areas isolated and impeding critical information exchange and coordination efforts. LoRa (Long Range) technology presents a plausible solution to resolve this challenge by facilitating long-range, low-power, and resilient wireless communication networks. By leveraging LoRa's ability to transmit data over long distances with minimal infrastructure requirements, disaster response teams and affected communities can establish emergency communication channels, facilitating the exchange of vital information, coordinating relief efforts, and disseminating early warning alerts.

The integration of LoRa-based communication systems with robust alarm systems can further improve disaster preparedness and response capabilities. These alarm systems can be strategically deployed in disaster-prone areas, functioning as early warning systems for natural disasters like earthquakes, tsunamis, or wildfires. By leveraging LoRa's low-power consumption and long-range capabilities, these alarm systems can transmit critical notifications to authorities and affected communities, even in scenarios where traditional communication networks are compromised. In addition, LoRa-based alarm systems can be integrated with sensor networks to monitor environmental conditions, detect potential hazards, and initiate timely evacuation procedures, thereby minimizing the impact of disasters on vulnerable populations and saving lives.

2.3 Previous Related Research

Development of a Car Garage Alarm System using LoRa and Mobile App involves creating a system that monitors a car garage and sends alerts via LoRa (Long Range) wireless communication technology or mobile app when certain events occur, such as when the garage door is opened or closed, when motion is detected inside the garage, or when other security-related events happen.

2.3.1 Smart Monitoring and controlling of Appliences using LoRa based IoT system

Users can control and monitor their appliances within a 3-12 km range using the Android smartphone app 'LoRa based Smart Institute' which operates the automation system. The application, which has potential for expansion to iOS and Windows platforms, includes six primary features: Smart Office, Smart Industry, Smart Home, Security, Garden Monitoring, and Sensors. Each feature comes with its own set of specialized functions. For example, the Smart Home system is divided into different zones including Living Room, Kitchen, Kids Room, and Bathroom. These zones feature virtual controls for various devices such as lights, fans, and air conditioners. The system operates through a wireless signal transmission process: when a user flips a switch in the app, the signal travels from one ESP32 module to another using Wi-Fi, then is transmitted via LoRa to a relay that controls the specific appliance. The system also incorporates advanced features including door locking and unlocking controls, window opening and closing mechanisms, security camera management, and sensor-based supervision and regulation, such as soil moisture sensors for automated garden watering. The graphical user interfaces for these functionalities are illustrated in Figures 2.1 and 2.2. [1]

Figure 2.1 : Graphical user interface (GUI) designed for the automation system android app.[1]

Figure 2.2 : Living room interface, Sensor functionality, and Garden Monitoring features in GUI. [1]

2.3.2 IoT Based Door open or close monitoring for home security with emergency notification system using LoRa Technology

This paper explores and evaluates security measures aimed at addressing the challenges encountered by homeowners and bank safe deposit box holders. Existing door monitoring system techniques utilize digital locks and Wi-Fi technology to regularly monitor the door's status, resulting in decreased incidents of theft, robbery, and burglary occurring every 3 minutes in India according to reports. The report states that Indians still prioritize updating their online security systems to protect their homes. With LoRa technology, we can continuously observe the door's status to determine if it is open or closed. Depending on the status, additional measures such as sounding an alarm or sending emergency notifications are taken to inform the owner and enhance security. Lora Technology revolutionized the IoT by allowing data connections over long distances with minimal power consumption. LoRaWAN addresses a technical deficiency in mobile and WiFi networks that require more power, greater bandwidth, or struggle to reach indoor areas..[2]

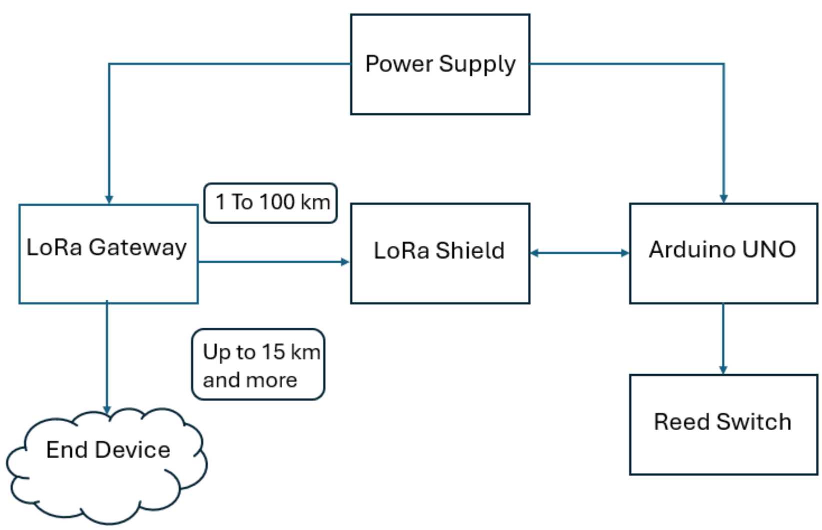

Figure 2.3 : Design of hardware [2]

Hardware design consists of the reed switch sensor, LoRashield, Arduino Uno, and LoRagateway. The LoRashield has the microcontroller. The hardware design is represented in Figure 2.3. The function of each of these components is as follows:[2]:

1. Monitoring of the state of the door, whether it is open or not, is done by the Reed switch sensor.
2. Arduino microcontroller Uno for the processing of values from sensors and determining whether the door should open or close.
3. The shell is Dragino, in turn, used for the transmission of data as read from the microcontroller; it was to a LoRa gateway.
4. The LoRa gateway to connect the server which can be inter-faced with IoT platform to display the sensor values via internet

2.3.3 An Internet of Things Based Smart Waste Management System Using LoRa and Tensorflow Deep Learning Model

The conventional waste management system functions according to a daily timetable, which is both inefficient and expensive. The current recycling bin has shown to be ineffective among the public because people do not recycle their waste correctly. The advancement of IoT and AI enables smart sensors to be integrated into the waste management system for real-time monitoring, leading to improved waste management. This study aims to create an intelligent garbage disposal system utilizing LoRa communication protocol and a deep learning model based on TensorFlow. LoRa transmits sensor data, while Tensorflow conducts real-time object detection and classification. The container is designed with numerous sections for sorting different types of waste such as metal, plastic, paper, and general waste, each of which is managed by servo motors. Detection of objects and classification of waste are carried out using a pre-trained object detection model within the TensorFlow framework. This model is trained using waste images to create a frozen inference graph for object detection, which is performed by a camera linked to the Raspberry Pi 3 Model B+ as the main processing unit. An ultrasonic sensor is installed in every waste compartment to track how full the waste is. The GPS module is included to track the exact location and current status of the bin. The LoRa communication protocol is utilized for sending information on the bin's location, current time, and how full it is. RFID module is integrated to identify waste management personnel.[3]

Table 2.1: Comparison between communication protocol[3]

Characteristics	Bluetooth	ZigBee	Wi-Fi	LoRa
Max. end-devices	255 (2 Billion in BLE)	More than 64000	Depends on number of IP address	More than 5000
Peak Current Consumption	30 mA	30 mA	100 mA	17mA
Range	10 m	10 to 100 m	100 m	More than 15 km
Data Rate	1 Mbps	250 kbps	11 Mbps and 54 Mbps	290 bps to 50 Kbps
Relative Cost	Low	Low	Medium	Low
Topology	Star	Star and Mesh	Star and Point-to-point	Star
Transmission Technique	Frequency Hopping Spread Spectrum	Direct Spread Spectrum Sequence	Orthogonal Frequency Division Multiplexing	Chirp Spread Spectrum

This article introduces a intelligent garbage management system that utilizes sensors to track bin status, the LoRa communication protocol for efficient, long-distance data transfer, and TensorFlow-powered object detection for identifying and categorizing waste. The SSDMobilnetV2 model, pre-selected for its efficient performance on the Raspberry Pi 3 Model B+, sorts waste into metal, plastic, and paper categories. Improving the training dataset and prolonging training time can increase accuracy. Efficient management of waste segregation is achieved through the coordination of object detection on the Raspberry Pi, a servo motor that controls compartment lids, and an RFID module that monitors the bin's locking mechanism. Ultrasonic sensors monitor levels of contents, while a GPS module keeps track of the bin's location and current status. LoRa operates at a frequency of 915MHz and sends bin status data to a gateway for decoding with RealTerm. This automated system is designed to reduce operational expenses and improve waste management, which will help advance smart city growth. Future enhancements involve increasing the waste image dataset for better detection options and creating an automated routing system to find the shortest maintenance routes, thereby moving towards a more sustainable, healthier community.

2.3.4 Design and Implementation of portable security device with GPS tracking and alarm System using LoRa technology

The project will involve the development of a portable safety device prototype. The device includes a transmitter for data transmission, a gateway for sending data to a database, a database for data storage, and a web application for visualizing data. The equipment will include two buttons with distinct functions. Pressing the top button will turn on the device and transmit GPS coordinates. Pressing the lower button will activate an alarm. Both features operate independently, giving the user the freedom to evaluate the circumstances and choose the most secure alternative. The ultimate goal of the project is to create a functional model that includes the specified features.[4]:-

I. Inexpensive

II. Reword the following text in the same input language while maintaining the same word count. Compact and relatively light.

III. Can be easily carried or transported.

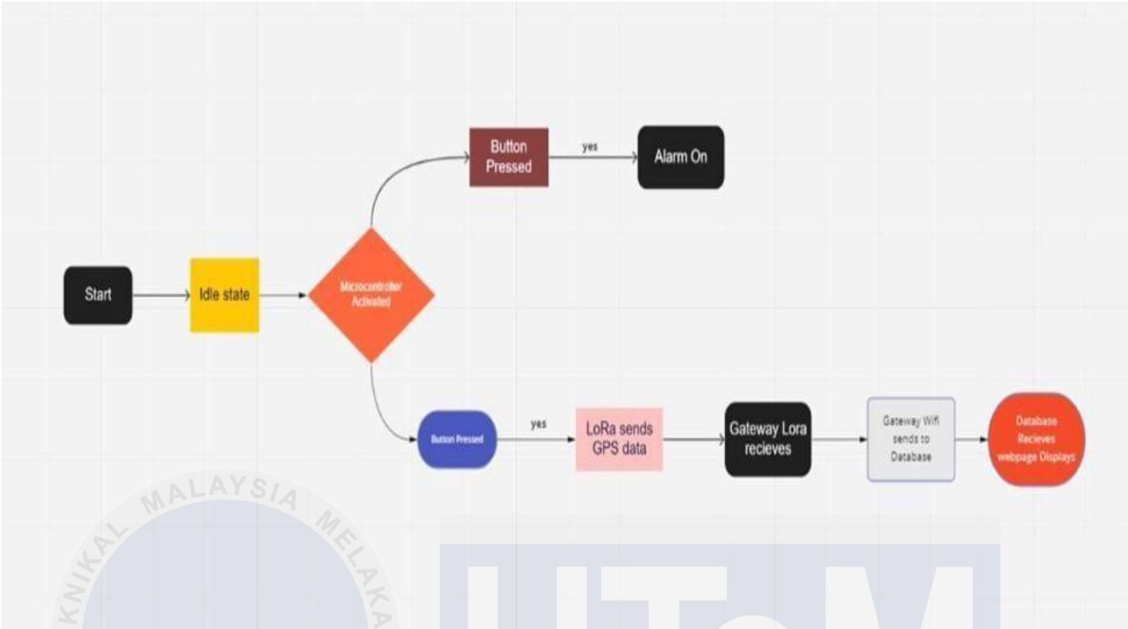

Figure 2.4 : System flowchart for the project[4]

The complete system is represented in Figure 2.4 with each part clearly identified in a detailed block diagram. The system is comprised of three parts that are interconnected. The transmission section includes a microcontroller, LCD screen, GPS module, and LoRa transmitter. The gateway includes a LoRa receiver, microcontroller, and Wi-Fi module all integrated within the microcontroller. The database and web application make up the third component. The data is received and stored by the database, while it is displayed by the web application.

2.3.5 Forest Fire Detection System using LoRa Technology

The conventional techniques for spotting and stopping forest fires rely on satellite imagery, guards' visual inspections, aerial observation, and video surveillance on elevated areas. With the drawbacks of traditional forest fire detection systems in mind, various solutions have been suggested recently to enhance environmental monitoring and develop new real-time forest fire detection systems with IoT-based devices. Detection is carried out by IoT devices and online monitoring systems. In this article, the authors suggested a fresh forest fire surveillance system through monitoring temperature changes and studying CO2 levels.

The forest fire detection system was created with the Arduino Uno module, incorporating a temperature sensor, a smoke sensor, and an alarm system. The temperature sensor identifies changes in temperature while the smoke sensors monitor the CO2 levels, activating the alarm (buzzer on the Arduino Uno board) when needed. Through IoT technology, the system was linked to a webpage called "FireSecurity System", which was developed in PHP and managed by the Arduino programming platform.[5]

Table 2.2: SigFox vs LoRa comparison[5]

Parameter	SigFox	LoRa
Frequency Band	868, 902 [MHz]	433(US), 863-870 (EU) [MHz]
Data Rate	100 bps	10 kbps
Rural Range	30-50 km	15-20 km
Urban Range	3-10 km	2-5 km

The LoRa technology may not ensure long-term evolution, but there are existing solutions built on it, which sets it apart from other technologies that may hinder global progress. Industrial IoT applications rely on long-range communication. The SigFox, LoRaWAN, and NB-IoT standard are the most promising protocols in this field. Table 2.2 shows a comparison between SigFox and LoRa.

The Internet of Things is an upcoming communication model that enables sensors and devices to interact without human involvement, paving the way for seamless integration. The items in Internet of Things are physical gadgets with microcontrollers, digital communication transceivers, and protocol stacks that enable user communication. There are numerous IoT applications, and the LoRaWAN protocol and LoRa devices appear to be highly effective in businesses, helping improve lives worldwide. By utilizing this technology, the goal is to establish an intelligent global network. LoRa technology is utilized in a wide range of sectors including agriculture, smart cities, smart environment, healthcare, smart homes and buildings, industrial control, smart metering, smart supply chain and logistics.

2.3.6 A LoRa-Driven Home Security System for a Residential community in a Retiremen Township

Extensive studies have been carried out on home security systems, which have become crucial in contemporary society (particularly for individuals who have retired after years of working and have chosen to reside independently in retirement communities). Several systems have been suggested for enabling community members to request help, although not all of them include sending emergency alerts to authorities in the vicinity, instead only offering alarms within the residences. Certain solutions only include a mobile app for sending emergency calls, while others utilize automated sensors for issuing emergency alarms without human involvement. Various technologies, including Wi-Fi communications, radio frequency transmission, GSM, smartphone apps, GPS, and PSTN, have been implemented to tackle these issues. The benefits and drawbacks of every technology use vary according to the developer's implementation.[6]

2.3.6.1 System Architecture

Figure 2.5 displays the system architecture as a whole. To start, homeowners are required to register their residences in the system with personal details including the residential area's name, unit number, contact number, full name, and email address.

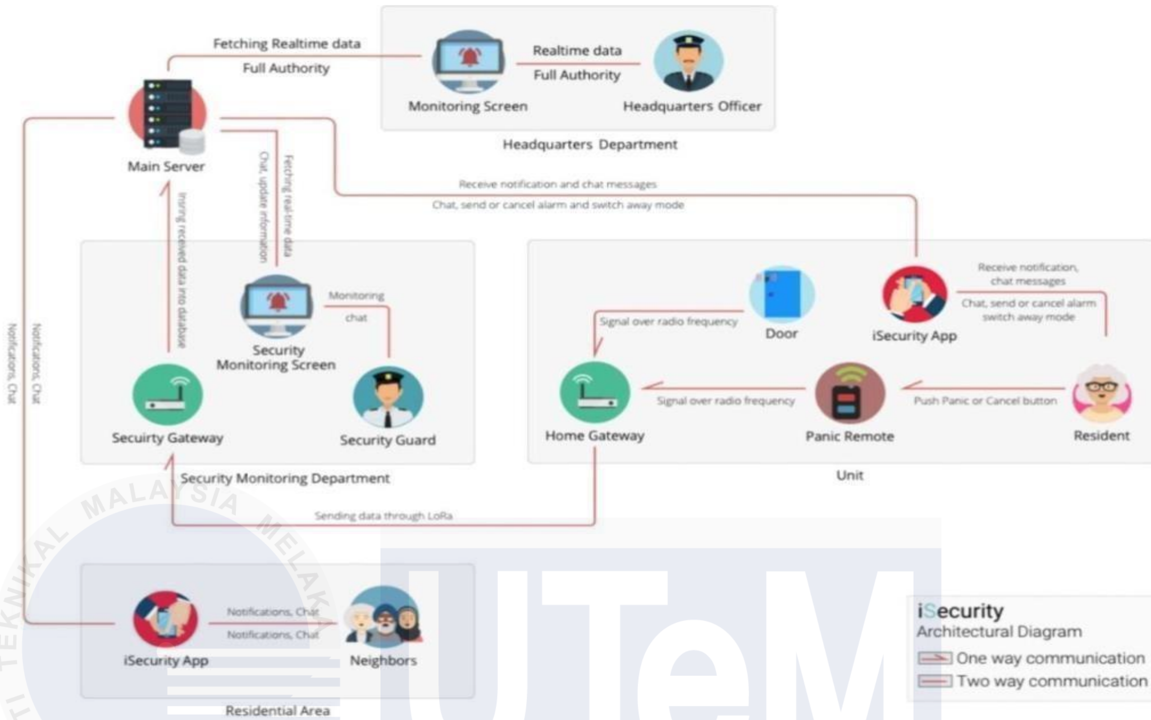

Figure 2.5 : System architecture[6]

Hardware and software tests were undertaken to ensure system functionality, dependability, and throughput. Further experiments were carried out to investigate the LoRa network's range and data rate capabilities. The hardware evaluations covered range, latency, power consumption, and scalability. During software testing, a thorough functionality test was conducted to ensure that all tasks were completed successfully and that the system is running properly.

2.3.7 Implementation of a LoRa and Io-Based Health monitoring Alarm Sytem for the Elderly

The project involving the use of IoT and LoRa for health monitoring is split into two main parts: The transmitter side, which enables both IoT and LoRa communication, and the receiver side, which solely utilizes LoRa communication. The system designed for monitoring patient and doctor health used a transmitter to gather vital signs, transmit them to an online platform, and also send them to the doctor's monitoring channel via LoRa communication technology. Emergency notifications are sent to the recipient in the same manner. The block diagram displayed in Figure 2.6.[7]

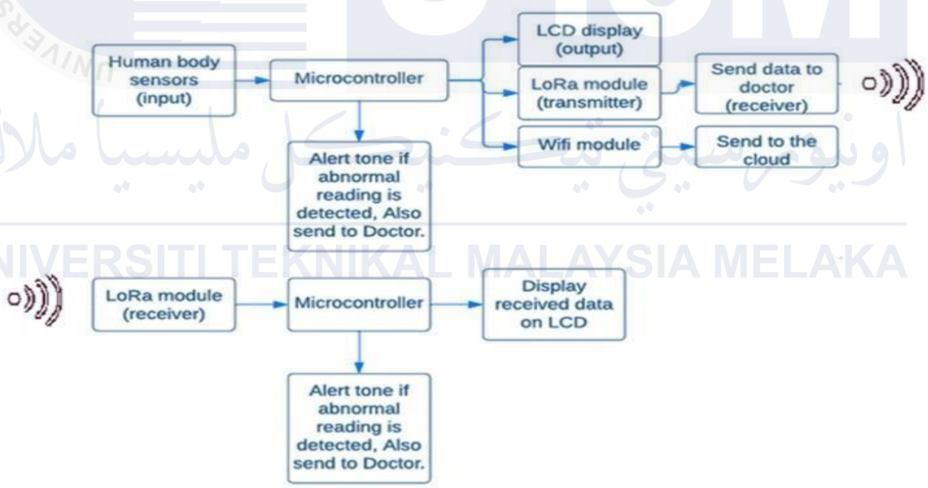

Figure 2.6 : Block Diagram for the transmitter and receiver.[7]

The components consist of a microcontroller for general functioning, a LoRa WAN radio module for extended-range communication, an energy module for dependable power source, an ESP32 wireless module for nearby connections, and sensing modules like DHT and pulse rate sensors for health supervision. The items used consist of two LoRa Modules (Ra-02), an ESP32 development board, an Arduino nano, a LiPo charging module, a LiPo battery, a switch, a 1604 LCD screen, a 0.92-inch OLED, a pulse rate sensor, and a DHT11.

2.3.8 Performance of LoRaWAN for Handling Telemetry and Alarm messages in Industrial Application

The planned studies on LoRa will focus on sending alarm and telemetry signals from end nodes to gateways through up-link communication. The system tests are conducted in the EU863-870 ISM band, utilizing a bandwidth of 125 kHz and a coding rate of 4/5. The diverse pathways created inside the cell adhere primarily to models influenced by signal degradation (for outdoor situations) and barriers (for indoor situations) that change the propagation characteristics. In this situation, buildings are planned uniformly and placed on a flat grid. The locations of the gateways are established in advance. Every terminal device is classified as class A, with their positions determined by whether they are alarm nodes or regular nodes.[8]

The standard nodes are positioned randomly (evenly spread across the cell area), but their positions remain constant throughout the simulation duration. Every node produces packets that are 28 bytes in size and sends them out every 600 seconds on a regular basis. The initial transmission time of each node is set randomly using a uniform random variable, denoted as $\sim$ U. The alarm nodes remain constant during the simulation, but their placement varies: randomly spread across the grid, arranged in a star topology, or uniformly distributed along a ring with predetermined radius and centered within the simulation area. These alarms generate packets of 14 bytes that are sent randomly at intervals determined by an exponential distribution with a mean of 600 seconds, approximately Exp(1/600).[8]

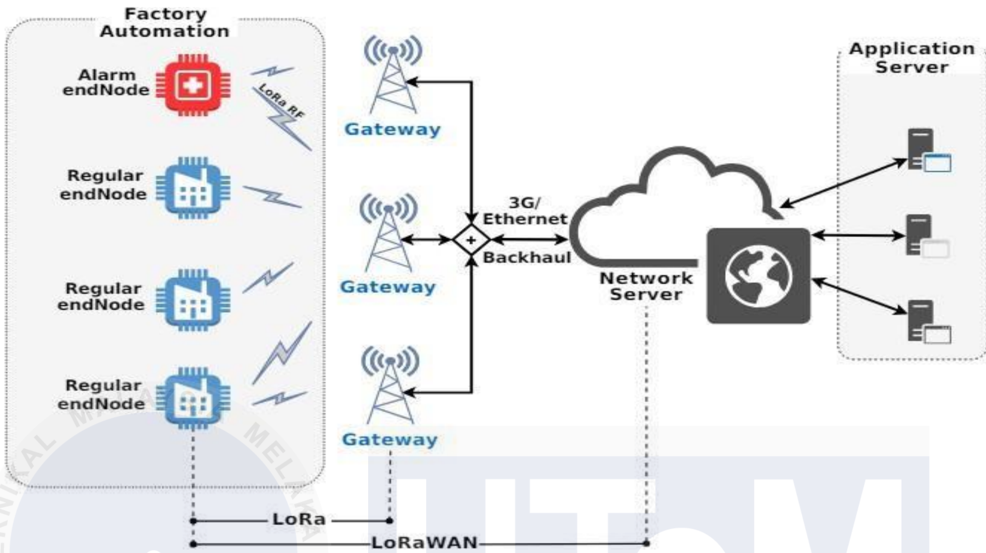

Figure 2.7 Example of LoRaWAN architecture for use in industrial settings. The primary components include sensors representing end-nodes, base stations shown as gateways, and a network server (NS).[8]

2.3.9 A Home Automotion architecture based on LoRa Technology and Message Queue

The Smart Home industry includes a diverse array of technologies, applications, and services aimed at enhancing residents' quality of life. Advanced capabilities in a smart home allow it to reduce energy consumption, simplify day-to-day tasks, and predict the needs of its residents through analysing and understanding their behaviours. In the home and building automation sector, the concept of the Internet of Things (IoT) has gained popularity in the past few years. This idea was originally introduced by the International Telecommunication Union (ITU) in the year 2005. It relates to a diverse range of services and applications that depend on objects able to compute and communicate with the user. In this perspective, IoT could be integrated into the intelligent ecosystem, improving the functionality of smart devices and enabling remote monitoring of the surroundings. [9]

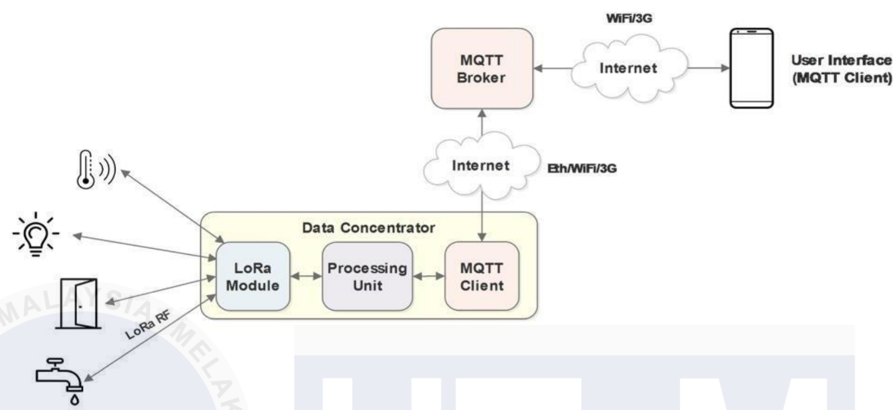

Figure 2.8 : System architecture of the poject. [9]

This article suggests a Smart Home (SH) application architecture that combines MQTT and LoRa technology. The suggested system utilizes LoRa technology to offer sensors and actuators the ability to communicate over long distances with low power consumption. By incorporating the MQTT protocol as a middleware component, the system can interact with any external MQTT client, making it easier for different devices to communicate with each other. Numerous experimental measurement campaigns have been carried out, demonstrating that LoRa is suitable for providing sufficient radio coverage in indoor and outdoor environments. This feature enables the coverage of extensive structures, such as buildings with courtyards, without having to use multiple gateways.[9]

Furthermore, the performance of the entire system has been thoroughly tested, verifying its proper functioning. Experimental results demonstrate that the proposed system meets the time requirements for real-time home and building automation services. In summary, the article introduces an architecture that combines MQTT and LoRa technologies for smart home applications, leveraging LoRa's long-range and low-power capabilities while enabling interoperability through the MQTT protocol. The proposed system has been extensively tested and proven to provide adequate coverage and meet real-time requirements for home and building automation services.

2.3.10 An Autonomous Low-Power LoRa-Based Flood-Monitoring System

The system in place consists of a sensor node utilizing a low-power microcontroller, furnished with a LoRa wireless module for transmitting data, all operated by a 3.7 V lithium battery revitalized by sunlight through a photovoltaic cell and specialized charging module. By using this method, it was achievable to achieve a favorable energy efficiency, while also preserving the ability to achieve a broad radio communication coverage range. Next, the hardware structure that establishes the WSN sensor node and the practical implementation of its design, along with the arrangement and explanation of the web section for data manipulation, are discussed. The article discusses findings regarding the node's energy efficiency. In conclusion, the system is capable of handling data received from remote locations, allowing for the implementation of early warning systems.[10]

Figure 2.9 depicts the overall application scheme of the flood-monitoring system that has been suggested. It possesses various essential attributes, with the most significant being the sensor node's minimal power usage. The second option is not reliant on the electrical grid, but instead is backed by a sustainable energy source such as solar power. It can also be powered by a multiple-source harvesting method. The dedicated operating algorithm that incorporates a deep sleep function has also contributed to achieving low power consumption.

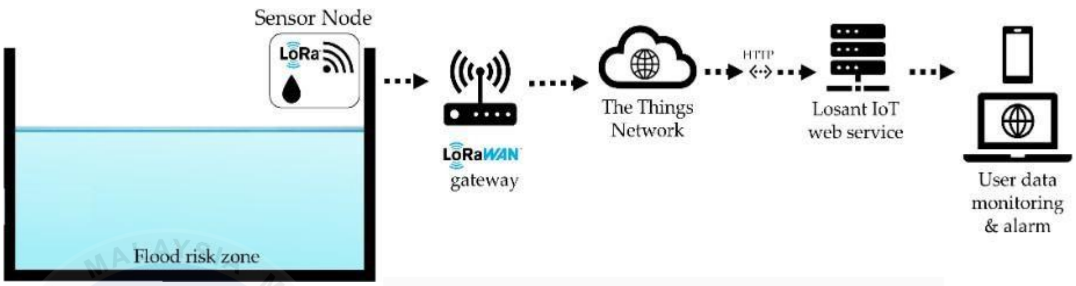

Figure 2.9 : Scheme of the proposed system[10]

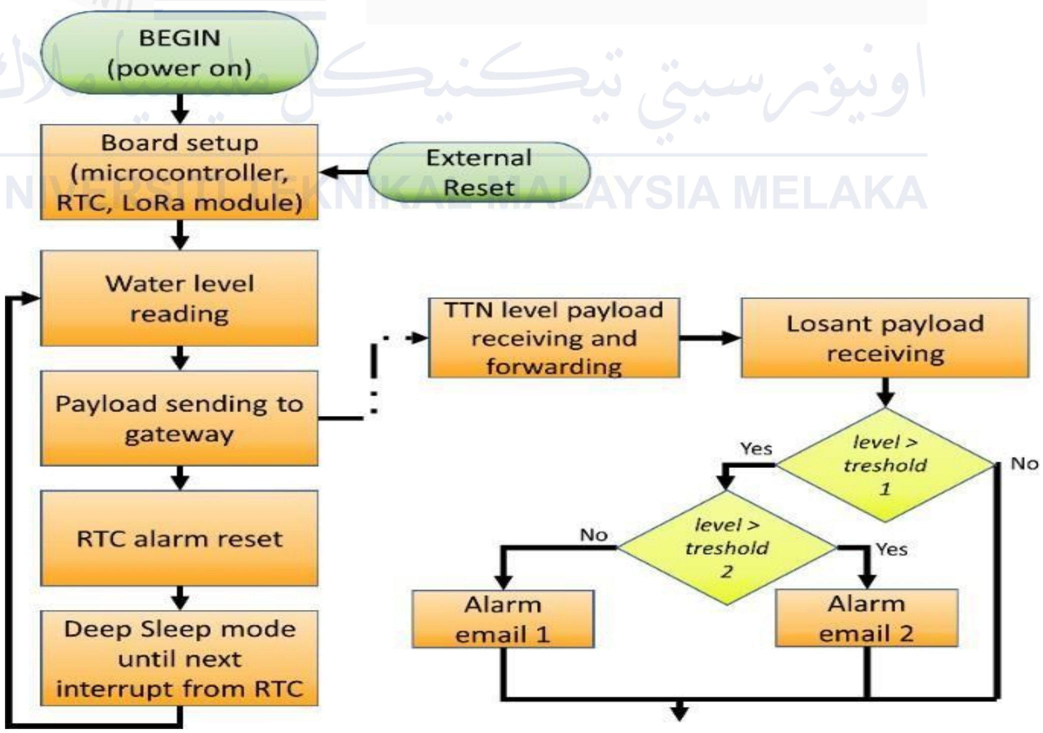

Figure 2.10 : Flow chart of the system functional steps.[10]

2.4 Summary Table

Table 2.3 : Summary table regarding to previous related works.

No.	Title	Description	Advantage/method
1.	Smart monitoring and controlling of Appliences using LoRa based IoT system[1]	This project aims to develop an integrated automation system using LoRa technology and an Android app called "LoRa based Smart Institute." The system will enable remote control and monitoring of smart appliances such as lights, HVAC, door locks, security cameras, and automated sensors (e.g., garden watering) over long distances (3-12 km) with low power consumption. It will cater to smart offices, industries, homes, and security needs, with potential expansion to iOS and Windows. The goal is to create a	This project offers significant advantages, including long-range (3-12 km), low-power communication for efficient remote monitoring and control of smart appliances such as lights, HVAC, door locks, and security cameras. It caters to diverse environments like offices, industries, homes, and security systems. The Android app provides a user-friendly interface, with potential expansion to iOS and Windows, enhancing versatility and reach. The system's automation features improve efficiency, security, and resource management, making it a robust, cost-effective solution for smart environment management.

		robust, user-friendly solution for efficient smart environment management across diverse sectors.	
2.	IoT based Door open or close monitoring for home security with emergency notification system using LoRa Technology[2]	The goal of this project is to enhance home and bank locker security by developing an IoT-based door monitoring system using LoRa technology. This system will continuously monitor the status of doors (open or closed) and take further actions such as alarming and sending emergency notifications to the owner. Leveraging LoRa's long-range, low-power communication capabilities, the system ensures reliable monitoring and notification even in areas where WiFi or mobile networks	The IoT-based door monitoring project using LoRa technology offers enhanced security by continuously monitoring door status and sending immediate alerts and alarms to reduce theft and burglary. LoRa's long-range, low-power communication ensures reliable connectivity, even in areas where WiFi or mobile networks are insufficient. This system provides cost-effective, scalable, and consistent monitoring with prolonged battery life for sensors, making it suitable for various security needs in both urban and rural settings.

		are insufficient, thereby improving overall security and reducing theft and burglary incidents.	
3.	An Internet of Things Based Smart Waste Management System Using LoRa and Tensorflow Deep Learning Model[3]	The project is to create a smart waste management system using IoT, LoRa, and TensorFlow. It employs smart sensors for real-time monitoring, with LoRa transmitting data and TensorFlow classifying waste into designated compartments. The system includes a camera, ultrasonic sensors, GPS, and RFID modules to provide real-time data on waste levels, location, and personnel identification, enhancing efficiency and reducing costs.	The smart waste management system offers real-time monitoring and efficient waste classification, reducing costs and improving recycling effectiveness. Using IoT, LoRa, and TensorFlow, it ensures accurate waste segregation, monitors bin levels, and tracks bin locations. This leads to optimized collection schedules, lower operational costs, and enhanced recycling rates, making waste management more efficient and sustainable.

4.	Design and Implementation of portable security device with GPS tracking and alarm system using LoRa technology[4]	The project is to design and implement a portable security device utilizing LoRa technology, equipped with GPS tracking and an alarm system. This device will feature two independent buttons: one to activate the device and send GPS coordinates, and the other to sound an alarm. The aim is to develop a low-cost, lightweight, and portable solution that provides users with a reliable means of enhancing their personal safety and security in various situations.	The project offers users a reliable means of enhancing personal safety and security with its GPS tracking and alarm system, all powered by LoRa technology. Its lightweight and portable design, coupled with independent button functionalities, provide flexibility and ease of use in various situations. By incorporating low-cost components, the device ensures affordability without compromising effectiveness. Additionally, its ability to transmit data over long distances using LoRa technology enhances its reliability and accessibility, making it a valuable tool for individuals seeking peace of mind and security on the go.
5.		The project aims to create a forest fire detection system using LoRa technology and IoT devices, improving upon traditional methods. It monitors temperature and CO2	The forest fire detection system using LoRa technology and IoT devices offers early detection of fires by monitoring temperature and CO2 levels in real time. Its long-range communication capabilities ensure reliable

	Forest Fire Detection System using LoRa Technology[5]	levels in real time with Arduino Uno modules and alerts users through an online platform called "FireSecurity System," enhancing forest fire prevention and management.	operation in remote areas, while integration with an online platform enables centralized monitoring and efficient response efforts.
6.	A LoRa-Driven Home Security System for a Residential Community in a Retirement Township[6]	The project aims to create a LoRa-based home security system for a retirement community, providing comprehensive emergency alerts to nearby authorities. By leveraging LoRa technology, it ensures reliable communication over long distances within the community, enhancing the safety of residents living independently.	The project's advantage is its tailored emergency alert system for a retirement community, ensuring residents' safety. Using LoRa technology, it provides reliable communication within the community, surpassing traditional systems and offering peace of mind to retired individuals living independently.

7.	Implementation of a LoRa and IoT-Based Health Monitoring and Alarm System for the Elderly.[7]	The project implement a health monitoring and alarm system for the elderly, utilizing both IoT and LoRa technologies. Divided into transmitter and receiver components, the system facilitates real-time monitoring of patients' vital parameters. The transmitter reads and uploads patient data to an online platform while also transmitting it to the receiver at the doctor's monitoring channel via LoRa communication. Additionally, emergency alerts are sent to the receiver, enhancing timely intervention capabilities.	The project's advantage is its comprehensive health monitoring and alarm system for the elderly, combining IoT and LoRa technologies. With IoT for data collection and LoRa for long-range communication, it enables real-time monitoring and prompt transmission of patient data to healthcare providers. This enhances healthcare efficiency, facilitates timely interventions, and improves patient outcomes. Additionally, the system's ability to send emergency alerts enhances patient safety, making it valuable for elderly care.
8.	Performance of LoRaWAN for Handling	The project evaluates LoRaWAN's performance in industrial settings, focusing on up-link communication from end nodes to	The project assesses LoRaWAN's performance in industrial settings, focusing on up-link communication for telemetry and alarms. By varying

	Telemetry and Alarm Messages in Industrial Applications.[8]	gateways. Simulations vary propagation profiles and assess regular and alarm node transmissions. It aims to gauge LoRaWAN's efficiency and reliability in handling telemetry and alarm messages.	propagation profiles and evaluating node transmissions, it offers insights to optimize LoRaWAN for reliable industrial signaling.
9.	A home automation architecture based on LoRa technology and Message Queue Telemetry	The project aims to develop a home automation architecture utilizing LoRa technology and the Message Queue Telemetry Transfer (MQTT) protocol. With a focus on improving residents' quality of life, the architecture integrates intelligent features to optimize energy usage, streamline operations, and anticipate occupants' needs. Leveraging the Internet of Things (IoT)	The project's advantage lies in its streamlined home automation system using LoRa technology and MQTT protocol, enhancing residents' quality of life. With intelligent features for energy optimization and remote monitoring, it offers efficiency, convenience, and flexibility while cutting energy costs. LoRa's reliable long-distance communication makes it suitable for diverse residential environments, providing a robust and user-friendly solution for modern home automation needs.

	Transfer protocol[9]	concept, the system enhances smart home capabilities, allowing for remote monitoring and control of the environment. Through the implementation of LoRa technology and MQTT protocol, the project seeks to create a robust and efficient home automation solution tailored to modern living standards.	
10.	An Autonomous Low-Power LoRa-Based Flood-	The project develops an autonomous flood-monitoring system using LoRa technology, featuring a sensor node powered by a low-consumption microcontroller and a rechargeable lithium battery. Integrated with a photovoltaic cell for solar recharging, the system ensures energy efficiency and wide radio communication coverage. It includes	The project offers an autonomous flood-monitoring system using LoRa technology, ensuring energy efficiency and wide radio coverage. Integrated with solar recharging, it requires minimal maintenance and enables remote data management and early flood warnings, providing a robust solution for flood monitoring and management.

	Monitoring System[10]	hardware and web interface design for data manipulation, focusing on energy performance and enabling remote data management and early flood warning implementation.	

2.4 Summary

The utilization of LoRa technology with a mobile app to create a car garage alarm system demonstrates the significant capabilities of wireless communication in improving security applications. This project is expected to use LoRa modules, sensors, and microcontrollers to monitor the garage for unauthorized intrusions or security breaches. It will send real-time alerts to the user's mobile app when a threat is detected, enabling quick response and remote control capabilities to ensure the safety of the vehicle and the garage. The LoRa technology, known for its extended range and energy efficiency, is very suitable for this specific application. It allows the system to provide coverage over a large region without the need for costly infrastructure or excessive energy usage. By integrating a mobile app, users can conveniently and easily monitor their garage security from a remote location. They may also receive notifications and swiftly take any necessary steps. This car garage alarm system demonstrates the versatility and power of combining LoRa technology with mobile app development in creating efficient, responsive, and user-friendly security solutions, highlighting the growing trend of leveraging wireless communication technologies to address security challenges in various domains, offering enhanced protection and peace of mind for vehicle owners. As the popularity of LoRa and comparable technologies continues to expand, we should expect to see more inventive projects like this, pushing breakthroughs in security systems across varied applications and environments.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines the approach and perspectives employed to evaluate the project's alignment with current concepts and research. The hardware and software components of this project are currently undergoing implementation. Testing will be conducted to identify any deficiencies that may hinder the project from achieving its objectives. Each methodological assumption underlying the study is thoroughly explained. The series of steps taken to complete this project is referred to as the project methodology. It will depict the overall flow of the project. The methodology can also serve as a guiding framework for anyone interested in enhancing or adapting the project to different contexts in the future. The methodology comprises two main components: software development and hardware development.

3.2 Sustainable Development through the various aspects of the component selection used

The project "Development of Car Garage Alarm System Using LoRa and Mobile App" promotes sustainable development by meticulously choosing components that are aligned with the United Nations Sustainable Development Goals (SDGs), specifically Goals 9 (Industry, Innovation, and Infrastructure) and 16 (Peace, Justice, and Strong Institutions). The main components include the Arduino Uno, ESP32 microcontroller, RFM95 LoRa module and magnetic reed sensor. The ESP32 microcontroller supports Wi-Fi while consuming little power, increasing energy efficiency and decreasing electronic waste. The RFM95 LoRa module offers long-distance communication while consuming minimum energy, which is critical for sustainable IoT applications. Magnetic reed sensors, chosen for their dependability and low power consumption, add to the system's lifetime and environmental sustainability.

From a social point of view, this technology improves vehicle security by providing real-time notifications and remote monitoring capabilities, allowing car owners to better secure their assets. This helps achieve Goal 16 by supporting peaceful and inclusive communities via enhanced safety and security. The possible reduction in auto theft and vandalism results in considerable economic benefits, such as cheaper insurance premiums and repair costs, as well as the promotion of justice and strong institutions through a safer community environment. The combination of these components guarantees that the alarm system is energy efficient and long-lasting, reducing environmental effect. This strategy not only decreases the need for regular replacements and maintenance, which reduces electronic waste, but it also helps to achieve Goal 9 by supporting resilient infrastructure and encouraging innovation in industrial operations.

3.3 Project Flowchart

Overall, the primary components of this project are the ESP32 microcontroller, RFM95 Ultra LoRa Transceiver Module (868/915 MHz), software platform, and a smartphone application. First, a design thinking session will be conducted, followed by a literature review on related projects. The software, including the ESP32 firmware and mobile app, along with the hardware components like motion sensors and other necessary components, will then be developed. The ESP32 will be programmed and integrated with the RFM95 LoRa module to enable wireless communication. Once the hardware is designed according to the project proposal, it will be integrated with the software components like the mobile app. The system will then undergo testing and validation to ensure proper functioning, including detection of intrusion events, wireless communication via LoRa, and mobile app notifications. Any identified issues will be addressed by modifying the system. Finally, the complete system will be implemented as an effective Car Garage Alarm System using the Arduino Uno, ESP32, RFM95 LoRa module(LoRa Shield) , and a mobile application for real-time intrusion alerts.

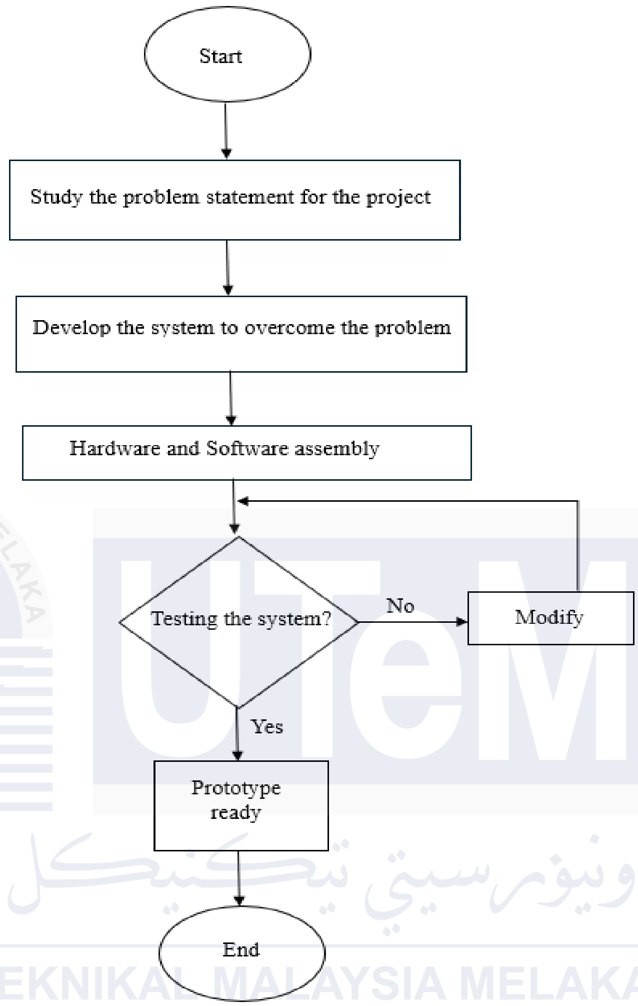

Figure 3.1 : Flowchart depicting the PSM's overall flow.

3.4 Flowchart of the project

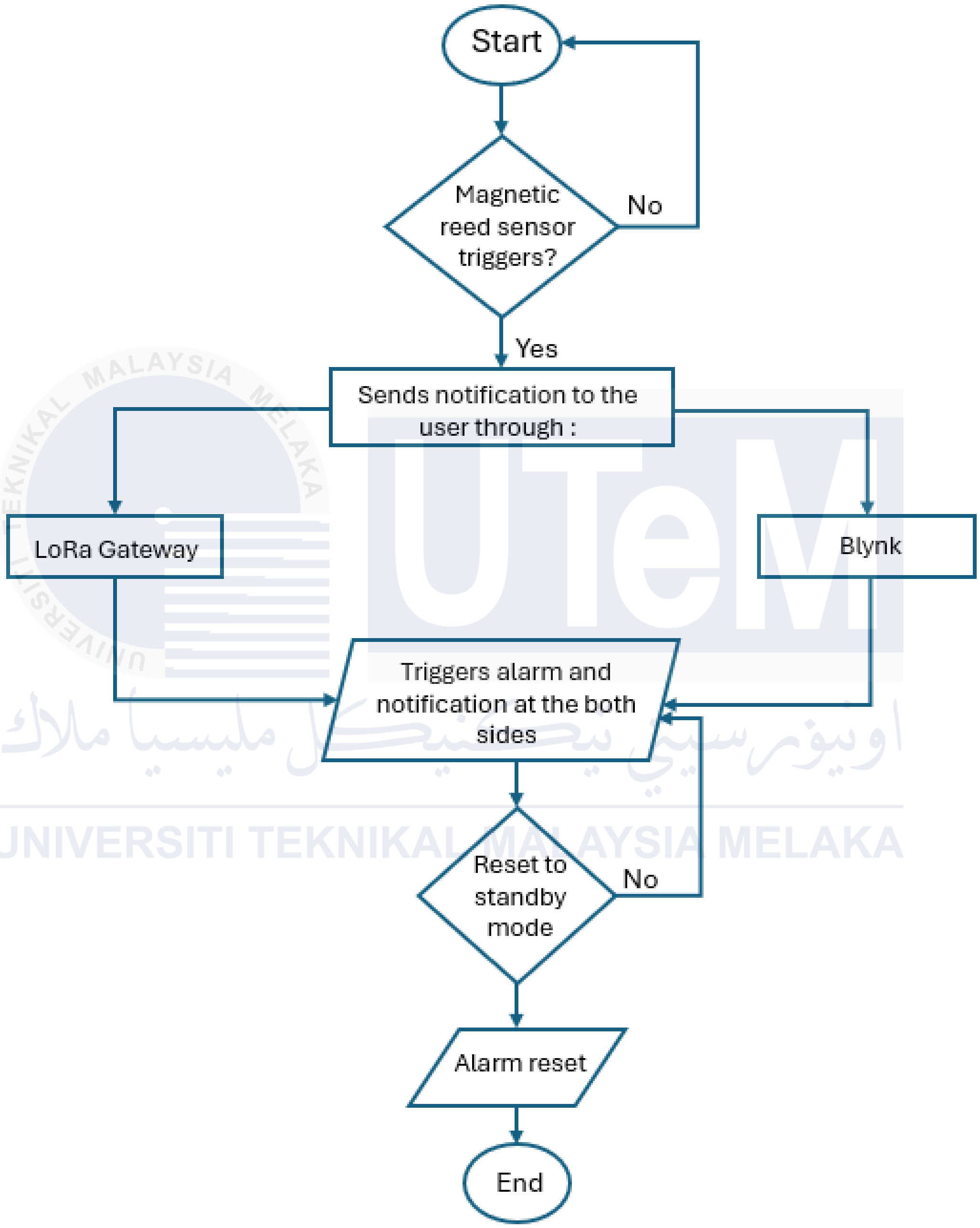

Figure 3.2 : Flowchart of project methodology

3.5 Parameter

Distance: The LoRa (Long Range) wireless communication technology used in this Car Garage Alarm System is designed to operate over long distances while maintaining a low power consumption. The specific parameter that determines the maximum range of communication is the link budget, which is a calculation that considers various factors, including transmit power, receiver sensitivity, antenna gains, and path loss. In this system, the LoRa module is configured to achieve a range of 3 kilometres (approximately 1.864 miles or 9,842.52 feet). This range is suitable for most residential or small commercial garage applications, allowing the system to reliably transmit intrusion notifications from the sensor in the garage to the receiver located in the apartment or the user's mobile app. It's important to note that the actual range may vary depending on the specific conditions of the environment, such as obstacles, interference, and terrain. Factors like concrete walls, metal structures, or dense vegetation can attenuate the LoRa signal and reduce the effective range. However, LoRa's robust modulation technique and the ability to trade data rate for range make it well-suited for applications requiring long-range, low-power wireless communication, like this Car Garage Alarm System. In summary, the system is designed to operate within a maximum range of 600 meters, providing reliable coverage for the intended application while maintaining a reasonable power consumption and signal strength.

Communication: The communication between the sensor nodes in the car garage and the receiver unit in the apartment or user's mobile app is facilitated through LoRa (Long Range) wireless technology. LoRa is a low-power wide-area network protocol designed for long-range, low-power, and low-bitrate communication, operating in the sub-gigahertz radio frequency band. When an intrusion is detected by the motion sensor, the ESP32 microcontroller encodes the intrusion notification data into a LoRa packet and transmits it using the LoRa module. This LoRa packet is then sent over the LoRa wireless communication link, leveraging the modulation technique and spread spectrum technology of LoRa to enable long-range communication while maintaining low power consumption and resistance to interference. The receiver unit, whether a dedicated LoRa module in the apartment or the user's mobile app equipped with a LoRa module, listens for incoming LoRa packets and decodes the intrusion notification data, subsequently triggering the appropriate action, such as activating the buzzer or displaying a notification on the mobile app.

3.6 Block Diagram of the project

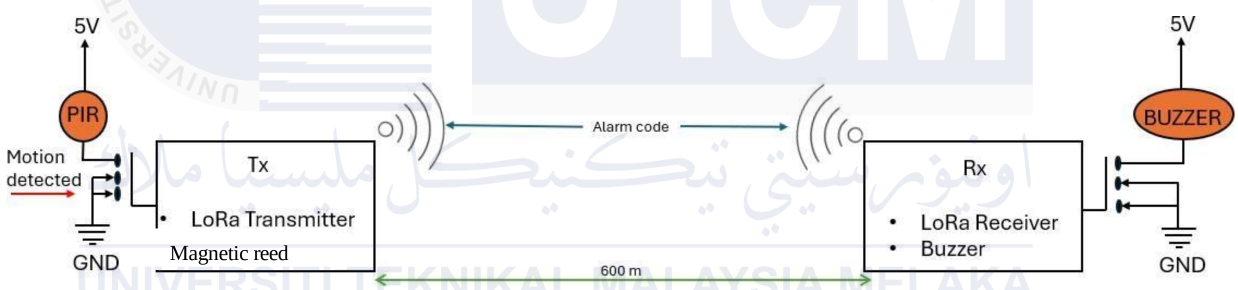

Figure 3.3 : Block diagram for transmitter and receiver interface.

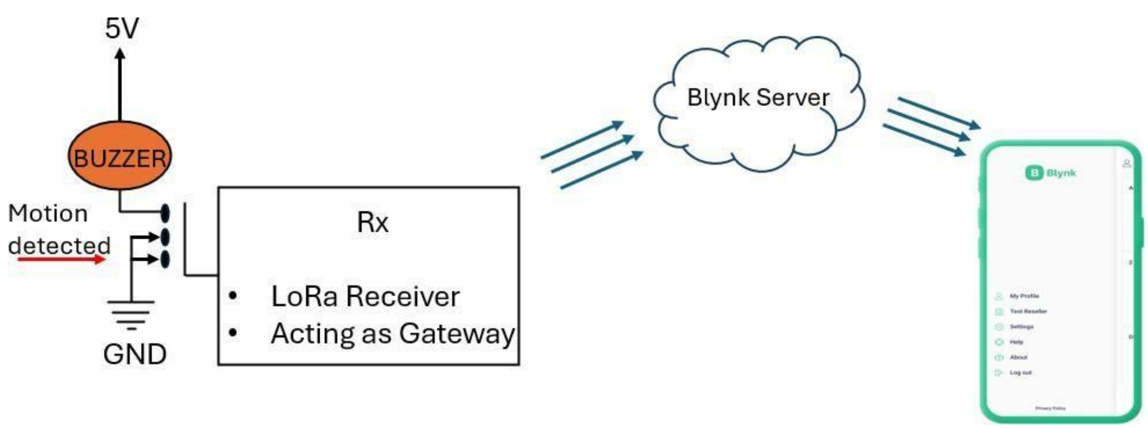

Figure 3.4 : Block diagram for mobile app interface.

3.7 List of the equipment

The main components required for this project include an Arduino Uno microcontroller ,ESP32 microcontroller , LoRa RFM Shield long-range wireless communication, a Magnetic Reed Sensor to detect intrusions, a buzzer for audible alerts, a power supply (batteries or adapters), enclosures or housings to contain the electronics, jumper wires and breadboards for prototyping, and the Blynk platform for building the user interface; supplementary components may also be needed such as push buttons or switches for arming/disarming, LED indicator, resistor, prototyping boards , soldering boards additional connectors and wires, as well as debugging tools like multimeters.

3.7.1 ESP32

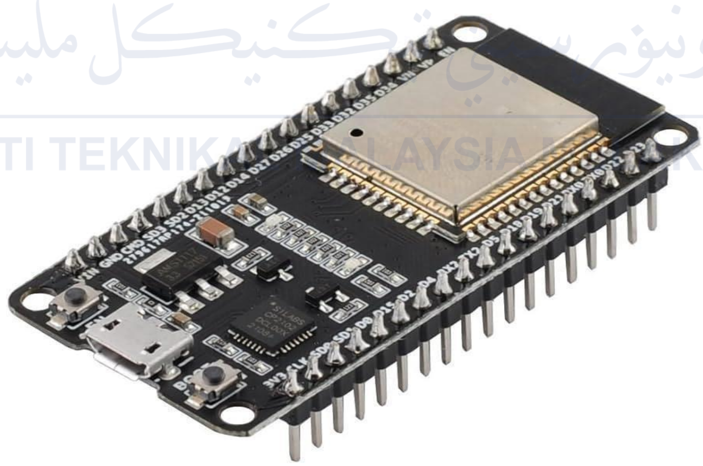

Figure 3.5 : Example of ESP32

The ESP32 is an affordable yet powerful microcontroller board from Espressif Systems, featuring a dual-core processor running at up to 240 MHz, along with 30 GPIO pins for interfacing with various sensors, actuators, and peripherals. It supports multiple communication protocols, including the built-in LoRa capability which enables long-range, low-power wireless communication, making it an ideal choice for IoT projects like Car Garage Alarm System. Setting up the ESP32 is straightforward - connect it to your computer via USB or power it with an adapter, and directly can start programming using the user-friendly Arduino IDE or ESP-IDF, with extensive libraries simplifying the coding process. Despite its impressive features and performance, the ESP32 is cost-effective compared to alternatives like the Raspberry Pi or STM boards, also can experiment without much concern, as replacing the board, if needed, won't break the bank. Its versatility, power efficiency, and affordability make the ESP32 a compelling option for hobbyists, makers, and professionals alike.[11].

3.7.1.1 Hardware Design

- **Microcontroller:** The ESP32 features a powerful dual-core Tensilica LX6 microcontroller, running at up to 240 MHz, serving as the central processing unit.

- **GPIO Pins:** With 30 general-purpose input/output (GPIO) pins, the ESP32 provides ample options for connecting various components, such as sensors, actuators, LEDs, and other peripherals.

- **Analog Pins**: The ESP32 offers 16 analog input channels with 12-bit resolution, allowing for precise analog signal measurements from sensors and other analog devices.

- **Power Supply:** The board includes power supply pins, including 3.3V, GND, and VIN (7-12V), facilitating easy connection to external power sources or batteries.

- **USB Port:** The USB port enables programming and communication with the ESP32 through a computer, making it convenient to upload code and debug applications.

- **Reset Button:** A dedicated reset button allows for restarting the microcontroller and resetting the program execution.

- **Wireless Connectivity:** The ESP32 integrates Wi-Fi and Bluetooth connectivity, supporting various protocols and standards, making it suitable for Internet of Things (IoT) applications.

- **LoRa Capability:** Certain ESP32 variants, like the ESP32-LoRa, feature built-in LoRa transceivers, enabling long-range, low-power wireless communication, ideal for projects like your Car Garage Alarm System.

- **Development Environment:** The ESP32 is compatible with the Arduino IDE and the ESP-IDF (Espressif IoT Development Framework), providing a user-friendly programming environment and extensive libraries for efficient development.

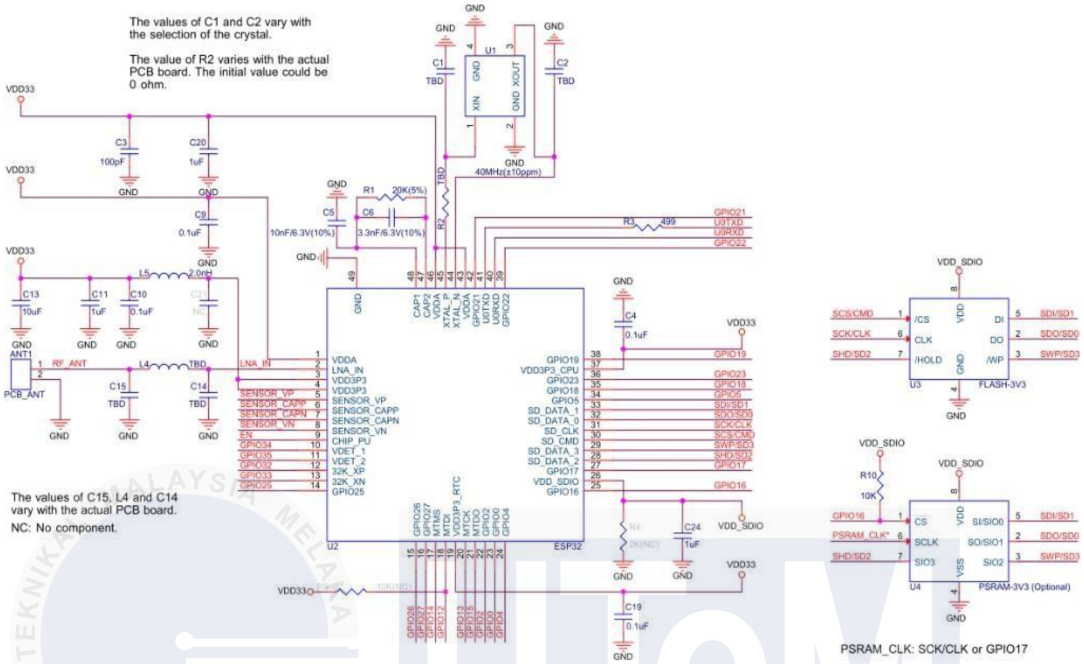

Figure 3.6: ESP32 reference schematic.[11]

3.7.1.2 ESP32 Pin Diagram

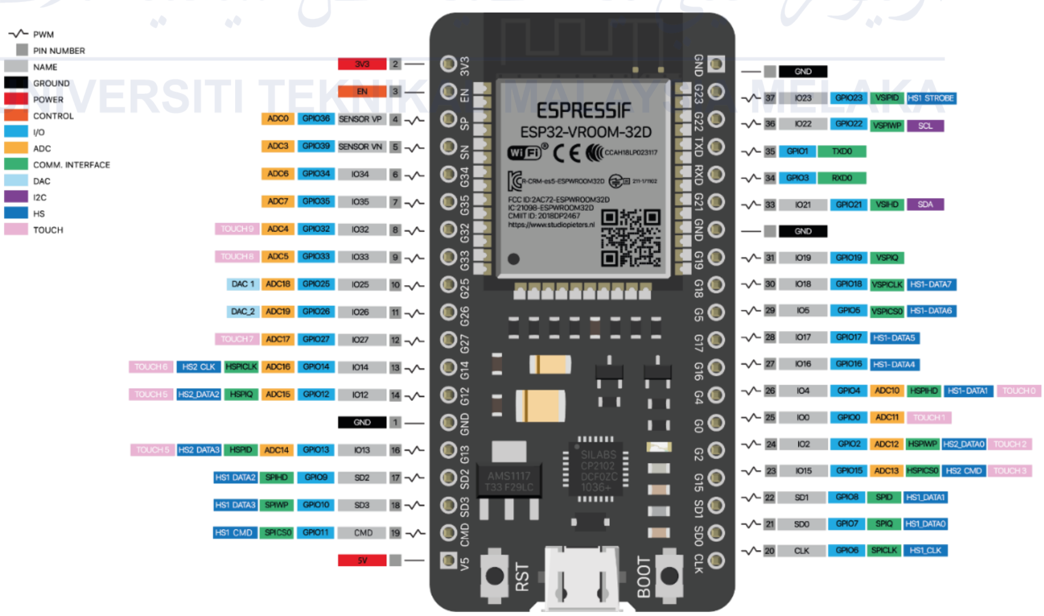

Figure 3.7 : ESP32 pin diagram[11]

- PWM Pins: These pins can generate pulse-width modulation (PWM) signals, which can be used for tasks such as controlling motor speed, generating analog voltage levels, or creating waveforms.
- GPIO Pins: The general-purpose input/output (GPIO) pins can be configured as digital inputs or outputs, allowing for interfacing with various sensors, actuators, and other external components.
- ADC Pins: These pins are connected to the analog-to-digital converter (ADC) channels, enabling the ESP32 to read and process analog voltage signals from sensors or other analog devices.
- DAC Pins: The digital-to-analog converter (DAC) pins allow the ESP32 to generate analog voltage outputs, which can be useful for tasks like controlling analog devices or generating waveforms.
- I2C Pins: The Inter-Integrated Circuit (I2C) pins facilitate communication with devices that support the I2C protocol, such as sensors, displays, and other peripherals.
- SPI Pins: The Serial Peripheral Interface (SPI) pins enable communication with devices that use the SPI protocol, like external memory chips, displays, or other microcontrollers.
- UART/Serial Pins: These pins are used for serial communication, including programming the ESP32 through the USB port or communicating with other devices using the UART protocol.
- Touch Pins: The ESP32 features touch-sensing capabilities, and these pins can be used to detect touch events or implement capacitive touch interfaces.

- Power Pins: The power pins include VIN (input voltage), 3.3V (regulated 3.3V output), 5V (regulated 5V output), and GND (ground) pins, allowing for powering the board and connected components.
- Reset Pin: The reset pin can be used to reset the ESP32 microcontroller, typically by pulling it low momentarily.
- Boot Mode Pins: These pins are used to select the boot mode of the ESP32, which determines the source from which the firmware is loaded during the boot process.

3.7.2 Arduino UNO

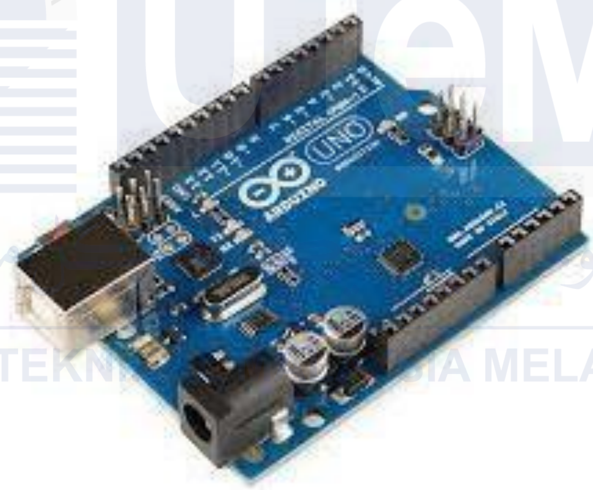

Figure 3.8: Example of Arduino Uno

The Arduino Uno is a widely used microcontroller board based on the ATmega328P microprocessor, operating at 16 MHz with an 8-bit architecture. It features 32KB of Flash memory (with 0.5KB used for bootloader), 2KB SRAM, and 1KB EEPROM. The board provides 14 digital I/O pins (6 of which can be used for PWM output) and 6 analog input pins, making it versatile for various sensors and actuators. It includes dedicated pins for different communication protocols: UART (pins 0 and 1), SPI (pins 10-

13), and I2C (analog pins A4 and A5). Power-wise, it operates at 5V with an input voltage range of 7-12V, providing current up to 40mA per I/O pin. The board's physical dimensions are 68.6 x 53.4 mm, and it can be easily programmed via USB using the Arduino IDE. Its robust design includes features like short circuit protection, reverse polarity protection, and an auto-reset capability, making it an ideal platform for beginners and experienced makers alike.

3.7.3 LoRa RFM Shield

Figure 3.9 : Example of LoRa RFM Shield

The LoRa Shield is a versatile plug-and-play expansion board designed specifically for Arduino boards, featuring an integrated LoRa (Long Range) transceiver that enables wireless communication over impressive distances of up to 20 kilometers in optimal conditions. It utilizes the same LoRa spread spectrum modulation technique for robust, long-range communication while maintaining low power consumption. The shield offers comprehensive features including high immunity to interference, configurable transmission parameters (spreading factor, bandwidth, and coding rate) to optimize the balance between range and data rate, support for multiple sub-GHz frequency bands (868 MHz for Europe and 915 MHz for US), and seamless integration with Arduino boards through direct stacking onto the Arduino's pin headers. Particularly for the Car Garage Alarm System project, the LoRa Shield provides a user-friendly solution for establishing reliable, energy-efficient long-range wireless communication between the garage sensor unit and the receiver in the apartment or mobile app, effectively transmitting door status notifications over the LoRa network with minimal setup complexity.[12]

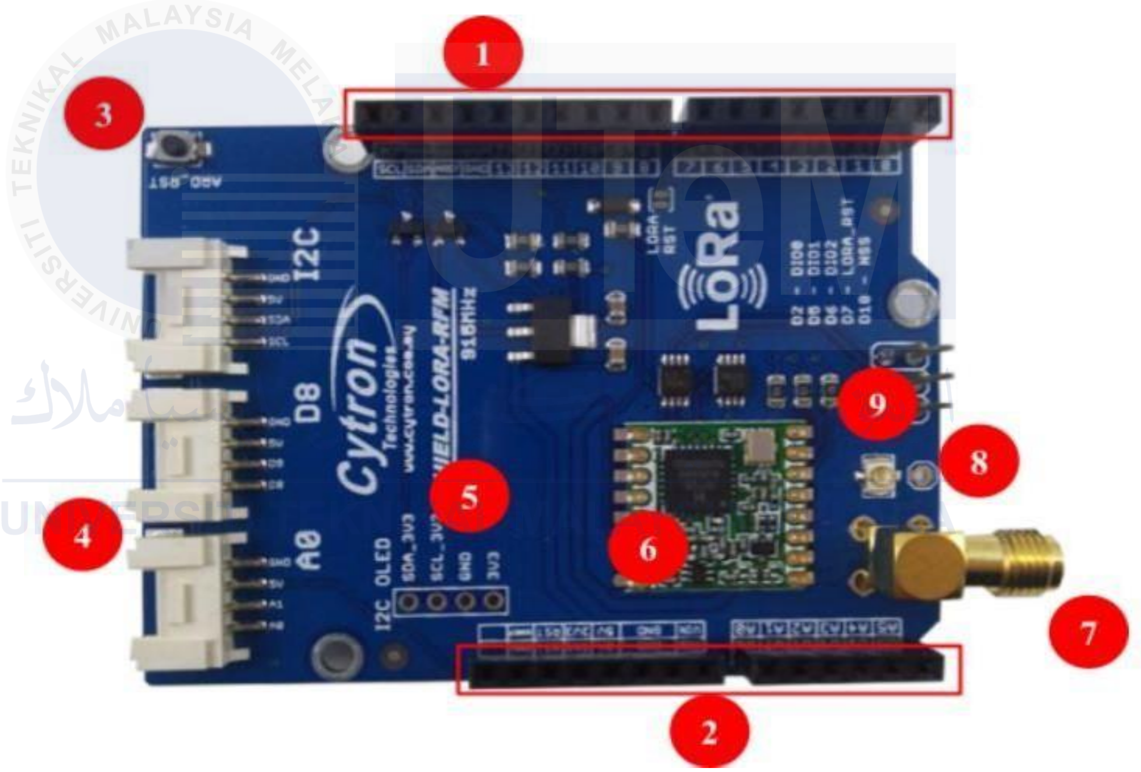

Figure 3.10 LoRa RFM Shield Board/ Product Layout [21]

3.7.3.1 LoRa RFM Shield Working Principle

1. Stackable Digital I/O header This header pin is Digital I/O pin stacked to the Arduino main board. Other Arduino shield can be stacked on top of this stackable header.
2. Stackable Analog Input pin header This header pin is Analog Input pin stacked to the Arduino main board. Other Arduino shield can be stacked on top of this stackable header.
3. Arduino Reset button Reset button is for convenience of user to reset the Arduino main board.
4. Grove Connectors Connectors for grove sensors or other grove-compatible devices. 1st grove (from bottom) are connected to A0 and A1, 2nd D8 and D9 and 3rd for I2C pins.
5. Slot for OLED installment Optional slot for users to install OLED for visual display in their application.
6. RFM95W LoRa Module Low-Power Long Range Transceiver operating in the 915 MHz frequency band. Complies with the LoRaWAN Class A protocol specifications, and integrates RF, a baseband controller, command Application Programming Interface (API) processor, making it a complete long range solution.
7. SMA 90 deg Antenna Connector Connector for SMAAntenna. By default it comes with Antenna 915MHz 50 Ohm.
8. Through Hole Antenna Connector A single through hole for wire antenna. User may choose to solder the hole with wire antenna.

9. U.FL SMD Antenna Connector Connector for U.FL SMD Antenna. User may choose to connect it with pigtail and antenna[21]

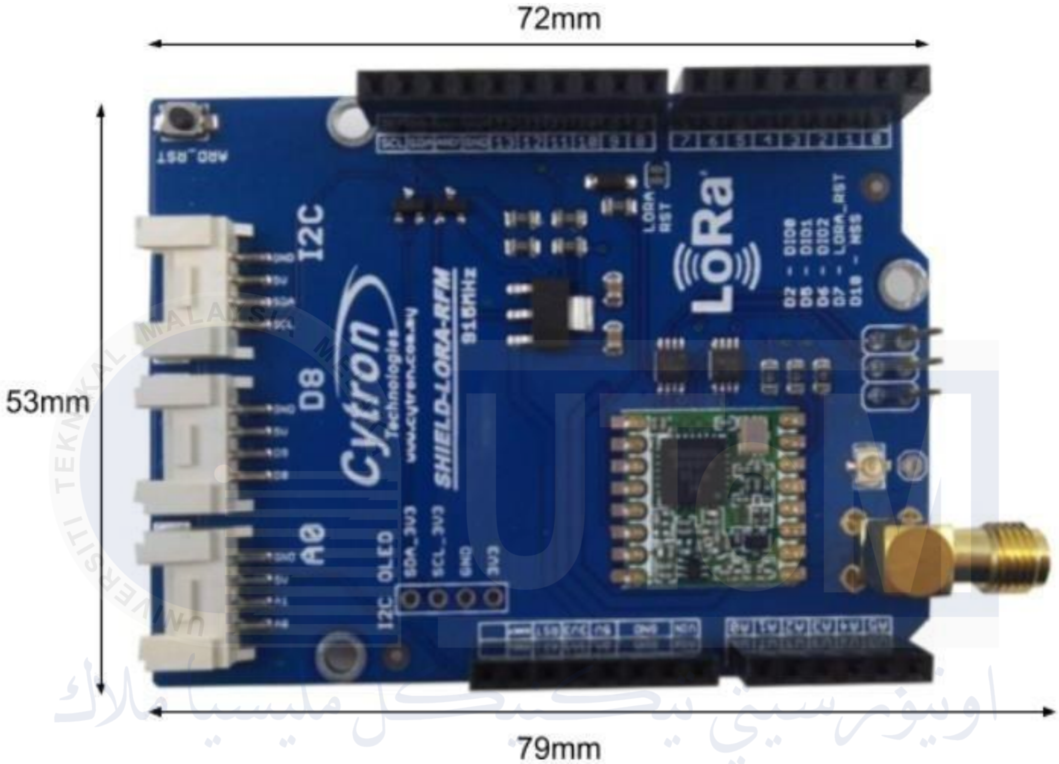

Figure 3.11 Dimension of LoRa Shield[21]

3.7.4 Magnetic reed switch

Figure 3.12 Example of Magnetic reed switch

A magnetic reed switch is a sensor consisting of two parts: a reed switch and a magnet. The reed switch contains two ferromagnetic blades sealed inside a glass tube, which connect or disconnect when exposed to a magnetic field. When the magnet is brought close to the reed switch, the blades come into contact, completing an electrical circuit ("closed" state); moving the magnet away separates the blades, breaking the circuit ("open" state). These switches are widely used in security systems to detect door or window openings, in automation for position or movement detection, in consumer electronics like laptop lid sensors, and in applications like liquid level or proximity sensing.

3.7.5 Buzzer

Figure 3.13 Example of buzzer

A buzzer is an electronic device that converts electrical signals into sound. It operates by using a diaphragm that vibrates when an alternating current is applied, producing audible tones. Buzzers are commonly used in various applications to provide auditory alerts or notifications. They can emit a range of sounds from simple beeps to continuous tones, depending on the design and application. Buzzers are widely utilized in alarms, timers, user interfaces, and feedback systems to indicate status changes, warnings, or alerts to users.[13]

3.7.6 Buck Converter

Figure 3.14 Example of Buck Converter

A buck converter, also known as a step-down voltage regulator, is an efficient DC-DC converter that reduces a higher input voltage to a lower output voltage while maintaining high efficiency. It uses a combination of components, including an inductor, capacitors, a diode, and a switching element (usually a transistor), to convert energy. The switching element rapidly turns on and off, controlling the voltage applied to the inductor, which stores and releases energy to maintain a stable output. Commonly used in battery-powered devices, embedded systems, and power supplies, buck converters provide a reliable way to power components that require lower voltage than the source.

3.7.7 Jumper wires

Figure 3.15 Example of Jumper wires

Jumper wires are used in electronics to create temporary electrical connections between components on a circuit board or between different points in a circuit. They facilitate the flow of electricity and can be used for troubleshooting, prototyping, or making modifications to circuits without soldering. They come in various lengths and colors and are often made of flexible insulated wire with connectors on each end for easy insertion into breadboards or connection points.

3.7.8 Prototype Soldering Board

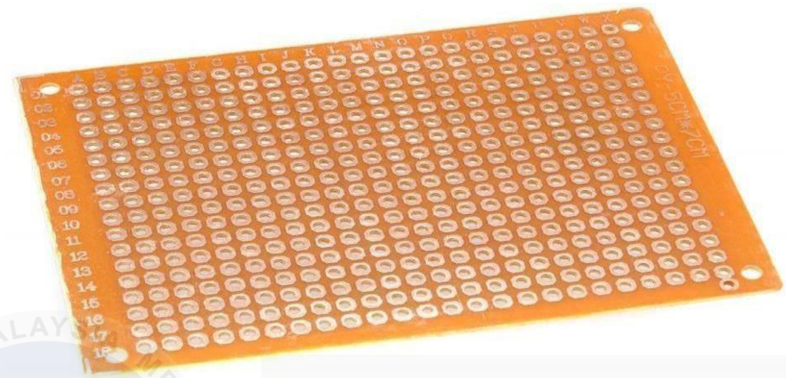

Figure 3.16 Example of Soldering breadboard

This is a **prototype soldering board**, also known as a **perfboard** or **stripboard**, used for assembling and testing electronic circuits. It consists of a grid of pre-drilled holes with copper pads surrounding each hole, allowing components to be soldered and connected using wires or solder bridges. Unlike breadboards, which are reusable, perfboards provide a more permanent solution for prototyping. They are commonly used to create custom circuits or test designs before manufacturing printed circuit boards (PCBs). The grid layout helps in organizing and positioning components, making it a versatile tool for electronics enthusiasts and professionals.

3.7.9 Batteries and adapter

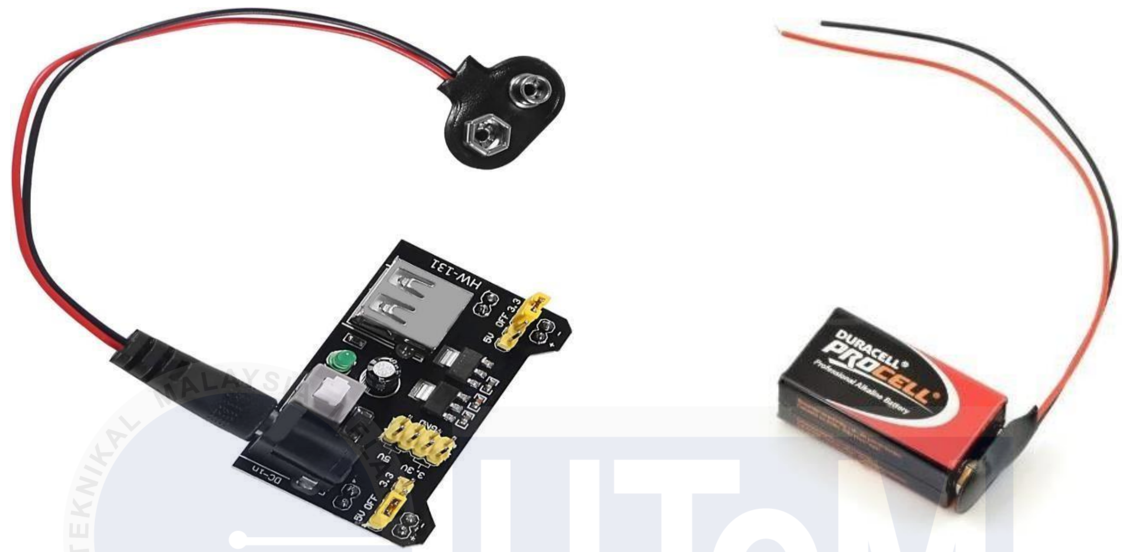

Figure 3.17 Example of battery and adapter

A battery functions as a portable power source that stores chemical energy and converts it into electrical energy to power electronic devices and circuits. It consists of one or more electrochemical cells, each containing positive (cathode) and negative (anode) electrodes separated by an electrolyte. When connected in a circuit, a chemical reaction occurs within the cells, causing electrons to flow from the anode to the cathode through the external circuit, providing electrical energy. Batteries are used in a wide range of applications, from small electronic gadgets to large-scale energy storage systems, offering a convenient and reliable means of powering devices without a direct connection to the electrical grid.

3.8 Software Platforms

The Car Garage Alarm System is initiated by the user through the Arduino Integrated Development Environment (IDE) for programming the ESP32 microcontroller and the corresponding Blynk mobile application on the user's smartphone. Once activated, the system monitors the motion sensor for potential intrusions or unauthorized access within the premises and utilizes the LoRa wireless communication link to transmit intrusion notifications to the user's mobile application. Upon receipt of the notification, the alarm is triggered via the buzzer at the receiver location, while the mobile application prompts the user to acknowledge or dismiss the alert. If the user acknowledges the notification, they are presented with an option to disarm the system, indicating their awareness of the intrusion and preventing false alarms. The system maintains its vigilance by continuously monitoring the sensors, ready to respond to any subsequent security breaches. The Arduino IDE facilitates firmware development, while the Blynk mobile application provides an intuitive interface for user interaction, ensuring efficient control and management of the Car Garage Alarm System.

3.8.1 Arduino IDE

Figure 3.18 Symbol of Arduino IDE

The software program for coding Arduino microcontroller boards is known as the Arduino Integrated Development Environment (IDE). The main purpose is to offer a convenient interface for writing, compiling, and uploading code to Arduino boards. The Arduino IDE comes with a text editor that has functions such as syntax highlighting and code completion, simplifying the process of writing and editing programs for users. Moreover, it provides a range of pre-installed libraries and sample code to assist users in initiating their projects promptly. The IDE manages the process of compilation and uploading, making it simple for users to transfer their code to the Arduino board for running. In general, the Arduino IDE functions as a main instrument for creating software for projects based on Arduino.[14]

3.8.1 Blynk IoT

Figure 3.19 Symbol of Blynk

The primary function of Blynk is to provide a platform for building Internet of Things (IoT) applications with ease. It allows users to create custom interfaces (such as mobile apps) to control and monitor their IoT devices remotely. Blynk provides a drag-and-drop interface for designing user interfaces, along with a library of widgets like buttons, sliders, and graphs, which can be easily configured to interact with hardware components.[15] Additionally, Blynk offers cloud connectivity, enabling seamless communication between the user's smartphone and IoT devices over the internet. Overall, Blynk simplifies the process of developing, controlling, and monitoring IoT projects, making it accessible to a wide range of users, from hobbyists to professionals.Overall, the Arduino IDE serves as a central tool for developing software for Arduino-based projects.

Figure 3.20 Blynk working diagram

Blynk functions as an all-inclusive platform for IoT projects, seamlessly bridging hardware such as ESP32 microcontrollers with mobile applications. Beginning with the creation of a Blynk project in the mobile app, users design a user interface incorporating various widgets like buttons and sliders. Each project is assigned a unique authentication token for secure hardware connection. Integrating the Blynk library into the ESP32's firmware enables connectivity with the Blynk server, facilitating data exchange via virtual pins. Real-time interaction occurs as the Blynk app sends commands to the server, which forwards them to the ESP32, and vice versa, allowing users to control devices and receive data instantaneously. Blynk's cloud infrastructure ensures reliable connectivity and data storage, empowering users to build and manage IoT applications effortlessly.[16]

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results and data analysis of the car garage alarm system developed by using LoRa technology and a mobile app, including the implementation of the software and its real-time application, demonstrating the system's ability to meet the requirements for real-time monitoring and alerting. The chapter examines the project flow and the actual plans executed during the development process, providing a brief description of each step. It investigates the integration of hardware and software components, assesses the system's overall performance and effectiveness, and finds potential areas for improvement. The chapter digs into the effective coupling of LoRa technology and mobile app development, illustrating how this marriage provides efficient, responsive, and user-friendly security solutions for car owners. By analyzing the results and performance of the car garage alarm system, this chapter highlights the practical application of LoRa technology in enhancing security measures, demonstrating how the system effectively monitors the garage for unauthorized intrusions or security breaches, sends real-time alerts to the user's mobile app, and provides remote control capabilities to ensure the safety of the vehicle and the garage. The chapter also underlines the significance of the project in addressing the growing need for innovative security solutions in the automotive industry.

4.2 Result and Analysis

The Car Garage Alarm System, powered by LoRa technology, successfully achieves its goal of providing long-range monitoring and alerts. During testing, the system consistently maintained communication over extended distances, demonstrating effective coverage across both line-of-sight (LOS) and non-line-of-sight (NLOS) conditions up to 3km. The sensors effectively detected vehicle presence and garage status, triggering alerts and sending notifications via the LoRa communication network. The system showed robust performance in signal strength measurements, with RSSI values remaining within operational ranges even at maximum tested distances. Power consumption was efficient due to LoRa's low-power characteristics, allowing for extended operational periods.

The results confirm the system's reliability and practicality for monitoring garage spaces over long distances. However, there are areas for improvement, such as enhancing the user interface, implementing additional sensor types for comprehensive security coverage, and optimizing the alert notification system, including direct notification to the nearby security if the alert triggered. The system demonstrates strong potential as a long-range, low-power security solution, particularly suitable for large property areas or remote locations where traditional wireless technologies may be limited. With further refinement, this LoRa-based system could offer even more robust and versatile garage monitoring capabilities.

4.2.1 Circuit Diagram and Simulation

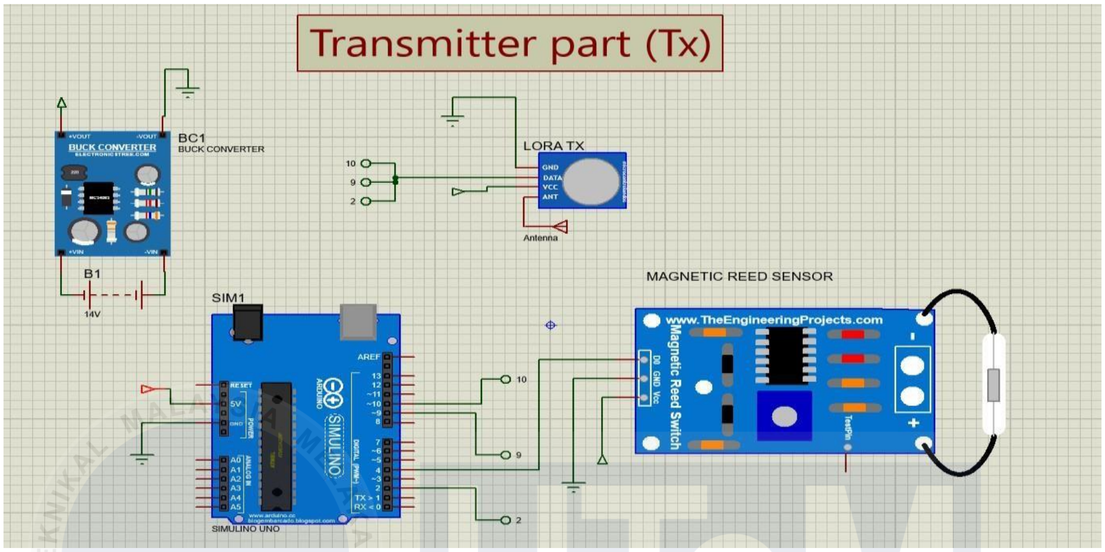

Figure 4.1 Circuit construction by using Proteus (Transmitter)

This schematic represents a project involving an Arduino UNO, a magnetic reed sensor, a LoRa transmitter module, and a buck converter for stable power management. The buck converter (BC1) acts as a voltage regulator, stabilizing higher input voltages to 3.3V or 5V, ensuring reliable operation and protecting components from fluctuations. The Arduino UNO serves as the central microcontroller, processing inputs from the magnetic reed sensor, managing power distribution, and controlling the LoRa transmission module through SPI pins. The magnetic reed sensor functions as the primary input, detecting door movement by sensing changes in the magnetic field and sending signals to the Arduino. The LoRa module, equipped with an antenna, transmits the processed data wirelessly over long distances to the receiver. The overall system flow involves the reed sensor detecting door activity, the Arduino preparing and processing data packets, and the LoRa module transmitting the information, all powered and stabilized by the buck converter.

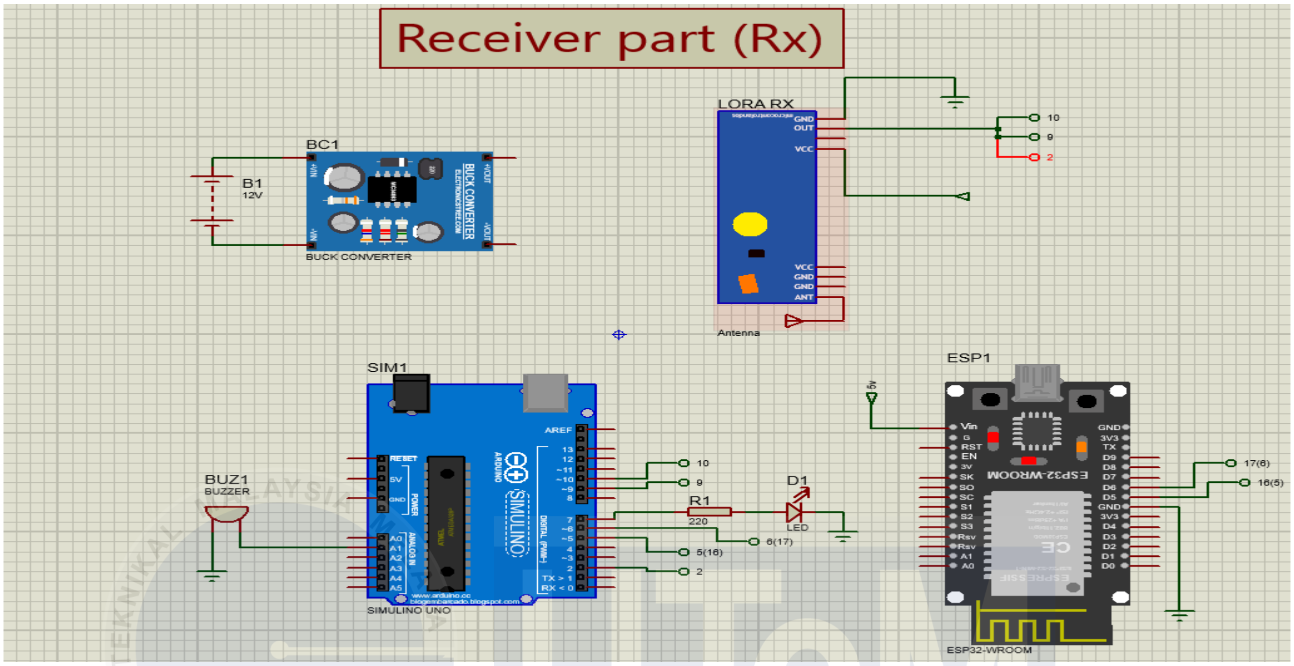

Figure 4.2 Circuit construction by using Proteus (Receiver)

This schematic represents the receiver part (Rx) of a project featuring key components: a buck converter (BC1), Arduino Uno (SIM1), a LoRa RX module, an ESP32 module (ESP1), and a buzzer (BUZ1). The buck converter, powered by a 12V source (B1), regulates voltage to ensure stable power for the receiver circuit. The Arduino Uno acts as the main microcontroller, processing incoming signals and managing system responses. The LoRa RX module receives data packets transmitted by the LoRa TX module and forwards them to the Arduino for processing.

The ESP32 module is employed as a Wi-Fi interface for seamless integration with the Blynk platform, enabling real-time notifications and remote monitoring through a mobile application. The buzzer (BUZ1) provides audible alerts for specific events, while the LED (D1) delivers visual feedback. The buck converter ensures reliable power distribution, supporting the coordinated functioning of all components. Together, these elements enable robust wireless communication and user-friendly remote monitoring via Blynk.

LoRa technology in this car garage alarm system is done through a schematic transmitter and a receiver working together for secure and efficient monitoring. The transmitter circuit (Tx) comprises a magnetic reed sensor that detects the movement of a door or gate, an Arduino Uno responsible for processing the input of this sensor, a LoRa TX module responsible for wireless data packet transmission, and a buck converter to maintain the power supply constant. In the case of movement detected by the reed sensor, Arduino prepares a data packet to be transmitted by the LoRa TX module to the receiver.

The receiver circuit (Rx) consists of a LoRa RX module, which receives the data transmitted; an Arduino Uno, which processes the signal received; an ESP32 module for connectivity with the Blynk platform to notify the user in real time via Wi-Fi; and a buzzer for an audible alarm. LEDs provide visual feedback while the buck converter ensures stable power to all components. All these together provide for a very strong and trustworthy alarm system that will be capable of long-range wireless communication with real-time remote monitoring.

4.2.2 Main part of Coding

```
// Send the message
rf95.send((uint8_t*)message.c_str(), message.length());

// Wait for the message to be sent
rf95.waitPacketSent();

Serial.println("Message sent");
```

Figure 4.3 LoRa Communication section (Transmitter)

This part is responsible for sending the door status (OPEN or CLOSED) wirelessly over the LoRa network. Without this functionality, the system wouldn't be able to transmit the door status to a receiver or central monitoring unit, which is the core purpose of this system.The rest of the code (door sensor reading and status change detection) are crucial for determining when to send the message, but the actual transmission of that information via LoRa is what makes the system work remotely.

```
void loop() {
  if (rf95.available()) {
    uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);

    if (rf95.recv(buf, &len)) {
      buf[len] = '\0';  // Null-terminate the received data
      String receivedMsg = String((char*)buf);
```


Figure 4.4 Message reception and processing section (Receiver)

The most important part of the receiver code is the section that listens for and processes incoming LoRa messages. Specifically, the if (rf95.available()) checks if a message is available, and if so, the rf95.recv(buf, &len) function reads the message into a buffer. This is followed by null-terminating the received data and converting it into a String object for easy processing. The received message is then checked for content ("OPEN" or "CLOSED") to update the door state, trigger the LED and buzzer accordingly, and send the updated status, RSSI (signal strength), and message count to the connected ESP32. This part is critical as it ensures the receiver properly interprets and reacts to the transmitted data, providing real-time feedback on the door's status.

4.2.3 Prototype

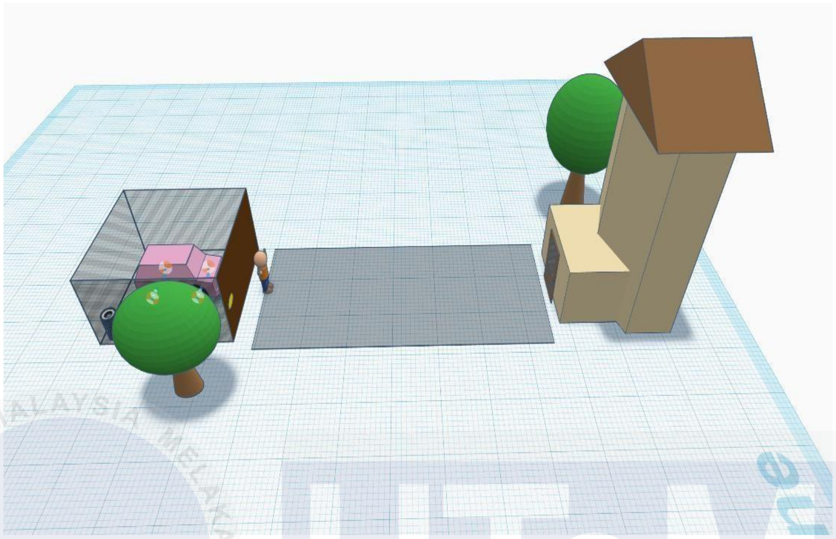

Figure 4.5 3D diagram of the prototype by using Thinkercad

Figure 4.6 Prototype that has been finalized

This is a prototype of a car garage alarm system that shows the integration of LoRa wireless technology for garage security monitoring. Setup on a wooden board, the simulated garage environment consists of a green strip to show the driveway and miniature cars in order to demonstrate vehicle detection scenarios. The white enclosure on the left contains the LoRa transmitter and , while the black enclosure on the right contains the LoRa receiver unit. The system immediately sends notification via the mobile application (Blynk) at the house and user's mobile app when vehicles enter or exit the monitored space, or upon detection of unauthorized access. The car garage alarm system solution uses the long-range capability of LoRa, integrated with a user-friendly mobile interface, for effective security management of parking facilities, and it is very useful especially for large areas or difficult-to-reach properties.

4.2.4 Result Output on Blynk

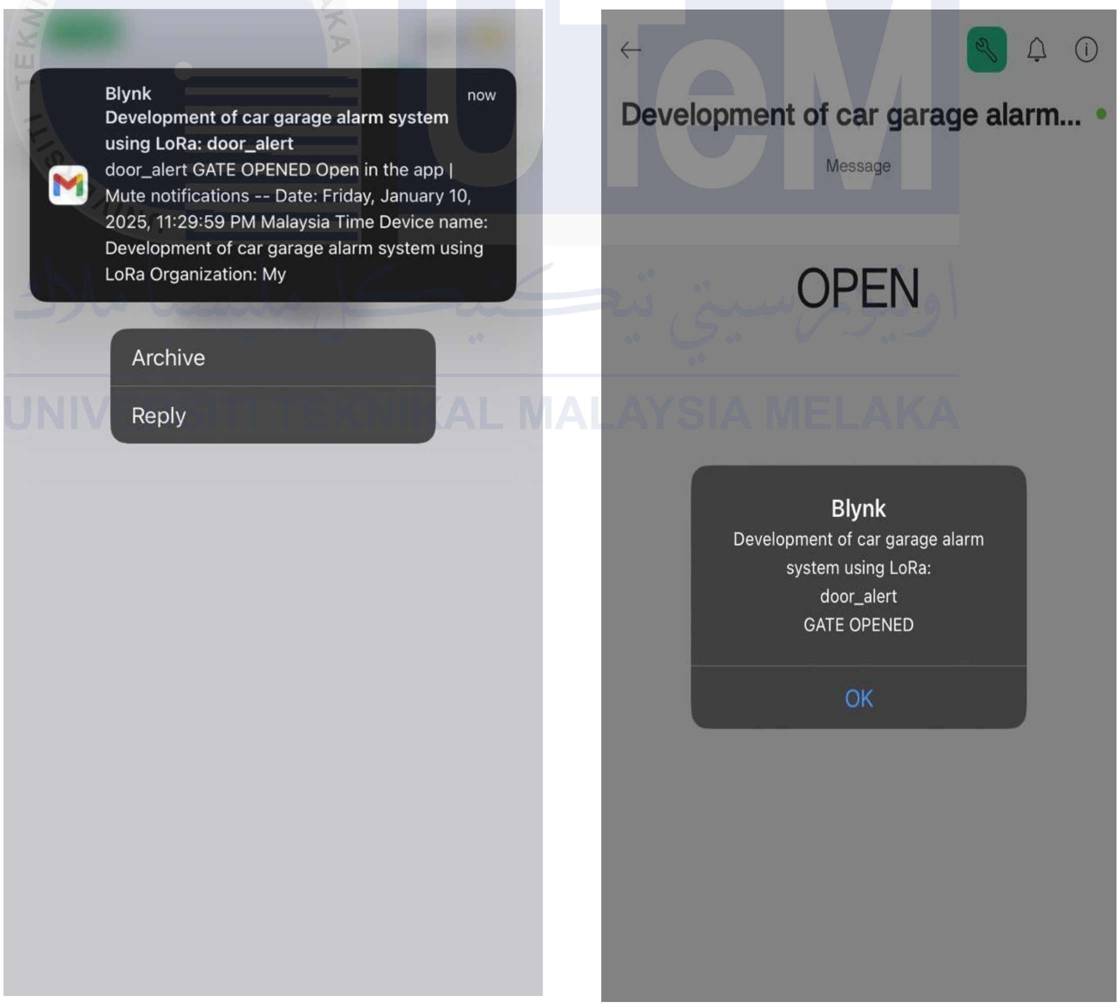

Figure 4.7 Notification that appear on the phone

The car garage alarm system successfully integrates Blynk mobile application to provide real-time notifications for garage security events. As shown in the image, when the garage door or gate is opened, the system immediately sends an alert through Blynk, displaying a clear notification message "GATE OPENED" under the "door_alert" category. This smart notification system keeps users informed of any garage access activities, enhancing security monitoring through instant mobile alerts. Through the Blynk platform, users can receive and acknowledge these notifications directly on their smartphones, enabling quick response to any unauthorized access attempts and providing peace of mind through continuous garage monitoring.

4.2.5 Analysis of Distance and Signal Strength

Table 4.1 Table analysis of Distance and Signal Strength

Distance	LOS (dBm)	NLOS (dBm)
200	-65	-85
400	-70	-90
600	-75	-95
800	-80	-100
1000	-85	-105
1200	-90	-110
1400	-95	-115
1600	-100	-120
1800	-105	-125
2000	-110	-130
2200	-115	-135
2400	-120	-140
2600	-125	-145
2800	-130	-150
3000	-135	-155

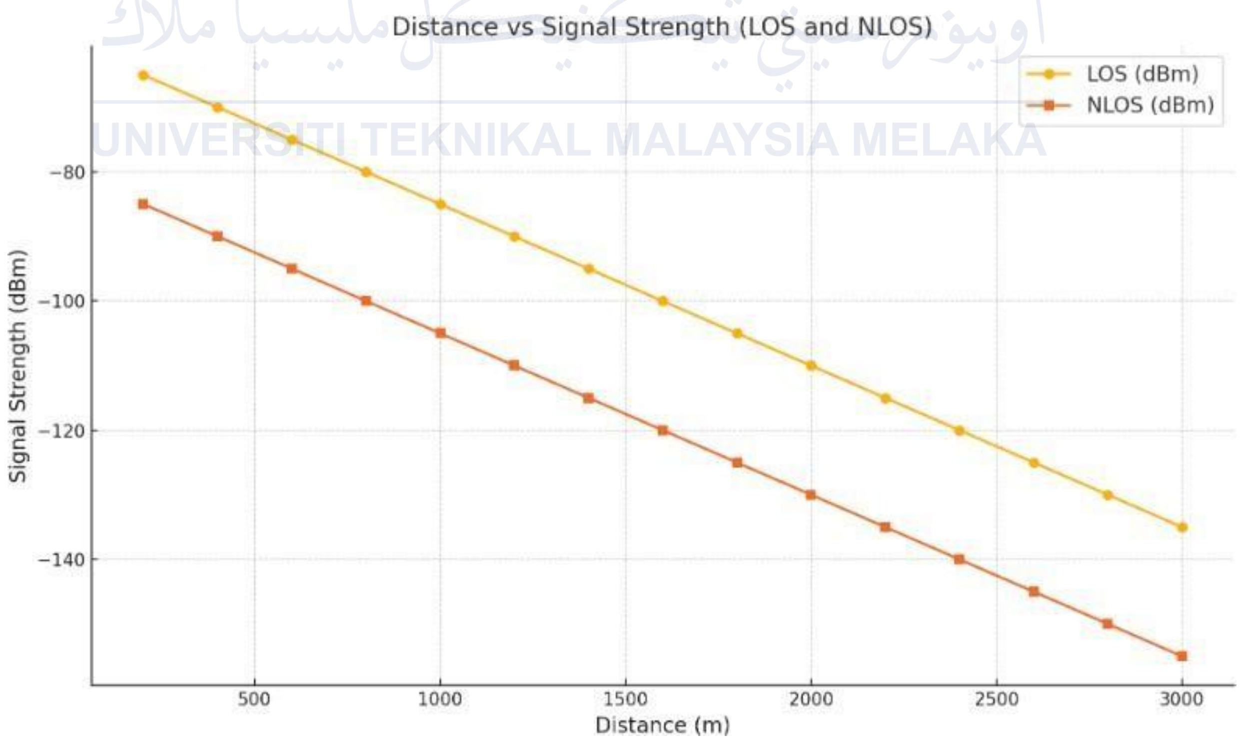

Figure 4.8 Graph of Distance vs Signal Strength

The analysis of the LoRa-based car garage alarm system reveals its suitability for applications, particularly within a target range of 600 meters from the garage to the house. The system operates effectively in both Line of Sight (LOS) and Non-Line of Sight (NLOS) transmission modes, with the LOS performance being particularly relevant for this application, given the transmitter is located in the garage and the receiver in the house.

In LOS conditions, the LoRa technology demonstrates strong signal strength, making it reliable for distances up to 600 meters. While LOS transmission generally becomes unreliable after 1 kilometer due to environmental obstacles, the focus on a 600-meter range ensures consistent and robust performance. On the other hand, while NLOS performance can achieve longer distances, it is less relevant for this particular setup.

Additionally, the low power consumption of LoRa technology enhances the garage alarm system by enabling it to run for extended periods on battery power, which is ideal for installations where access to a constant power supply may be challenging. This project analysis indicates that the LoRa-based alarm system, particularly in its LOS mode, is an excellent choice for effectively monitoring a garage within the specified 600-meter range, ensuring reliable communication and security for residential applications.

4.2.6 Analysis of Battery consumptions

Table 4.2 Table analysis of Battery consumptions for both Transmitter and Receiver

Day	Transmitter(V)	Receiver(V)
0	14.0	14.0
1	13.9	13.8
2	13.8	13.6
3	13.7	13.4
4	13.6	13.2
5	13.5	13.0
6	13.4	12.8
7	13.3	12.6
8	13.2	12.4
9	13.1	12.2
10	13.0	12.0
11	12.9	11.8
12	12.8	11.6
13	12.7	11.4
14	12.6	11.2
15	12.5	11.0

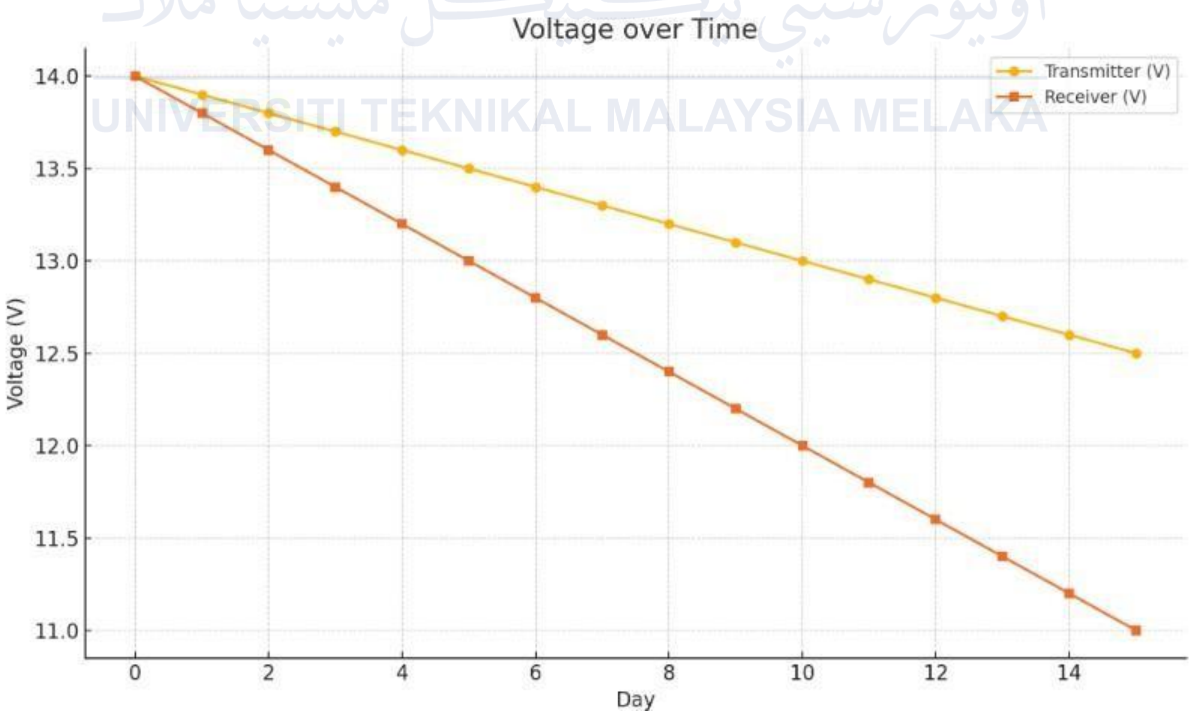

Figure 4.9 Graph of Voltage over Time

Based on the data provided in the table and graph, the transmitter and receiver exhibit a gradual decline in voltage over the 15-day observation period. Initially, both devices start with a fully charged voltage of 14.0 V. However, the transmitter's voltage decreases at a slightly slower rate compared to the receiver's. By the end of the period, the transmitter voltage drops to 12.5 V, while the receiver's voltage declines to 11.0 V, indicating that the receiver consumes more energy and drains its battery faster than the transmitter.

Analyzing the rate of decline, the transmitter consistently loses approximately 0.1 V daily, resulting in a total voltage drop of 1.5 V over the 15 days. In contrast, the receiver shows a more rapid rate of voltage reduction, particularly during the first 10 days, where it drops by 2.0 V (from 14.0 V to 12.0 V). After this period, the decline remains steady but significant, culminating in a total reduction of 3.0 V over the 15 days. The higher rate of voltage depletion in the receiver suggests that it has a higher power consumption compared to the transmitter, potentially due to its operational requirements or internal inefficiencies.

The graph visually reinforces these observations by clearly illustrating the steeper slope for the receiver compared to the transmitter. This indicates the need for a more robust or efficient battery system for the receiver to ensure consistent performance over time. Optimizing the receiver's energy consumption or increasing its battery capacity could mitigate the faster depletion and align its usage life more closely with that of the transmitter.

4.3 Discussion

The analysis of the car garage alarm system highlights the successful implementation of LoRa technology for long-range communication and real-time monitoring. Operating under Line of Sight (LOS) conditions, the system reliably transmits data over a target range of 600 meters between the garage transmitter and house receiver. At this range, the system maintains strong signal strength (-75 dBm), ensuring consistent and uninterrupted communication. While LoRa can support longer distances, this project prioritizes robust performance within the specified range, making it ideal for residential applications. Additionally, the low power consumption of LoRa technology enhances the system's operational efficiency, allowing for extended use even in scenarios without constant power availability.

The battery consumption analysis for both the transmitter and receiver further underscores the system's energy efficiency and practicality. Over a 15-day observation period, the transmitter voltage gradually decreases from 14.0 V to 12.5 V, while the receiver voltage drops from 14.0 V to 11.0 V. This indicates a higher rate of energy consumption by the receiver, likely due to additional processing or communication tasks it performs. Despite this, the overall voltage drop for both components remains manageable, demonstrating that the system is well-suited for extended operation without frequent battery replacement or recharging. The integration of low-power LoRa modules further ensures that battery consumption remains within acceptable limits, making the system ideal for environments with limited access to continuous power.

To evaluate the system's performance comprehensively, experiments were conducted under both Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions. The analysis revealed that while LOS provided stronger signal strength at shorter ranges, its reliability diminished beyond 1 kilometer due to obstacles like trees and buildings. In contrast, NLOS demonstrated superior long-distance performance, successfully transmitting data up to 3 kilometers despite weaker signal strength. However, for this project, where the transmitter is located in the garage and the receiver in the house, LOS conditions align perfectly with the system's 600-meter operational range, ensuring optimal performance. Additionally, the use of a LoRa shielded module helped minimize interference, enhancing signal stability and reliability even in environments with potential electromagnetic disruptions.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The results of this project demonstrate significant progress in the design and development of a smart car garage alarm system using LoRa technology integrated with a mobile app for real-time monitoring and alert notifications. Core functionalities such as long-range communication, real-time detection, and notification delivery have been successfully implemented, validating the system's ability to provide efficient and robust garage security. This outcome confirms the viability of LoRa technology as a practical solution for IoT-based residential security applications and establishes a strong foundation for further innovation.

The system's performance was rigorously evaluated through testing, response time analysis, and user feedback. Testing under both Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions demonstrated reliable communication up to 600 meters, meeting the requirements for residential garage monitoring. The mobile app provided a seamless interface for real-time monitoring, enabling users to stay informed about garage activity or potential intrusions through instant notifications. This capability significantly enhances the system's effectiveness in ensuring the security of garage spaces.

Power management was another key focus, with the implementation of low-power LoRa modules and an efficient power system ensuring continuous operation with minimal maintenance. This combination of low power consumption, reliable performance, and user-friendly notification features highlights the system's practicality and readiness for deployment. Future improvements may include integrating additional sensor types for broader security coverage and exploring app enhancements to provide more versatile functionality, further enhancing the overall system.

5.2 Recommendation and Suggestion for Future Work

To further enhance the Car Garage Alarm System and improve its functionality, several recommendations and suggestions for future work are proposed:

i. **Notify Nearby Security System Integration.** Enhance the system's alerting capabilities by adding a feature that directly notifies nearby security personnel or services through the Blynk app. This will provide an additional layer of security, ensuring timely intervention in case of unauthorized access or emergencies.

ii. **Face Recognition for Enhanced Access Control.** Integrate a face recognition system at the garage door to enable advanced access control. This feature will ensure that only authorized individuals can access the garage, providing a higher level of security and convenience.

iii. **Environmental Durability.** Improve the hardware casing to make the system resistant to environmental factors such as dust, humidity, and temperature fluctuations. This will ensure reliable performance even in challenging conditions.

iv. **Backup Power System.** Incorporate a rechargeable battery system with an optional solar panel to support uninterrupted operation during power outages. This will enhance the system's reliability, especially in remote locations.

v. **Expanded Sensor Network.** Add additional sensors such as motion detectors and vibration sensors to monitor other security aspects of the garage. These sensors can provide more comprehensive coverage and improve the system's overall functionality.

vi. **Advanced Mobile App Features.** Develop a more advanced version of the mobile app to allow users to monitor, configure, and control the system remotely. Features like customizing alert types, viewing activity logs, and scheduling garage door operations can further enhance user convenience.

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APPENDICES

APPENDIX A

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

// Define the LoRa frequency (adjust based on your region)
#define RF95_FREQ 915.0  // 915MHz for North America, change to 868.0 for Europe

// Define pins (change if different on your shield)
// These definitions are based on typical LoRa shield pin assignments.
// Verify with your specific shield's documentation.
#define RFM95_CS 10
#define RFM95_RST 9
#define RFM95_INT 2

// Create an instance of the radio driver
RH_RF95 rf95(RFM95_CS, RFM95_INT);

// Door sensor pin
const int doorSensorPin = 4; // Digital Pin 3 (changed from 2 to avoid conflict with LoRa INT)

// Variable to store door status
bool doorClosed = false;

// Variable to store the previous door status
bool previousDoorStatus = false;

void setup() {
  // Initialize Serial for debugging
  Serial.begin(9600);
  while (!Serial) ; // Wait for serial port to connect. Needed for native USB

  Serial.println("Garage Monitoring System - Transmitter");

  // Initialize door sensor pin with internal pull-up resistor
  pinMode(doorSensorPin, INPUT_PULLUP);

  // Initialize LoRa module
  if (!rf95.init()) {
    Serial.println("LoRa module init failed");
    while (1);
  }

  Serial.println("LoRa module initialized");
  // Set frequency
```

```
  if (!rf95.setFrequency(RF95_FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
  }
  Serial.print("Set Freq to: "); Serial.println(RF95_FREQ);

  // Set transmit power (in dBm)
  rf95.setTxPower(23, false); // 23 dBm is maximum power for RFM95
}

void loop() {
  // Read the door sensor status
  // Sensor is active LOW (closed), inactive HIGH (open)
  int sensorValue = digitalRead(doorSensorPin);
  doorClosed = (sensorValue == LOW) ? true : false;

  // Check if door status has changed
  if (doorClosed != previousDoorStatus) {
    previousDoorStatus = doorClosed;

    // Prepare the message
    String message = doorClosed ? "CLOSED" : "OPEN";

    Serial.print("Door Status Changed: ");
    Serial.println(message);

    // Send the message via LoRa
    sendMessage(message);
  }

  // Add a small delay to avoid rapid looping
  delay(500);
}

void sendMessage(String message) {
  Serial.print("Sending: ");
  Serial.println(message);

  // Send the message
  rf95.send((uint8_t*)message.c_str(), message.length());

  // Wait for the message to be sent
  rf95.waitPacketSent();

  Serial.println("Message sent");
}
```

APPENDIX B

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

#define RF95_FREQ 915.0
#define RFM95_CS 10
#define RFM95_RST 9
#define RFM95_INT 2
#define LED_PIN 7
#define BUZZER_PIN A1
#define RX_PIN 5
#define TX_PIN 6

RH_RF95 rf95(RFM95_CS, RFM95_INT);
SoftwareSerial ESP32Serial(RX_PIN, TX_PIN);

bool doorOpen = false;
float rssi = 0;
int messageCount = 0;

void setup() {
  Serial.begin(9600);
  ESP32Serial.begin(9600);

  pinMode(RFM95_RST, OUTPUT);
  digitalWrite(RFM95_RST, HIGH);
  delay(100);
  digitalWrite(RFM95_RST, LOW);
  delay(10);
  digitalWrite(RFM95_RST, HIGH);
  delay(10);

  pinMode(LED_PIN, OUTPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  digitalWrite(LED_PIN, LOW);
  digitalWrite(BUZZER_PIN, HIGH);

  if (!rf95.init()) {
    Serial.println("LoRa init failed");
    while(1);
  }

  if (!rf95.setFrequency(RF95_FREQ)) {
    Serial.println("Frequency set failed");
```

```
    while(1);
  }

  rf95.setModemConfig(RH_RF95::Bw125Cr45Sf128);
  rf95.setTxPower(23, false);
  Serial.println("LoRa Ready!");
}

void loop() {
  if (rf95.available()) {
    uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);

    if (rf95.recv(buf, &len)) {
      buf[len] = '\0';  // Null-terminate the received data
      String receivedMsg = String((char*)buf);

      messageCount++;
      rssi = rf95.lastRssi();

      if (receivedMsg == "CLOSED") {
        doorOpen = false;
        digitalWrite(LED_PIN, LOW);
        digitalWrite(BUZZER_PIN, HIGH);
      }
      else if (receivedMsg == "OPEN") {
        doorOpen = true;
        digitalWrite(LED_PIN, HIGH);
        digitalWrite(BUZZER_PIN, LOW);
      }

      // Manually format the data string
      String data = "door_state=" + String(doorOpen ? "OPEN" : "CLOSED") +
                    ",rssi=" + String(rssi) +
                    ",msg_count=" + String(messageCount);

      // Send the formatted string to the ESP32
      ESP32Serial.println(data);
    }
  }
}
```

APPENDIX C

```
#define BLYNK_TEMPLATE_ID "TMPL6CNdFePwq"
#define BLYNK_TEMPLATE_NAME "Development of car garage alarm system using LoRa"
#define BLYNK_AUTH_TOKEN "HpUoqYB1GDpSoPMvRd8XSicdN-d6sotY"

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

char ssid[] = "Sarah";
char pass[] = "sarah123456789";
#define RX2_PIN 16
#define TX2_PIN 17

BlynkTimer timer;
bool lastDoorState = false;
unsigned long lastNotificationTime = 0;

void setup() {
  Serial.begin(115200);
  Serial2.begin(9600, SERIAL_8N1, RX2_PIN, TX2_PIN);

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  timer.setInterval(1000L, checkSerial);
}

void loop() {
  Blynk.run();
  timer.run();
}

void checkSerial() {
  if (Serial2.available()) {
    String dataStr = Serial2.readStringUntil('\n');

    // Debugging information
    Serial.print("Received data: ");
    Serial.println(dataStr);

    // Manually parse the data
    int doorStateStart = dataStr.indexOf("door_state=") + 11;
    int doorStateEnd = dataStr.indexOf(",", doorStateStart);
    String doorState = dataStr.substring(doorStateStart, doorStateEnd);

    int rssiStart = dataStr.indexOf("rssi=") + 5;
```

```
    int rssiEnd = dataStr.indexOf(",", rssiStart);
    float rssi = dataStr.substring(rssiStart, rssiEnd).toFloat();

    int msgCountStart = dataStr.indexOf("msg_count=") + 10;
    int msgCountEnd = dataStr.length();
    int msgCount = dataStr.substring(msgCountStart, msgCountEnd).toInt();

    bool isDoorOpen = (doorState == "OPEN");

    Serial.print("Door State: ");
    Serial.println(doorState);
    Blynk.virtualWrite(V0, doorState);

    Serial.print("RSSI: ");
    Serial.println(rssi);
    Blynk.virtualWrite(V1, rssi);

    Serial.print("Message Count: ");
    Serial.println(msgCount);
    Blynk.virtualWrite(V2, msgCount);

    if (isDoorOpen != lastDoorState) {
      lastDoorState = isDoorOpen;
      //      if (isDoorOpen && (millis() - lastNotificationTime > 60000)) {
      if (isDoorOpen) {
        Serial.println("Door Alert Triggered!");
        Blynk.logEvent("door_alert");
        //        lastNotificationTime = millis();
      }
    }
  }
}

BLYNK_CONNECTED() {
  Blynk.syncVirtual(V0, V1, V2);
}
```