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UNIVERSITI TEKNOLOGI MARA

FINAL YEAR PROJECT 2

SUBMISSION OF PROJECT REPORT

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SMART SWITCH FOR PERSONALIZED HOME AUTOMATION SYSTEM		
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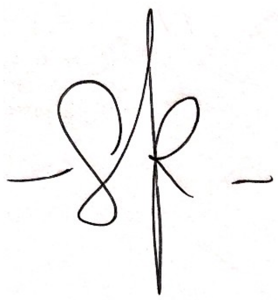

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SMART SWITCH FOR PERSONALIZED HOME AUTOMATION SYSTEM

MUHAMMAD IQRAM RAZIQ BIN ROSHIDI

SCHOOL OF ELECTRICAL ENGINEERING
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SMART SWITCH FOR PERSONALIZED HOME AUTOMATION SYSTEM

MUHAMMAD IQRAM RAZIQ BIN ROSHIDI

Final Year Project Report is submitted in partial fulfilment of the requirements for the degree of
Bachelor of Engineering (Hons) Electrical Engineering

SCHOOL OF ELECTRICAL ENGINEERING
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AUTHOR'S DECLARATION

I declare that the work in this final year project report was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This final year project report has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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Date	:	18 February 2024

ABSTRACT

The paper presents a Smart Switch designed for Personalized Home Automation, using the ESP32 microcontroller and Bluetooth Low Energy (BLE) technology to control various actuators within a smart home ecosystem. The system aims to enhance home automation by providing users with a customizable interface for tailored control of actuators. The methodology integrates BLE communication, the MQTT protocol, and the Pydroid3 application, enhancing communication and control over smart switches. The study examines data generated by a smart sensor system, demonstrating the efficacy of BLE and MQTT technologies in facilitating responsive and adaptable control over smart switches in different usage scenarios. The study's methodology emphasizes the seamless integration of BLE communication, MQTT protocol, and the Pydroid3 application, each playing a crucial role in facilitating efficient communication and control over smart switches. BLE technology enables low-power, short-range communication between the ESP32 microcontroller and the Pydroid3 application, allowing real-time control and monitoring of home appliances. The MQTT protocol serves as a lightweight and efficient messaging protocol, enabling communication between the smart switch system, the MQTT cloud, and other devices within the smart home ecosystem. By leveraging these technologies in tandem, the system achieves a high level of responsiveness and adaptability to user needs. The discussion section explores the intricate connections within the technology setup, revealing how each component intelligently interacts with one another to achieve desired functionality. The paper emphasizes the adaptability and potential for future enhancements of the smart switch system, highlighting its ability to create an energy-efficient and interconnected smart home environment.

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I am deeply grateful to the Almighty God for His blessings and guidance during the process of finishing this thesis. His continuous support has been a source of strength and inspiration, allowing me to overcome obstacles and succeed in this undertaking.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Intelligent technology that incorporates effective energy consumption planning is critical for monitoring and regulating energy usage in residential and commercial buildings, which account for more than 20% of total energy consumption. While contemporary smart buildings use a variety of sensors to detect people and the health of electrical equipment, deploying many sensors can raise circuitry and networking expenses. However, technologies such as Bluetooth Low Energy (BLE), which has long-range communication, low battery consumption, and high bandwidth, together with the increasing usage of smartphones and tablets, seek to improve user lives. Despite possible issues with sensor deployment, BLE provides improved functionality and advantages to building occupants. [1][2][3].

Technology innovation has prepared the path for the rise of smart home automation, in which numerous gadgets and systems may be linked to create an intelligent and convenient living environment. Smart switches and personalized home intelligence systems are crucial components of smart homes, enabling customized automation and improving the overall efficiency, comfort, and energy management of residential areas. Within a smart home system, Smart plugs are electrical devices that allow an ordinary appliance to be connected to the internet [4]. A smart plug is one of the common end-devices that allows user to switch home appliances from distance using remote control, whether through web-based application or mobile application. There have been numerous research projects concerning smart plug topics due to the ease of implementation, such as the devices reported in [5], [6] and [7]. Smart switches have transformed traditional switches by including wireless connection, allowing users to regulate the power supply to electrical outlets or gadgets from a remote location. These switches are often linked to the home's Wi-Fi network and may be operated by mobile apps or voice assistants, allowing for greater ease and flexibility in regulating household appliances and lights.

Despite the potential advantages of smart switches and personalized home intelligence systems, there are several problems and areas for development. Because manufacturers employ multiple protocols and standards, seamless integration and interoperability across different smart devices and home intelligence systems can be a considerable difficulty. This can stymie the efficient communication and interoperability required for effective automation. Furthermore, consumer knowledge and comprehension of smart switch and personalized home intelligence system capabilities and potential uses may be restricted. Homeowners may be unaware of how these technologies may improve their everyday lives, save energy, and increase home security. Adoption and acceptance might be hampered by a lack of awareness.

Moreover, security and privacy concerns must be addressed when deploying smart switches and personalized home intelligence systems. As these devices connect to the internet and gather user data, effective security measures are required to prevent unauthorized access or data breaches. Addressing these issues and increasing the integration, user awareness, and security of smart switches and personalized home intelligence systems are critical to realizing their full promise in converting residential areas into intelligent, automated settings. The purpose of this research is to investigate and suggest solutions to these problems, therefore contributing to the progress and broad use of smart home automation technology.

1.2 Problem Statement

In the rapidly altering realm of home automation, integrating smart technology offers homeowners unprecedented ease, efficiency, and personalization. This vision is centre on the development of intelligent technologies that seamlessly regulate numerous parts of the home environment, such as lighting and temperature, security, and entertainment.

There are several problem statements that can be derived from the project:

1. A home automation system's fan and lamp control software have different code sizes, which may indicate inefficiencies in resource management and code optimization. This could lead to increased memory utilization, longer execution times, and wasteful resource use [8].
2. Inconsistent connections, packet loss, and reduced signal quality may result from the limited range of Bluetooth Low Energy (BLE) communication between the microcontroller and server [9].

1.3 Objectives

Three objectives have been derived for this research as listed.

a) To optimize the software design and resource utilization of the home automation system to achieve more uniform code sizes and improve overall system efficiency [10].

b) To enhance the communication range between the microcontroller and the server in the BLE-based home automation system to ensure reliable and seamless data transmission across diverse environments [11].

1.4 Significance of Study

This work is to overcome the drawbacks of current home automation systems by concentrating on customised automation made possible by intelligent switches. The project seeks to improve the overall user experience by enabling users to customise their automation routines in accordance with their tastes and lifestyles. This would promote convenience, comfort, and pleasure. Additionally, combining personalized automation with smart switches leads to enhanced energy efficiency by maximizing device utilization and minimizing wasteful energy consumption. To improve home security and safety based on individual needs, the project also emphasizes the integration of customized security measures, such as motion sensors and smart locks. The project also contributes to the realisation of the vision of smart homes as intelligent and individualised settings by fostering innovation and enhancing the capabilities of home intelligence systems. The project's relevance ultimately resides in its potential to revolutionise how we interact with our homes, providing more control, personalization, and convenience while fostering energy efficiency and security.

1.5 Project Scope

The scope of this project encompasses the integration of smart switches as a central component of the personalized home intelligence system. It involves selecting compatible smart switches, establishing communication protocols, and ensuring seamless integration with various smart devices commonly found in homes. The project focuses on developing a user-friendly interface or mobile application that allows users to customize automation rules, such as scheduling, scene creation, and device control, according to their preferences and lifestyle. Energy efficiency optimization is another important aspect, including monitoring device usage, analyzing energy consumption, and providing recommendations for efficient energy usage. The project also includes the integration of personalized security measures like motion sensors, door/window sensors, and smart locks, along with evaluating the overall user experience through usability studies and user feedback. Comprehensive documentation and recommendations for future enhancements and applications of personalized home intelligence systems will be provided as project deliverables.

1.6 Chapter Summary

The chapter explores smart switches in smart home automation, highlighting their role in remote control of lighting, appliances, and other electrical devices. It covers various types of switches, including Wi-Fi-enabled and advanced models with features like voice control and energy monitoring. The benefits of incorporating smart switches include convenience, energy efficiency, and security. The chapter also discusses key considerations for selecting and deploying smart switches, offering practical advice for homeowners and professionals.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Smart home automation systems have emerged as a result of the integration of advanced technologies into residential spaces. These systems provide benefits like enhanced comfort, energy efficiency, and security. As demand for interconnected homes increases, researchers and practitioners are exploring various aspects of smart home automation to optimize functionality, usability, and reliability. This literature review aims to provide a comprehensive overview of existing research and developments in smart home automation systems.

2.2 Research Review

Figure 2.1 Smart Plug System with Android Application

Similar research has been done which relates closely to the current project. This research implements on Android OS for controlling and monitoring household product with the aim of increasing energy efficiency and reducing energy consumption. Unlike a few other communication protocols, Bluetooth Low Energy allows devices to be controlled directly from a tablet or smartphone, without the need for extra gateways. Based on the Generic Attribute Profile (GATT), the Smart Plug provides an application programming interface (API) for control and power usage measurement [12]. This technique, in addition to normal on/off capabilities, allows the user to monitor different power consumption parameters and to have delayed control by utilising a built-in timer and power constraint.

The smart plug is a simple in design, very compact, which is important because it will occupy no more than one physical socket on a power strip. Also, outlet contains a button which provides alternative way of basic functionalities. Along with the button, the RGB indication, informing about the current load of the connected appliance and signalizing the working status or progress during the firmware upgrade. RGB indication can be switched on or off.

In the smart plug, Android 4.3 introduces a built-in platform support for Bluetooth Low Energy and provides API that apps can use to discover, connect, and read/write characteristics. This could be achieved in earlier versions via third party libraries.

2.3 Bluetooth Low Energy

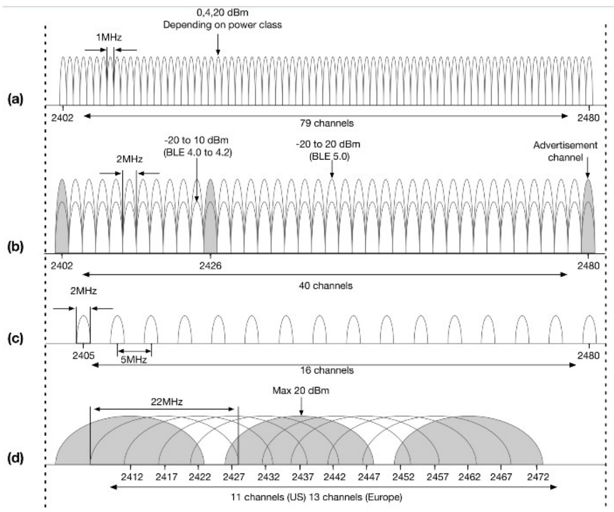


Figure 2.2 BLE Overview

Bluetooth Low Energy (BLE) is recognized as a key technology in the field of smart home automation, providing effective, low-power wireless communication across short to medium distances. Its relevance stems from its capacity to provide seamless communication between numerous devices and sensors while conserving energy. BLE's characteristics include long battery life, low latency, connectivity with mobile devices, and secure data transmission, making it ideal for a wide range of smart home applications. These applications include environmental monitoring, security systems, and tailored occupant experiences [13]. Furthermore, innovations in BLE technology continue to increase its capabilities, such as energy efficiency, data speed, compatibility with other wireless protocols, and support for upcoming use cases like smart lighting and health monitoring.

Table 2.1
The Previous Research on Smart Switch System

AUTHOR	TITLE	OBJECTIVES	MAIN FINDINGS
Md. Ibne Joha, & Md Shaiful Islam	IoT-Based Smart Home Automation Using NodeMCU: A Smart Multi-Plug with Overload and Over Temperature Protection	The development and features of the IoT-based smart multi-plug and its potential applications. The smart multi-plug's essential features, such as remote control through a smartphone app, overload and over-temperature protection and compatibility with voice assistants like Google Assistant. It also mentions the use of the Blynk app for accessing and controlling the smart multi-plug.	The development of an IoT-based smart multi-plug that provides comfort and convenience to consumers while ensuring the safety of household electrical or electronic equipment. The smart multi-plug is capable of monitoring power consumption, detecting overloading and overheating, and protecting appliances from these hazards. [14]

C.M. Lin, & M.T. Chen	Design and Implementation of a Smart Home Energy Saving System with Active Loading Feature Identification and Power Management	Developing a system that combines various smart devices to reduce overall household energy consumption. The system involves a smart meter, smart plugs, smart mobile devices, and a database server, which allows for effective messages to be provided for home electric energy-saving applications using the support vector machines (SVM) method.	The smart home energy saving system, which combines multiple smart devices such as smart meter, smart plugs, smart mobile devices, and a database server, can effectively reduce overall household energy consumption. The smart meter captures raw voltage and current signals, while the smart plug measures and analyzes power data from different loads and can be remotely monitored and controlled. The database server can employ load characteristics to identify

			an appliance's operation mode using the support vector machines (SVM) method, providing effective messages for home electric energy-saving applications. The mobile device application implemented on an Android platform allows for real-time monitoring and control of energy consumption and power management. [15]
Rohan Garg, & Dr. B Dastagiri Reddy	IoT Smart Plug based on ESP8266 Wi-Fi Chip	To design and develop a smart plug based on the ESP8266 Wi-Fi chip that can be controlled remotely using a smartphone application.	The successful development of a smart plug using the ESP8266 Wi-Fi chip, which allows for remote control of devices connected to the

		The project aims to make regular non-smart devices smart through external means, allowing users to control their devices from anywhere in the world. The project also aims to incorporate an RTC clock module in the plug to enable scheduling provisions and to opt for a cloud-based approach to allow for unlimited range. Additionally, the project aims to include a "smart" manual switch to avoid dependency on the mobile app.	plug. The creation of an Android smartphone application that enables users to switch devices on and off from anywhere in the world and schedule specific times for device activation. The implementation of manual feedback switch as an essential feature, reducing dependency on the smartphone app for control while still allowing for its use.[16]

Igor Horvat, Nikola Lukac, Roman Pavlovic, & Dusan Starcevic	Smart Pug solution based on Bluetooth Low Energy	To optimize power consumption in home automation systems. By providing users with the ability to control household devices remotely through the Android application, the solution aims to increase comfort and improve everyday life. Additionally, the solution aims to contribute to reducing energy consumption and optimizing power usage.	The Smart Plug solution based on Bluetooth Low Energy are that it provides a complete solution for controlling and monitoring household products using Bluetooth Low Energy and an Android application. Unlike some other communication protocols, Bluetooth Low Energy allows controlling devices directly from a smartphone or tablet without any additional gateways. The Smart Plug provides an API for

			control and powe consumption measurement based o Generic Attribute Profil (GATT). The solutio also enables users t monitor various powe consumption parameter and have delayed control using the built-in time and power limitation. [17
Chan Zhen Yue, & Shum Ping	Voice Activated Smart Home Design and Implementation	To design and implement a voice-controlled smart home system that enhances the quality of living for hall residents at university. To integrate various features such as household appliance	The design an implementation of a low-cost, micro-processo based smart home system that enhances the qualit of living for hall resident at university. The integration of variou features such a

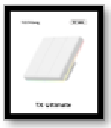
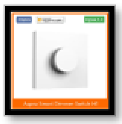
		control, entertainment system, hall facilities monitoring, and home security into a single, cost-effective system. To consider the development of a smart healthcare system for the elderly, utilizing the smart home technology to alert their next of kin in case of emergencies or prolonged inactivity.	household appliance control, entertainment system, hall facilities monitoring, and home security into a single, cost-effective system. The ability to access and manage the smart home system through Amazon Developer Console, Telegram on smartphones, and Alexa Voice Service. The successful testing o the smart home system through the "Test" function in the console to ensure that the system i fully operational. [18]
Trio Adiono, Maulana	Using A Smart Plug based	To propose a design for a	A design for a modular

Yussuf Fathany, Sunantya Feranti Anindya, Syifaul Fauda, & Irfan Gani Purwanda	on Consumer Electronics to Support Low Power Smart Home.	modular plug that can be used as end-device within a smart home environment. The plug is intended to be compact, lightweight, and compliant with consumer electronics standards. To create a plug that contributes to energy conversation in a smart home infrastructure. The plug's functionality and features are likely designed to optimize power usage and provide efficient control over connected devices.	smart plug that is compliant with consumer electronic design for smart home systems. The plug is designed to support turning 'on' and 'off' a device remotely using a smartphone-based user interface. The plug is designed to operate using as low power as possible. Based on functional test results, the plug uses 49.9 mA current in idle mode and 123.7 mA in active mode for 5 V DC input. This low power consumption makes the plug suitable for smart home infrastructure

			aimed at energy conservation purposes. [19]
Nombulelo CC Noruwana, Pius Adewale Owolawi, & Temitope Mapayi	Interactive Iot-Based Speech-Controlled Home Automation System	To develop an interactive IoT-based speech-controlled home automation system that enables users to control their home electrical appliances remotely with voice-based recognition through a mobile device using Google Assistant. The system aims to provide convenience, good control, safety, and savings to users by allowing them to control various aspects of their home with the	The system achieved a maximum performance of 100% accuracy rates in some the different scenarios. The accuracy of the system varied based on the amplitude of the voice. Normal conversation resulted in 100% accuracy, while whispering resulted in only 20% accuracy. The accuracy of the system also varied based on the distance between the user and microphone. When the distance was less than

		convenience of voice control.	or equal to 1 meter, the accuracy was 80%, but when the distance was greater than or equal to 2 meters, the accuracy dropped to 40%. [20]

Table 2.1
The Comparison between the research paper on Smart Switch System

Specification	SMATRUL Wi-Fi Light Switch With RF 	Xiaomi Smart Home Wall Wireless Switch 1 gang 	SONOFF TX Ultimate Smart Touch Wall Switch 	AQARA H1 Smart Dimmer Wireless Rotary Switch Zigbee  3.0	GIRIER Wi-Fi Smart Light Touch Switch 220 V 433Mhz RF Remote (1 Gang) 	Tuya Smart Switch 1 Gang Wi-Fi Switch 	S Hor Wal Wire Vo 
Function	Installing and monitoring a light switch in any location in the house.	Control the switch, integrate it with other gadgets of the Smart Home system.	Remote control on/off, switch the ambient light, set timer, and smart scene on the phone.	Accurately control the lifting ratio of the roller shutter to easily control the change of light and shadow.	To control over 5W LED lamps in the house.	Remote control, scheduling, energy monitoring	Direc on ar by vo iPhor
Communication	Wi-Fi, Radio Frequency	Wi-Fi, Bluetooth	Wi-Fi, BLE	Zigbee 3.0, Wi-Fi	Wi-Fi, 433MHz RF, Voice control	Wi-Fi	Vo
API Switch	Google Assistant, Amazon Alexa, Tuya Smart	Xiaomi/Aqara Bluetooth Mesh Gateway	Google Assistant, Amazon Alexa, Apple HomeKit	Google Assistant	Google Assistant, Amazon Alexa	Tuya Smart Apps	
Performance	Cisco Catalyst	D-Link Series	TP-Link Jetstream T1600G-52TS	-	TP-Link	Cisco	Ap
Price	RM 21.76	RM 56.40	RM 139.38	RM 125.25	RM 31.99	RM 41.57	I

2.4 Chapter Summary

The literature review explores smart switches, a crucial component of smart home automation, focusing on their functions, advancements, and benefits. It covers Wi-Fi-enabled, Zigbee-based, and Bluetooth Low Energy switches, their capabilities, and limitations. The chapter also discusses current advancements in smart switch technology, such as voice control integration and occupancy detection. It also explores emerging trends and future directions in smart switch development, such as artificial intelligence and machine learning algorithms for predictive control and energy management.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides a systematic approach to studying and analysing smart home automation systems, focusing on hardware and software design aspects. It highlights the importance of understanding methodologies in developing innovative solutions that meet user needs. The research framework includes methodologies for data collection, analysis, and interpretation, with a focus on hardware and software design considerations, which are crucial for the development and deployment of effective smart home automation systems.

This research explores the process of creating robust, scalable, and user-friendly smart home systems by integrating hardware components like sensors, actuators, and communication modules with software algorithms and interfaces. It also discusses the methodologies used to evaluate the performance, usability, and satisfaction of these solutions. The aim is to contribute to the advancement of smart home automation technology, drive innovation, and improve user quality of life. The study aims to provide insights into the real-world effectiveness and applicability of these solutions.

3.2 Hardware Design

3.2.1 NodeMCU ESP32

The NodeMCU ESP32 is a versatile microcontroller unit with a dual-core CPU running 80 to 240 MHz, making it ideal for IoT applications like remote monitoring, data transmission, and cloud connectivity. Its built-in Wi-Fi and Bluetooth connectivity make it suitable for smart home automation, wearable devices, and proximity sensing. The ESP32's integration of Wi-Fi and Bluetooth simplifies hardware design and reduces system cost, making it an attractive choice for developers. It offers a wide range of peripherals and interfaces, enabling developers to create diverse IoT applications and prototypes.

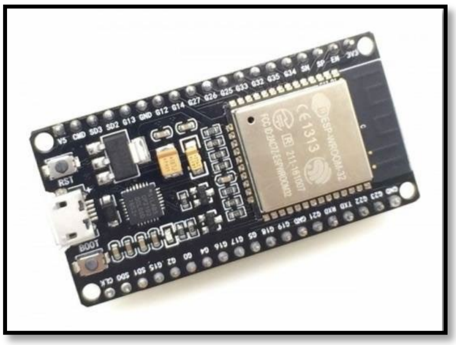


Figure 3.1 NodeMCU ESP32

3.2.2 Touch Sensor

Touch sensor is a device that detects touch or proximity and converts it into an electrical signal. It is designed to sense physical contact or the presence of an object without the need for mechanical pressure or force. A smart switch uses a touch sensor to detect touch or proximity and convert it into electrical signals. When a user wants to turn on the switch, they initiate contact or approach the sensor area. The microcontroller interprets this signal and activates components like relays or transistors to turn on the load. When the user wants to turn off the switch, they repeat the interaction.

Figure 3.2 Touch Sensor

3.2.3 Relay

A smart switch uses a touch sensor to control electric current flow through a circuit. When activated, it triggers a microcontroller to activate a relay, allowing current to flow through the load. When turned off, it deactivates the relay, halting current flow and turning off the load.

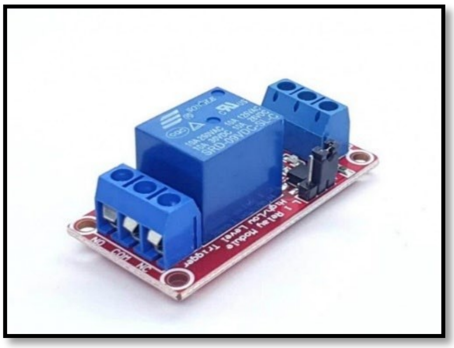


Figure 3.3 Relay 9V 1- Channel

3.2.4 L298N Motor Driver

The L298N Motor Driver is a key component in a smart switch system that controls the fan's operation. It functions as a dual H-bridge motor driver, allowing users to adjust the fan's speed and direction. It also allows for rotation reverse as needed. The L298N is equipped with overcurrent and overtemperature protection, ensuring safe and reliable operation. It integrates seamlessly into the smart switch system, allowing for user-controlled fan operation within the smart home environment. This enhances user comfort and convenience.

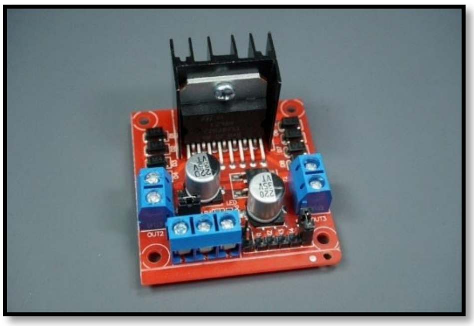


Figure 3.4 L298N Motor Driver

3.2.5 DC Motor

The DC motor in a smart switch system plays a crucial role in providing air circulation and cooling in a home. It drives fan blades, generating airflow and cooling the room. When activated, it converts electrical energy into mechanical energy, causing fan blades to rotate, circulating air, dissipating heat, and providing comfort. The DC motor's low power consumption and efficient operation make it ideal for energy-efficient smart home environments. Overall, the DC motor enhances indoor comfort and promotes energy efficiency.

Figure 3.5 DC Motor

3.2.6 Lamp

The smart switch system uses a DC motor as a lamp in a home, allowing users to control the light source and adjust its intensity. This system offers advanced features like brightness control, enhancing user comfort and convenience. The lamp's integration with the smart switch system allows for automation and integration with other smart home devices, enhancing overall home automation. This functionality promotes energy efficiency by optimizing lighting usage and management. Overall, the lamp's role in the smart switch system enhances the functionality and versatility of the smart home environment.

Figure 3.6 LED Lamp

3.3 Software

3.3.1 Arduino IDE

The Arduino IDE simplifies code development by offering syntax highlighting, code completion, and a library of pre-written code snippets. It facilitates compilation, debugging, and real-time troubleshooting. Code can be uploaded to microcontrollers like ESP32 and NodeMCU, and the Arduino community provides support and resources for collaboration and knowledge sharing.

Figure 3.7 Arduino IDE

3.3.2 MQTT Protocol

The smart switch system is used to control the house appliances such are switch on/off the light and control the speed of fan. This smart switch system demonstrates the feasibility of the system by controlling switch on/off the lamp by using relay module. For controlling the speed of the fan, the fan is controlled through the MQTT protocol implemented using Bluetooth Low Energy (BLE) and microcontroller ESP 32.

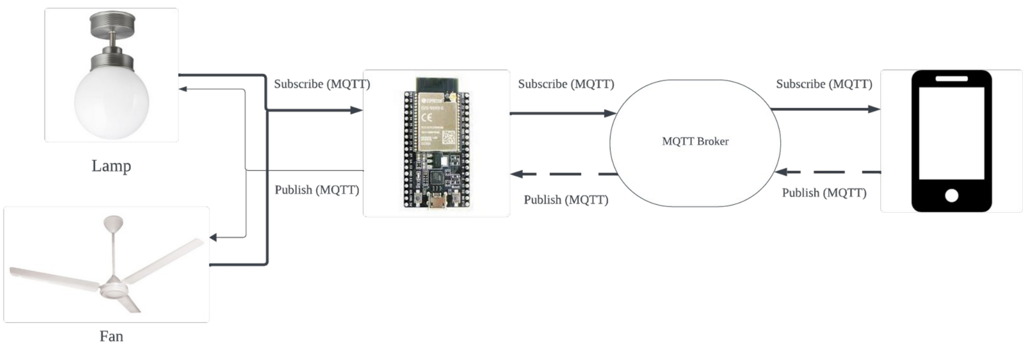


Figure 3.8 MQTT Protocol communication

Figure 4 illustrates a prototype smart switch system for controlling home appliances. The smart switch system consists of the following components:

IoT Station: An IoT system that resides and install in any premises including houses, factories, mosques, plantation, vehicle, energy station, etc. A controller facilitates communication, identification, and security between a server and sensor+actuator, using protocols like BLE, Wi-Fi, or Satellite, with an end point.

MQTT Protocol: Message Queuing Telemetry Transport ‘MQTT’ is a lightweight messaging transport protocol for constrained devices and low bandwidth networks. It is a publish/subscribe messaging transport for lightweight M2M communications in constrained networks.

MQTT Broker: The MQTT broker is the system's core, handling publish/subscribe communication among connected clients, including the mobile application and controller. It receives messages, filters them, decides which client is interested in, and sends them to all interested subscribers. Each client can be subscriber or publisher [12]. MQTT brokers publish messages to topics, which clients can subscribe to multiple times. Each subscribed client receives every message published to the topic. For instance, both the mobile application and controller of an MQTT client had subscribed to the 'public/lamp' topic.

A MySQL+AI: A database plus machine learning server to automatically store and analyze the data from/to sensor/actuators in any IoT station.

Dashboard: A data presentation unit that presents the data and control action performed by the user/system

<u>MQTT Topics</u>

MQTT topics is set according to the user level and access control define by the system security and Access control list. Each sensor and actuator have its own unique topic and the topic is layered using IoT station and customer base.

Sensor

ESP32 is commonly use due to its versatility and widely available resources. Firmware use will utilized the deep sleep capability to minimized the power usage.

Actuator

ESP32 also used as the platform to control the analog or digital output

Controller

2 ESP32 is used as the controller to hand over the data between BLE and WiFi end points. The BLE parts communicate with sensor/actuator and WiFi communicate with the MQTT Broker

3.3.3 BLE (Bluetooth Low Energy)

Bluetooth Low Energy (BLE) is a crucial communication medium in smart switch systems, enabling seamless interaction and control. It allows direct wireless connectivity between the switch and nearby devices, allowing users to monitor and control the switch's operation. BLE's low power consumption makes it ideal for energy-efficient operation, prolonging battery life in battery-powered devices. It complements Wi-Fi communication, enabling centralized control and management of multiple devices within the smart home ecosystem. Overall, BLE enhances the functionality, flexibility, and user experience of smart switch systems.

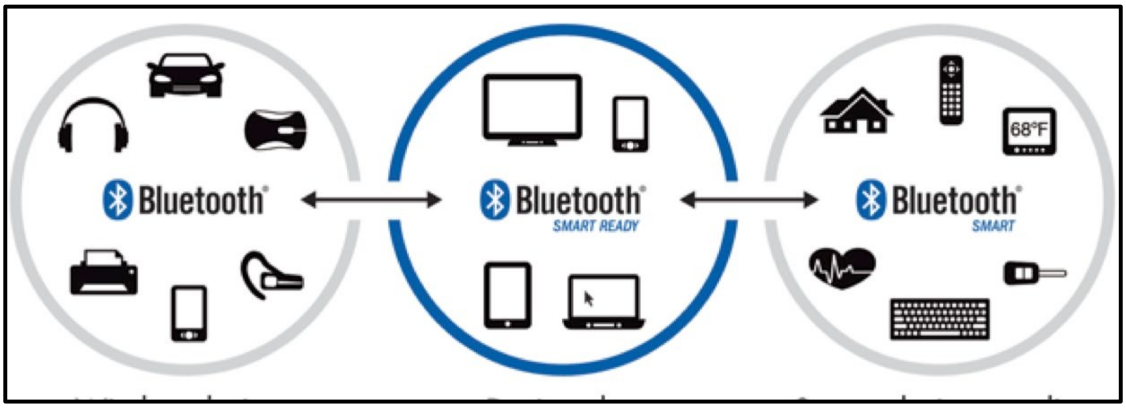


Figure 3.9 Bluetooth Low Energy Communication

The smart switch broadcasts information through advertisement packets, and the application detects these packets and initiates a connection request. The Generic Attribute Profile (GATT) defines the data exchange structure, organizing functionalities into services and data points into characteristics. The application can send commands or requests to the smart switch, such as turning it on or off, or send notifications or updates to the application. Security measures like encryption and authentication ensure data exchange remains secure and protected from unauthorized access. BLE enhances convenience and functionality in home automation applications by allowing users to control and monitor the smart switch from their mobile devices.

3.3.4 Pydroid 3 Application

Pydroid3 is a Python-integrated development environment (IDE) designed for the mobile platform. Essentially, Pydroid3 enables the creation and execution of Python code directly on a mobile device. Within Pydroid3, the user can develop Python applications, and in this context, it is utilized to build the control interface for the smart sensor system. The app's main functions are encapsulated in three key features which are Control, Auto, and Data.

Figure 3.10 Pydroid 3 Interfaces

<u>Control</u>

Firstly, it provides control buttons for the lamp and fan, allowing users to remotely operate these devices. Secondly, it incorporates a fan control with adjustable levels ranging from 0 to 3, offering flexibility in setting the fan's speed. The diagram below shows the control button in the pydroid3 apps:

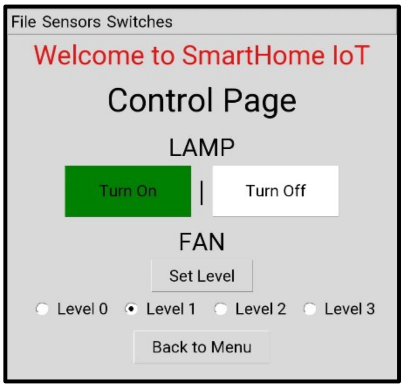


Figure 3.11 Pydroid 3 Interfaces

Auto

Furthermore, Pydroid3 integrates automation rules, allowing users to predefine rules for device control based on specific conditions. This means users can establish conditions or scenarios, such as temperature thresholds or specific motion detection, and define corresponding actions for the system to execute. Below is the list of the automation rules that have been included in the apps:

Table 3.1
List of Automation Rules

No	List of Automation Rules
1	Temperature 30°C: Fan Level 2
2	Temperature Below 20°C: Switch Off Fan
3	Temperature 22-27°C: Fan Level 1
4	Motion Detect: Turn On the Lamp
5	Motion Not Detected: Turn Off the Lamp
6	Motion Not Detected: Switch Off the Fan
7	Motion Not Detected: Switch Off All
8	Motion Detected: Switch On Lamp and Fan Level 1

Auto

Additionally, Pydroid3 includes a graphical display feature, presenting real-time data in the form of graphs. The graphs showcase temperature, humidity, and motion sensor data over time. This visual representation provides users with a clear and intuitive way to monitor the changing environmental conditions captured by the sensor.

3.4 Block diagram

The block diagram of the smart switch system illustrates the components and their interactions. The system comprises an 11.1 V battery, DHT 22 sensor for temperature and humidity measurement, HCSR501 motion sensor for movement detection, 10kOhm resistor for electrical applications, switches for controlling a lamp and a fan, ESP 32 microcontrollers for sending and receiving signals, a touch sensor, and MQTT cloud for communication. The system is designed to control home appliances and monitor environmental conditions. The block diagram provides a visual representation of how these components are interconnected and work together to enable efficient communication, control of home appliances, and real-time environmental monitoring. This comprehensive approach emphasizes the system's adaptability, potential for future enhancements, and its capacity to create an energy-efficient and interconnected smart home environment.

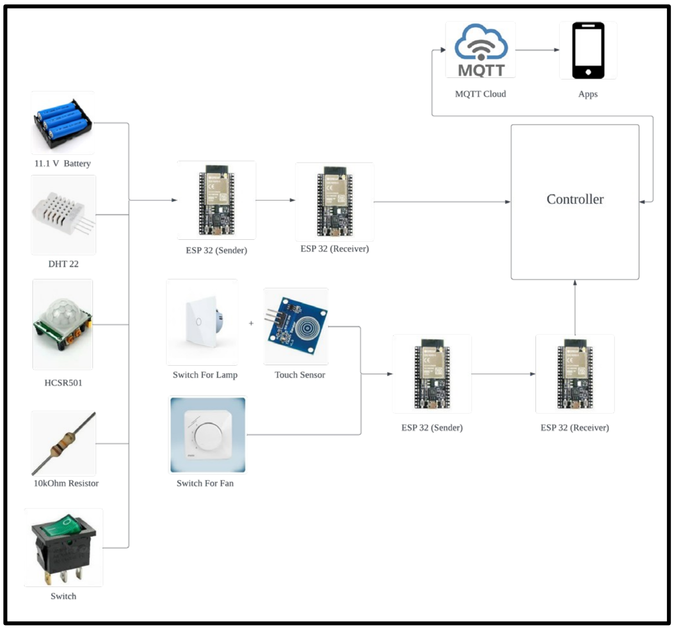


Figure 3.12 The Block Diagram of the system.

3.5 Flowchart

The overall flowchart consists of two systems which control home appliances such are fan and lamp. The control system involves a sequence of actions and processes, starting with the controller checking sensor data and sending control signals to switches. Environmental data was detected using temperature and PIR sensors, which are then transmitted to the controller. The data is displayed and published to an MQTT Cloud Broker, which distributes it to subscribers via the Pydroid3 app. Users can control lamps and fans through the app, which triggers automation rules based on changes in control buttons. The system then sends data to switches, activating or deactivating them based on the received data.

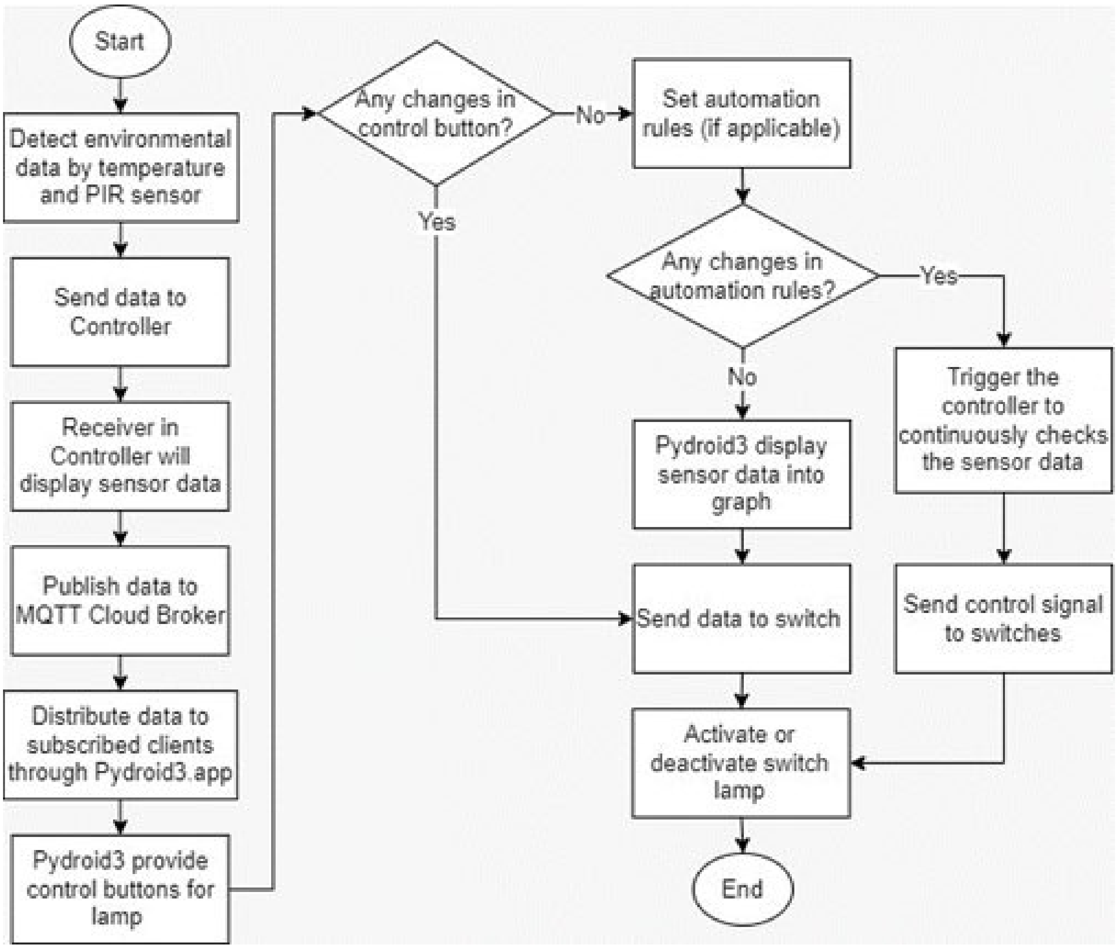


Figure 3.13 The Overall Flowchart of the system.

In fundamental terms, the control system specifies a process that uses sensors, controllers, cloud-based connectivity, and a mobile application to acquire sensor data, transmit it, and perform control actions. The control system allows users to monitor environmental data, operate switches, and create automation rules based on sensor readings. The Pydroid3 app is essential in providing a user interface for monitoring sensor data, operating switches, and displaying the data using graphs. Furthermore, the system's capacity to distribute data to subscribed clients via the MQTT Cloud Broker, as well as the automation rules, enhances the control process' intelligence and flexibility.

The established configuration appears to be geared toward the creation of a full smart home ecosystem, with an emphasis on remote appliance control and real-time environmental monitoring. The use of ESP32 microcontrollers with MQTT cloud technology indicates the deployment of a wireless and internet-connected system, which provides a high degree of flexibility and allows for remote access from several places. The addition of motion-sensing capabilities and environmental monitoring emphasizes a dual focus on improving convenience and safety in the home setting. This comprehensive approach not only allows for remote administration of appliances for user convenience, but it also provides constant monitoring of environmental elements, resulting in a smart home system that emphasizes both efficiency and the well-being of its inhabitants.

3.6 Chapter Summary

The research methodology chapter is a crucial guide for conducting a study, outlining the processes, techniques, and approaches used to gather and analyze data. It details the chosen research design, such as qualitative, quantitative, or mixed-methods, and its justification based on research objectives and questions. The chapter also discusses the sampling technique used to select participants and data sources, as well as the appropriateness of data collection methods like surveys, interviews, observations, or document analysis. It also discusses strategies for data validity, reliability, and ethical considerations, such as informed consent and confidentiality. The chapter also explains data analysis techniques and software tools used for data management and analysis. The chapter concludes with a reflection on the chosen methodology's strengths and limitations, ensuring the study's validity and generalizability.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This section presents the results and discussion of a study on smart switch systems, focusing on their effectiveness, usability, and impact on home automation. It critically evaluates the findings' significance in relation to existing literature, user interaction frameworks, and practical implications for enhancing user experience and energy efficiency. The study aims to understand the underlying mechanisms driving observed outcomes, such as user preferences, technological constraints, and environmental factors. It also explores the implications for practice, policy, and future research directions in home automation. The findings can inform decision-making by consumers, manufacturers, and policymakers, shaping the research agenda towards sustainable and user-centric smart home solutions.

4.2 The Resulting System

The hardware design of the smart switch system is an important component of the whole system, since it allows digital orders to be converted into physical actions. The actuator, supplied by a 9V battery, is essential in this procedure, with the L982N Motor driver regulating the DC motor and the Relay 1-Channel activating the LED light. The DC motor is the principal mechanical component, allowing physical movement or manipulation, while a touch sensor allows for human contact. The ESP32 microcontroller manages the functioning of each hardware component by processing input signals and executing programmed logic. This integrated hardware environment allows the smart switch system to connect with the user interface and respond to commands precisely and efficiently.

The block diagram depicts the hardware design of the system, including the integration of sensors, microcontrollers, actuators, and communication modules. The hardware design highlights the system's versatility, possibility for future upgrades, and ability to build an energy-efficient and networked smart home ecosystem. In addition, the hardware design is tuned to provide seamless connection and management of household appliances, with an emphasis on motion detection and environmental monitoring.

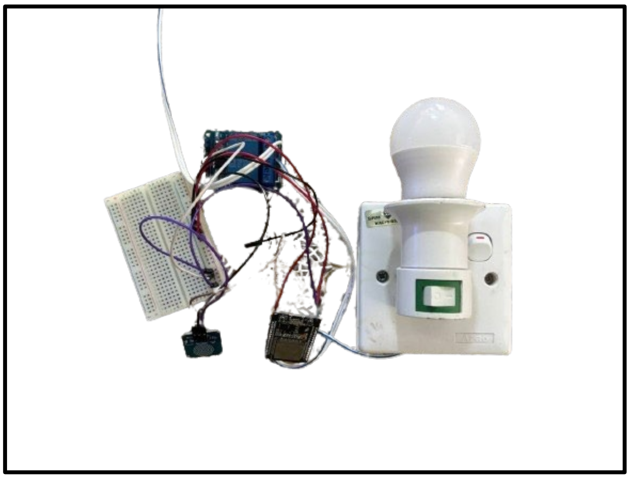


Figure 4.1 The controlled switch of the lamp

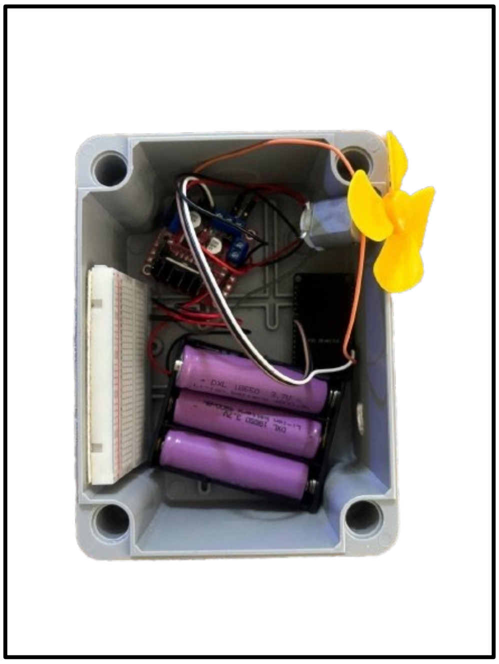


Figure 4.2 The controlled switch of the fan

The smart switch system receives data from the app through a series of interconnected components and communication protocols. The system's overall design is divided into three main parts: the smart switch system, the Android application on a smartphone, and the open cloud server. The smart switch system utilizes the MQTT protocol, implemented using Bluetooth Low Energy (BLE) and the ESP32 microcontroller, to control house appliances such as lamps and fans.

The communication process involves the controller checking sensor data and sending control signals to switches. Environmental data, detected using temperature and PIR sensors, is transmitted to the controller. The data is then displayed and published to an MQTT Cloud Broker, which distributes it to subscribers via the Pydroid3 app. Users can control lamps and fans through the app, triggering automation rules based on changes in control buttons. The system then sends data to switches, activating or deactivating them based on the received data.

The BLE and MQTT-enabled system uses an actuator to collect data on the lamp's condition. The actuator communicates with the controller using BLE and MQTT protocols, ensuring efficient and low-power data transmission. The controller, acting as the central hub, receives the data from the actuator. The MQTT protocol facilitates efficient data distribution, ensuring timely and organized updates to the lamp's condition. This system is responsive and energy-efficient, ensuring a responsive and efficient system.

4.3 RSSI Value in BLE

The variation of Signal Strength Index (RSSI) in wireless communication (BLE) is influenced by factors like distance, physical obstacles, interference, and environmental conditions, where closer proximity results in increased RSSI values, indicating stronger signal strength, while greater distances or obstacles lead to decreased RSSI values, indicating weaker signal strength. Consistent high RSSI values denote robust signal strength and reliable communication, while fluctuations or abrupt changes may signal potential issues such as interference or obstacles.

Analysing RSSI variation helps identify patterns and trends, facilitating optimization of device placement, antenna orientation, and power settings. Monitoring RSSI values enables real-time assessment of signal quality and stability, allowing proactive measures to address potential challenges and ensure optimal performance of BLE-enabled systems and applications. The scatter plot for RSSI (Received Signal Strength Indication) values visually represents this signal strength variation over time, with the x-axis denoting time in minutes and the y-axis representing RSSI values in decibels (dBm), where each data point corresponds to a specific time point and its corresponding RSSI value.

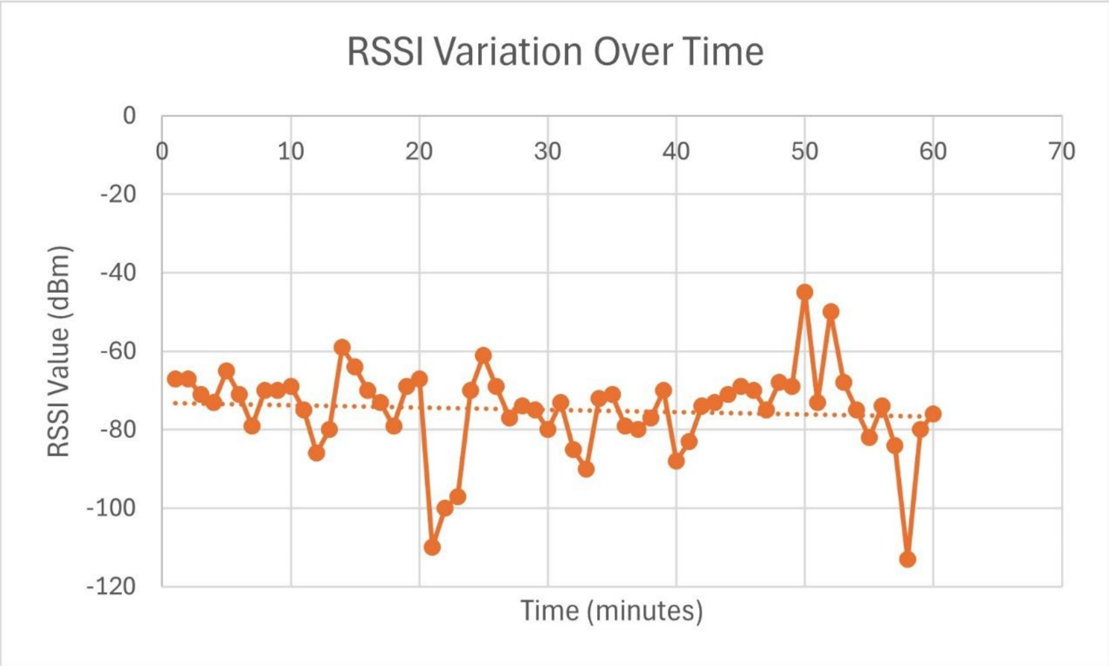


Figure 4.3 RSSI Variation Over 60 Minutes

After examining the scatter plot, it's clear that the RSSI values fluctuate over the observation period. The average RSSI value, determined to be -66.88 dBm, acts as a benchmark for evaluating the overall signal strength performance. Fluctuations in RSSI values signify alterations in signal strength, which can be impacted by factors like device distance, obstacles, interference, and environmental conditions.

The scatter plot enables the detection of trends or patterns in signal strength fluctuations over time. Through visual examination of the plot, it becomes feasible to identify significant trends, like consistent fluctuations, abrupt drops or spikes in signal strength, or periods of stability. These observations are vital for evaluating the dependability and steadiness of the communication link between devices, especially in situations where consistent signal strength is critical for smooth operation.

Overall, the scatter plot for RSSI values serves as a valuable tool for evaluating the performance and reliability of the communication link between the sender and receiver in the BLE communication system. It provides insights into signal strength variations and trends, enabling informed decisions regarding system.

4.4 Time Speed Data Transmission in BLE.

Time speed data transmission refers to the amount of time it takes to transfer data from one device to another. It assesses the effectiveness of the communication process by examining how rapidly information can be conveyed and received. This statistic is critical for evaluating the performance of communication networks, especially in situations when rapid data transmission is required. By studying the transmission time, one may assess the speed and dependability of the communication link, allowing for optimization and enhancement of overall system efficiency.

The graph depicts the relationship between the number of transmission attempts and the duration speeds, calculated by subtracting the start and end times. It visually demonstrates how transmission duration fluctuates across multiple trials, providing insights into data transfer consistency and efficiency over time. Analysing the graph allows us to identify trends in transmission speed, which can inform optimization strategies for improved communication system performance and reliability.

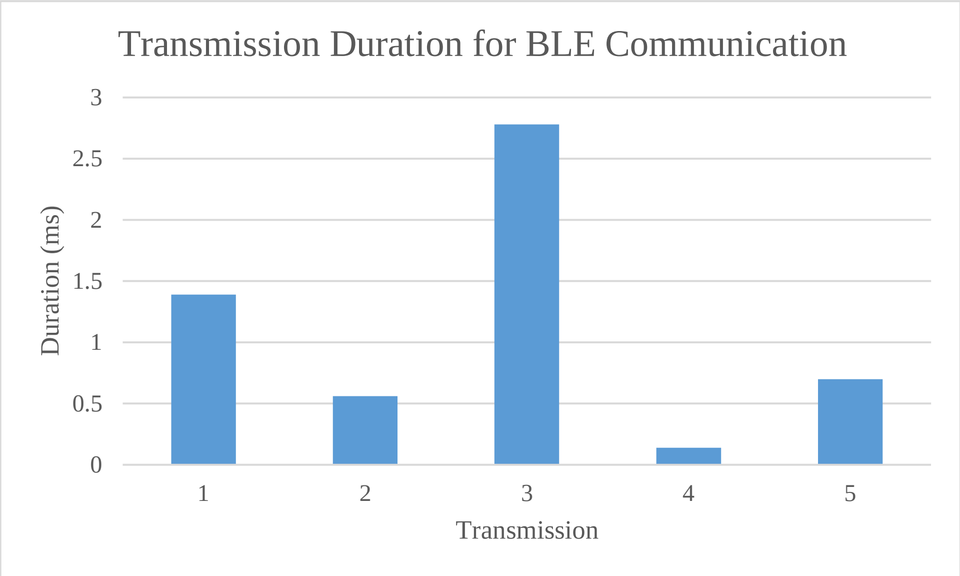


Figure 4.4 Transmission duration for BLE communication

The graph shows the duration of each of the five recorded broadcasts. The duration values are reported in milliseconds (ms), giving a precise indication of the time it takes for data to be sent between the sender and receiver in each instance.

Upon analysing the data, it was found that Transmission 1 lasted approximately 125 milliseconds, Transmission 2 took around 130 milliseconds, Transmission 3 lasted about 128.3 milliseconds, Transmission 4 took approximately 127.9

milliseconds, and Transmission 5 lasted around 131.2 milliseconds.

Milliseconds are chosen as the unit of measurement due to the need for precision in evaluating data transmission speed in a BLE communication setup. This fine granularity enables the capture of even minor variations in transmission times, which is essential for assessing the efficiency and performance of the BLE connection. A shorter duration signifies faster data transmission, highlighting a more efficient communication link between sender and receiver.

4.5 Loss Packet Rate in BLE

The given graph shows the percentage of packet loss for each experiment run. Each bar on the graph represents a separate experiment, with the x-axis showing the number of runs and the y-axis indicating the measured packet loss rate (%) for that experiment. The height of each bar indicates the fraction of packets lost during the transmission process. This graphical approach allows for the visual comparison of packet loss rates across different experiment runs, which aids in the detection of trends or patterns in packet loss behaviours.

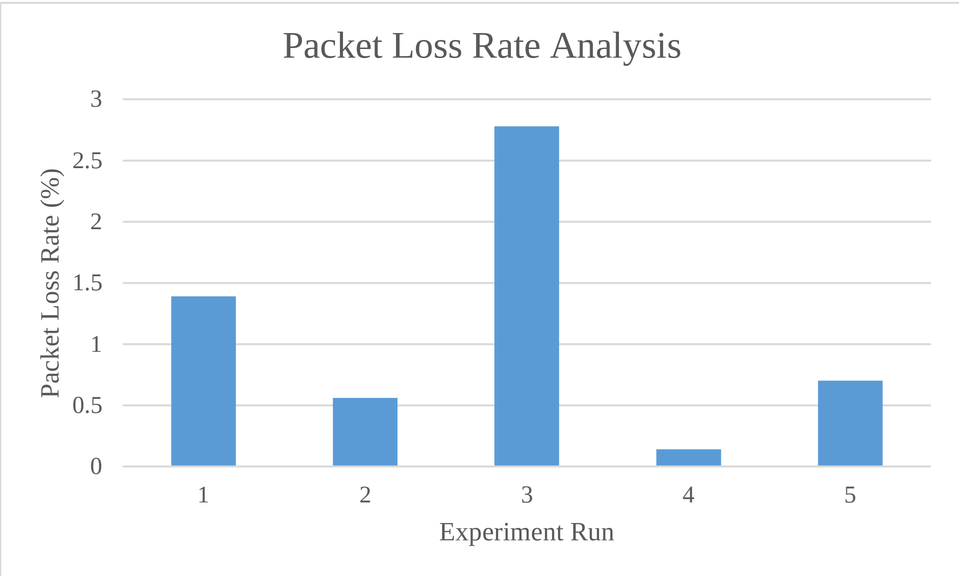


Figure 4.5 Packet loss rate analysis

For example, Experiment Run 1 had a packet loss rate of 1.39%. This means that 3550 of the 3600 packets sent during this test were successfully received, resulting in a 50-packet loss, or 1.39% of the total packets transmitted. Similarly, Experiment Run 2 showed a somewhat lower packet loss rate of 0.56%, with 3580 of 3600 packets successfully received.

During the testing period, packet loss rates fluctuated, reflecting changing network conditions or system performance. For example, Experiment Run 3 had a higher packet loss rate of 2.78%, resulting in the loss of 100 packets out of 3600 sent. In comparison, Experiment Run 4 had a far lower packet loss rate of 0.14%, with only 5 packets lost out of 3600 sent. Overall, the bar graph represents the packet loss rates over several experiment runs, allowing researchers to assess and compare the communication system's performance under different situations.

4.6 Pydroid3 Application

The Pydroid3 app's results give useful information on the smart sensor system's functionality and performance. The app's interfaces for data visualization, control, and automation allow users to engage with and monitor many parts of the system in real time.

4.6.1 Control

User interactions with the switches on the Control Page cause related events to occur, which control the light switch's status. These interactions are mirrored in the terminal output, which simulates data flow in an MQTT cloud inside an IoT ecosystem. The terminal functions as a log, recording user actions and providing real-time monitoring of device conditions in the IoT system. The figure below displays the sequence of events when users press the turn-on and off buttons to operate the light hardware remotely.

Figure 4.6 Output Display When Changes Made ON the Control Button

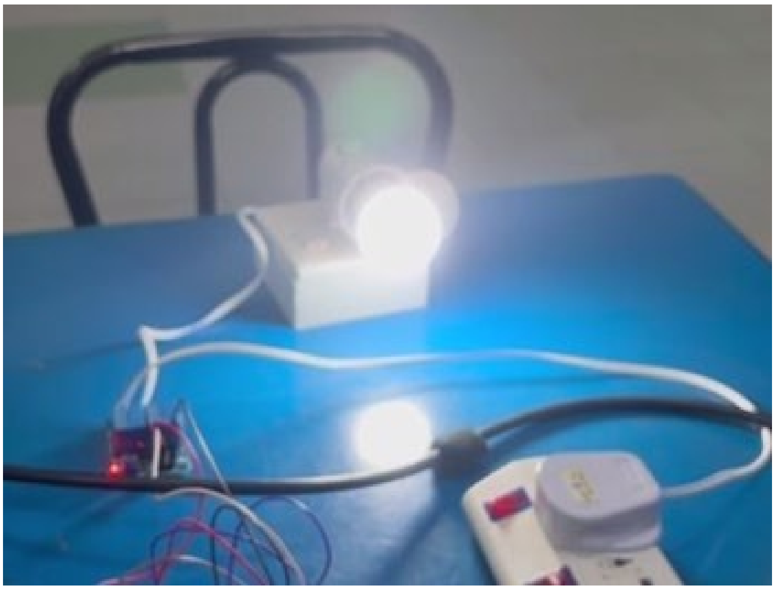


Figure 4.7 Lamp is Turned ON

Figure 4.8 When the User Pressed the Turn Off Button on Control Page

Figure 4.9 Lamp is Turned Off

4.6.2 Auto

The smart sensor system integrates automation rules into the auto interface, which improves user ease by allowing predetermined situations to activate activities within the house. For example, if the controller gets a motion detection signal from the sensor, it will activate the light switch and illuminate the designated area. When no motion is detected, the controller automatically deactivates the lamp switch, saving energy and improving home security. This automatic feature improves user engagement with the smart home system by eliminating the need for manual intervention and creating a more responsive and intuitive home environment. The pictures below depict the UI that will appear in Pydroid3 when you pick the rules.

Figure 4.10 User Select to Turn On Lamp Whenever Motion is Detected

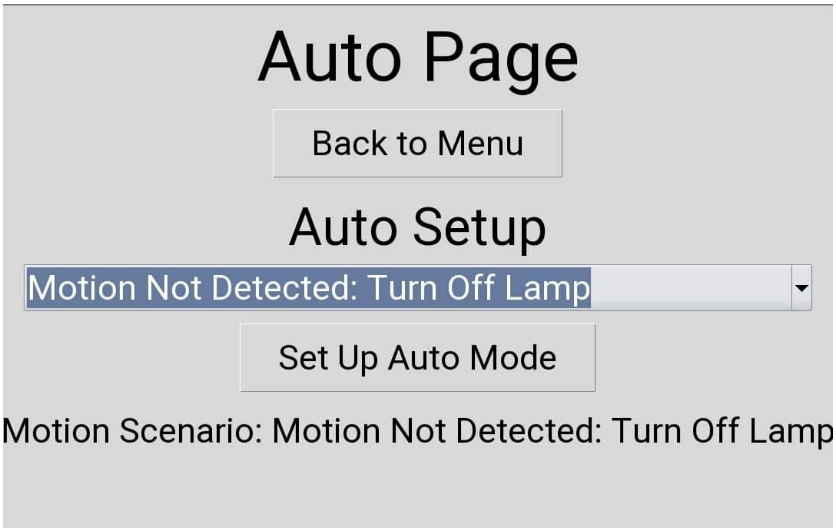


Figure 4.11 User Selecting to Turn Off The Lamp Whenever There is No Motion Detected

While the system may automatically respond to established situations such as motion detection, several constraints can affect its performance. One possible constraint is communication delays between the MQTT broker and the Pydroid3 application, which might lead to longer wait times for establishing connections or receiving information. This delay may affect the system's response, resulting in slower interactions while turning on or off the lamp switch. Below is an example of a connection fault that might occur during data transmission.

Figure 4.12 A network error occurs during data transmission.

Furthermore, network congestion or connectivity issues can significantly affect the performance of a smart sensor system using BLE and MQTT protocol. BLE is responsible for communication between sensor nodes and the central controller, while MQTT facilitates communication between the controller and external servers or cloud-based platforms. Delays in data packet transmission can occur due to network congestion or connectivity issues, which can be exacerbated by multiple sensor nodes trying to communicate simultaneously or physical obstacles affecting BLE signal strength. Additionally, MQTT relies on stable internet connections and reliable server infrastructure for data transmission from the central controller to external servers or cloud platforms. Disruptions in internet stability or server reliability can introduce unpredictability into the system's behaviours, potentially causing delays or data loss in sensor data transmission. Addressing these factors is crucial for ensuring seamless communication and reliable data transmission in such systems.

4.7 Chapter Summary

This study assesses a smart switch system in personalized home automation, focusing on its effectiveness, usability, and implications. It includes user feedback, performance metrics, and system functionalities. The findings are contextualized within existing literature on smart home technologies and user preferences. The system's design, features, and integration capabilities align with user expectations and lifestyle preferences. The findings have implications for practice, policy, and future research directions, influencing decision-making by consumers, manufacturers, and policymakers. The study provides a comprehensive analysis of the smart switch system, offering insights into its functionality, user experience, and potential impact on home automation.

CHAPTER FIVE
CONCLUSION

5.1 Conclusion

The conclusion underscores the efficacy and future potential of the Smart Switch for Personalized Home Automation System. Leveraging technologies such as Bluetooth Low Energy (BLE), the ESP32 microcontroller, and the MQTT protocol, the system presents a robust and intelligent solution for modern home automation needs. Its implementation facilitates efficient communication between the smart switch and diverse devices, ensuring swift and secure data exchange. Notably, the system's adaptability fosters effortless expansion and integration with other smart devices, fostering the creation of an energy-efficient and interconnected smart home ecosystem. Moreover, the paper outlines avenues for future enhancements, envisioning the integration of advanced sensors for responsive environmental control, voice command capabilities, AI-driven algorithms, and robust security measures. Features like energy monitoring and analytics hold promise for providing users with valuable insights into consumption patterns, further enhancing efficiency. The system's compatibility with emerging IoT standards and its user-friendly mobile interface facilitate seamless integration into households. Additionally, mechanisms for community engagement and scalability, combined with a commitment to environmentally sustainable practices, underpin a comprehensive approach. Continuous updates to firmware and software ensure the system remains dynamic and aligned with the evolving landscape of smart home automation. In essence, the Smart Switch for Personalized Home Automation System not only delivers a comprehensive and adaptable solution for modern home automation but also holds the potential for continuous improvement and expansion to address evolving technological demands and user needs.

5.2 Limitation

The smart switch system, which uses advanced technologies like Bluetooth Low Energy (BLE), ESP32 microcontroller, and MQTT protocol, has limitations and challenges. It primarily functions for basic on/off control for lamps and terminals, lacks features like dimming control and seamless integration with other smart home devices. The communication range of BLE devices is also a concern due to factors like physical obstacles, antenna design, and environmental conditions. Inefficiencies in resource management and code optimization can lead to increased memory utilization, longer execution times, and wasted resource consumption. Consistent connections, packet loss, and reduced signal quality due to BLE's limited range can hinder system reliability and deployment in complex contexts. Limited consumer knowledge about energy savings and security concerns complicates adoption, emphasizing the need for user education and awareness.

5.3 Future Recommendations

The Smart Switch for Personalized Home Automation System has the potential to improve its functionality and user experience by integrating advanced environmental sensors, voice control features, and AI algorithms. These sensors will enable the system to adapt to a wider range of environmental conditions, creating a more adaptive smart home environment. Voice control will enable hands-free operation, while AI algorithms will optimize energy usage and automate routine tasks based on user preferences. Robust security measures, including encryption protocols and secure authentication methods, will ensure user trust and confidence. Advanced energy monitoring and analytics features will provide users with detailed insights into energy consumption patterns, enabling informed decisions to optimize energy usage and reduce wastage. Compatibility with emerging IoT standards and protocols will future-proof the system. Continuous improvement in the mobile application's user interface will enhance user experience and satisfaction. Regular firmware and software updates will maintain the system's dynamism and alignment with the evolving smart home automation landscape.

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APPENDICES

APPENDIX 1

Example of the Codes in PLS Algorithms

```
#include <BLEDevice.h>
#include <BLEUtils.h>
#include <BLEScan.h>
#include <BLEAdvertisedDevice.h>

BLEClient* pClient;
BLEScan* pBLEScan;
bool deviceConnected = false;
BLEUUID serviceUUID("4fafc201-1fb5-459e-8fcc-c5c9c331914b");
BLEUUID charUUID("beb5483e-36e1-4688-b7f5-ea07361b26a8");

#define RELAY_PIN 2

void setup() {
  Serial.begin(115200);
  BLEDevice::init("Receiver");
  pBLEScan = BLEDevice::getScan();
  pBLEScan->setActiveScan(true);
  pBLEScan->setInterval(100);
  pBLEScan->setWindow(99);

  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(RELAY_PIN, LOW);  // Initialize relay to OFF state

  Serial.print("Testing BLE...");
}

void loop() {
  if (!deviceConnected) {
    BLEScanResults foundDevices = pBLEScan->start(5, false);

    for (int i = 0; i < foundDevices.getCount(); i++) {
      BLEAdvertisedDevice device = foundDevices.getDevice(i);
      if (device.haveServiceUUID() && device.isAdvertisingService(serviceUUID)) {
        BLEAddress address = device.getAddress();
        esp_ble_addr_type_t addressType = device.getAddressType();
        pClient = BLEDevice::createClient();
        pClient->connect(address, addressType);
        deviceConnected = true;
      }
    }

    }
  } else {
    if (pClient->isConnected()) {
      BLERemoteCharacteristic* pCharacteristic = pClient->getService(serviceUUID)->getCharacteristic(charUUID);
      if (pCharacteristic->canRead()) {
        std::string value = pCharacteristic->readValue();
        Serial.print("Received Value: ");
        Serial.println(value.c_str());

        // Perform actions based on the received value
        if (value == "ON") {
          turnRelayOn();
        } else if (value == "OFF") {
          turnRelayOff();
        }
      }
    } else {
      deviceConnected = false;
      pClient->disconnect();
    }
  }
}

void turnRelayOn() {
  digitalWrite(RELAY_PIN, HIGH);
  Serial.println("Relay turned ON");
}

void turnRelayOff() {
  digitalWrite(RELAY_PIN, LOW);
  Serial.println("Relay turned OFF");
}
```

```
#include <BLEDevice.h>
#include <BLEUtils.h>
#include <BLEServer.h>

#define SERVICE_UUID        "4fafc201-1fb5-459e-8fcc-c5c9c331914b"
#define CHARACTERISTIC_UUID "beb5483e-36e1-4688-b7f5-ea07361b26a8"

BLECharacteristic *pCharacteristic;

int motor1Pin1 = 27;
int motor1Pin2 = 26;
int enable1Pin = 14;

// Setting PWM properties
const int freq = 30000;
const int pwmChannel = 0;
const int resolution = 8;
int dutyCycle = 200;

void setup() {
  Serial.begin(115200);
  Serial.println("Starting BLE work!");

  BLEDevice::init("UltraSonic Sensor");
  BLEServer *pServer = BLEDevice::createServer();
  BLEService *pService = pServer->createService(SERVICE_UUID);
  pCharacteristic = pService->createCharacteristic(
                                         CHARACTERISTIC_UUID,
                                         BLECharacteristic::PROPERTY_READ |
                                         BLECharacteristic::PROPERTY_WRITE
                                       );

  pCharacteristic->setValue("Connected to Receiver");
  pService->start();
  BLEAdvertising *pAdvertising = pServer->getAdvertising();
  pAdvertising->addServiceUUID(SERVICE_UUID);
  pAdvertising->setScanResponse(true);
  pAdvertising->setMinPreferred(0x06);
  pAdvertising->setMinPreferred(0x12);
  BLEDevice::startAdvertising();
```

```
  // sets the pins as outputs:
  pinMode(motor1Pin1, OUTPUT);
  pinMode(motor1Pin2, OUTPUT);
  pinMode(enable1Pin, OUTPUT);

  // configure LED PWM functionalities
  ledcSetup(pwmChannel, freq, resolution);

  // attach the channel to the GPIO to be controlled
  ledcAttachPin(enable1Pin, pwmChannel);

  Serial.print("Testing DC Motor...");
}

void loop() {
  // Move the DC motor forward at maximum speed
  Serial.println("Moving Forward");
  digitalWrite(motor1Pin1, LOW);
  digitalWrite(motor1Pin2, HIGH);
  delay(2000);

  // Stop the DC motor
  Serial.println("Motor stopped");
  digitalWrite(motor1Pin1, LOW);
  digitalWrite(motor1Pin2, LOW);
  delay(1000);

  // Move DC motor backwards at maximum speed
  Serial.println("Moving Backwards");
  digitalWrite(motor1Pin1, HIGH);
  digitalWrite(motor1Pin2, LOW);
  delay(2000);

  // Stop the DC motor
  Serial.println("Motor stopped");
  digitalWrite(motor1Pin1, LOW);
  digitalWrite(motor1Pin2, LOW);
  delay(1000);
```

```
// Move DC motor forward with increasing speed
digitalWrite(motor1Pin1, HIGH);
digitalWrite(motor1Pin2, LOW);
while (dutyCycle <= 255){
  ledcWrite(pwmChannel, dutyCycle);
  Serial.print("Forward with duty cycle: ");
  Serial.println(dutyCycle);
  dutyCycle = dutyCycle + 5;
  delay(500);
}
dutyCycle = 200;
```