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# AUTOMATE TO ELEVATE – A WIRELESS SWITCH CONTROL SYSTEM USING LORA COMMUNICATION

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***Abstract:*** This journal presents a comprehensive exploration of a highly advanced remote switch control system powered by LoRa (Long Range) technology, boasting an impressive operational range of up to 5 kilometers. The system architecture is meticulously engineered, featuring a constellation of cutting-edge hardware components meticulously integrated to optimize performance and reliability. Central to its design is the transmitter unit, equipped with four tactile push buttons, facilitating seamless user interaction for remote switch activation. Intricate firmware logic and communication protocols govern the transmitter's operation, ensuring robust signal transmission and data integrity preservation. Leveraging state-of-the-art LoRa transceiver modules and highfidelity microcontrollers, the system orchestrates precise command dissemination to the receiver unit, thus enabling unparalleled control over relay switches across vast distances. A focal point of this advanced remote switch control system is its receiver unit, which serves as the nexus for decoding incoming signals and executing precise switch actuation sequences. Delving into the intricacies of firmware implementation, this paper elucidates the receiver's role in processing command data with utmost accuracy and efficiency. Real-time feedback mechanisms, facilitated by an integrated OLED display unit, empower users with instantaneous insights into the operational status of the switches. As a testament to its adaptability and foresight, this project anticipates future research trajectories aimed at enhancing network scalability, refining signal modulation strategies, and integrating with emerging IoT paradigms. By embracing a forward-thinking approach, this advanced LoRa-enabled remote switch control system heralds a new era of connectivity and automation, with transformative implications spanning smart homes, industrial automation, and smart city infrastructure.

***Index Terms* – LoRaWAN, Wireless communication, NodeMCU, User-friendly**

## I. INTRODUCTION

### 1.1 Overview

LoRa technology represents a significant advancement in wireless communication protocols, offering a unique combination of long-range capability and low power consumption. Unlike traditional wireless protocols, LoRa utilizes spread spectrum modulation and advanced error correction techniques to enable communication over distances of several kilometres while consuming minimal power. This makes it particularly well-suited for applications such as switch control systems, where reliable long-distance communication is essential. Additionally, LoRa's ability to penetrate obstacles and operate in challenging environments enhances its suitability for IoT deployments in remote or inaccessible areas. Overall, the implementation of LoRa technology holds secure future for revolutionizing wireless communication in various industries, providing efficient and scalable solutions for remote control and monitoring applications.

### 1.2 Relevance of work

Exploring the significance of implementing LoRa technology in switch control systems, particularly focusing on its long-range capabilities and energy efficiency. Discussing how such a system addresses the requirement for remote and reliable control in various applications, including home automation, industrial automation, and agriculture.

### 1.3 Issues and challenges

Identifying and addressing the technical, practical, and regulatory issues associated with using LoRa-based switch control systems. This section can delve into issues such as signal interference, power consumption optimization, regulatory compliance, and ensuring data security over long-distance communication. Additionally, optimizing power consumption is crucial for maximizing battery life in battery-powered nodes, especially in applications where replacing batteries frequently is impractical.

### 1.4 Problem statement

Clearly defining the problem statement that the project aims to address, such as the need for a reliable, long-range switch control system. Outlining the specific objectives of the project, including designing a robust transmitter with push buttons, integrating relay control for switches, incorporating an OLED display for real-time status feedback, and ensuring seamless communication over a 5km range using LoRa technology.

### 1.5 Significant original contributions

Highlighting the unique contributions of the project, such as integration of LoRa technology with switch control systems, the development of a user-friendly transmitter with push buttons, the implementation of a real-time status display using OLED technology, and the design of a reliable relay control mechanism. Emphasizing how these contributions advance the field of remote control systems and offer practical solutions for various applications.

## II. Literature Survey

The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance. In this paper [1], Internet of things (IoT) brings connectivity everywhere in today's world. In a smart and accessible working environment, many sensor nodes can be laid and communication between these sensors helps to access any perilous environment, thus making any industry much more productive and safe. Long-range (LoRa) communication is very essential in such scenario. This paper reviews many research to bring out the concept of LoRa technology. LoRa PHY and LoRaWAN are two basic building blocks of this technology. LoRaWAN is user-accessible part of the technology that defines network architecture, communication protocols, operating frequencies and nature of the connected devices, whereas LoRa PHY is the proprietary part that gives an idea of used modulation technique and its characteristics. Literature survey presented in this paper gives an idea about its performance under different scenarios and few implementation hindrance of this new technology.

In this paper [2], The LoRa radio technology is one of the most prominent choices in the Internet of Things Low-Power Wide Area Networks (LPWANs) industry due to its versatile and robust technical characteristics along with its ability to achieve long communication ranges combined with low energy consumption and reduced cost. One of the main issues in LoRa networks is how many end-devices can be reporting efficiently while meeting the requirements set by the application they support. Throughout this survey, a number of performance determinants that stand out are highlighted. These factors span five main categories that encompass physical layer characteristics, deployment and hardware features, end device transmission settings, LoRa MAC protocols, and application requirements. Discussion follows the presentation of each of the factors pinpointing the relevant research, and describing the impact of each one of them on the achieved network efficiency focusing especially on the capacity metric. Open issues and research directions are also highlighted for each of the five identified categories

In this paper [3], LPWAN technologies are playing a major role in the IoT scenario due to their extensive radio range, use of free frequency bands, and low energy consumption. Among these technologies, long range WAN (LoRaWAN) transmits through several kilometers with data rates up to 5.5 kb/s, making it useful for applications such as smart city monitoring, precision agriculture, and environmental tracking. Therefore, different studies have proposed using routing schemes to create multi hop communication and improve LoRaWAN performance. The article has the following contributions: first, we present the main approaches to build multi hop communication in LoRa networks. Second, we summarize different routing protocols proposed for the technology. Finally, we describe different challenges to improve the performance of routing protocols for LoRaWAN.

In this paper [4], it entails both theoretical analysis and experimental assessment of the results in the long-range (LoRa) technology. Starting with a mathematical recall section of the very basics that we will use during the experiments, we move to a simulative model where we can test the performance of LoRa channels under AWGN conditions, in order to uncover the capabilities and limits of the long-range low power and narrowband technology in negative SNR values. The already obtained accuracy of the results for a Hamming coded system from both the theory and the numeric yielded the same closed-form BER expression conveniently evaluated in terms of SNR in AWGN channels. To be precise, communication in both the urban and the open areas within ranges of up to $\approx$ 3 km and 10 km respectively was a preserve, according to the measurements conducted to determine the average received signal strength of every where it was -100 dBm for an average SNR $\approx$ 5 dB. It was proven by the consistency between the theoretical and the effective noise floors' results and by the observation of the CR parameter contribution into the system PER that the present analysis is useful.

In this paper [5], they have explored the state of the art in solutions for low power wide area (LPWA) networks and technologies serving the Internet of Things (IoT) and Connectivity for Everything markets. These networks are forecast to capture up to 55% market share using battery-powered devices operating up to 10 years and link distances measured in tens of kilometers. In this paper, we survey two LPWA technologies; ultra-narrow band solutions by SigFox and the LoRa technology by Semtech. Both technologies operate in the licence-exempt industrial, scientific, & medical (ISM) bands (EU 868 MHz / US 915 MHz). Finally, we provide example results demonstrating a received SNR consistently exceeding 20 dB over this test link distance.

In this paper [6], it is mentioned that nowadays IoT (Internet of Things) sensor networks deployed in high density applications are under almost constant research and analysis to collect and define new solutions. LoRa is a system of modulation which is able to cover huge distances by using small amount of data. The objective of the present paper is to focus on the peculiarities and problems of IoT issues in the context of LoRa system. The technology employed in such a network is an LPWAN (Low Power Wide Area Network), which entails devices with a battery that enable communication by providing a bidirectional link. This research is related to the assessment of the LoRa technology in the terms of implementing the IoT requirements. Subsection IV contains the technical details of LoRaWAN protocol architecture requirements, whereas in Subsection V LoRa modulation performance is evaluated and reviewed. To summarize, IoT challenges can be alongside LoRa if they are properly addressed.

## III. Proposed Methodology

### 3.1 Hardware requirements

#### 3.1.1 HiLink 5V power supply module

The HiLink 5V power supply module is a compact and efficient solution for providing stable power to electronic devices and circuits. With its high-quality design and reliable performance, it's commonly used in a variety of applications, including embedded systems, IoT devices, and DIY projects. Featuring a wide input voltage range and built-in protections against overcurrent, overvoltage, and short circuits, the HiLink module ensures safe and reliable operation in diverse environments. Its compact size and simple integration make it ideal for space-constrained designs, while its high efficiency helps minimize power consumption and heat generation.

#### 3.1.2 ESP8266 WiFi module:

The ESP8266 WiFi module is a versatile and cost-effective solution for adding wireless connectivity to various electronic projects. With its small form factor and low power consumption, it's widely used in IoT (Internet of Things) applications, home automation systems, and DIY electronics projects. Equipped with a powerful microcontroller unit and built-in WiFi capability, the ESP8266 can connect to WiFi networks, host web servers, and communicate with other devices over the internet. Its popularity stems from its ease of use, extensive community support, and a wide range of compatible development tools and libraries. Whether you're a hobbyist or a professional developer, the ESP8266 offers an affordable and efficient solution for implementing wireless connectivity.

#### 3.1.3 LoRa module:

LoRa, short for Long Range, is a wireless communication technology developed to enable long-distance communication with low power consumption, ideal for IoT (Internet of Things) and M2M (Machine-to-Machine) applications. LoRa utilizes spread spectrum modulation techniques to achieve long-range communication while operating within license-free frequency bands, typically in the sub-GHz range. Its key features include long-range coverage (up to several kilometers in urban environments and tens of kilometres in rural areas), low power consumption, and robustness against interference and obstacles. LoRa technology typically operates in a star-of-stars network topology, with end devices communicating with gateways that forward data to a central server or cloud platform.

#### 3.1.4 OLED display:

OLED, or Organic Light-Emitting Diode, displays are cutting-edge display technology known for their vibrant colors, high contrast ratios, and thin form factor. Unlike traditional LCDs, OLED displays generate light themselves, eliminating the need for a backlight and allowing for deeper blacks and better energy efficiency. OLED displays consist of a series of organic thin films sandwiched between two conductors, which emit light when an electric current passes through them. This technology enables OLED displays to achieve faster response times, wider viewing angles, and higher flexibility, making them suitable for a wide range of applications, from smartphones and smartwatches to TVs and automotive displays. With their ability to produce crisp images and vivid colours, OLED displays offer an immersive viewing experience and are continually pushing the boundaries of display technology.

#### 3.1.5 JST connectors:

short for Japan Solderless Terminal, are widely used electrical connectors known for their reliability, compact size, and ease of use. They consist of male and female connector housings with corresponding pins and sockets that securely mate with each other to establish electrical connections. JST connectors are available in various sizes, configurations, and pitch sizes, making them versatile for different applications. Commonly found in consumer electronics, robotics, automotive systems, and more, JST connectors offer a convenient solution for connecting components such as sensors, actuators, LEDs, and power sources.

#### 3.1.6 Push button

The push button, a ubiquitous component in electronics, serves as a simple yet essential interface for user interaction in countless devices and systems. Consisting of a button that can be pressed or released, it facilitates input commands or triggers actions when activated. Whether it's powering on a device, initiating a function, or signaling a response, the push button's versatility makes it indispensable across a very wide range of applications. With variations such as momentary or latching types, illuminated buttons, and tactile feedback options, it can be tailored to suit specific requirements for tactile feedback, visibility, and operational characteristics. Despite its simplicity, the push button plays a important role in user interfaces, providing a tactile and intuitive means of interaction that remains fundamental in modern technology.

#### 3.1.7 Latched switch:

A latched switch, also known as a latching switch or a toggle switch, is a type of electrical switch that maintains its state after being activated until it is manually toggled again. Unlike momentary switches that return to their default position when released, latched switches have a mechanism that physically locks into place, keeping the circuit either open or closed until intentionally changed. This feature makes latched switches ideal for applications where it's necessary to maintain a specific state without continuous pressure on the switch. Common examples include power switches for electronic devices, lighting controls, and selector switches for different operational modes.

#### 3.1.8 Resistors:

Resistors are fundamental components in electronic circuits, essential for controlling current flow, voltage levels, and signal attenuation. They are passive two-terminal devices that resist the flow of electric current, converting electrical energy into heat. Resistors are typically composed of a ceramic or metal film wrapped around a cylindrical core, with leads attached to each end for connection to the circuit. They come in various types, including fixed resistors with a specific resistance value, variable resistors (potentiometers) that can be adjusted manually, and specialized resistors designed for specific applications such as high precision, high power, or surface mount technology.

#### 3.1.9 Female header pins:

Female header pins, also known as female headers or socket connectors, are essential components in electronics used for creating connections between printed circuit boards (PCBs) and other electronic components or devices. They consist of a row of receptacles or sockets arranged in a plastic housing, with each socket designed to accept a male pin or header. Female header pins are available in various configurations, including single-row, dual-row, and surface-mount options, with different pin counts and spacing to accommodate different PCB layouts and requirements. They provide a reliable and convenient way to establish electrical connections between PCBs and components such as microcontrollers, sensors, displays, and expansion boards.

#### 3.1.10 Wire connectors:

Wire connectors are essential components in electrical and electronic systems, facilitating secure and reliable connections between wires or cables. They come in a variety of types, including twist-on wire connectors, crimp connectors, solder connectors, and compression connectors, each suited for different applications and requirements. Wire connectors provide a means to join wires together while ensuring proper electrical continuity, mechanical strength, and insulation integrity. They are used in a wide range of industries and applications, from household wiring and automotive systems to industrial machinery and aerospace technology. Wire connectors play a crucial role in simplifying installation, maintenance, and repair tasks, enabling safe and efficient electrical connections in diverse environments.

#### 3.1.11 General-purpose PCB:

A general-purpose PCB (Printed Circuit Board) is a versatile platform used for creating electronic circuits and prototypes across a wide range of applications. These PCBs typically feature a grid of pre-drilled holes or pads, allowing components to be soldered onto the board in various configurations to build circuits. They are commonly made of fiberglass or other non-conductive materials, with copper traces etched onto the surface to provide electrical connections between components. General-purpose PCBs offer flexibility in circuit design and assembly, making them ideal for prototyping, experimentation, and small-scale production.

#### 3.1.12 5-7.4V Battery:

A 5-7.4V battery refers to a rechargeable power source that provides a voltage output ranging from 5 to 7.4 volts. These batteries are commonly used in various electronic devices and applications where moderate voltage levels are required, such as remote-controlled toys, portable gadgets, and small electronic projects. The voltage range of 5-7.4 volts typically corresponds to lithium-ion (Li-ion) or lithium polymer (LiPo) batteries, which offer high energy density and lightweight properties, making them ideal for portable and compact designs. With their versatility and relatively stable voltage output, 5-7.4V batteries are favoured for powering a wide range of devices, providing a balance between power output and size constraints. Additionally, many of these batteries come equipped with built-in protection circuits to prevent overcharging, over-discharging, and short circuits, ensuring safe and reliable operation in various applications.

#### 3.1.13 Wire ties:

Wire ties, also known as cable ties or zip ties, are versatile fastening devices used to secure and organize cables, wires, and other items in various applications. Typically made of nylon or plastic, wire ties feature a flexible strap with a serrated surface on one side and a small ratchet mechanism on the other. To use a wire tie, the strap is threaded through the ratchet mechanism and tightened around the items to be secured, then the excess strap is trimmed off. Wire ties provide a simple and effective solution for bundling cables in home wiring, organizing computer cables, securing hoses in automotive applications, and more. They come in various lengths, widths, and colours to accommodate different needs and preferences. With their ease of use, durability, and affordability, wire ties are essential tools for tidying up and managing cables and wires in both professional and DIY settings.

### 3.2 Software Requirement

#### 3.2.1 Arduino IDE:

The Arduino Integrated Development Environment (IDE) is the primary software tool used for writing, compiling, and uploading code to the Arduino microcontroller. It provides a user-friendly interface for programming and debugging Arduino-based projects. Specify the version of Arduino IDE used in your project, or mention the minimum version required for compatibility with your code. You can also include instructions for downloading and installing the Arduino IDE from the official Arduino website.

#### 3.2.2 LoRa Library:

The LoRa library is essential for implementing LoRa communication between the transmitter and receiver modules in your project. This library provides functions and utilities for configuring LoRa transceivers, sending and receiving data packets, and managing communication parameters such as frequency, spreading factor, and bandwidth. Specify the name of the LoRa library used in your project (e.g., Arduino LoRa library), along with the version number or source for downloading the library. You can also provide instructions for installing the library in the Arduino IDE, either through the Library Manager or by manual installation.

#### 3.2.3 OLED Display Library:

If you used an OLED display to provide real-time status feedback in your project, you likely employed a specific library for interfacing with the display module. The OLED display library abstracts the low-level communication with the display hardware, allowing you to easily draw text, graphics, and images on the screen. Mention the name of the OLED display library used in your project (e.g., Adafruit SSD1306), along with the version number or source for downloading the library. Provide instructions for installing and configuring the library in the Arduino IDE, including any necessary setup steps or dependencies.

## 3.3 Block Diagram

### 3.3.1 Transmitter module

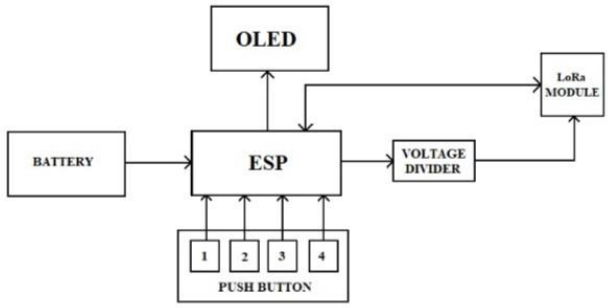


**Fig 3.14. Transmitter Module block diagram**

At the core of the transmitter module lies the ESP8266 microcontroller, serving as the main control unit for the system. Four push buttons are directly connected to the ESP8266, enabling user input for controlling the operation of four relays situated at the receiving end of the system. The relays serve as switches for controlling various devices or appliances remotely. To power the transmitter module, a battery is connected to the ESP8266, providing the necessary electrical energy for its operation. This battery ensures portability and flexibility in deploying the transmitter module in various environments without relying on a constant external power source. Facilitating long-range communication between the transmitter and receiver modules is a LoRa (Long Range) module, interfaced with the ESP8266. The LoRa module utilizes the LoRaWAN protocol to transmit data packets over significant distances, enabling reliable communication even in remote or challenging environments. To ensure stable voltage levels for the LoRa module, a voltage regulator is employed, connected from the ESP8266 to the LoRa module. The voltage regulator regulates the input voltage from the battery to provide a consistent and suitable voltage level for the operation of the LoRa module, enhancing overall system reliability and performance. Together, these components form the transmitter module, providing a compact and efficient solution for remote control and communication, with the ESP8266 serving as the central processing unit, the push buttons enabling user interaction, the relays facilitating device control, the battery providing power, the LoRa module enabling long-range communication, and the voltage regulator ensuring stable voltage supply to the LoRa module.

### 3.3.2 Receiver Module

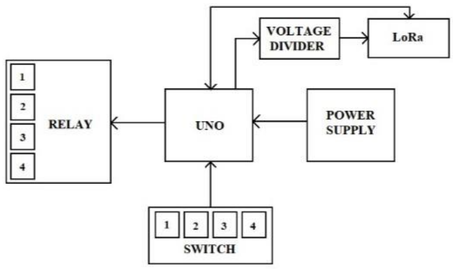


**Fig 3.15. Receiver Module block diagram**

At the heart of the receiving module lies the Arduino Uno microcontroller, serving as the central processing unit for the system. Four relays are directly connected to the Arduino Uno, acting as switches for controlling four different appliances or devices. These relays provide the means to remotely toggle the power state of the connected appliances based on signals received from the transmitter module. To enable manual control of the appliances, four manual switches are connected to the Arduino Uno. These switches allow users to manually override the remote control functionality and directly toggle the power state of the appliances, providing redundancy and flexibility in operation. Facilitating long-range communication with the transmitter module is a LoRa (Long Range) module, interfaced with the Arduino Uno. The LoRa module utilizes the LoRaWAN protocol to receive data packets transmitted by the transmitter module, allowing for reliable communication over significant distances. To ensure compatibility between the voltage levels of the LoRa module and the Arduino Uno, a voltage divider is employed. This voltage divider adjusts the voltage levels as necessary to ensure proper communication between the LoRa module and the Arduino Uno, enhancing overall system stability and performance. To power the receiving module circuitry, a power supply is connected to the Arduino Uno, providing the necessary electrical energy for its operation. This power supply ensures continuous operation of the receiving module, enabling seamless remote control and manual override functionality for the connected appliances. Together, these components form the receiving module, providing a robust and versatile solution for remote appliance control. With the Arduino Uno serving as the central control unit, the relays enabling appliance switching, the manual switches providing manual override capability, the LoRa module facilitating long-range communication, the voltage divider ensuring compatibility, and the power supply supplying the necessary electrical energy, the receiving module offers reliable and efficient operation in various remote control scenarios.

## IV. RESULTS AND EVALUATION

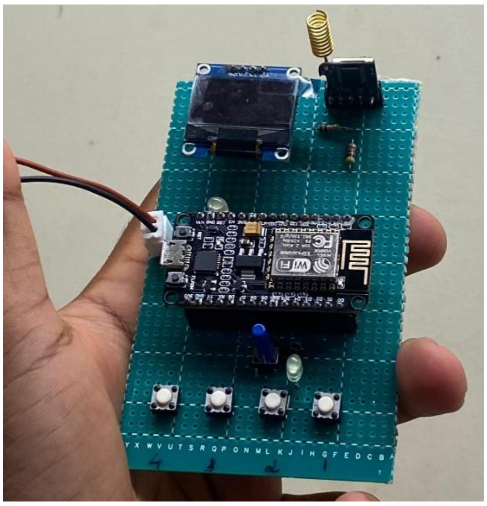

**Fig 4.1. Transmitter Module**

Fig 4.1 shows the transmitter module with ESP 8266 microcontroller at the center. The four push buttons at the bottom are used to control the four appliances connected at the receiving end. The OLED display at the top left gives the real time feedback of the appliances, whether they are turned on or off. The signals from the transmitter is sent to the receiver through a LoRa module integrated at the top right of the transmitter module.

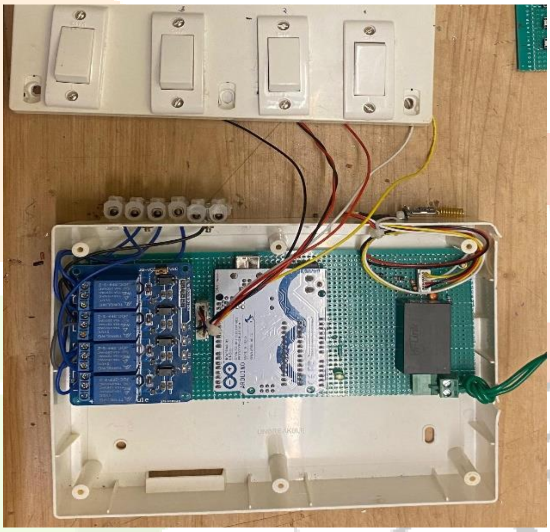

**Fig 4.2. Receiver Module**

The Fig 4.2 shows the receiving module with Arduino UNO at the center of the circuit module. Four relays at the left are to connect with four different appliances that are to be controlled by the transmitter. Manual switches at the top are to use the appliances in the absence of transmitter. The signal sent from the transmitter is received by the receiver with the help of a LoRa module integrated at the top right of receiving module.

| Distance (meters) | Avg. Response Time (milliseconds) |
|---|---|
| 500 | 2000 |
| 1000 | 2500 |
| 2000 | 2500 |
| 3000 | 3000 |

**Table. 5.1 Average response time**

The Table 5.1 shows the average response time or the latency of receiving signal as the distance between the transmitter and the receiver increases. Few time samples were tested with the transmitter and the receiver and the following table is plotted.

## V. FUTURE WORK

Moreover, the significant contributions made by this project lay a solid groundwork for future advancements in remote control systems. As technological landscapes continue to evolve, there remain promising avenues for further exploration. Strengthening the system's security protocols to fortify against unauthorized access and data breaches represents a crucial area for enhancement. Additionally, ongoing optimization efforts focusing on power consumption and communication protocols hold the potential to extend battery life and overall system efficiency. Furthermore, delving into the integration of advanced sensor technologies and actuators could unlock more sophisticated control and monitoring capabilities, thereby amplifying the system's versatility and relevance in diverse application scenarios. In essence, this project not only marks a milestone in remote control innovation but also serves as a catalyst for continued research and development, propelling the field towards more resilient, efficient, and intelligent solutions in the years to come.

## VI. Conclusion

In conclusion, this project has successfully demonstrated the viability and effectiveness of implementing LoRa technology in switch control systems. Through the design and development of a transmitter unit with intuitive push-button controls, integration of relay mechanisms for seamless device switching, and incorporation of an OLED display for real-time status feedback, the system offers a robust solution for remote device management across extensive distances. By addressing challenges such as signal interference, power optimization, and regulatory compliance, this project has delivered a reliable and user-centric switch control platform. The utilization of LoRa technology not only extends the reach of remote control applications but also showcases its potential across a myriad of domains, spanning from smart homes to industrial automation and agricultural management systems.

## VII. Acknowledgment

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