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SMART-RANGE: Advanced Home Automation Using Long-Range Wireless Communication

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Abstract: This paper presents the design and implementation of a longrange smart home automation system using LoRa (Long Range) technology. The system consists of a transmitter and a receiver circuit that utilize the RYLR896 LoRa (Long Range) module to communicate over a range of 1–2 km, with potential coverage up to 15 km. A push button at the transmitter end triggers signals that are received and acknowledged via an OLED (ORGANIC LIGHT-EMITTING DIODE) display on the receiver side, which also controls an appliance through a relay. Integration with Google Home via the ESP8266 NodeMCU (Node Micro Controller Unit) allows voice-based control, enhancing user accessibility. The use of LoRa (Long Range) ensures reliable, low-power communication suitable for large homes or remote areas, addressing the limitations of conventional Wi-Fi and Bluetooth-based systems. The proposed system demonstrates efficiency, scalability, and real-time responsiveness, making it ideal for modern smart home applications.

Keywords: AC relay; Arduino Uno; ESP8266 NodeMCU (Node Micro Controller Unit); Google Home; home automation; Internet of Things (IoT); LoRa; Long Range Communication; OLED (ORGANIC LIGHT-EMITTING DIODE) display; push button; RYLR896; smart home

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1. Introduction

The rapid evolution of the **Internet of Things (IoT)** has revolutionized the way we interact with our environment, particularly within the domain of **smart homes**. The integration of Internet of Things (IoT) in domestic settings has enabled the **automation** and **remote control** of household appliances, lighting, security systems, and energy management— enhancing **convenience**, **efficiency**, and **security** in everyday life. However, a major limitation in existing home automation systems lies in the **communication technologies** used—such as **Wi-Fi**, **Bluetooth**, and **Zigbee**—which tend to be effective only in small, localized environments [1]. These technologies suffer from drawbacks like **limited range**, **high power consumption**, **network congestion**, and **signal attenuation** due to obstacles like walls or floors, making them less suitable for large residences, multi-storey buildings, or rural areas.

In response to these challenges, **LoRa (Long Range) (Long Range)** technology has emerged as a powerful **wireless communication protocol** tailored for **low-power**, **longdistance**, and **low-bandwidth** applications [1]. Operating in the **sub-GHz frequency bands**, LoRa (Long Range) (Long Range) can support communication ranges up to **15 kilometers** in open outdoor environments and **1–2 kilometers** in urban or semiobstructed settings. Its ability to **transmit data over long distances** with minimal energy usage makes it highly suitable for applications in **remote monitoring**, **smart agriculture**, **environmental sensing**, and **home automation**.

This research paper presents the **design and implementation** of an **advanced smart home automation system** using **LoRa (Long Range) communication**, focused on **longrange**, **reliable**, and **low-energy** data transmission. The system is composed of two main circuits: a **transmitter circuit** and a **receiver circuit**. The transmitter module includes a **push button**, which, when pressed, initiates a signal using the **LoRa (Long Range) RYLR896 module**. The receiver module, also equipped with

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the LoRa (Long Range) module, listens for the incoming signal and upon reception, performs two key actions: it **displays a confirmation** message on a **0.96-inch OLED (ORGANIC LIGHT-EMITTING DIODE) display** and **triggers a relay** to switch off an appliance, such as an **AC-powered light**.

To ensure compatibility with modern smart home ecosystems, the system is also **integrated with Google Home**, allowing **voice-activated commands** and **cloudbased automation routines**. Key components used in the project include the **Arduino Uno**, **ESP8266 NodeMCU (Node Micro Controller Unit)**, **5V relay module**, **AC plug circuit**, **LEDs**, **resistors**, and the **Arduino IDE** for programming and interfacing the microcontrollers.

The primary motivation behind this project is to **bridge the communication gap** in areas where conventional networks like Wi-Fi are **ineffective** or **impractical** due to **distance**, **terrain**, or **infrastructure limitations**. The solution aims to offer a **scalable**, **energy-efficient**, and **costeffective** alternative for home automation systems, especially in **rural settings** or **large residential areas** where centralized Wi-Fi coverage is either inconsistent or nonexistent.

By combining **LoRa's exceptional range** and **low power consumption** with the ease-of-use and interactivity of platforms like **Google Home**, the proposed system demonstrates a new direction for smart home innovation— focusing on **accessibility**, **reliability**, and **practicality**.

Key Features

I. Dual-Circuit Architecture

The system comprises a transmitter circuit with a push button and a receiver circuit with a relay and OLED (ORGANIC LIGHT-EMITTING DIODE) display, enabling seamless wireless communication and device control [2].

II. Long-range wireless communication

The system uses LoRa (Long Range) RYLR896 modules capable of transmitting data over distances ranging from 1 to 15 kilometers, making it suitable for large homes, remote areas, and agricultural fields.

III. Low power consumption

LoRa (Long Range) technology ensures energy efficiency, allowing components to function for extended periods without frequent recharging or high energy demand.

IV. Instant Device Control

Pressing the transmitter button sends a signal to the receiver, which activates or deactivates appliances using a 5V relay.

V. Offline Operation

Core functions between transmitter and receiver work without internet, ensuring reliable control even in remote areas.

VI. Google Home Integration

Through ESP8266 NodeMCU (Node Micro Controller Unit), the system supports voice commands and automation via Google Home, enhancing smart control.

VII. Real-Time Feedback

The 0.96″ OLED (ORGANIC LIGHT-EMITTING DIODE) display on the receiver provides immediate feedback upon signal reception, confirming successful communication.

2. Implementation

This system integrates wireless communication, manual control, and automated relay switching using two microcontrollers: Arduino UNO and ESP8266 NodeMCU (Node Micro Controller Unit), both interfaced with the REYAX RYLR998 LoRa (Long Range) module for long-distance data transmission. Let us explore both circuits and their implementation.

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I. Transmitter Circuit (Based on Arduino UNO)

The **Arduino UNO** serves as the **transmitter**, controlling the relays based on button inputs and sending the data to the **ESP8266** via the **LoRa (Long Range) module**.

i. **RYLR998 LoRa (Long Range) Module**: **REYAX** Enables **long-range wireless communication** between the Arduino and NodeMCU (Node Micro Controller Unit). Operates over Universal Asynchronous Receiver-Transmitter (UART) using TX and RX pins.
ii. **Four Push Buttons (S1 to S4)**: Each button is assigned to a respective relay. When pressed, the button triggers a HIGH/LOW signal that is processed by the Arduino.
iii. **5V Relay Module**: Used to **switch AC appliances** like bulbs. The relays are triggered via digital pins (D2 to D5) on the Arduino.
iv. **Visual Feedback**: A basic **LED with a 1kΩ resistor** is connected to pin A3 for indicating transmission status.
v. **Power Management**: All modules are powered using a **+5V and GND rail**.
vi. **Serial Communication**: The **LoRa (Long Range) module** communicates with the Arduino via software serial to avoid conflicts with the USB serial port.

II. Receiver Circuit (Based on ESP8266 NodeMCU (Node Micro Controller Unit)) The **ESP8266 NodeMCU (Node Micro Controller Unit)** acts as the **receiver**, decoding LoRa (Long Range) commands to reflect button states and displaying status on an **OLED (ORGANIC LIGHT-EMITTING DIODE) display**.

i. **REYAX RYLR998 LoRa (Long Range) Module**:

Communicates with Arduino UNO over LoRa (Long Range) protocol to **receive control commands** wirelessly

ii. **OLED (ORGANIC LIGHT-EMITTING DIODE) Display**:

Connected via I2C (SCL and SDA), it displays the **status of each appliance**, making the system user-friendly and interactive

iii. **Five Push Buttons**:

These provide **manual override** capability for switching appliances locally. One extra **STATUS** button is included for general-purpose feedback or test commands.

iv. **Status LED**:

Glows based on received data or internal logic to **indicate connectivity and command execution**

v. **Power LED**:

Shows whether the NodeMCU (Node Micro Controller Unit) is powered, aiding in debugging and monitoring.

vi. **Proper Pull-Up Resistors**:

Ensures clean signals are transmitted from switches.

vii. **Power Supply**:

NodeMCU (Node Micro Controller Unit) runs on **3.3V** and components like LoRa (Long Range) module and buttons are powered using **regulated 3.3V and 5V lines**.

III. Working

i. When any button (S1–S4) on the Arduino side is pressed, the corresponding command is **transmitted via the LoRa (Long Range) module**.
ii. The **ESP8266 NodeMCU (Node Micro Controller Unit) receives the signal**, decodes the command, and toggles the **status LED** and updates the **OLED (ORGANIC LIGHT-EMITTING DIODE) screen** accordingly.
iii. The user can **manually control the relays** via the local buttons on the NodeMCU (Node Micro Controller Unit) side as well.
iv. The system can operate **reliably across long**

v. **distances**, thanks to LoRa's **high range and low power** capabilities.
vi. This two-way setup allows **robust home automation**, even in environments with limited Wi-Fi or Bluetooth coverage.

3. Methodology

The first step in the project involved designing the transmitter circuit, as shown in **Figure 1**. A LoRa (Long Range) module, such as the Dragino 915 MHz, was chosen for its long-range communication capabilities. This module was interfaced with a microcontroller, typically an Arduino or ESP32, to manage the signal transmission. A push button was connected to the microcontroller, allowing the user to initiate data transmission manually. When the button is pressed, it sends a signal to the microcontroller, which in turn triggers the LoRa (Long Range) module to transmit the predefined data. The microcontroller is programmed to detect the push button press through its digital input pins and to control the LoRa (Long Range) module via digital I/O connections.

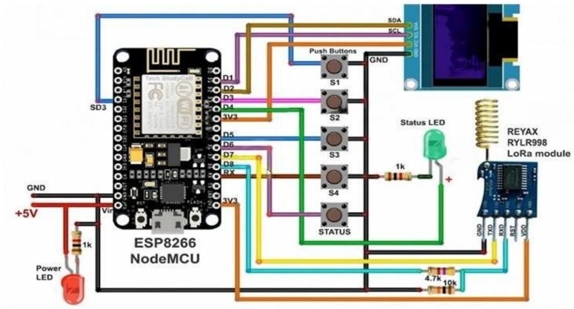

Figure 1.

The second phase focused on the receiver circuit design, which is illustrated in **Figure 2**. A similar LoRa (Long Range) module, operating at the same frequency (915 MHz), was configured to receive the transmitted signal. The microcontroller on the receiver side listens for incoming data from the LoRa (Long Range) module and processes it upon receipt. Based on the specific command received (such as turning off a device), the microcontroller activates a relay or a transistor to perform the required action. Additionally, an LCD or OLED (ORGANIC LIGHT-EMITTING DIODE) display is incorporated into the circuit to provide real-time visual feedback to the user, displaying messages like "Signal Received" or "Device Off," depending on the situation.

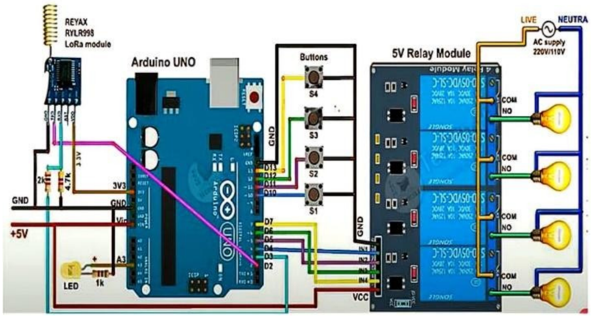

Figure 2.

Next, both microcontrollers—transmitter and receiver—were programmed to manage their respective tasks, with the overall workflow between them depicted in **Figure 3**. The transmitter microcontroller is continuously monitoring the push button state. When a press is detected, it sends a specific signal via the LoRa (Long Range) module. On the other side, the receiver microcontroller is programmed to constantly listen for incoming transmissions. When the signal is received, it interprets

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the command, activates the relay or transistor accordingly, and updates the display with the corresponding message to notify the user of the system's status. Finally, to establish reliable communication, both LoRa (Long Range) modules were configured to operate on the same frequency, with identical communication parameters such as the data rate and spreading factor. Ensuring that both modules share these settings was crucial for the accurate transmission and reception of data between the transmitter and receiver circuits.

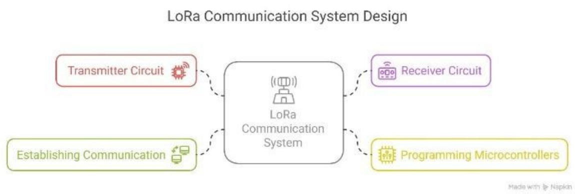

Figure 3.

4. Results and Discussion

The proposed **Internet of Things (IoT) -based Smart Home Automation System using LoRa (Long Range)** represents a transformative shift in how smart technologies can be implemented in both **urban and remote environments**. Unlike traditional systems that are heavily reliant on **WiFi or Bluetooth**—which are limited by range, scalability, and power inefficiency—this project utilizes **LoRa (Long Range) (Long Range) technology**, enabling **communication over distances of up to 15 kilometers** while consuming **minimal power**. This is a game-changer for **rural and agricultural regions**, large estates, and **off-grid areas** where internet access is unreliable or unavailable [1].

The system's ability to control household appliances remotely, monitor activity in real time, and respond to voice commands via Google Home integration significantly improves user convenience, especially for the elderly or individuals with physical limitations. This opens new possibilities for inclusive smart living, making home automation more accessible and empowering for all demographics.

Beyond individual homes, the project's scalable and modular design can be extended to commercial buildings, farms, warehouses, or community infrastructure [2]. The use of energy-efficient components, such as the ESP8266 NodeMCU (Node Micro Controller Unit), OLED (ORGANIC LIGHT-EMITTING DIODE) displays, and 5V relays, supports a sustainable approach to automation that reduces unnecessary power consumption and allows for low-maintenance operation.

Moreover, the inclusion of **dual circuit architecture**—with a transmitter and receiver—ensures **robust and secure communication** across various nodes. The system's flexibility allows for **easy integration of additional sensors** for temperature, humidity, or gas detection, further enhancing safety and control.

In the future, by integrating with advanced microcontrollers like **LPC2148**, the system can be upgraded to handle **real-time data processing**, **edge computing**, and **improved hardware interfacing**, making it suitable for more complex applications. This paves the way for **automated scheduling**, **predictive maintenance**, and **AI-driven decision making** within the home environment.

Ultimately, the anticipated impact of this project lies in its potential to democratize smart home technology. By offering a **cost-effective**, **energy-efficient**, and **longrange solution**, it breaks traditional barriers of entry, encouraging **widespread adoption** across varied geographical and economic settings. The project is wellaligned with future trends in Internet of Things (IoT), sustainability, and human-centered design, promising to shape the next generation of **intelligent, adaptive living spaces**.

5. Future Add On's and Further Development

- The system's modularity enables upgrades like LPC2148 integration for real-time, low-latency appliance control.
- A custom mobile app can provide remote access, realtime alerts, and energy usage statistics.
- Voice assistant support (Google Home, Alexa) allows hands-free commands for daily convenience.
- Sensor integration (Passive Infrared Sensor, DHT11, gas) enables automation based on motion, temperature, or gas leaks.
- Two-way LoRa (Long Range) communication with acknowledgments ensures reliable control and device feedback.
- OTA firmware updates can fix bugs or add features without needing physical access.
- Cloud dashboards (via Firebase/Node-RED) offer remote monitoring, scheduling, and analytics.
- Together, these add-ons build a smart, scalable system ideal for modern homes and remote facilities.

List of Abbreviations

ABBREVIATION	EXPANSION
AC	Alternating Current
AI/ML	Artificial Intelligence / Machine Learning
Arduino	Arduino Uno (microcontroller platform)
ESP8266	Node Micro Controller Unit (NodeMCU)
GPIO	General Purpose Input/Output
I2C	Inter-Integrated Circuit
IoT	Internet of Things
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LoRa	Long Range
LoRaWAN	Long Range Wide Area Network
NodeMCU	Node Micro Controller Unit
OLED	Organic Light-Emitting Diode
PIR	Passive Infrared Sensor
SCL/SDA	Serial Clock/Serial Data (I2C pins)
TX/RX	Transmit/Receive (serial communication)
UART	Universal Asynchronous Receiver-Transmitter

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