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Lora-Based Smart Home System Design using Modbus Protocol and Antares Platform

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ABSTRACT

A smart home integrates intelligent technologies to automatically respond to occupants' needs, enhancing energy efficiency, comfort, security, and convenience. This paper presents the design and implementation of a smart home monitoring and control system using LoRa (Long Range) wireless communication, the Modbus protocol, and the Antares IoT platform. LoRa was selected for its low power consumption and long-distance transmission capabilities, ideal for Internet of Things (IoT) applications. The system employs microcontrollers programmed via Arduino IDE to enable real-time data acquisition and device control. Modbus RTU/TCP is implemented to ensure reliable and standardized communication between devices, promoting interoperability and system scalability. Data collected from sensors are transmitted through LoRa to a gateway, then forwarded to the Antares platform for remote monitoring and user interaction. An experimental approach was used to evaluate the system's performance in terms of packet delivery ratio, latency, and data consistency on Antares. Results show stable and consistent communication over distances up to 300 meters in urban environments, with successful device control and minimal data loss. The integration with Antares provides an intuitive interface for remote access and visualization. This study demonstrates that combining LoRa, Modbus, and Antares offers a cost-effective, scalable, and robust solution for smart home automation, suitable for deployment in residential environments.

Keywords: smart home, LoRa, antares, Internet of Things, arduino ide.

1. INTRODUCTION

The development of information and communication technology has brought significant transformations to various aspects of life, one of which is residential management through the concept of the smart home. A smart home is a system that integrates data processing and automation technology to improve energy efficiency, comfort, security, and ease of centralized control of electronic devices for residents [1][2][3][4][5][6]. However, despite the convenience offered, challenges remain in suboptimal energy management, such as electricity waste due to devices left on unattended, and a reliance on smartphones that makes users less aware of their surroundings [7][8][9][10][11].

Furthermore, the use of LPG as a substitute for kerosene poses the risk of gas leaks, which can cause fires if not detected promptly. Therefore, the integration of gas sensors (MQ-6) is crucial for providing early warnings and improving household safety. Furthermore, remote monitoring and control are essential features of a smart home system. Unfortunately, many currently available systems rely on Wi-Fi networks or expensive cloud-based services, making them vulnerable to connectivity disruptions and less efficient over long distances and in remote areas [12][13][14][15][16].

The development of communications technology has undergone a rapid transformation, from simple systems based on voice and analog signals to global digital networks connecting billions of devices in real time. This development has not only changed the way humans interact but has also revolutionized the education, healthcare, industry, and government sectors [17][18][19][20][21].

Long Range (LoRa) technology offers a long-range, low-power wireless communication solution, ideal for Internet of Things (IoT) applications in smart home environments. The LoRa SX1276, operating at 920 MHz, is capable of transmitting data even through physical obstacles, making it ideal for communication between devices within a home. To support real-time data visualization and monitoring, the Antares platform—developed by PT Telkom Indonesia—provides an easily accessible cloud-based interface integrated with the LoRa system [22][23][24][25][26][27].

This research aims to design and build a Modbus-based smart home system using LoRa technology and the Antares platform. The Modbus protocol was chosen for its ability to ensure interoperability between devices with a standard and reliable communication format. This system is designed to monitor electrical parameters, detect gas leaks, and remotely control electronic devices in a cost-effective and stable manner, without relying entirely on a Wi-Fi network. The main contributions of this research include:

1. Integration of the Modbus protocol into a LoRa-based smart home architecture to improve system interoperability and scalability;
2. Implementation of an energy- and cost-efficient remote monitoring and control system through a combination of LoRa and the Antares platform;
3. Development of a more reliable smart home solution in areas with limited internet connectivity, with support for early detection of security threats such as gas leaks.

2. METHOD

2.1. LONG RANGE (LORA)

LoRa (Long Range) is a low-power, long-range wireless communication technology (LPWAN) specifically designed for Internet of Things (IoT) applications. This technology enables devices to transmit small amounts of data periodically over very long ranges and with very low power consumption, making it suitable for systems that operate on batteries for extended periods. LoRa operates at sub-GHz frequencies, such as 868 MHz in Europe, 915 MHz in the United States, and 920 MHz in Indonesia, allowing signals to effectively penetrate physical obstacles (walls, buildings, etc.). Communication is conducted using chirp spread spectrum modulation, which makes the signal resistant to interference and noise, and capable of reaching distances of up to several kilometers, even in urban environments [28][29][30][31][32].

Main Components of a LoRa System

- End Device (Node): An end device such as a temperature sensor, gas sensor, or switch that collects data and transmits it via a LoRa module (e.g., SX1276).
- Gateway: Receives signals from nodes, which then forwards data to the core network (usually via Wi-Fi, Ethernet, or cellular).
- Network Server: Manages communication between devices, encryption, and data routing.
- Application Server: Where data is displayed and processed, such as Antares, ThingSpeak, or TTN (The Things Network).

LoRa Advantages

- Long range: Up to 3–10 km in open areas.
- Power efficient: Devices can last for weeks to months on a small battery.
- High capacity: A single gateway can handle thousands of nodes.
- Low cost: Infrastructure and devices are relatively inexpensive compared to cellular solutions (4G/5G).
- Good signal penetration: Effective for indoor use or in densely populated areas.

2.2. Modbus Protocol

Modbus is an open-source communication protocol developed by Modicon (now Schneider Electric) in 1979. This protocol is used to transfer data between devices in industrial control and automation systems, such as between PLCs (Programmable Logic Controllers), HMIs (Human Machine Interfaces), sensors, and computers. Modbus allows data exchange over various communication media, such as serial (RS-232/RS-485) and Ethernet (TCP/IP). Modbus supports the following communication types: Modbus RTU (Remote Terminal Unit) – serial-based (RS-232/RS-485), Modbus ASCII – also serial-based, but in ASCII character format, and Modbus TCP/IP – running over an Ethernet network [33][34][35][36][37]. Modbus Architectural Structure

- Master-Slave (Modbus RTU & ASCII)
  - Master: sends commands (requests)
  - Slave: responds to commands
- Client-Server (Modbus TCP/IP)
  - Client: sends requests
  - Server: provides data

Modbus Advantages

- Simple and lightweight
- Open protocol (free to use)

- Compatible with many industrial devices
- Supports multi-device communication

2.3. Antares Platform

Antares is a cloud-based IoT (Internet of Things) platform developed by PT Telkom Indonesia. This platform is designed to simplify the development, integration, and management of small to large-scale IoT applications, for academic, research, and commercial purposes. This platform provides an end-to-end infrastructure for developers, educational institutions, startups, and industries to create IoT solutions without having to build servers and networks from scratch [38][39][40][41][42]. Antares acts as middleware—an intermediary layer that connects physical devices with user applications (user interfaces). Its functions include:

- Connectivity: Receives data from IoT devices using standard protocols.
- Data Storage: Automatically stores sensor data in the cloud.
- Data Visualization: Displays data in graphs, tables, or dashboards.
- Remote Monitoring: Allows users to monitor device conditions from anywhere.
- Device Control: Sends commands from the cloud to the device (downlink).
- API Integration: Enables integration with other applications such as Telegram, Google Sheets, or third-party dashboards.

Antares Main Components

1. Device (End Device)
   - A device equipped with a sensor/actuator (e.g., temperature sensor, gas sensor, relay, etc.).
   - Uses a microcontroller such as ESP32, Arduino, or Raspberry Pi.
   - Connects to the internet via Wi-Fi, Ethernet, or LoRa (with a gateway).
2. Gateway (for LoRa)
   - Because Antares initially supports the HTTP/CoAP protocol, LoRa devices require a LoRa gateway to translate LoRa signals into data that can be sent to the internet.
   - This gateway acts as a bridge between the LoRa network and the Antares platform.
3. Project & Workflow (Project & Channel)
   - In Antares, users create projects, which serve as containers for system logic.
   - Each project consists of one or more channels, which represent data flows from a single device.
   - For example, the "SmartHome_Sensor" channel receives temperature and humidity data.
4. REST API and Communication Protocol
   - Antares uses HTTP/HTTPS and CoAP as its primary protocols.
   - Developers send/receive data to Antares using an API (Application Programming Interface).
   - The data format is generally JSON.
   - Each access is protected by an Access Key for security.
5. Dashboard and Visualization
   - Antares provides a web interface that allows users to:
   - View real-time data from sensors.
   - Monitor device status.
   - Create dynamic graphs.
   - Set triggers (automatic alerts if values exceed limits).

2.4. Internet of Things (IoT)

The Internet of Things (IoT), or in Indonesian, the Internet of Everything, is a networking concept that connects physical devices in the real world to the internet, allowing them to collect data, communicate with each other, and be controlled automatically without direct human intervention [43][44][45][46].

- IoT is an ecosystem of physical objects ("things") equipped with:
- Sensors (to measure temperature, motion, light, gas, etc.),
- Actuators (to perform actions such as turning on lights, unlocking locks),
- Connectivity (Wi-Fi, Bluetooth, LoRa, 4G/5G, etc.),
- Processors & software (to process data and make decisions).

These devices are connected to the internet and can exchange data with each other to provide information, trigger actions, or be controlled remotely. IoT systems work in four main stages:

- Data Collection

Sensors on devices collect data from the environment (e.g., room temperature, machine status, blood pressure).

- Data Transmission
  Data is sent via a network (Wi-Fi, LoRa, cellular, etc.) to a server or cloud platform.
- Data Processing & Analysis
  Data is processed by a computer system or AI to generate useful information (e.g., detecting outages or providing recommendations).
- Response or Action
  The system provides a response, such as:
  - Notifying the user,
  - Activating an actuator (e.g., turning off the AC when the temperature is cool),
  - Updating the dashboard in real time.

IoT Benefits

- High efficiency – Automation reduces human error and energy waste.
- Real-time monitoring – Data can be accessed anytime, from anywhere.
- Cost and energy savings – The system operates automatically, requiring minimal intervention.
- Increased convenience and security – For example, the home can be locked remotely.
- Problem prediction and prevention – Such as early detection of gas leaks or machine failures.

By connecting the physical world to the digital world, IoT opens up enormous opportunities for improving efficiency, convenience, and sustainability in nearly every aspect of life.

2.5. Node-RED

Node-RED is a visual programming platform designed to simplify the creation of connected applications, particularly in the context of the Internet of Things (IoT), system automation, and web service integration. Developed by IBM and now maintained by the JS Foundation, Node-RED allows users to create logical flows by simply dragging and connecting functional blocks (called nodes), without having to write code manually [47][48][49][50][51]. Node-RED uses a "flow-based programming" approach—that is:

- A node represents a specific function:
  - Input (sensor, button, MQTT, HTTP request)
  - Process (logic, math, data filter)
  - Output (actuator, notification, send to cloud)
- Connections between nodes indicate data flow.
- When data enters from one node, it "flows" to the next node according to the connection.

Node-RED Basic Components

- Palette :A collection of available nodes (input, output, function, storage, etc.).
- Workspace : Where you arrange and connect nodes.
- Flows : A collection of interconnected nodes that form a single work logic.
- Deploy : A button to start the created flow running.
- Debug Panel : Displays data currently being processed, aiding in testing and improvement.

3. PROPOSED METHOD

This research employs an experimental method to test hypotheses by manipulating independent variables and observing their effects on dependent variables, thereby enabling cause-and-effect analysis. The study focuses on the design and implementation of a LoRa-based smart home system integrated with the Antares platform to facilitate remote monitoring and control, allowing users to efficiently manage electronic devices and monitor environmental conditions such as air quality and energy consumption.

The Internet of Things (IoT) technology, combined with a LoRa communication network, enables long-range data transmission—up to several kilometers—with low power consumption, making it highly suitable for smart home and industrial automation applications. This research was conducted at the K4 Vocational Building, Universitas Surabaya, during the odd semester of 2022/2023. The methodology consisted of several stages: literature review, problem identification, conceptual innovation, system design (both hardware and software), and evaluation of results.

The study began with a comprehensive literature review to identify existing challenges in smart systems, particularly in the context of public street lighting (PJU) control using YOLOv3-based camera systems and IoT integration. Based on these findings, this research proposed an innovative solution through the development of a smart home control system using the TTGO ESP32 LoRa SX1276 OLED module as the core microcontroller. The system integrates multiple sensors—including the DHT22 (temperature and humidity), DSM501A (air quality), PZEM-004T (voltage and current), and a Modbus RTU-controlled relay—to collect and transmit real-time environmental and electrical data.

Data from these sensors is transmitted via a LoRa wireless network to a gateway, which forwards it to the Antares IoT platform. The received data is then visualized and monitored in real time using a Node-RED dashboard, providing an intuitive interface for remote access and control. This integration demonstrates a scalable, low-cost, and energy-efficient solution for smart home automation with potential applications in both residential and public infrastructure systems.

The wiring design of the smart home system, which integrates the Modbus protocol over a LoRa communication network and the Antares platform, is developed to ensure seamless and efficient interaction between control and monitoring components. In this final project, all subsystems operate under an Internet of Things (IoT)-based automation framework. This includes a DSM501A sensor for particulate matter detection (e.g., cigarette smoke), an MQ-6 sensor for LPG leak detection, and a Passive Infrared (PIR) sensor to enable automatic lighting control upon motion detection. The complete wiring configuration of the system is illustrated in Figure 1.

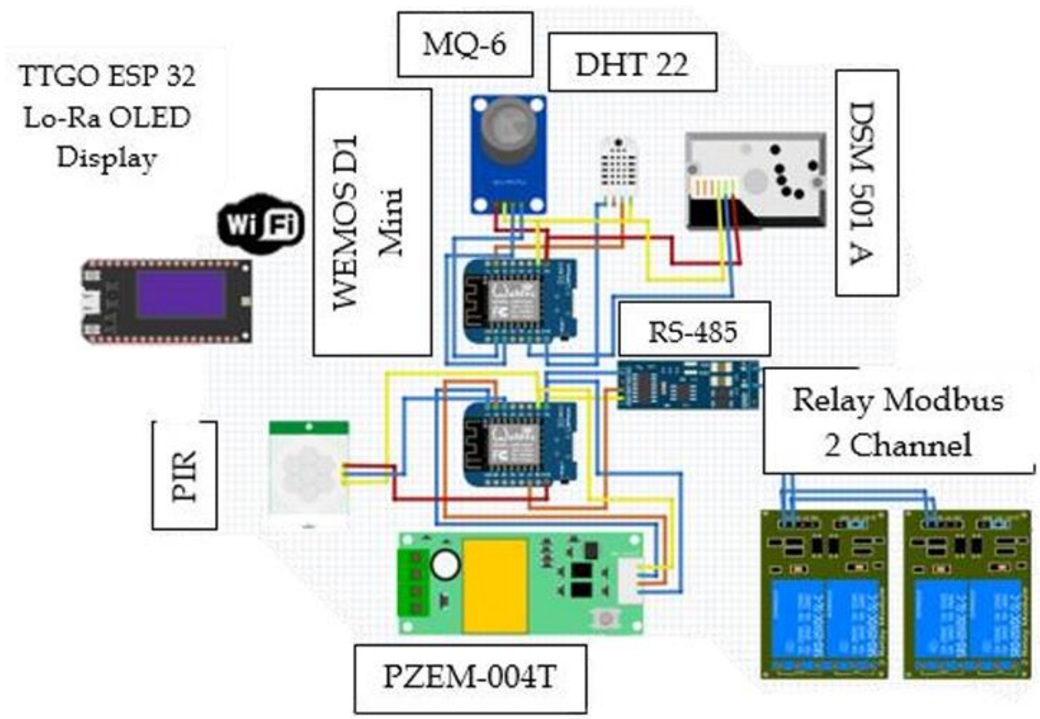

Figure. 1. Hardware Wiring Design

In designing this system, the ESP32 microcontroller is used, which supports programming in C++ (via the Arduino IDE) and Python (via MicroPython), allowing flexibility in system development. The monitoring mechanism is explained through several stages, as shown in Figure 2. The process begins with the DHT22 and DSM501A sensors, which measure environmental parameters such as temperature, humidity, and air quality (particulate matter). These sensors then transmit the data to the ESP8266 module, which serves as the primary data collection unit. The MQ-6 sensor is used to detect LPG gas leaks and sends real-time signals to the ESP8266. Meanwhile, the Passive Infrared (PIR) sensor detects human movement and sends data to the PZEM-004T module, which, in addition to measuring electrical voltage quality, also functions as a relay controller. Based on input from the PIR, the PZEM-004T activates the lights via a Modbus relay.

Data from all sensors is collected by the ESP8266 and then forwarded to the ESP32 LoRa module. The ESP32 LoRa then sends the data to the Antares platform using the UDP communication protocol over a Wi-Fi network. The data received by Antares is then displayed in real time on the Node-RED dashboard, enabling intuitive and responsive remote monitoring.After hardware assembly, the system is configured to ensure integration between components is as designed. The next phase includes functional testing of each sensor and actuator, as well as debugging and repairing any communication errors or data discrepancies.

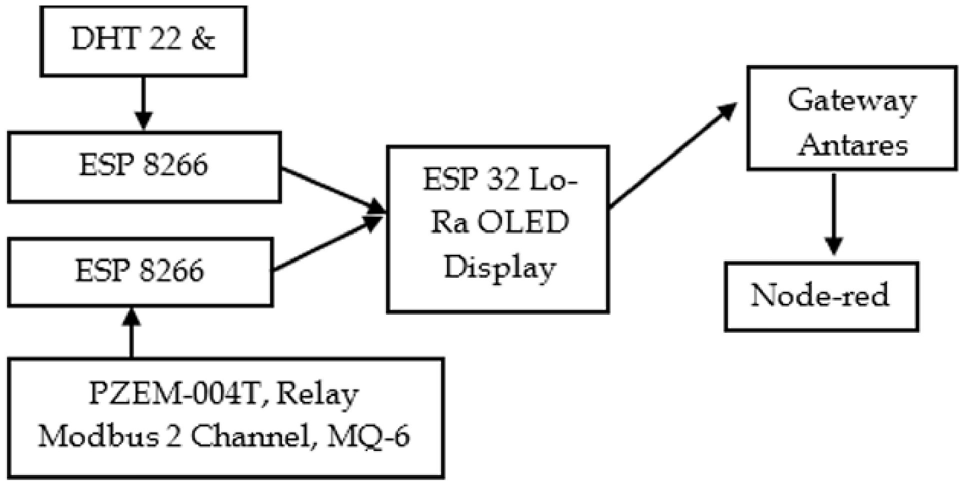

Figure. 2. Software Design Diagram

4. RESULT AND DISCUSSION

Data collection from the MQ6 sensor was performed by exposing it to butane and propane gases released from common lighters and LPG canisters. The sensor's response to gas leaks was recorded and tabulated, including measured concentrations in parts per million (PPM), observed reactions, and corresponding conclusions regarding detection sensitivity and reliability. Testing of the air quality detection system was conducted to evaluate indoor air cleanliness. The results are presented in a table summarizing 24-hour particulate matter (PM) measurements, categorized into standardized air quality levels (e.g., good, moderate, unhealthy), along with a color-coded status indicator to represent the health implications of the indoor air conditions.

A smart home system based on the Modbus protocol over a LoRa network and integrated with the Antares platform represents an innovative application of Internet of Things (IoT) technology. This system enables users to remotely monitor and control household activities, enhancing energy efficiency, security, and environmental sustainability. It supports automated control of electrical devices—such as streetlights—for optimized energy usage and incorporates an MQ-6 gas sensor to detect hazardous leaks of butane or methane, improving home safety. Additionally, the system utilizes a DSM501A particulate matter sensor to detect cigarette smoke, helping to maintain healthier indoor air quality by identifying and mitigating exposure to harmful pollutants.

Passive Infrared (PIR) Sensor Integration Testing

This test aimed to assess the integration between a PIR motion sensor and a 2-channel Modbus relay for controlling incandescent lamps. The evaluation focused on hardware-software compatibility and communication effectiveness between the components. The experiment examined key performance factors such as detection range, operation under varying lighting conditions, and relay response time. The results provide insight into the system's ability to function synergistically and reliably under diverse operational scenarios. PIR (Passive Infrared) testing to determine whether the sensor properly executes commands. When the system detects movement to turn on the lights, the PIR test results table below shows whether the relay will turn the lights on and off according to the smart home system's detection results. The detail can be seen in Table 1

TABLE 1. INFRARED TEST RESULTS ON LAMPS

Experiment	Lamp On	Lamp Off	Modbus Relay Response (s)
No Person	0	1	1
1	1	0	1
2	1	0	1
3	1	0	1

Based on the table above, the results show that if no person is detected, the lights are off (Lights OFF), with a relay response of 1 second. And at 1 meter: One light is on, no lights are off (Lights OFF), with a relay response of 1 second. At 2 meters: One light is on, no lights are off (Lights OFF), with a relay response of 1 second. At 3 meters: One light is on, no lights are off (Lights OFF), with a relay response of 1 second. At 4 meters, the lights are on (Lights ON) and no lights are off, with a relay response of 1 second. It can be concluded that the system automatically adjusts the number of lights turned on according to the distance of the detected person, with a consistent relay response of 1 second. This experiment was conducted by detecting motion using the PIR sensor, which then recorded the time of the incident and sent to the Antares gateway.

Air Quality Detection System Testing

Based on Table 2, the air quality detection system shows that when indoor cigarette smoke exposure is detected, the particulate matter per meter will show an increase, triggering an alarm in the air quality detection system. After the alarm sounds, the exhaust fan will turn on to filter out the cigarette smoke, which is considered unhealthy.

TABLE 2. AIR QUALITY DETECTION SYSTEM TEST RESULTS

Date and Time	24-hour particulate matter (PM2.5) µg/m3	Category	Status
23-12 2024, 11.45 WIB	7.29	Good	Green
23-12 2024, 11.46 WIB	18.29	Fair	Green
23-12 2024, 11.47 WIB	108.2	Unhealthy	Yellow
23-12 2024, 11.48 WIB	5.22	Good	Green
23-12 2024, 11.49 WIB	2.15	Good	Green

Gas Leak Detection System Testing

The gas leak detection system was tested to evaluate the integration between the MQ-6 sensor and a 2-channel Modbus relay within the context of indoor air quality and safety management. This assessment aims to determine the system's ability to operate synergistically under varying conditions, ensuring reliable and automated responses to potential gas leaks. The test focuses on the sensor's sensitivity to butane and propane—common components of LPG—and its capability to trigger the Modbus relay to activate alarms or shut off gas valves, thereby enhancing household safety. The following section presents the experimental results of the MQ-6 sensor performance. The Data can be seen in Table 3.

TABLE 3. GAS DETECTION SENSOR TEST RESULTS

Number of PPM	Reaction	Conclusion
610 ppm	The alarm sounds and the exhaust fan turns on	If a gas other than natural gas is detected, it will trigger an alarm and the fan will turn on.
506 ppm	The alarm sounds and the exhaust fan turns on	If a gas other than natural gas is detected, it will trigger an alarm and the fan will turn on.
497 ppm	No gas leak detected	If no methane or butane gas is detected, the alarm and the fan will turn off.
487 ppm	No gas leak detected	If no methane or butane gas is detected, the alarm and the fan will turn off.

In Table 3, the gas leak detection system collects data by spraying butane and propane gas contained in a lighter/LPG. The test results show that the MQ6 sensor, which functions as a gas leak detector, is working properly. When the gas detector is working properly, it will start at a PPM of less than 500, as it detects natural gas. When the PPM exceeds 500, it will detect methane or butane leaks.

Antares Platform and LoRa Network Field Testing

The Antares IoT platform was evaluated through a mobile field test (commonly known as a drive test) to assess uplink data transmission performance. A LoRa-enabled device was mounted on a motorcycle and carried across various locations in Sidoarjo and Surabaya. During the journey, data packets were transmitted via the LoRa network to a gateway, which forwarded them to the Antares platform. The received data included GPS coordinates (latitude and longitude), signal strength indicators (RSSI), signal-to-noise ratio (SNR), and transmission delay. These metrics were compiled into a table to analyze coverage, connectivity stability, and geolocation accuracy across urban and suburban environments. This test will cover all location data reporting within the area connected to the Antares platform, including longitude, latitude, SNR (Signal-to-Noise Ratio), RSSI (Receive Signal Strength Indication), and delay.

TABLE 4. ANTARES PLATFORM TEST RESULTS

Longitude	Latitude	RSSI	Snr
112.7308817	-7.226485	-112	-1
112.7346733	-7.3049817	-109	-13
112.7298683	-7.3100833	-84	8.2
112.7228483	-7.3152667	-108	-11.2
112.7571017	-7.3305817	-113	-5.8
112.735345	-7.3308067	-113	-14.2
112.7108866	-7.3280367	-103	-0.5
112.7384733	-7.3281933	-113	-9.5
112.7293566	-7.3608383	-113	-7
112.7289333	-7.3717883	-112	-6.2
112.716435	-7.44851	-85	9
112.7072083	-7.46233 -	-109	-14
112.7036283	-7.4492233	-109	-17.5

The electrical energy monitoring system can be viewed through the Antares platform. Sensor readings can be seen in Figure 4.14, which contains the Data Log. This data is stored and can be downloaded. The coordinates above show the areas of Surabaya-Sidoarjo that can be connected: Perak, Wonokromo, Ketintang, Karah, Kendangsari, Siwalankerto, Rungkut, Kebonsari, Waru, Sawotratap, Gedangan, Magersari, Jati, and Sidokare.

5. CONCLUSION

Based on the design and performance evaluation of the Modbus-based smart home system using a LoRa network and the Antares platform, the following conclusions can be drawn: The development process began with a site survey in the Sidoarjo–Surabaya area to identify locations with reliable LoRa signal coverage and determine optimal placement for the gateway. This was followed by the design and implementation of a smart home system centered on a LoRa-enabled microcontroller (ESP32 LoRa). The system integrates three core functional subsystems: An air quality monitoring system using the DSM501A sensor, A gas leak detection system using the MQ-6 sensor, An automated lighting control system based on Passive Infrared (PIR) motion detection. A drive test was conducted to evaluate connectivity with the Antares gateway across the region. The test successfully identified 13 GPS coordinates where stable LoRa-to-Antares communication was achieved, confirming the feasibility of wide-area IoT deployment in urban and suburban environments. Sensor data—including PIR motion detection, gas leak status, electrical parameters, and air quality—were successfully transmitted from the ESP32 LoRa module to the Antares IoT platform . This data is accessible to users in real time, either through direct download or via a web-based dashboard. To enhance user experience and enable intuitive monitoring, the data from Antares is further visualized using Node-RED , which provides real-time graphs and status indicators. This integration allows users to remotely monitor their home environment and respond promptly to potential hazards. In conclusion, the implemented system demonstrates a reliable, low-cost, and energy-efficient solution for smart home automation. The integration of LoRa for long-range communication , Modbus for device interoperability , Antares as a cloud platform , and Node-RED for real-time visualization proves effective in creating a scalable and user-friendly smart home ecosystem.

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