
Utilization Of Multihop Communication Technology Based on Lora for Maintenance of Airport Street Lighting

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Abstract

This study aims to design and implement a monitoring and maintenance system for airport street lighting using LoRa-based multihop communication technology. This technology was chosen for its ability to transmit data over long distances with low power consumption and to support large wireless sensor networks through multihop mechanisms. The system design consists of hardware components including an Arduino Uno microcontroller, SX1278 LoRa modules, ACS758 current sensors, and BH1750 light sensors, as well as software for real-time lamp condition monitoring. Tests were conducted on Bluetooth HC-05 connectivity, sensor accuracy, LoRa signal strength at various distances, and data transmission time between nodes. The results showed that all components functioned properly, with an average inter-node data transmission time of 540 ms and RSSI values that decreased proportionally with distance but remained stable up to 250 meters. In addition, the ACS758 and BH1750 sensors demonstrated consistent accuracy in monitoring current flow and light intensity, ensuring reliable detection of anomalies. The LoRa multihop configuration allowed coverage extension beyond single-node limitations, making the system adaptable for large-scale airport environments. This system has proven effective in improving maintenance efficiency, enabling early fault detection, and supporting more reliable and energy-efficient management of airport street lighting. Future research may expand this approach by integrating renewable energy sources, advanced fault-prediction algorithms, or interoperability with smart city infrastructures to further enhance sustainability and scalability.

Keywords: *LoRa, Multihop Communication, Airport Street Lighting, Monitoring, IoT*

INTRODUCTION

The rapid advancement of technology today can be observed in both industry and society. One example is the use of existing technologies such as remote control and monitoring systems. This technology is needed by considering various aspects, including the efficiency of manpower, the working hours of personnel, and energy savings.

This study seeks to apply these technological advancements. One of the emerging and widely used technologies today is low-power wireless technology. An example of this is LoRa (Long Range). LoRa is a wireless technology that offers long-range communication with low power consumption, capable of reaching distances up to 2 km.

However, LoRa has several limitations, one of which is its inability to communicate over long distances directly due to limited resources. Therefore, a method is needed to enable LoRa devices to communicate over longer distances in a large network. One such method is the multihop approach, where data is transmitted through several LoRa nodes within a network until it reaches its destination, thus overcoming the short-range limitation.

Multihop LoRa-based technology can be applied to airport street lighting systems. Street lighting is a public facility that plays a crucial role in providing illumination along roadways. Adequate lighting enhances aesthetics and increases safety and comfort for road users, while insufficient lighting can potentially lead to negative impacts such as traffic accidents.

The use of LoRa-based multihop communication technology for the maintenance of airport street lighting is an innovative step to improve the efficiency, reliability, and safety of lighting systems at airports. Airport street lighting is vital in ensuring flight safety, especially during adverse weather conditions or at night.

By implementing LoRa-based multihop communication technology, the monitoring and maintenance systems for airport street lighting can be integrated efficiently and effectively. The following are some benefits of using LoRa multihop technology for airport street lighting maintenance:

1. With LoRa technology, airport street lights can be connected to an Internet of Things (IoT) network, enabling remote supervision and monitoring. Operational data of the lights, such as status, brightness, and reliability, can be monitored in real-time from a distance.
2. With continuous data collection through LoRa technology, the airport street lighting maintenance system can implement data analysis methods to detect potential damage or failures early. This allows for timely preventive maintenance and reduces the risk of operational disruptions.
3. The energy-efficient nature of LoRa can help optimize the energy usage of airport street lighting. An integrated power management system can schedule lighting, identify inefficient lights, and significantly reduce energy consumption.
4. By adopting multihop communication technology, the airport street lighting monitoring system can achieve better redundancy and higher reliability. Multihop networks allow data to be transmitted through several nodes, minimizing the risk of communication failure.

The implementation of LoRa-based multihop communication technology for airport street lighting maintenance is expected to improve operational efficiency, reduce maintenance costs, and provide optimal lighting to support airport safety.

RESEARCH METHODS

This study employed an experimental research approach to design, implement, and evaluate a multihop LoRa-based communication system for the monitoring and maintenance of airport street lighting. The research was conducted in several stages as follows:

1. Literature Study

A literature study was carried out to understand the theoretical foundation and related works on LoRa technology, multihop communication, and airport street lighting maintenance systems. This stage helped in identifying system requirements, selecting appropriate components, and understanding potential implementation challenges.

2. System Design

The system design stage consisted of two parts: hardware design and software design.

- **Hardware Design:** The hardware components used include an Arduino Uno microcontroller, SX1278 LoRa module for long-range wireless communication, ACS758 current sensor to measure electrical current, and BH1750 light sensor to measure light intensity. Three lamp nodes were built to form a multihop network.
- **Software Design:** The software was developed using MIT App Inventor to create a monitoring application that displays each lamp node's condition (on/off status, current, and light intensity) in real time. A flowchart was created to outline the software's data acquisition and communication process.

3. System Implementation

The designed system was implemented at the Politeknik Penerbangan Medan laboratory. The sensors were installed on each lamp node, and the LoRa modules were configured to form a multihop communication network. A central control server was set up to collect and display data from all nodes.

4. Data Collection

Data collection was conducted by testing:

- Bluetooth HC-05 Connectivity: To verify stable connection between the prototype and mobile devices.
- ACS758 Current Sensor Accuracy: Compared to a digital ammeter.
- BH1750 Light Sensor Accuracy: Compared to a lux meter.
- LoRa Communication Performance: By measuring RSSI values at various distances (10–250 meters).
- Node-to-Node Transmission Time: To measure data delivery time between nodes in the multihop network.

5. System Evaluation

The collected data were analyzed to assess the accuracy of the sensors, the stability and strength of the LoRa signal over distance, and the consistency of data transmission times between nodes. The evaluation focused on system performance in terms of communication reliability, data accuracy, and response time.

6. Improvement and Development

If performance gaps or errors were found, the system was refined through hardware adjustments, software optimization, and reconfiguration of network parameters to improve overall efficiency and reliability.

RESULTS AND DISCUSSION

Device Design Results

The device for this study was successfully designed through a series of systematic and well-planned processes. The design is divided into two parts: software design and hardware design. The hardware design, as shown in Figure 4.1, consists of three lamp nodes.

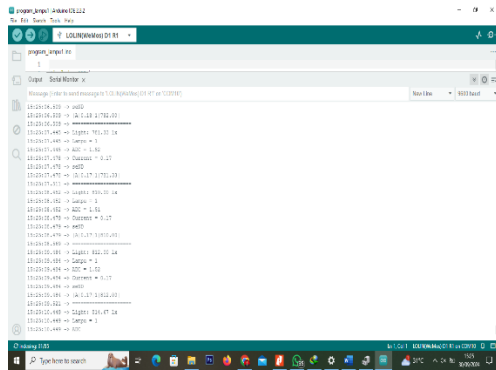


Figure 4.1 Hardware Design

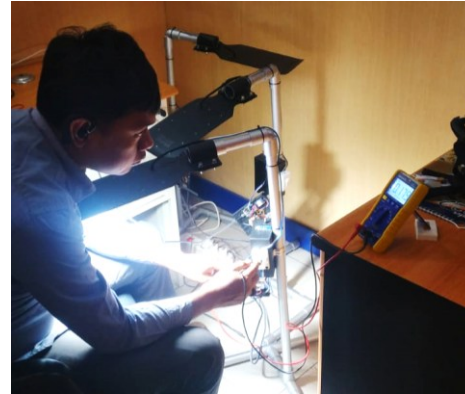
The software is designed to monitor each lamp node, as seen in Figure 4.2. The monitoring software displays lamp conditions, such as current on/off and lamp intensity.

4.4 ACS758 Module Testing

The ACS758 module was tested to verify its performance in measuring electrical current in the circuit. The module was calibrated using a digital ammeter as a reference. Data collection can be seen in Figure 4.4.



(a)



(b)

Figure 4.4 (a) Results of current measurement using the Arduino Serial Monitor (b) Results of current measurement using a digital ammeter

Table 4.2 Test Results of the ACS758 Module and Digital Ammeter.

No	information	Modul ACS758 (Amper)	Digital Ammeter (Amper)
1	Experiment 1	0.17	0,179
2	Experiment 2	0.18	0,179
3	Experiment 3	0.17	0,187
4	Experiment 4	0.18	0,187
5	Experiment 5	0.17	0,187

The test results shown in Table 4.2 indicate that the module is capable of measuring DC current. The difference between the measurements of the ACS758 and the digital ammeter ranged from -0.001 A to 0.017 A. The readings from the ACS758 demonstrated good consistency, with only slight variations between 0.17 and 0.18 A. The digital ammeter showed slightly greater variation, but still within an acceptable range.

4.5 Light Sensor Module Testing

Testing of the BH1750 module was conducted to verify its performance in measuring light intensity. The module was calibrated using a lux meter as a reference. The testing of the BH1750 module can be observed through the data transmitted via the serial monitor of lamp node 1, as shown in Figure 4.5 below.

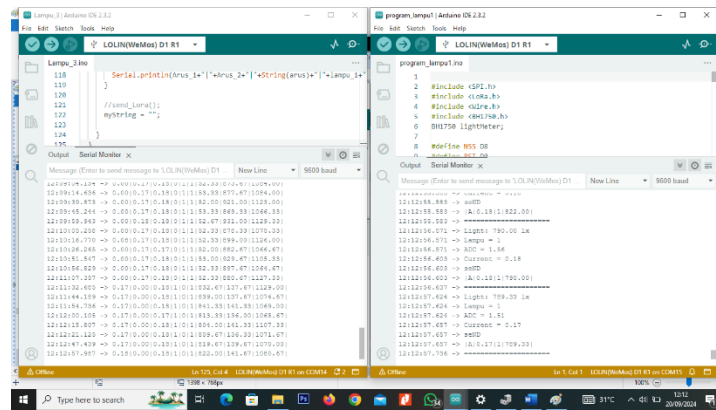


Figure 4.5 Sending Lux Meter Data from the BH1750 Module

Table 4.3 Test Results for the BH1750 Module and Lux Meter

No	Information	Modul BH1750	Lux Meter
1	Experiment 1	800	823
2	Experiment 2	790	810
3	Experiment 3	853	830
4	Experiment 4	866	840
5	Experiment 5	850	846

The test results show that the module is capable of measuring light intensity with good accuracy. The difference between the BH1750 readings and the lux meter ranged from -26 lux to 23 lux. Measurements from both devices showed fairly consistent values, with only small variations between trials. In addition, the module demonstrated good stability against temperature changes. The light intensity data obtained from the BH1750 module was then used to implement an automatic brightness adjustment feature in the lighting system.

4.6 Communication Testing

LoRa communication testing was conducted by periodically transmitting data packets from the LoRa node to the gateway. The RSSI values received by the gateway were then recorded and analyzed. Different distances between the node and the gateway were used to observe the effect of distance on the received signal strength. The results of the LoRa communication testing are presented in Table 4.4.

No	Distance (meters)	Data Transmission	RSSI Value (dBm)
1	10	Sent	-68
2	25	Sent	-71
3	50	Sent	-74
4	75	Sent	-80
5	100	Sent	-83
6	150	Sent	-90
7	200	Sent	-95
8	250	Sent	-100

From Table 4.4, it can be seen that the RSSI values tend to decrease as the distance increases. There is a clear relationship between distance and signal strength (RSSI), where the farther the distance, the lower the RSSI value. Good RSSI values are generally above -70 dBm, while values below -85 dBm indicate a significant decline in signal quality.

4.6 Testing Each Node

The testing of the first lamp node was carried out gradually. First, the connection between the node and the power source was verified to be correct. Then, the supply voltage was applied, and during the testing process, parameters such as voltage, current, and lamp light intensity were recorded. Visual observations were also conducted through the monitoring application designed to detect any anomalies in the components or behavior of lamps one through three. The monitoring results can be seen in Figure 4.6.



Figure 4.6 Street Light Monitoring

Further testing was conducted to determine the performance of the system, which implemented multi-hop communication, using the transmission time test parameter. This time is calculated from the time the data is sent by the sensor at each node. The test results are shown in Table 4.5. Based on the data in Table 4.5

No	Node 1 to 2 (ms)	Node 2 to 3 (ms)	Node 3 to gateway (ms)
1	534	578	523
2	545	532	514
3	523	523	556
4	523	524	567
5	544	512	535
6	523	512	534
7	543	556	565
8	555	534	534
9	545	567	578
10	567	578	589

Table 4.6 shows the travel time from Node 1 to Node 2, from Node 2 to Node 3, and from Node 3 to the gateway, for 10 measurements. From the data in table 4.6, the average travel time from node 1 to 2 can be calculated as 536 ms, the average travel time from node 2 to 3 is 535.4 ms, and the average travel time from node 3 to the gateway is 549 ms. And the average delivery time from node 1 to the gateway is 540 ms.

CONCLUSION

From the results of this study, it can be concluded that the designed device, consisting of hardware and software, successfully functioned well in monitoring and controlling a node-based lighting system.

The HC-05 Bluetooth module performed stably in connecting with other devices. The ACS758 and BH1750 modules demonstrated good accuracy in measuring current and light intensity, with acceptable measurement differences compared to reference devices. LoRa communication was successful, with RSSI decreasing with distance, while maintaining good communication within the tested range.

Transmission Time: Data transmission time between nodes remained consistent, with an average transmission time of 540 ms. However, the transmission time from Node 3 to the gateway showed a slight increase, indicating potential for further optimization.

Overall, the developed system demonstrated adequate performance and could be used for smart lighting applications with efficient inter-node communication. Further testing can be conducted to improve system performance, particularly in terms of data transmission.

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