

Automated Monitoring and Control of Public Street Lighting [PSL] with Placement Strategy Using LoRa-Based Web System

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Article Info

Article history:

Received May 07, 2025

Revised November 15, 2025

Accepted November 28, 2025

Available Online November 30, 2025

Keywords:

Public Street Lighting,
Monitoring, LoRa, Web-Based
System

Abstract

Effective PSL (Public Street Lighting) is central to the safety of roadways and the security of a city's center. PSL's maintenance is still deficient as a result of reliance on manual inspections for the detection of faults. This inefficiency and a subsequent increase in operational costs, wasted energy, and safety risks are all consequences of delayed fault detection. The PSL systems' automated control and monitoring systems are the focus of this research, emphasizing the energy, cost, and safety problems created by inefficient fault detection and manual inspections. A web-based system paired with a Long Range (LoRa) communication system for streetlight monitoring is designed for this study. The proposed approach is a combination of streetlight nodes with sensors for light intensity, voltage, current, and temperature. The nodes transfer their sensor data to the central gateway via the LoRa system. The web-based monitoring system processes and visualizes the data collected from the nodes and provides remote control and automation of a dimming system for brightness adjustment along with a scheduling module for environmental condition operations. Furthermore, the placement of streetlight nodes within the LoRa range is intended to improve communication and overall system efficiency. The system can deliver real-time monitoring functions, measure electrical parameters accurately, and communicate over long distances without signal instability. Furthermore, the system provides an innovative and adaptable approach to the management of smart PSL's, especially for urban settings that demand better infrastructure for sustainable and efficient lighting.

INTRODUCTION

In the context of urban development, Public Street Lighting (PSL) serves as a vital infrastructure to enhance the comfort and safety of road users. A well-planned and efficient lighting system offers significant benefits, including energy conservation and improved security. However, many regions still rely on outdated maintenance methods, where repairs are only carried out after issues are reported, potentially endangering road users [1].

The integration of Internet of Things (IoT) technology enables the development of an advanced and more efficient remote street lighting control system. Long-Range (LoRa) communication provides a cost-effective and energy-efficient solution for long-distance wireless communication [2]. This research aims to design a smart PSL system utilizing LoRa technology for centralized, real-time light monitoring and control. Despite LoRa's limited application in PSL, its potential for enhanced remote configuration and management remains significant.

LoRa is a key technology within Low Power Wide Area Networks (LPWANs), offering extended battery life due to its low energy consumption. However, it faces challenges such as low data throughput and high message collision rates, especially in large-scale implementations [3]. Despite these challenges,

LoRa has been successfully utilized in renewable energy monitoring systems, demonstrating its effectiveness in IoT-based infrastructure applications [9].

Previous studies indicate a correlation between inadequate street lighting and increased accident and crime rates. Smart lighting systems, equipped with illumination sensors and motion detection, can dynamically adjust brightness levels to optimize safety and energy efficiency. Cloud-based solutions, such as Firebase Cloud System, provide real-time database access and secure data transmission, ensuring rapid and reliable system responses [4]. Similar cloud-based approaches have been successfully applied in smart agriculture systems, demonstrating the effectiveness of LoRa and cloud integration for remote monitoring and control [10].

This study aims to develop a web-based smart Public Street Lighting (PSL) monitoring system that enables remote management and real-time monitoring of street lighting infrastructure. The use of LoRa technology is motivated by its proven effectiveness in low-power, long-range communication for smart lighting and infrastructure monitoring systems, as demonstrated in previous studies [5]–[8]. By leveraging LoRa-based communication, the proposed system is expected to reduce energy consumption, enhance remote control capabilities, and improve operational reliability, particularly in large-scale urban deployments [6], [7].

Furthermore, the implementation of intelligent monitoring and adaptive lighting control has been shown to improve safety and security in high-risk areas by enabling timely fault detection and optimized illumination levels [5], [8]. Widespread adoption of such systems can contribute to urban safety, environmental sustainability, and energy efficiency, as supported by prior research on smart lighting and IoT-based monitoring infrastructures [7], [9], [10]. In addition, this study proposes a strategic placement scheme for PSL nodes to optimize LoRa coverage and communication reliability, following established gateway placement and network optimization approaches reported in earlier works [3], [6]. The proposed approach is specifically evaluated for application in the East Surabaya area.

METHODS

This study employs a structured methodology to develop an intelligent Public Street Lighting (PSL) system by integrating Long-Range (LoRa) communication and a web-based control interface, based on established theoretical frameworks and prior studies on IoT-based smart lighting systems. The adoption of LoRa technology is justified by its low-power and long-range communication characteristics, which have been widely validated in previous research on smart street lighting and infrastructure monitoring systems [7].

The research process consists of several stages, including system requirement analysis, hardware and software design, system implementation, and experimental validation. The overall system architecture follows smart lighting control models that integrate sensor nodes, LoRa gateways, and centralized servers to enable real-time monitoring and remote operation, as reported in related works [5][8].

To ensure optimal system performance, a differential control technique is applied to regulate light intensity based on real-time environmental conditions. This adaptive lighting approach is consistent with theoretical concepts of smart lighting systems, where dynamic brightness adjustment is used to improve energy efficiency and operational reliability, as demonstrated in earlier studies [5], [6]. The system design integrates hardware components—including light intensity, voltage, current, and temperature sensors—with software modules to support continuous data acquisition, processing, and visualization through a web-based platform, in line with methodologies adopted in previous LoRa-based monitoring research [9].

By grounding the proposed method in established theories and validated reference studies, the methodology ensures scientific validity and provides a reliable basis for evaluating the system performance, as elaborated in the following sections.

RESULT AND DISCUSSION

Differential Technique

Siddarthan Chitra Suseendran et al. [5] conducted a study on smart lighting systems that utilize sensors to regulate streetlights by dynamically adjusting brightness levels as needed. The system is built on Internet of Things (IoT) technology, enabling significant energy conservation while enhancing road safety by reducing accident risks. Additionally, by illuminating specific areas, it creates a safer environment for pedestrians at night.

Nathawat Sukhathai et al. [6] introduced a LoRaWAN-based smart street lighting control system that autonomously operates streetlights with minimal energy consumption. The system incorporates illuminance sensors and motion detection to assess lighting conditions and traffic flow. Each streetlight is equipped with a LoRaWAN communication module, which transmits data to a central server. The system autonomously determines which lights should dim based on motion sensor data, conserving energy by switching off lights when no vehicles are detected. If a vehicle approaches, nearby streetlights automatically increase brightness to an optimal level.

Ngo Thanh Tung et al. [7] developed a smart street lighting control system integrating LoRa wireless communication and LED lighting. Conventional streetlights typically use timers or day/night sensors for automated operation, but LED technology offers numerous advantages, such as energy efficiency, longer lifespan, high reliability, and environmental friendliness. The proposed system leverages wireless transmission at frequencies below 1 GHz for real-time monitoring and control. The smart lighting infrastructure at Hochiminh City University of Technology was designed to meet specific data transmission requirements.

Sanchez-Sutil et al. [8] introduced a PQ Analyzer Meter equipped with LoRa long-range wireless communication technology, making it ideal for public lighting applications with a coverage range of up to 5 km. The PQ Analyzer with LoRa (PQAL) was developed as a fully functional prototype, available in single-phase and three-phase versions for diverse street lighting installations. Built on an open-source Arduino platform, PQAL adapts to various monitoring needs and supports non-invasive current sensors for seamless deployment without modifying existing infrastructure.

This study aims to enhance previous research [5]–[8] by incorporating different analytical approaches. The system is designed to optimize LoRa coverage deployment strategies and automate hardware performance, specifically tailored for implementation in East Surabaya. A comparative analysis between the proposed system and existing research is presented in Table 1.

Table 1. Comparison with Previous Research

<i>Previous Research</i>	<i>Objects</i>	<i>Systems</i>	<i>Outputs</i>
[5]	Smart Lighting System	Arduino, Raspberry Pi, LDR, Data Sensor, NodeMCU, Intesity Control Circuitry, Lamps	Using vehicles and pedestrians to turn on lights at night.
<i>Previous Research</i>	<i>Objects</i>	<i>Systems</i>	<i>Outputs</i>
[6]	LoRaWAN based smart street lighting control system	Motion Sensor, Light Sensor, LoRaWAN	Reduce the energy usage when no one using street at a certain time.
[7]	Smart street lighting control system based using Led lamp and Lora Wireless communication	LED Module, wireless temperature sensors, ambient light sensors, Controller, LoRa Node, LED Driver	Intelligent lighting systems are designed to control and monitor devices through wireless transmission frequencies below 1

			GHz using LED lights.
[8]	Smart regulation and efficiency energy system for street lighting with LoRa LPWAN	AN Board, Voltage Sensor, Current Sensor, Street Light, AC Dimmer, Motion Sensor, Analog/Digital Converter, Power Supply	Complete control and monitoring system to achieve energy savings in SL installations
Proposed System	Smart street lighting that can be monitored on the website	Arduino, LDR Sensor, Voltage Sensor, Current Sensor, Temperature Sensor, Relay, Power supply, Lora Chip Arduino, Lamp, AC Light Module, Dimmer, Platform Telkom Console	The system is equipped with motion detection features and automatic lighting settings and PJU monitoring can be performed in real time via the website as well as with placement schemes in specific areas.

System Design

The system design process involves integrating and assembling electronic components to build a functional smart Public Street Lighting (PSL) system. At the core of this system is the ATmega 328p 3.3V 8Hz microcontroller, which manages and interfaces with all sensors and modules. Key components include an LDR sensor, temperature sensor, voltage sensor, current sensor, relay, power supply, and LED lights for testing purposes. Each component is systematically integrated to ensure proper functionality, allowing the system to effectively respond to environmental changes and optimize energy usage.

The next step in system design is to develop a block diagram that illustrates the overall monitoring system architecture. This diagram provides a visual representation of how different components interact and communicate within the system. Before proceeding to the system implementation phase, all necessary installations must be completed to facilitate the development of a web-based monitoring system for Smart PSL. Additionally, system calibration is essential to ensure that sensors provide accurate readings, minimizing potential errors during real-time operation. The integration of wireless communication through LoRa technology further enhances the system’s capability by enabling long-range data transmission with low power consumption. The block diagram representation is provided in Figure 1, offering a structured overview of the entire system.

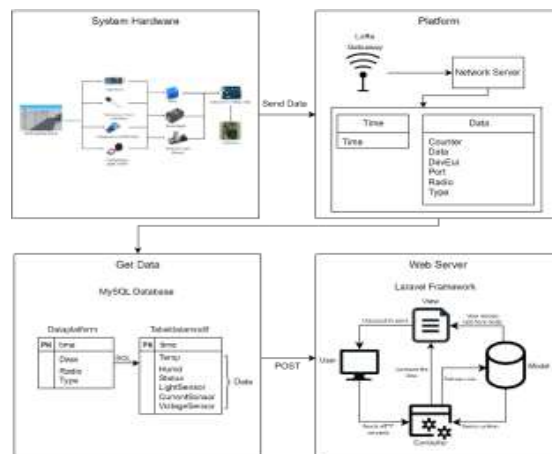


Figure 1. System Block Diagram

The system workflow is depicted in Figure 2, where the LDR sensor captures real-time light intensity data and processes it based on predefined input conditions. If the surrounding light intensity is low, the system activates and the lamp brightness is adjusted accordingly. When the ambient light is bright, the lamp dims, whereas in darker conditions, the lamp illuminates fully. This regulation is achieved through the integration of a dimmer module with the LDR sensor. Additionally, the temperature sensor monitors environmental temperature variations.

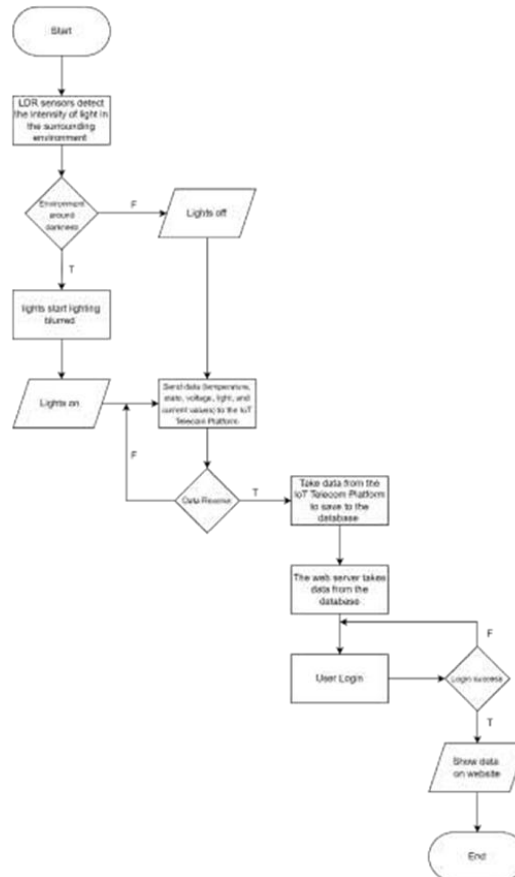


Figure 2. System Flowchart

The hardware design includes a Printed Circuit Board (PCB) layout, which connects all components and sensors in a structured manner. Figures 3 and 4 illustrate the top and bottom PCB schematic designs, serving as a reference for system implementation. This design incorporates essential components such as the ATmega 328p microcontroller, LoRa chip, relay circuit, power supply, LDR sensor, current sensor, voltage sensor, and LED circuit. The finalized PCB layout is shown in Figure 4.



Figure 3. Schematic of the PCB Design on Top Port



Figure 4. Schematic of the PCB Design on Bottom Port

The proposed smart street lighting system enables wireless communication through LoRa technology. In this setup, each streetlight unit is equipped with sensors that measure parameters such as light intensity, temperature, voltage, and current. These sensor readings are transmitted via the LoRa module attached to each streetlight, which then communicates with a LoRa gateway. The gateway acts as an intermediary, forwarding data to a base station, which collects and organizes information from multiple streetlights.

Additionally, the base station has the capability to send control commands back to the LoRa modules in the field, ensuring real-time adjustments. The collected data is also transmitted to a web server, where it is processed, stored, and displayed through a web-based interface. This interface enables system administrators to schedule operations, monitor real-time streetlight status, and conduct predictive maintenance based on the collected data. By leveraging IoT and wireless communication, the smart PSL system enhances operational efficiency, facilitates remote monitoring, and reduces maintenance costs. The system implementation is illustrated in Figure 5.

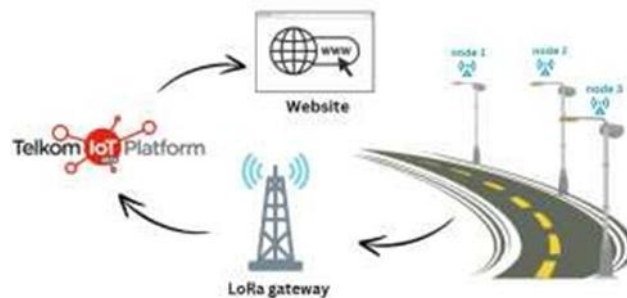


Figure 5. Scheme of the System

Performance Evaluation and Analysis

The system testing aims to verify whether the developed system aligns with the initial design plan. By analyzing the test results, potential flaws within the system can be identified. The evaluation of system performance helps determine how effectively the system meets its intended objectives. This testing includes verifying the integration of modules and dimmers to ensure they function properly under varying lighting loads. Additionally, the synchronization between website outputs and Arduino module responses is assessed. The test results provide a comprehensive overview, allowing further evaluation and refinement.

1. Module Testing with Dimmer and Load Lamp

This test was conducted to assess the performance and features of LED street lights. In compliance with BSN SNI standards for public street lighting, LED lamps were used as the primary lighting source. The experiment focused on integrating the Arduino Uno module with

a dimmer, operating as a standalone system to determine whether the dimmer alone is sufficient for adjusting brightness levels.

Table 2. Testing the unit module's and dimmer's integration with the load of an incandescent light

No	Program			power meter			Error % (absolute)		
	V (V)	I (A)	S (VA)	V (V)	I (A)	S (VA)	V	I	P
1.	218.36	0.20	44.52	218.9	0.203	44.25	0.25	0	0.62
2.	218.75	0.20	44.25	218.9	0.203	44.25	0.07	0	0.01
3.	220.58	0.20	44.40	219.1	0.203	44.25	0.68	0	0.35
4.	218.67	0.20	44.30	218.1	0.203	44.25	0.26	0	0.12
5.	220.19	0.20	44.41	219.2	0.203	43.84	0.45	0	1.31
6.	219.19	0.20	44.61	218.9	0.203	44.25	0.13	0	0.82
7.	219.67	0.20	44.62	218.9	0.203	44.25	0.35	0	0.84
8.	219.26	0.20	44.36	218.9	0.203	44.25	0.16	0	0.26
9.	218.10	0.20	44.31	218.9	0.203	43.84	0.37	0	1.08
10.	218.33	0.20	44.37	218.9	0.203	44.25	0.26	0	0.28

During testing, variations in power measurements were observed. While the power meter readings provided values in watts (W), the program output displayed values in volt-amperes (VA). To validate the accuracy of the results, the power factor formula was applied:

$$\cos \varphi = \frac{P}{S} \tag{1}$$

where $\cos \varphi$ must not exceed 1. The consistency of the obtained results with this formula confirms the accuracy of the system's power calculations. The computed values are presented in Table 3.

Table 3. Testing the unit module's and dimmer's integration with the load of an incandescent light

P	S	Cos φ
32.3	44.52	0.73
32.3	44.25	0.73
32.3	44.40	0.73
32.3	44.30	0.73
32.0	44.41	0.72
32.3	44.61	0.72
32.3	44.62	0.72
32.3	44.36	0.73
32.0	44.31	0.72
32.3	44.37	0.73

2. Webiste Features Testing and Public Street Lighting Placement Scheme in LoRa Coverage for East Surabaya

As part of the LoRa gateway deployment strategy, data from multiple LoRa gateways were collected in the East Surabaya area, as detailed in Table 4.

Table 4. Longitude and Latitude LoRa Gateway in East Surabaya

Gateway 1	
Address	Electronics Engineering Polytechnic Institute of Surabaya. ITS Street, Keputih, Sukolilo, Surabaya, East Java 60111, Indonesia
Longitude	112.79344177246094
Latitude	-7.276895046234131
Altitude	24
Gateway 2	
Address	Kenjeran Street No. 621, Dukuh Sutorejo, Mulyorejo District, Surabaya, East Java 60113, Indonesia
Longitude	112.79135131835938
Latitude	-7.251399993896484
Altitude	26
Gateway 3	
Address	Telkom University Street Ketintang No.156, Ketintang, Gayungan District, Surabaya, East Java 60231
Longitude	112.73600006103516
Latitude	-7.289170742034912
Altitude	42
Gateway 4	
Address	Kapuas Street No. 59, DR. Soetomo, Tegalsari District, Surabaya, East Java 60264
Longitude	112.73600006103516
Latitude	-7.289170742034912
Altitude	42
Gateway 5	
Address	Margoyoso Street No.1 - 3, Kedungdoro, Tegalsari District, Surabaya, East Java 60261
Longitude	112.79135131835938
Latitude	-7.251399993896484
Altitude	26

Figure 6 illustrates the gateway implementation scheme on the developed web-based platform, accurately mapped to latitude and longitude coordinates obtained during data collection.



Figure 6. Placement Scheme of The Website

The deployment scheme involves placing seven nodes within the coverage of a single LoRa gateway, ensuring a 30–40 meter spacing between each node. This follows the standard placement guidelines for public street lighting. The configuration of these seven nodes within a single gateway is shown in Figure 6.



Figure 7. Scheme of Placement of 7 Nodes in 1 Gateway on the Website

Further details on the arrangement of nodes for each gateway are provided in Table 5.

Table 5. Details Coordinates of the Nodes

Point 1	Longitude : 112.795135 Latitude : -7.276222
Point 2	Longitude : 112.794846 Latitude : -7.276169
Point 3	Longitude : 112.794456 Latitude : -7.276053
Point 4	Longitude : 112.794106 Latitude : -7.276032
Point 5	Longitude : 112.793808 Latitude : -7.276054
Point 6	Longitude : 112.793510 Latitude : -7.276024
Point 7	Longitude : 112.793190 Latitude : -7.275958

CONCLUSION

This study analyzes the management of Public Street Lighting (PSL) caused by the inefficiency of manual inspections, slow fault reporting, and the lack of real-time monitoring. In the absence of real-time monitoring, automated fault reporting, and energy-efficient PSL systems, the range of efficient PSL systems is the first of its kind and has been designed and tested, integrating the web to control and monitor the PSL. Results from the evaluation show that the proposed system solves the PSL maintenance, energy efficiency, and monitoring problems by providing automated control and reporting of the PSL system, helping to monitor and report the system's different operational conditions, including monitoring light levels, energy, and temperature (voltage, current, and temperature) from multiple sensors. The main focus of this research is integrating web-based monitoring systems and strategically spaced streetlight nodes using LoRa, a Long Range, Low Power energy communication system. By combining these systems, communication reliability and low operational and maintenance costs and energy efficient Public Safety are added. The proposed systems are a viable, low-cost alternative to smart public street light systems (PSL) for urban areas that require economically sustainable remote management of lighting systems

ACKNOWLEDGMENT

This research was supported by the Research and Community Service Center (P3M) of Politeknik Elektronika Negeri Surabaya, whose contributions are gratefully acknowledged.

REFERENCES

- [1] P. V. A. Wibawa, K. O. Saputra, and A. A. Amrita, "Rancang Bangun sistem monitoring Lampu Penerangan jalan umum berbasis web," *Jurnal SPEKTRUM*, vol. 6, no. 4, p. 51, 2019. doi:10.24843/spektrum.2019.v06.i04.p8.
- [2] D. Ziouzos and M. Dasygenis, "A smart bin implementation using LoRa," in *Proc. 4th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conf. (SEEDA-CECNSM)*, 2019. doi:10.1109/seeda-cecnsm.2019.8908523.
- [3] F. Loh, N. Mehling, S. Geisler, and T. Hosfeld, "Graph-based gateway placement for better performance in LoRaWAN deployments," in *Proc. 20th Mediterranean Communication and Computer Networking Conf. (MedComNet)*, Jun. 2022. doi:10.1109/medcomnet55087.2022.9810404.
- [4] W.-J. Li, C. Yen, Y.-S. Lin, S.-C. Tung, and S. Huang, "JustIoT: Internet of Things based on the Firebase real-time database," in *Proc. IEEE Int. Conf. Smart Manufacturing, Industrial & Logistic Engineering (SMILE)*, 2018. doi:10.1109/smile.2018.8353979.
- [5] S. C. Suseendran, N. K. B. J. Andrew, and M. S. B. Praba, "Smart street lighting system," in *Proc. 3rd Int. Conf. Communication and Electronics Systems (ICCES)*, 2018. doi:10.1109/cesys.2018.8723949.
- [6] N. Sukhathai and T. Tayjasant, "Smart street lighting system with networking communication," in *Proc. IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia)*, 2019. doi:10.1109/isgt-asia.2019.8881684.
- [7] N. T. Tung et al., "Development and implementation of smart street lighting system based on LoRa technology," in *Proc. Int. Symp. Electrical and Electronics Engineering (ISEE)*, 2019. doi:10.1109/isee2.2019.8921028.
- [8] F. Sanchez-Sutil and A. Cano-Ortega, "Development and implementation of a PQ analyser to monitor public lighting installations with a LoRa wireless system," *Internet of Things*, vol. 22, p. 100711, 2023. doi:10.1016/j.iot.2023.100711.
- [9] C.-S. Choi, J.-D. Jeong, I.-W. Lee, and W.-K. Park, "LoRa-based renewable energy monitoring system with open IoT platform," in *Proc. Int. Conf. Electron., Inf., Commun. (ICEIC)*, Honolulu, HI, USA, 2018, pp. 1-2. doi: 10.23919/ELINFOCOM.2018.8330550.
- [10] M. Saban et al., "A smart agricultural system based on PLC and a cloud computing web application using LoRa and LoRaWAN," *Sensors*, vol. 23, no. 5, p. 2725, 2023. doi: 10.3390/s23052725.