TELEKONTRAN: Jurnal Ilmiah Telekomunikasi, Kendali dan Elektronika Terapan
Vol. 12, No. 2, Oktober 2024
DOI : 10.34010/telekontran.v12i2.14111
p-ISSN : 2303 – 2901; e-ISSN : 2654 – 7384

Prototype Web-Based Surveillance and Management Reporting System for Public Street Lighting

Prototipe Sistem Pelaporan Manajemen dan Pengawasan Berbasis Web untuk Penerangan Jalan Umum

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Abstract *- The growing global population and rapid urbanization have escalated the demand for smart city technologies that promote sustainability and efficient resource management, particularly through IoT-based data processing systems. Efficient urban infrastructure management, such as public street lighting, is crucial to meet these demands. However, many local governments continue to rely on manual inspections, which are inefficient and costly, underscoring the need for automated, real-time monitoring solutions that improve reliability and reduce operational expenses. This research presents a system that automates streetlight control based on predefined schedules and reports any malfunctions to a central database. The system leverages an Arduino Nano as the main controller, an RTC (Real-Time Clock) for timing, a GSM Shield SIM900 for communication, and solar panels as an energy source. Experimental results demonstrate that the lighting system operates reliably according to the specified schedule. Experimental results show that the lighting system operates according to the specified schedule and the SIM900 module sends data from the sensors to the website in real-time.*

Keywords *: Public street lighting, Reporting system, SIM 900, Solar panel, PIR sensor*

Abstrak - Pertumbuhan populasi global dan pesatnya urbanisasi telah meningkatkan permintaan akan teknologi kota pintar yang mendukung keberlanjutan dan pengelolaan sumber daya yang efisien, khususnya melalui sistem pemrosesan data berbasis IoT (*Internet of Things*). Pengelolaan infrastruktur perkotaan yang efisien, seperti penerangan jalan umum, sangat penting untuk memenuhi kebutuhan ini. Namun, banyak pemerintah daerah masih mengandalkan inspeksi manual, yang tidak efisien dan mahal. Hal ini menunjukkan perlunya solusi pemantauan otomatis dan *real-time* yang meningkatkan keandalan dan mengurangi biaya operasional. Penelitian ini menyajikan sistem pengendalian lampu jalan berdasarkan jadwal yang telah ditentukan dan melaporkan setiap kerusakan ke database pusat secara automatis. Sistem ini memanfaatkan Arduino Nano sebagai pengontrol utama, RTC (*Real-Time Clock*) untuk pengaturan waktu, GSM Shield SIM900 untuk komunikasi, dan panel surya sebagai sumber energi. Hasil percobaan menunjukkan bahwa sistem pencahayaan beroperasi sesuai jadwal yang ditentukan serta modul SIM900 mengirimkan data dari sensor ke situs web secara *real-time*.

Kata kunci *:* Penerangan jalan umum, sistem pelaporan, SIM 900, Solar Panel, Sensor PIR.

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I. INTRODUCTION

As the global population grows and urbanization increases, there is a rising need for technology that supports smart and sustainable environments. This technology should reduce environmental impact while also improving the quality of life for residents [1], [2]. Considerable research inquiry into the creation and execution of smart city projects has been spurred by this demand. Aspect's investigation range related to smart city technologies, such as incorporating Internet of Things (IoT) devices to collect and analyses data in real time. This allows for the effective management of urban resources, including waste, water, and electricity [3], [4]. Research has demonstrated that smart networks may increase energy efficiency and lower carbon emissions by improving electricity distribution and consumption patterns.

One of the essential parts of urban infrastructure is public street lighting. It offers citizens protection, security and a higher standard of living. Despite the value of public street lighting, many local governments struggle to effectively manage and maintain these systems. The monitoring task is often carried out manually, with an officer visiting the place to assess the lights' state, including if they are still there and whether they are functioning correctly. Sometimes, officers just wait for reports from the public, so this method is still less efficient in dealing with damage to streetlights [5]. Effective management of street lighting systems is necessary to guarantee dependability, limit energy consumption, and save operating expenses [6]. Manual inspections and reactive maintenance are part of the traditional street lighting management procedures, which can be labor- and resource-intensive [7]. Typical problems include irregular maintenance schedules, a deficiency of real-time data, and challenges in quickly locating and fixing flaws [8]. This makes fixing damage to street lighting extremely slow. So that officers' jobs are made easier, a system that allows lights to report messages when an application is damaged is required.

Some previous works were carried out to realize effective management of street lighting systems. In [9], using ESP8266 as a sender of sensor data to the database so that it can be monitored directly in real-time [10]. Meanwhile, other research using Lora as a sender of sensor data so that it can be monitored without cables and send the data a maximum distance of 300 meters [11]. In [12], Wemos d1 Mini is used to connect hardware to the internet, so it can be accessed via Android but requires an external internet network to be able to transmit data.

In this study, a system was built where the lights can turn on according to a certain hour or time and the system can send a report to the database if the lights are damaged. This system also uses a website where it can be accessed by the public and they can provide reports if there is damage not only to lights but also to other public facilities. The system uses Arduino nano as the controller, RTC (Real - Time Clock) as the trigger, and GSM (Global System for Mobile Communications) Shield SIM900 as the sender. On the other side, solar panel is used as for energy source, there has been a trend towards renewable energy sources due to the increased awareness of climate change and the need for sustainable energy solutions [13]. Solar power has emerged as a competitive alternative for public street lighting [14], [15].

II. METHOD

The method used in designing or developing street lights consists of several stages. This system is designed from main hardware devices and software. As for the prototype design for street lighting is shown in **Figure 1** and the block diagram of the hardware is displayed in **Figure 2**.

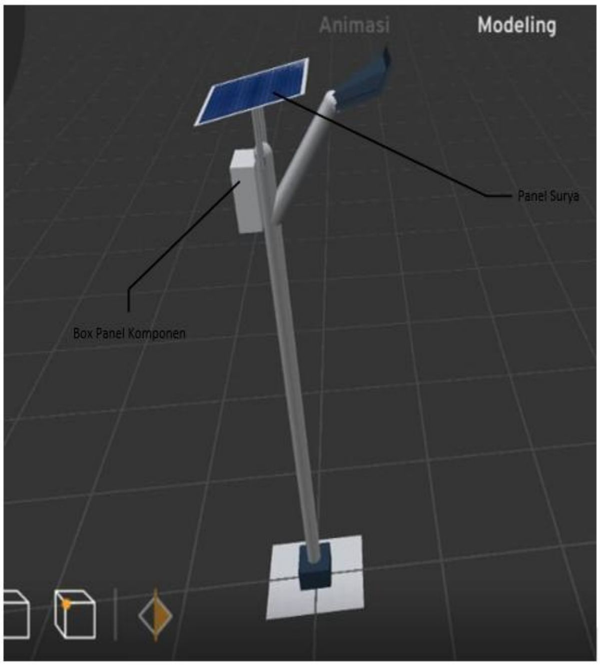

Figure 1. Public street lighting prototype design

A. Hardware system

General steps on the monitoring, controlling and system work reporting public street lighting can be seen in **Figure 2**. Initializing the system is the first stage, then RTC will provide a trigger according to the specified target time (18.00 UTC+7 for lights and 20.00 UTC+7 for sensors). This trigger will be sent to Arduino so that it can turn on the lights, current sensors and light sensors. When the light is on, the current and light sensor will read the existing data. The current and light sensor have been given targets according to the existing system conditions. When the sensor is under the minimum limit, the Arduino will send a command to the GSM Shield SIM900 to send a warning directly to the database.

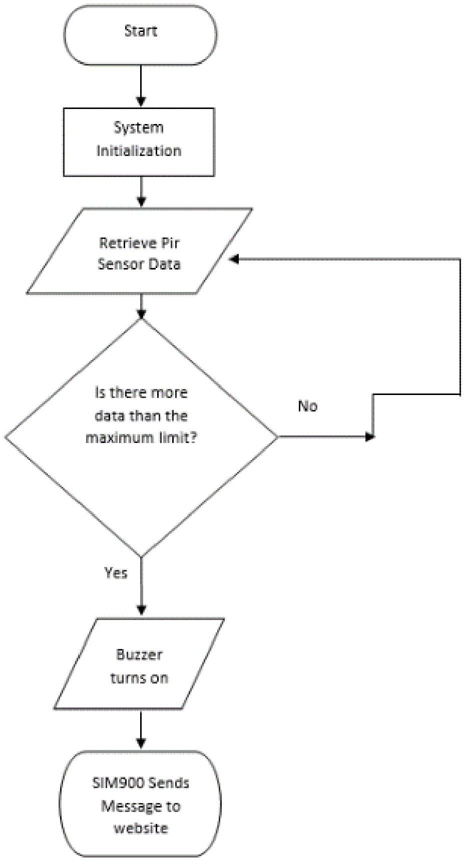

Figure 2. Flowchart of Monitoring, Controlling, and Reporting System

As illustrated in the hardware system block diagram in **Figure 3**, this research utilizes the GSM or SIM 900 module to facilitate communication between the monitoring system and the website, enabling the transmission of sensor data and warning messages to a database for display on the web platform. This GSM module can replace the ESP8266, which requires an external network connection, and if not, the Arduino cannot connect to the internet.

The INA219 sensor is a precision instrument designed for measuring direct current (DC) and voltage within electrical circuits. In this study, the INA219 is employed to measure DC current and voltage from the power supply to the lamp, with a measurement range of ±26 Vdc and ±3.5 A. Additionally, by applying Ohm's law, the sensor can calculate power values, achieving a measurement capacity of up to 75 watts.

The PIR sensor has a fast, instant movement response and can run with a voltage of 5 – 12 V, so it is used for the security system in this prototype [16]. The PIR sensor is also unaffected by sunlight, so it can work 24 hours. The sensitivity range of the PIR sensor can reach a distance of 6 meters where the average height of a public lighting pole for the protocol is ± 9 meters, so this sensor is used for a prototype security system. Whereas **Figure 4** shows security system flow chart.

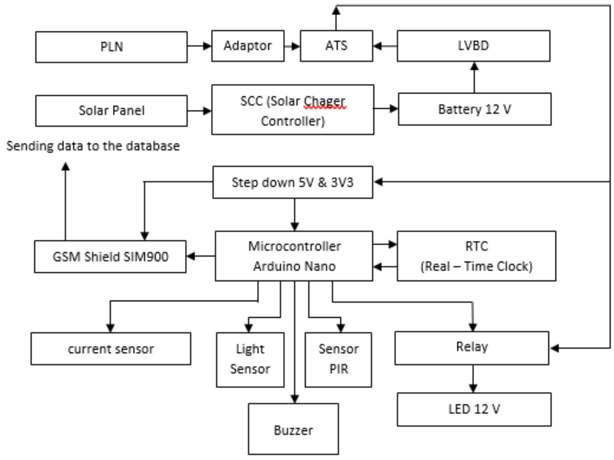

Figure 3. Hardware block diagram

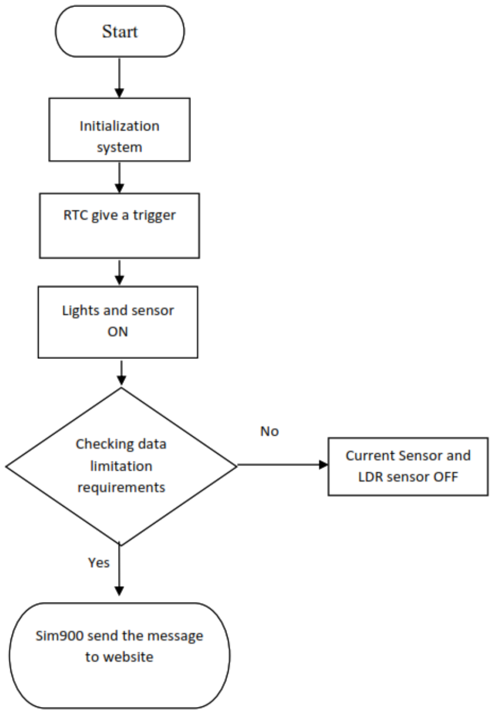

Figure 4. Security system flow chart

B. Software system

In this study, a website was used to receive a warning from the GSM Shield SIM900 when the sensor is less than the minimum limit, and each GSM Shield SIM900 will be given the coordinates of where the device is placed. The diagram shows a view and report where the general public can use these two features to see and report if there are damaged public facilities. Admin can use all the features on the website system, such as login, view, report, edit report and complete checkout. The report editing feature is a feature that can only be used by admins to delete or add any existing reports either from the public or the street light monitoring system. In the complete checkout feature, technicians can notify the admin that the damaged lamp has been corrected. The use case diagram is displayed in **Figure 5**.

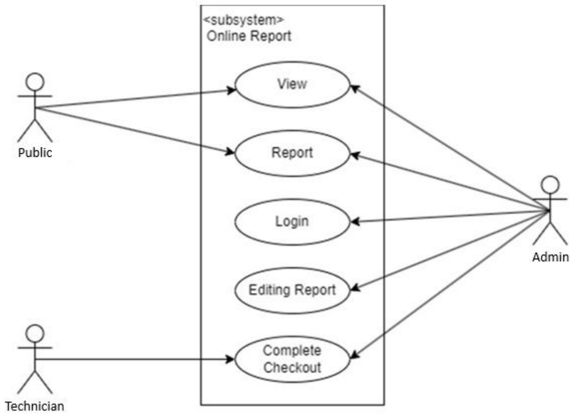

Figure 5. Use Case Diagram

III. RESULT AND DISCUSSION

In this study, the design outcomes reveals that the prototype consists of a 174 cm pole with a diameter of ¾ inch. A panel box measuring 30 x 40 x 17 cm contains a hardware system including a battery, SCC (Solar Charger Controller), LVBD (Low Voltage Battery Down), stepdown, SIM900, Arduino nano and others. The panel box measures 30 x 40 x 17 cm allowing users to add other components if needed. The realization of the prototype shown in **Figure 6**.

The prototype utilizes a 3.5 Ah dry battery to power a 4.72 W lamp. During testing, the battery was connected to a lamp to assess its discharge duration. Results indicated that a fully charged battery sustained the lamp for approximately 8 to 9 hours (527 minutes). Additionally, under peak sunlight intensity (between 10:00 and 15:00 UTC+7), the battery achieved full capacity within 5 hours. Even though compared to [16] and [17] which reported almost the same results when it was sunny.

This is making it adequate for typical overnight usage. Considering that nighttime generally spans 10 to 12 hours, the battery's capacity to sustain the lamp for 8–9 hours ensures consistent illumination for most of the night. This feature is particularly advantageous in scenarios where reliable lighting is essential for safety or visibility during nighttime hours.

However, limitations arise when, during the rainy season or periods of diminished solar radiation, the system may encounter difficulties in attaining a full charge within the 5-hour peak sunlight period (10:00–15:00 UTC+7). Decreased sunlight exposure can extend the charging duration, potentially leading to suboptimal charging performance if low solar irradiance persists over multiple consecutive days .

Figure 6. Public street lighting realization

Figure 7. Public street lighting realization

For the security system, the sensor detects a sudden change in heat, the buzzer will turn on for

10 seconds, and SIM900 will send a warning message to the admin's telephone number. According to the specifications, the PIR sensor can detect a distance of up to 6 meters, so when testing the PIR sensor, it is stimulated in the form of human body heat every 1 meter. The PIR sensor has 2 potentiometer that can adjust the sensitivity level of the PIR sensor, and in this test, the potentiometer was set at the lowest level. The placement PIR sensor can be seen at **Figure 7**.

Table I. PIR Sensor Testing

Distance (m)	Result
1	Detected
2	Detected
3	Detected
4	Not Detected
5	Not Detected
6	Not Detected

PIR sensors with the lowest sensitivity can detect human body heat from a distance of 1 to 3 meters as shown in **Table I**. However, this distance can change if the sensitivity level of the PIR sensor is increased by rotating the potentiometer on the PIR sensor. The buzzer will also light up for 10 seconds when the PIR sensor receives stimulation in the form of human body heat (the duration of the buzzer can be changed according to existing conditions). In this study, the SIM 900 is being tested for signal strength and send its values to the website. SIM 900 is tested at 5 different places and times, namely, Pabelan in the afternoon, Marina Beach in the Semarang area in the afternoon, Telomoyo in the morning, Kos Dana Pensiun at night, and Lapangan Pancasila at dawn. The result of SIM 900 testing for signal strength and power test is shown in **Table II** and the test result of SIM 900 testing for message result and serial monitor is shown in **Table III**.

Table II. SIM 900 signal strength and power test

Place	Cell phone signal strength	Power Test
Marina Beach	-90 dBm 50 asu	+CSQ : 28,0
Telomoyo	-102 dBm 38 asu	Error
Pabelan	-69 dBm 71 asu	+CSQ : 14,0
Kos Dana Pensiun	-81 dBm 59 asu	+CSQ : 12,0
Lapangan Pancasila	-73 dBm 65 asu	+CSQ : 24,0

Table III. SIM 900 message test result

Place	Message Result	Serial Monitor
Marina Beach	Send	Ok
Telomoyo	Not Send	Error
Pabelan	Send	Ok
Kos Dana Pensiun	Send	Ok
Lapangan Pancasila	Send	Ok

The functionality of the developed website was thoroughly tested, encompassing both the admin interface, as illustrated in **Figure 8**, and the public report form, depicted in **Figure 9**. All features operated seamlessly without encountering bugs or malfunctions. This includes the login, form submission, and sign-up functionalities, which are equipped with validation warnings to prompt users if any required fields are left incomplete.

Figure 8. Table Report results from public

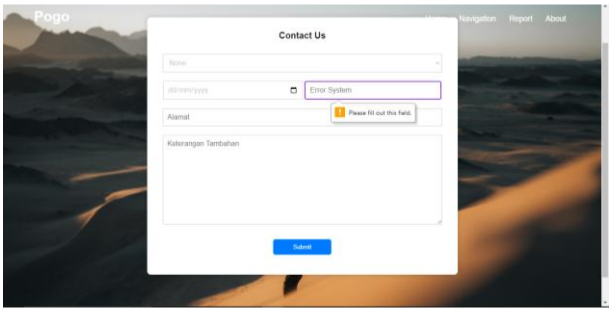

Figure 9. Public Report Form Page

For sensor testing within the ATS system, the light is programmed to activate at 7:00 PM, as illustrated in **Figures 10** and **11**. Ten minutes after the light is activated, the sensor begins operation and remains active for one hour. During this period, the SIM900 module transmits data collected from the current sensor and LDR sensor to the designated website, as shown in **Figure 12**. This configuration allows the sensor to begin monitoring only after the light has been turned on for a brief period of time, which could be useful for data collection once the lighting system has stabilized. Furthermore, this schedule ensures that the SIM900 module provides data to the website during the sensor's active period, resulting in consistent data transfer within a specific duration each evening. Furthermore, this system confirms that the light and sensor systems operate reliably according to the pre-set schedule.

Figure 10. ATS System

Subsequently, the device was tested with a non-functional lamp to verify whether the website could accurately display a warning message. The lamp was programmed to activate at 7:00 PM, with the sensor initiating operation 10 minutes after the lamp was turned on. Although the system successfully activated the lamp at the designated time, the sensor readings indicated a current value close to 0 mA and a light sensor value of 73 Ohms due to the lamp's malfunction. Since these readings exceeded the predefined maximum and minimum thresholds—500 mA to 200 mA for the current sensor and 20 Ohms to 70 Ohms for the light sensor, as specified by the developer based on component requirements—a warning message was generated and displayed in the warning table, identifying the specific device experiencing the issue.

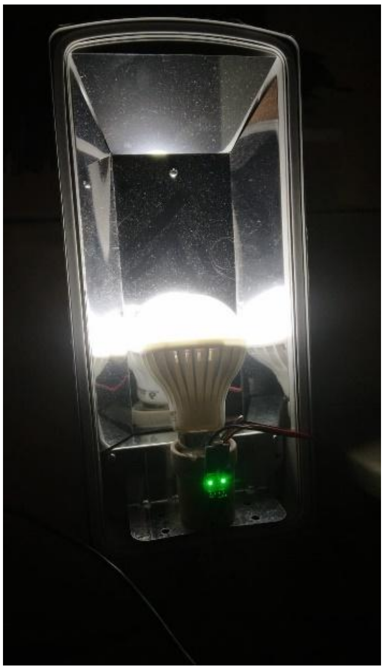

Figure 11. The light is on at night

As shown in **Figure 13**, the warning data is presented in the report table, indicating an error in the current supplied to the lamp. This warning message is triggered when the current deviates from the established limits of 400 mA to 100 mA, ensuring timely detection of anomalies in the system.

Overall, the prototype system has met the requirement, there are improvements that can be considered in its development. It is recommended to use more advanced battery technology such as lithium ion and upgrading to module that supports 4G/5G for the signal transmission system.

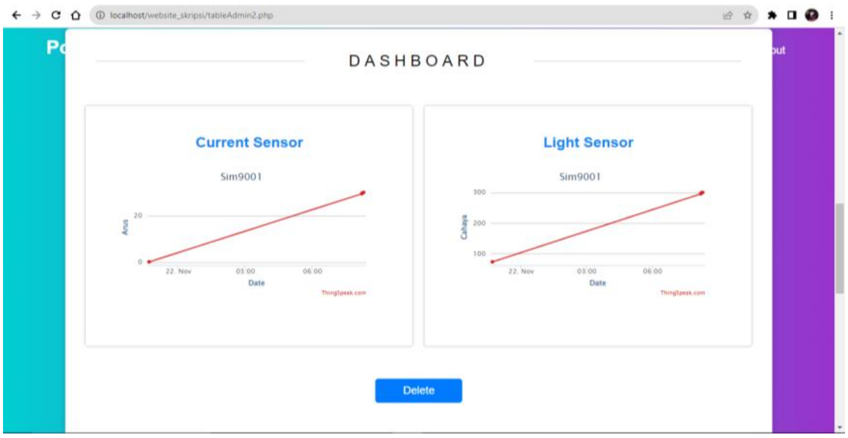

Figure 12. Current and Light Sensor Data Displayed on the Website.

Figure 13. Warning Message Data Displayed on the Website

IV. CONCLUSION

This study successfully demonstrates the development and testing of a solar-powered lighting and security system prototype, integrating a 3.5 Ah dry battery, a 20 Wp solar panel, and a 4.72 W lamp. The system achieves a battery life of 8–9 hours, ensuring consistent illumination for most of the night, which is particularly advantageous for safety and visibility in nighttime applications. Under optimal sunlight conditions, the solar panel charges the battery fully within 5 hours. However, the system faces limitations during periods of reduced solar radiation, such as the rainy season, where extended charging times may result in suboptimal performance. Despite this, the prototype proves to be a reliable and efficient solution for solar-powered lighting, with potential for further optimization to address low-light challenges.

The integrated security system, equipped with a PIR sensor, effectively detects human body heat within a range of 1–3 meters, triggering a 10-second buzzer alarm and sending warning messages via the SIM900 module. The SIM900 module demonstrated reliable signal strength and data transmission across various locations and times. The accompanying website, tested for functionality, operates seamlessly, featuring validation warnings for user inputs such as login and form submission. Additionally, the ATS system's sensor testing confirmed reliable operation, with the system detecting anomalies, such as a malfunctioning lamp, and generating warning messages when sensor readings deviate from predefined thresholds. Overall, the prototype represents a robust and versatile solution for solar-powered lighting and security, with significant potential for further refinement and expanded applications.

This study provides a foundation for enhancing web-based monitoring and reporting systems for street lighting, contributing to more sustainable, efficient, and user-centric urban solutions. Future work should explore integrating advanced smart sensors capable of detecting ambient light, motion, and weather conditions to optimize lighting efficiency further. Additionally, connecting this system with other urban infrastructure networks may offer broader applications within smart city frameworks.

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