Research Article

Design and Development of a Wireless Technology-Based Automatic Lighting System and IoT at Madrasah Aliyah Bayyinul Ulum Santong

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Abstract: Madrasah Aliyah or MA Bayyinul Ulum Santong is one of the Madrasahs or High Schools that still uses manual switches for classrooms, where the switches used are in each class of 12. The use of this manual switch can take a long time to turn on and off the lights in each classroom. This research designs and builds a light automation system that can reduce the amount of time needed to turn on and off the lights. This system is made using two switch methods, namely a virtual manual switch and a time switch, where this time switch can turn on and turn off the lights as a whole according to the time specified by the operator. In addition to the time switch, there is also a manual switch that can be used to turn on and off the lights one by one. This system can help reduce the use of electricity, which is usually wasteful because of negligence in forgetting to turn off the lights. With this system, the finished lamp can always be monitored by the operator. This system is designed from the arrival of the main tools, namely NodeMCU as a microcontroller, RTCDS3231 as a timer, and Relay as an ON/OFF switch. With the IoT-based real-time monitoring system using NodeMCU, a flexible monitoring and control system will be created.

Keywords: Lighting automation, NodeMCU, Automation System, Design and Construction, Internet of Things

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1. Introduction

The latest technological developments allow for the utilization of internet technology connected to various household electronic devices. This is supported by the increasing use of the internet, especially in urban and rural areas. Household electronic devices are one of the necessities for every household. Many providers offer competitive WI-FI networks, so almost every home has its own WI-FI connection. With this WI-FI network, we can take advantage of it by creating a smart home electrical control device using a microcontroller and wireless network. This involves writing code for the microcontroller device to connect to the WI-FI network, enabling remote control via Android or smartphones. Not only household electronic devices, but various institutions also have electronic devices, such as educational institutions and other organizations (Kusuma et al., 2024).

One interesting application is the lighting control system, which plays an important role in energy efficiency. In this context, devices like the NodeMCU (ESP8266) microcontroller serve as the main controller that sends commands to the relays and Real-Time Clock (RTC). Supporting components such as the RTC module (DS3231) provide real-time clock functionality for scheduling, while a 4-channel relay acts as an electrically controlled switch powered by DC to manage the ON/OFF switching of AC-powered lights (Hidayat et al., 2025). NodeMCU: This system allows users to monitor and control electronic devices via the web or mobile applications more easily and efficiently. Electronic devices generally refer to devices around us that are connected and can communicate via the internet (Chandra, 2025).

In educational institutions, precisely in Madrasah Aliyah Bayyinul Ulum Santong, one of the problems that has not been fully resolved is the use of efficient electrical energy. In various institutions, the use of electricity is one of the mandatory needs in carrying out activities, including in the field of education. At the Madrasah Bayyinul Ulum Santong school, the use of classroom lights is still done manually. In addition to lights, there are many electronic devices in this school that still use very large amounts of electricity, starting from computers, photocopy machines and other electronic devices, from the large use of electricity, it is certainly a challenge for the school in reducing electricity costs, in this case the most common is the classroom lights are left on 24 hours, there are many cases where the lights are left on even though the room is empty, either due to negligence or ignorance. This certainly results in energy waste and an increase in school operational costs that should be able to be reduced.

The selection of Madrasah Aliyah Bayyinul Ulum Santong as the location for implementing this project is also based on the importance of equalizing access to technology in schools, which often do not receive more attention in the development of technology facilities. By presenting a wireless-based lighting automation system in the madrasah environment, it is hoped that it can be an example of the application of affordable, useful technology that can be replicated in other educational institutions with similar conditions.

With this background, it can be concluded to design and build a wireless-based lighting automation system that can automatically turn the lights on and off remotely, either by setting the time for the lights to turn on and off or controlling the lights on and off with the ON/OFF button on Android, this system can control the lights remotely as a real solution to support energy efficiency and improve the quality of learning facilities at Madrasah Aliyah Bayyinul Ulum Santong, as well as a small step towards a modern technology-based school with an environmental perspective.

The IoT system that is built must be able to provide convenience for users, and also be able to provide flexibility seen from various parameters such as delay (ms) or latency (ms), power consumption, battery management, end-nodes, or various other essential parameters. Rajput, A., et.al (2022), Siregar, Y., & Manurung, Y. R. P. (2023), Sekar, G., et.al (2024), Verma, Y. K, et.al. (2023). This research specifically provides an understanding of the use of electricity as well as the regular expenses incurred by schools, hence the need for effective electricity savings. N. D. K., Gowda, et.al. (2022), Madhav, A. B. S., et.al (2024), Gaikwad, S., et.al. 2024, Kalavathi Devi, T., et al. (2023), Narender, K, et.al (2024),

The Internet of Things built using Wi-Fi modules usually has a 2.4 GHz Frequency, which can be analyzed in detail on the traffic side and can also be analyzed in real time from the Protocol side. The Internet Protocol used can use HTTP or MQTT. The working principle of this monitoring system is known as Publish and Subscribe. Muthukrishnan, V., et.al.(2024), Donavalli, S., et.al (2024), Imran, M. A., et al. (2024), Chandra, B. R., et.al.(2023), Kumar, A., Gupta, S. K., & Rai, M. (2021),

Moreover, with the ability or strength of Wi-Fi Signal, it will strengthen the transmission process, for example, Uplink and Downlink without large latency, in other words, getting high Quality of Service (QoS) in terms of Throughput (kbps). Balamurugan, S., et.al (2022), Gopi, A., et.al (2021), Challa, N. P., et.al.(2023), Kumar, P. V., et.al.(2025), Kumar, J., et.al.(2019), Waluyo, W., et.al.(2021), Ahmad, I., et.al.(2021).

2. Methodology

2.1 Research and Development Method and other parameters

The research method used in this study is the Research and Development (R&D) method. R&D is a research method used to produce products and test the effectiveness of the product (Wahyudi et al., 2025). R&D is a research approach that focuses on developing product specifications and testing their effectiveness (Aisyah Pringsewu et al., n.d.). The R&D method is a method that aims to develop a product, be it a learning model, teaching materials, or learning media. The R&D method also aims to produce new products or develop existing products (Nurhamidah et al., 2025).

Figure 1 is the work structure using the R&D method, which carries out several stages to produce a product or system from the start of the work to completion. Literature study involves collecting data and information through various library sources, such as reference books, similar previous research results, articles, notes, and formulating data using certain methods and programs. (Damri et al., n.d., 2025).

In qualitative research for the level of customer satisfaction of the IoT system built, we use the Interview method. Interviews are also an important part of this research. An interview is a data collection method by asking questions directly between officers. Researchers and respondents. Interviews are a good tool for examining opinions, beliefs, motivations, feelings, and projections of a person towards the future. Interviews are a dyadic communication process with a serious purpose and intent designed for behavioral exchange and involving a question-and-answer process. What is meant by the process in this case is the occurrence of a dynamic process that alternates with asking the variables involved, where the degree of the system/structure is uncertain (flexible). While what is meant by dyadic is that an interview is an interaction between two parties (individual to individual), no more than two parties, namely the interview (researcher) and the interviewee (the person being interviewed) (Lisiana et al., 2025). Figure 1 in detail discusses the entire Hardware and system to be built.

As for monitoring software, hardware, and their performance, a reliable monitoring system is needed, so that it can comprehensively determine Quality of Service (QoS). In general, the definition of observation is a way of collecting information materials that is carried out by conducting systematic observations and recording phenomena that are used as objects of observation. Observation as an evacuation tool that is a widely used tool to assess individual behavior or the process of an activity that can be observed. The observation method is a data collection technique that is carried out through observation, accompanied by the recording of the conditions or behavior of the target object. Observation is a systematic observation and recording of the symptoms being studied. In a broad sense, observation is actually not limited only to observations and recordings that are carried out either directly or indirectly. From the definition above, it can be interpreted that the observation method is a way of collecting data through direct observation of objects and events in the field (Lisiana et al., 2025).

The method of data measurement in this study is quantitative data measurement by looking at the serial monitor output to see the performance of the device. The type of quantitative research is a systematic scientific study of parts and phenomena and the causality of their relationships. The purpose of quantitative research is for researchers to develop and use mathematical models and theories related to a phenomenon. Research using quantitative methods is research that tests a theory consisting of variables, measured by numbers and analyzed so that it can determine whether the theory is true and runs smoothly (Izzati Maghfirah, 190503082, FAH, IP, n.d., 2025).

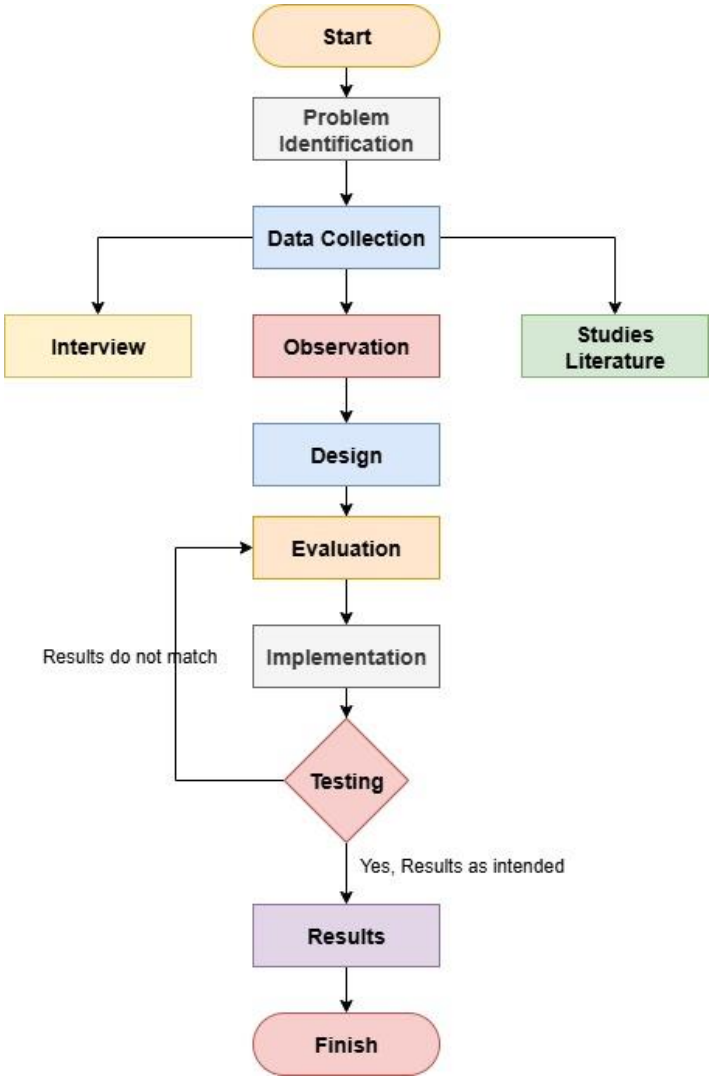

Figure 1. The Flowchart of Research and Development Method

This level of accuracy will be seen from the results of evaluating the system on a serial monitor. The accuracy of this automatic time is the accuracy of the turn-on time and the turn-off time of the automatic light system. Measurement of the system response time will also be seen from the evaluation results on the Arduino IDE serial monitor by looking at the response delay of command execution and command execution. The effect of distance on testing will be tested in several trials with different distances to see the delay in the system or the effect of distance on the system. The reliability of this system can be seen from the program output when running on a serial monitor, which will display how fast the wireless connection is to the lighting automation system.

The success rate is seen from the evaluation results of how many commands are executed by the system and how many packets are lost or commands are not executed by the system. This success rate is seen from the output on the serial monitor. The analysis method used in this study is the descriptive statistical analysis method. Descriptive is a study that intends to create an addiction or process of providing a clear and detailed description or description of an object. This descriptive study aims to create a systematic, factual, and accurate joke (Izzati Maghfirah, 190503082, FAH, IP, n.d., 2025).

Descriptive statistics is a technique used in estimating data and displaying it in a form that can be understood by everyone. This involves the quantitative process of finding a phenomenon. Descriptive statistics can be displayed in the form of a table containing data from the analysis results(Della+Afriana+Tasya, n.d., 2025).

3. Result and Discussion

Based on the results of interviews with various students and teachers regarding the advantages of using a lighting control system in the classroom, several important points can be concluded, such as: Time Efficiency. Many respondents stated that this system can save time in turning on and off lights, especially during learning activities. This allows teachers and students to focus more on learning without having to keep pressing the switch. Ease of Access, Several students mentioned that having a manual button or a system that can be operated remotely allows them to control the lights without having to move far, which is very helpful during activities such as reading the Koran. Teacher Control: Several respondents emphasized the importance of teacher control in the use of this system, especially to maintain discipline and ensure that students do not use the devices carelessly. Availability of Tools: Most respondents stated that these benefits can only be realized if the school provides the necessary tools. Without these tools, the expected benefits cannot be achieved. Use of Technology, Respondents also indicated that the use of technology in controlling lighting can enhance the learning experience, especially in situations where lights need to be turned on or off quickly and efficiently.

The results of observations conducted in the classroom at Madrasah Alliah Bayyinul Ulum Santong obtained results where the switch buttons for each class consisting of 12 classes consisting of 1A, B, C, 2A, B, C, 3A, B, C still use manual buttons in each class and will be very time consuming in turning on and off the lights and the switches are located far apart between classes. The class is also used at night for studying books and religious studies, so from the results of this observation, it shows that the system can make it easier for schools to control lights and reduce the amount of electricity used because there are several electronic devices that require large electrical energy.

Figure 2. The Manual Switch in each class

Figure 2 is a manual switch in each class where the distance between classes is far apart. The class at the Madrasah Alliah Bayyinul Ulum Santong school has 9 classes, and it will take a lot of time to turn on and off the lights for the school guard. A system block diagram is a diagram of a system, where the main parts or functions represented by blocks are connected by lines, which show the relationships of the blocks. Block diagrams are widely used in the engineering world (Putri W, D, n.d., 2025). A block diagram is a sequential statement of the relationship of one or more components that have a unity, where each component block affects other components. The block diagram has a special meaning by providing information in that it. For each block connected, which shows the direction of work (Rachman et al., 2025).

Furthermore, Block diagrams will be used in this study as a description of the relationship between each component that is connected and to provide an explanation regarding the relationship between each component.

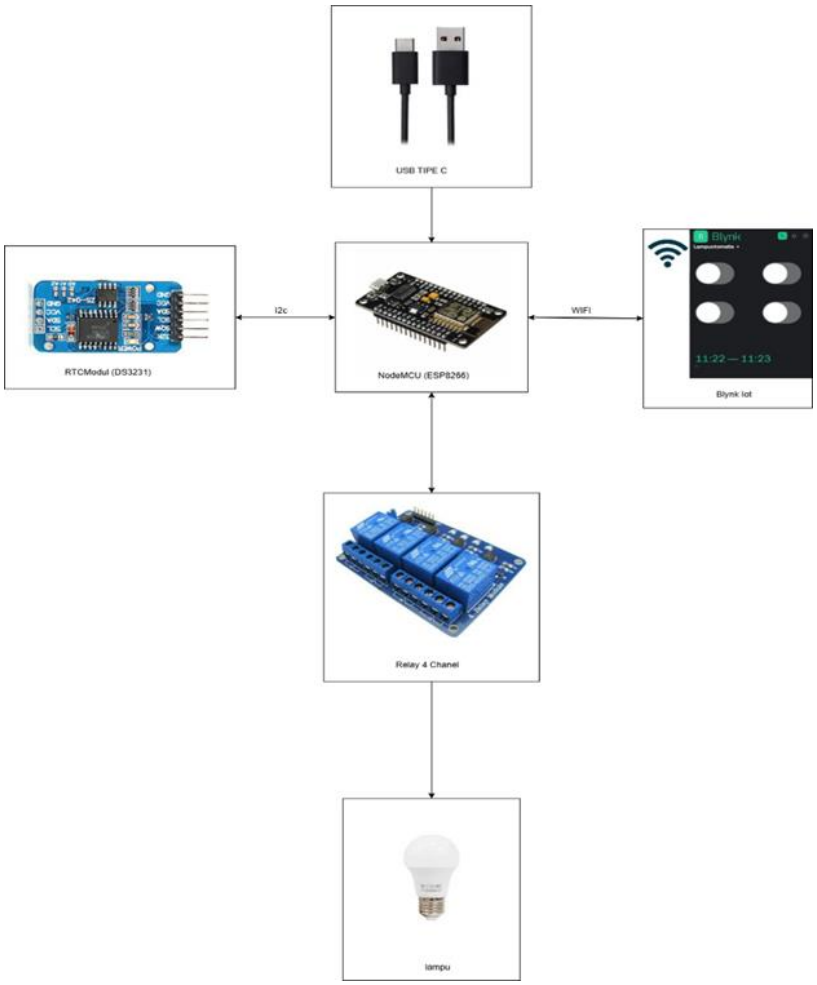

Figure 3. Architecture and Hardware, and IoT Connectivity that will be built in this research

Figure 3 illustrates the relationship between each module, where the Blynk IoT Application is installed on an Android device and functions as the main controller of the system, sending and receiving commands to and from the NodeMCU via a Wi-Fi connection and TCP protocol, including manual button settings and timers for light automation. The NodeMCU ESP (8266) acts as a microcontroller that receives commands

from Blynk and sends instructions to the RTC and Relay modules, and can turn the lights on or off directly through manual commands without having to set the time. The USB Type C component provides the 5V electrical voltage needed to operate the NodeMCU, Relay, and RTC modules, because the Relay requires a higher voltage than the NodeMCU, which only operates at 3.3V. The RTC DS Module (3231) functions to set the time for the lights to turn on and off; after receiving the time from Blynk, the RTC sends a message to the NodeMCU to activate the Relay according to the specified time, and also uses the TCP protocol to communicate with the NodeMCU. The 4 Channel Relay acts as the main switch connecting the system to the lights, receiving commands from the NodeMCU to turn the lights on or off, either based on a specified time or via a manual button on Blynk. The lights act as the output of the system, indicating whether the system is functioning properly, and are connected to the Relay, which acts as a switch to control the flow of electricity.

Table 1. USB Connectivity

Bread Board	**USB-C Type**
GND Pin (-)	Cable (-)
VCC pin (+)	Cable (+) 5v

Table 2. RTC Connectivity

RTC Modul	**Node MCU**	**Bread Board**
VCC		(+)
GND		(-)
SDA	D2	
SCL	D1	

Table 3. Relay Connectivity

Relay 4 Channel	**Node MCU**	**Bread Board**
IN1	D5	
IN2	D6	
IN3	D7	
IN4	D8	
VCC		(+)
GND		(-)

Tables 1, 2, and 3 explain the connections between the various components in an electronic system. Table 1 shows how to connect a USB Type C to a breadboard, where the GND (-) pin is connected to the negative wire and the VCC (+) pin is connected to the 5V positive wire. Table 2 details the connections of the RTC module to the NodeMCU, with VCC and GND connected to the positive and negative pins on the NodeMCU, and SDA and SCL connected to pins D2 and D1. Table 3 illustrates the connections of a 4-channel relay, where each input (IN1 to IN4) is connected to pins D5 to D8 on the NodeMCU, while VCC and GND are connected to the positive and negative pins on the breadboard. This explanation gives a clear picture of how the components are connected to each other in the system. The hardware design in this study shows the hardware circuit or circuit of each component, such as NodeMCU, RTC Module, Relay4 Channel, Breadboard, Lamp, and USB-C Type.

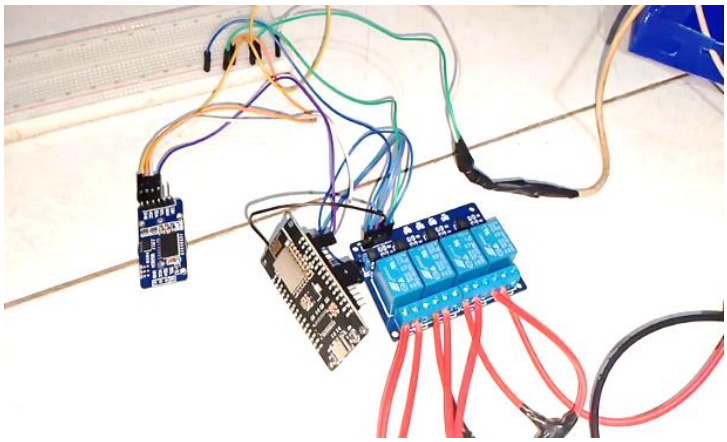

Figure 4. Relay, RTC Module, and Node MCU Connectivity

Figure 4 is a hardware circuit where each component is connected to the other components using the pins of each component. The IoT-based precision irrigation system demonstrated significant water conservation capabilities across all tested crop configurations. System performance evaluation revealed 8.6 % water savings compared to theoretical FAO-56 calculations, with actual measured consumption of 449.17 mm versus predicted 491.49 mm over the 37-day experimental period. System testing is important to find out whether the system is running well or not. In this study, the test results will be seen from the serial monitor, namely the tool in the Arduino IDE.

Table 4 shows the results of the tests carried out for the system, whether the system can receive time from Blynk, and the impact of executing it well. The results of this test show that the system works well, and the manual button also works. The placement of the access point or Wi-Fi internet source within the system affects the strength of the RSSI signal.

Table 4. Test Result

Parameter	Data	Results
The system can receive time from Blynk.	RTC received the time from Blynk, which was 22:47 – 22:48, and was received at 22:46	Can receive and set on time within a time range, and off outside the time range.
Automatic control delay	Delay is between 1 ms – 206 ms.	The delay is small, especially when the relay is active; the delay is only 206 ms.
Signal strength	RSSI signal strength:35dBm – 45dBm	The Wi-Fi connection is strong and remains stable because it is still below 70 dBm
The system displays Wi-Fi status.	Wi-Fi status remains connected.	Status still shows Wi-Fi connected.

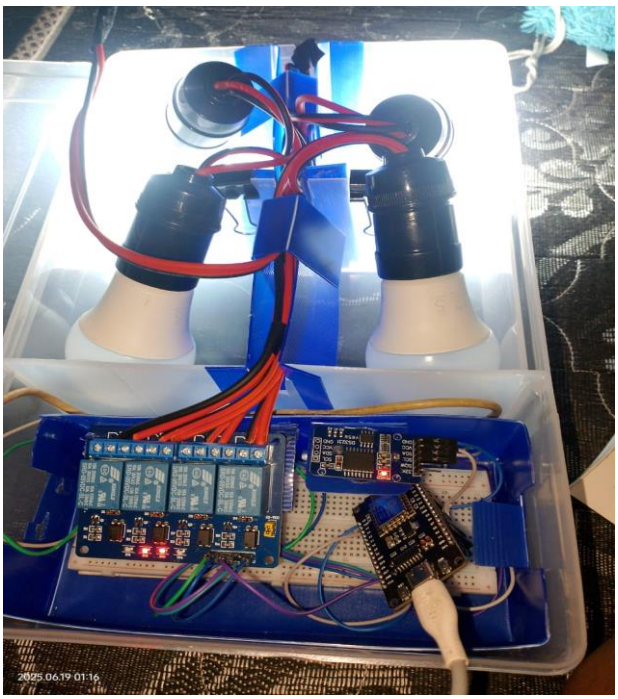

Figure 5. Relay and Node MCU Connectivity, and also Output in the form of Lights

Figure 5 is the concept that was successfully built. After the process of testing and testing this connectivity is complete, the next step is certainly the installation at every point in the classrooms will be carried out. While the control system is based on IoT using

Blynk IoT, it will make it easier to monitor lights more easily and flexibly. Figure 5 is the overall circuit of the system according to the design and has passed the testing stage. The final result shows that the system has run well, where the lamp is connected to the relay with the No/Normally Open pin connected to the electric current source, and the Com pin is connected to the lamp; the use of this pin is repeated from Relay 1-4.

There are several functions applied to this system that can be controlled remotely by connecting the system to Wi-Fi, the functions of the system such as can be controlled with manual buttons and by using a timer/time and when the timer is running then the lights are on the manual button will be locked from the results of the system test in the manual button test the lights successfully turn on according to the button that is turned on from each button. In the use of time, the system can receive the time set from Blynk and can execute it properly, where all the lights automatically turn on if within the time range that has been set in Blynk and turn off when it is outside the time range. The locked manual button feature also works well according to logic, where all manual buttons will be locked when the lights are on within the time range, and the button will open again when the lights go out outside the time range. Analysis of the functions of the systems applied in this study went well. Be it manual buttons, timers, or locked manual buttons. The purpose of the locked manual button feature when the timer is running is to ensure that no errors occur when two commands are executed.

From the results of the analysis, the testing of this system runs according to the research objectives, where researchers can design and build a wireless technology-based lighting automation system. This system can also be controlled remotely, either manually or with a timer/time setting. The system starts from identifying existing problems, then collecting data, continuing with designing system logic, and continuing with building a system that has been designed to produce a wireless technology-based lighting automation system that has manual button, timer, and manual key features. The advantages of this system include: The system can save time in turning the lights on and off compared to manual switches in each classroom, which take a long time to turn the lights on and off. This system can overcome the existing problem where classroom lights are often left on when the classroom is empty. The system can be controlled from anywhere using the Blynk application on Android as long as the system remains connected to Wi-Fi/internet. The system has a timer that can be reset at any time from the Blynk application. This system combines NodeMCU, RTCDS3231, and a relay as a manual controller and automatic time controller. This system can help teachers remember the start time and end time of learning.

The disadvantages of this system include: This system does not have a local backup for manual control if the NodeMCU has a problem. This system relies on a Wi-Fi internet connection, which affects system performance when the system is far from a Wi-Fi connection. Overall, this system still uses the 3.3V nodeMCU, which requires an external power supply to supply 5V power for the Relay. This system can lock the virtual switch button in Blynk when the timer light is on, but cannot turn off one of the lights while it is still on the timer. This system also does not have a notification feature as a reminder when an error occurs with one of the lights.

From the final test results, this system can work well and all features are adjusted to the research results, where the timer is set every time the learning time is started by the operator repeatedly, and the manual button remains locked when the timer is still active and opens when it is finished, and the manual button also functions well. Researchers conducted testing by making a prototype of the light flow with the system, which makes it easier during testing.

Additional analysis of this article is about the Light Sensor Data (LDR) during the day or night, and also the threshold of the light status when ON/OFF, the real-time power consumption, and the Wi-Fi signal quality. The response time of the system is also essential to be discussed. Specifically, there is a daily pattern and energy consumption of the system conditions built, so that from this system, additional analysis can be drawn. This system can be described as an additional analysis as following the Graphs, an Advanced monitoring system that can be done other than on the Blynk Server, can be seen in real-time. From the side of Real-time Light Intensity Monitoring in Lux units compared to the Time that is constantly running, the light intensity is influenced by the condition of the control or the ON/OFF status of the automatic lights, and is also influenced by real-time power consumption. A more detailed analysis can be seen in the quality of the Wi-Fi signal. Poor Wi-Fi signal quality will affect the delay time (ms) on the ESP32 or Node 8266 communication used to transmit data to the server. ESP32 or Node 8266 communication is used for transmitting data to the server. More details can be seen in Figure 6.

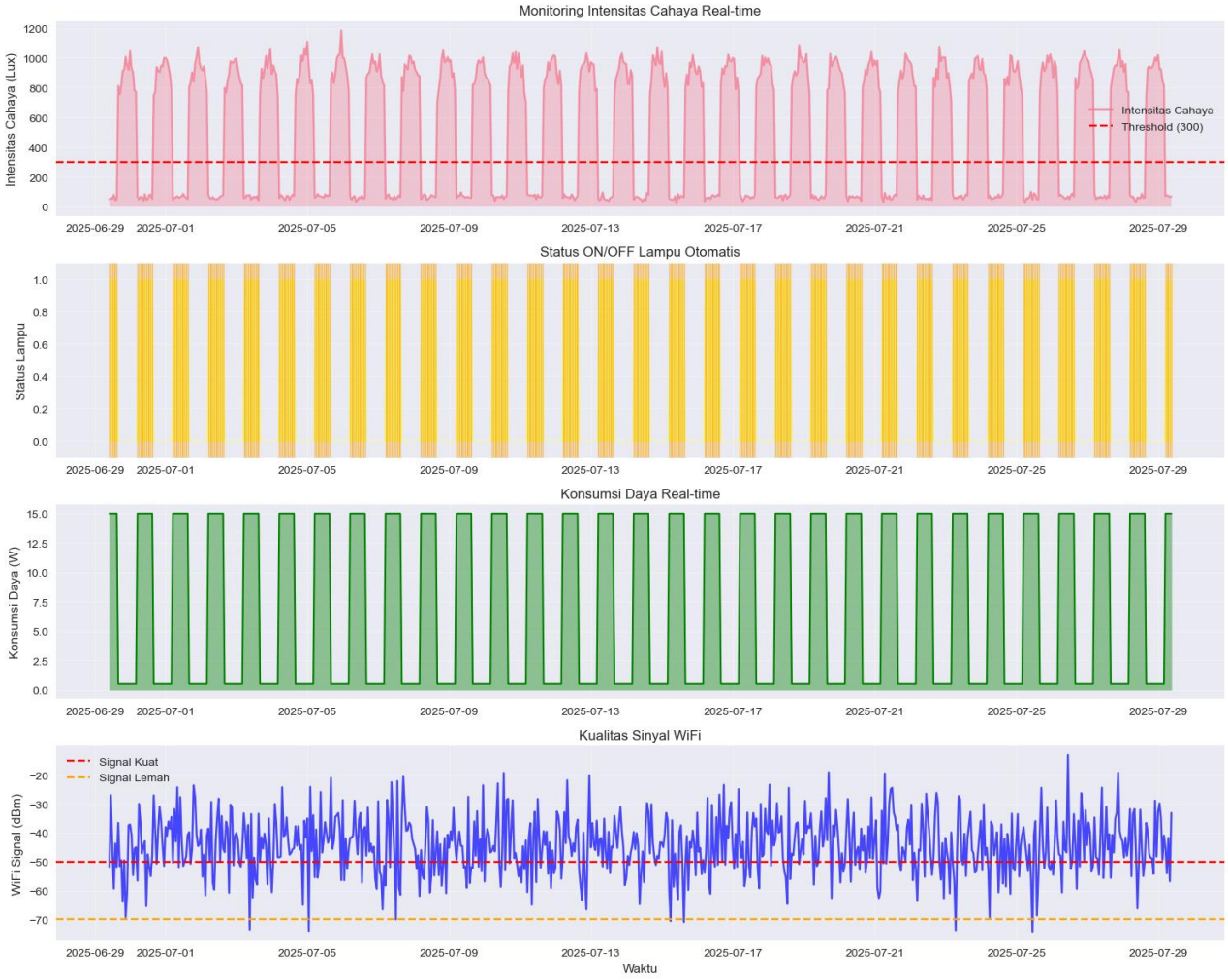

Figure 6. Example of Realtime System built

As for the use of lights per hour can also be analyzed in detail as in Figure 7, the probability of lights on can be seen in Figure 7, and the daily Light Profile can be seen with a profile comparison of average light intensity (Lux) and Hours (24h). Hourly Power Consumption is a comparison between Average Power Consumption (W) compared to Time or 24hours, and also the Response Time System distribution is a comparison between Frequency compared to Response Time (seconds). Figure 8 is the entire correlation of parameters in the Correlation Matrix of its IoT System Variables, consisting of Response time, Wi-Fi Signal, Power Consumption, Lamp_Status, and Light_Intensity. High comparison or correlation is red, until yellowing and white for the lower, until blue if there is no correlation. From the data, it can be seen that the largest correlation of value 1 occurs in the status of the lamp with its power consumption. An example Dashboard of daily Power Consumption, Light Intensity Distribution, Lamp status per day, and Wi-Fi Performance can be seen in Figure 9.

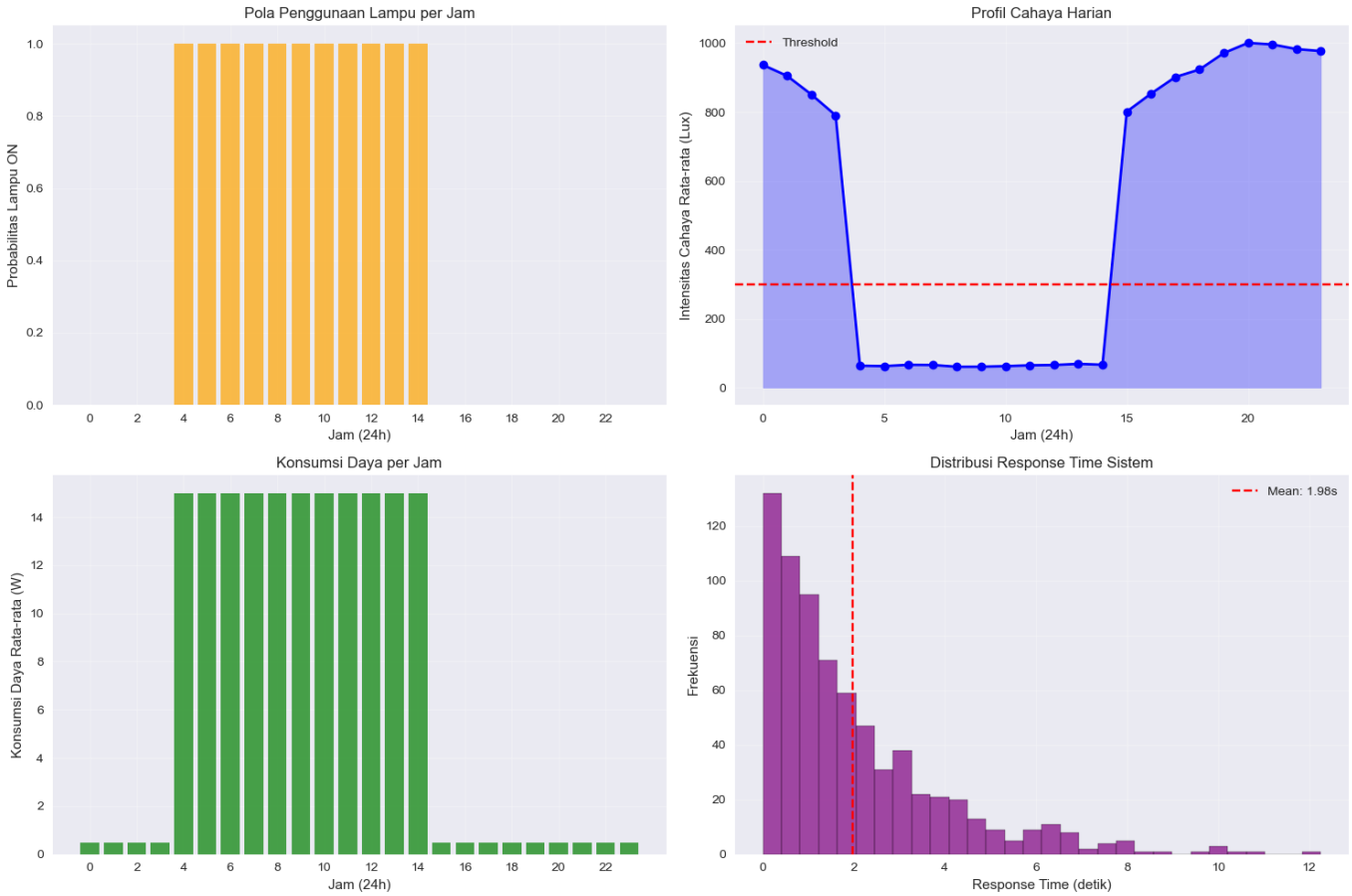

Figure 7. Sample Analysis of Power Consumption, Light Intensity, and Response Time

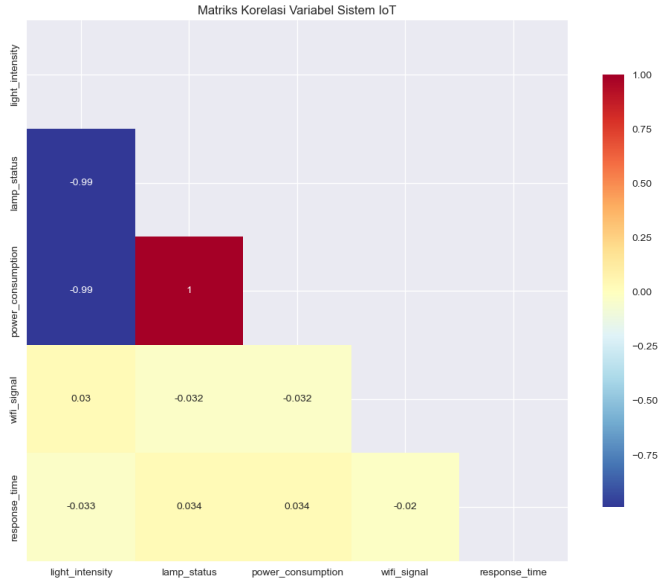

Figure 8. Correlation Matrix of IoT System Variables

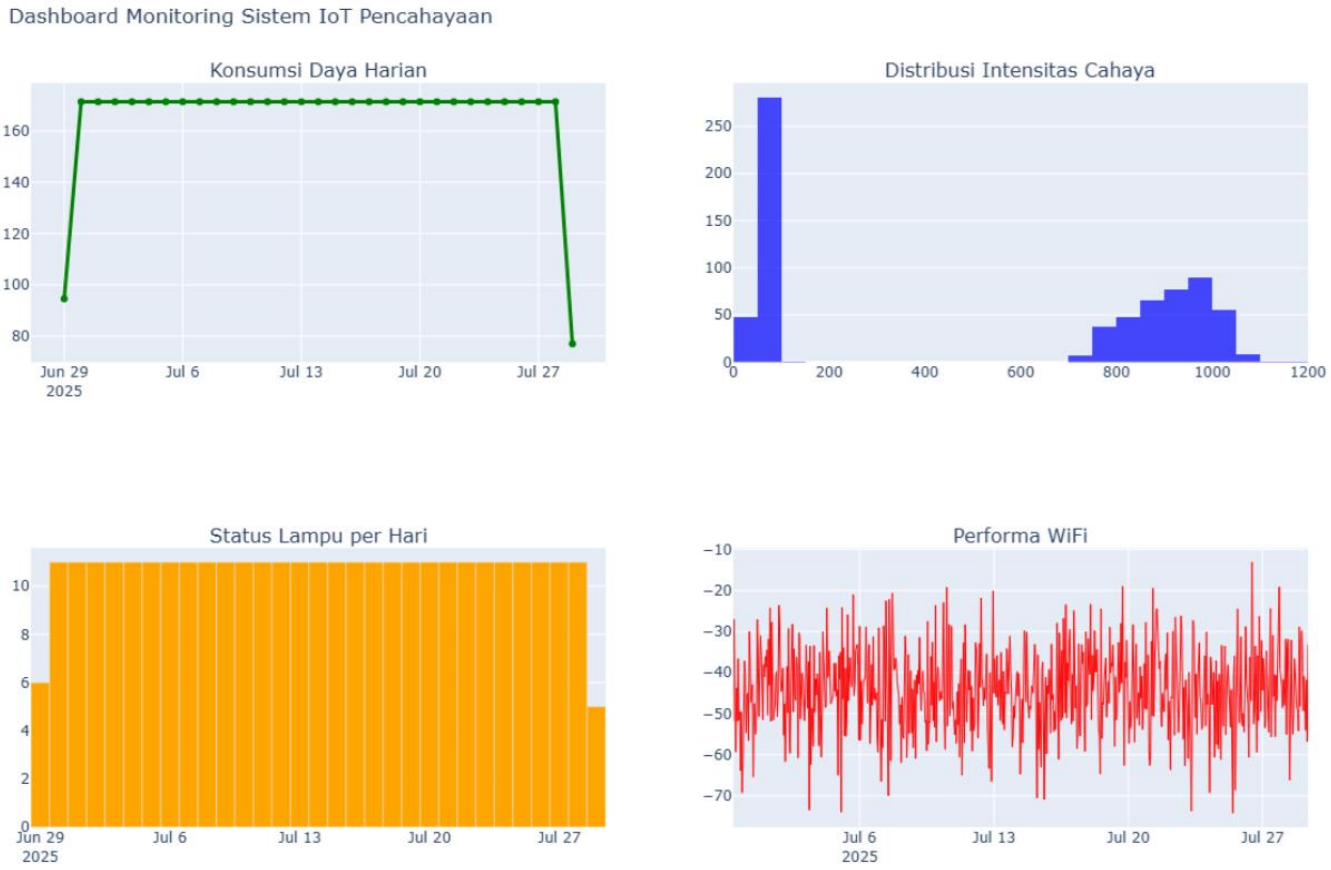

Figure 9. Example of Lighting IoT System Monitoring Dashboard

4. Conclusions

Based on the results of the research and discussion that have been carried out in this study, it can be concluded that the wireless technology-based lighting automation system that was designed and built successfully met the research objectives, namely designing and building a wireless technology-based lighting automation system. This system allows remote control of lights via the Blynk application, either manually or automatically with a timer. The existence of the system is beneficial in the teaching and learning process, especially in saving time. The system design involving components such as NodeMCU, RTCDS3231, and Relay has functioned well, with tests showing that the system can receive and execute commands accurately. Although this system has advantages, such as time efficiency, saving electrical energy, and being able to be controlled remotely. There are also system weaknesses that need to be considered, such as dependence on the distance of the internet and system placement, and the absence of local backup for manual control. Overall, this system was successfully designed and built following the formulation of the problem proposed, namely designing and building a wireless technology-based lighting automation system. In building IoT systems, especially those related to light automation, the essential parameters are Light Intensity, Lamp Status, Power Consumption, Wi-Fi Signal or Wi-Fi performance, Response Time, Daily power consumption, Light Intensity Distribution, and status on IoT Servers such as MQTT, which can be analyzed for Publish and Subscribe systems.

The suggestions that need to be considered are: Development of local backup features for manual control so that the system can continue to function when there is a disruption to the NodeMCU or internet connection. Use of a more appropriate power supply to meet the voltage needs of the relay and NodeMCU can improve the reliability of the system as a whole. Addition of electricity consumption monitoring features that are useful for schools in managing electricity usage and reducing operational costs. Addition of a notification control system if one of the lights is short-circuited or is off

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Conflicts of Interest: The authors declare no conflict of interest.
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