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Android-Powered Home Lighting: A Control and Monitoring System for Smart Living

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ABSTRACT

This research aims to address the manual control and maintenance of community lights by developing a remote light controller and detector using the Internet of Things (IoT) concept. The process involves the use of an Android-based smartphone application to control and monitor the lights. The system utilizes a lamp current, which is charged on the ledge, and a relay driver to turn the lights on or off. The Wemos microcontroller, with the ESP8266 Wi-Fi module, serves as the link between the smartphone and the server. The results of the research show that the photodiode light sensor operates effectively when activated, and the current sensor can determine the number of lights that are turned off. Users can access the control and monitoring of the lights through the Android application, allowing them to control the lights remotely and keep track of the number of lights that are functioning properly.

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1. INTRODUCTION

The rapid advancement of technology, particularly in the field of the Internet of Things (IoT), has significantly influenced modern lifestyles and industrial practices[1]. IoT-based systems have paved the way for smarter, more efficient solutions in various domains, including home automation, urban planning, and energy management[2]. In the context of lighting systems, traditional manual control methods often pose challenges, including inconvenience, inefficiency, and lack of real-time monitoring[3], [4]. These limitations necessitate the development of smarter solutions that align with the growing demand for convenience and sustainability.

The field of electronics is experiencing advancements, particularly in the area of control systems. As communities engage in more diverse and unpredictable activities, there arises a need for automatic control systems that can accommodate these changing demands. Previously, control of electrical devices was limited to infrared-based remote controls or cable-connected switches, both of which had limited range[5], [6], [7]. However, with the increasing popularity of smartphones, a solution has emerged that simplifies control and expands its range. This solution involves utilizing the Android mobile operating system, which is experiencing rapid growth. Through the use of smartphones as remote control devices, individuals can now easily control lights and other electronic devices while enjoying the benefits of a larger range[8].

Lighting systems are integral to both residential and community infrastructures, ensuring safety, comfort, and functionality[9]. However, traditional lighting control methods often require physical interaction, which can be inconvenient and inefficient, particularly in larger settings. Furthermore, the inability to monitor the operational status of lights in real-time can lead to increased energy consumption and maintenance delays.

Addressing these issues requires the integration of advanced technologies that provide seamless control and monitoring capabilities

The use of Android as a smartphone communication tool has experienced development at this time[10], such as a room light control device combined with a microcontroller component in the form of NodeMCU by using wireless facilities on Android.

NodeMCU is a microcontroller development based on the ESP8266 microcontroller module[11]. The NodeMCU microcontroller was created as a solution to the high cost of other microcontroller-based wireless systems. In his research, stated that the ESP wireless module used has a factory default firmware that supports AT command commands. By using the NodeMCu microcontroller, the cost of building a microcontroller-based WiFi system is very low, only one-tenth of the cost of building a WiFi system using the Arduino Uno microcontroller and WiFi Shield.

According to [12], defines IoT as follows: The interconnection of sensing and actuating devices, which provides the ability to share information across platforms through a unified framework, developing a common operating picture that enables innovative applications. This can be achieved by using seamless ubiquitous sensing, data analysis, and information representation with cloud computing as the unifying framework. Meanwhile[13], explains that IoT has three main characteristics objects are given a measuring device/tool, autonomous terminals that are interconnected, and intelligent services. As such, IoT is an advanced technology that is truly cross-disciplinary, encompassing: computer science, communications, microelectronics, and sensor technology.

ESP8266 is referred to as a System On Chip (SOC) that has the ability to connect to TCP/IP networks via Wi-Fi in addition to microcontroller-like capabilities as a “brain”[14]. NodeMCU is an open source IoT platform and development kit that uses the Lua scripting language or by using the Arduino IDE software. NodeMCU can be analogized as an Arduino board that is connected to ESP8266. NodeMCU has packaged ESP8266 into a board that has been integrated with various features such as microcontrollers and access to Wi-Fi and communication chips.

This research aims to overcome the limitations of manual lighting control and maintenance by developing an IoT-based solution. The proposed system integrates a remote light controller and detector, leveraging an Android-based smartphone application for real-time control and monitoring. The system incorporates key components such as the Wemos microcontroller with the ESP8266 Wi-Fi module, a relay driver for switching lights, and sensors for detecting light and current levels. This setup enables users to remotely control the lighting system and monitor its operational status, enhancing convenience and efficiency.

The results of this study highlight the system's ability to effectively control and monitor lights through the Android application. The photodiode light sensor demonstrates reliable performance in detecting light conditions, while the current sensor accurately determines the operational status of individual lights. By enabling users to remotely access and manage lighting systems, this research contributes to the advancement of smart home and community lighting technologies. Furthermore, the proposed system supports energy efficiency and reduces the need for manual intervention, aligning with contemporary efforts to create sustainable and user-friendly technological solutions.

2. METHOD

Discussion of hardware and software design for the development of a light control and monitoring system using Android. In this research system has a working description of the relationship between its components. The comparison between existing research is that this designed research can provide feedback in the form of sending email messages to users when the lights are turned on and off, providing feedback in the form of notifications on the android application to find out the current load on each block of lights when the condition is on (ON) the whole system can be described as a block diagram as shown in Figure 1.

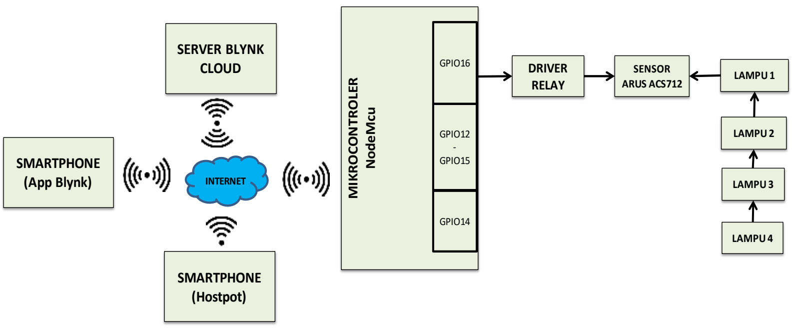

Figure 1. Block Diagram

The flow of electricity to the load is controlled by a relay driver, functioning as a connector or breaker of electricity. The current sensor connected in series by the relay driver and the load will calculate the value of the current. Each relay driver is controlled through the pins of the NodeMCU microcontroller. Controlling and monitoring is done with the concept of Internet Of Things, the data will be sent to a Blynk cloud server. The physical diagram as shown in Figure 2 will show the connection relationship between the supporting components.

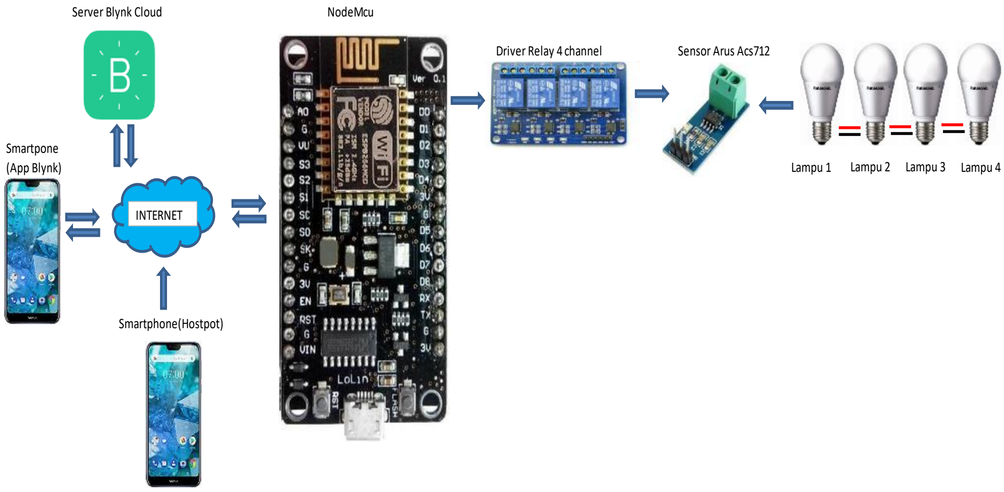

Figure 2. Physical Diagram

Components to support so that the tool can work in accordance with its purpose and function, there is a series of block diagrams needed, as for the NodeMCU microcontroller circuit and supporting circuits such as relay drivers, ACS712 current sensors. In Figure 3 below will be shown with the overall block diagram of the hardware design.

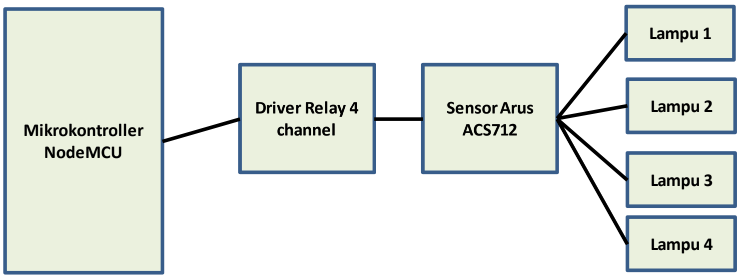

Figure 3. Hardware Design

With the main control using NodeMCU microcontroller with ESP8266 chip that supports WiFi connection. This microcontroller is connected to a 4-channel 5V Relay Module that will control four lights. The NodeMCu microcontroller is connected to a USB cable with 5V power and relays that use 220V power. This design is divided into microcontroller software design and software design of supporting applications. In the design of this thesis, the author does not create new applications or special applications, the author only utilizes existing applications, such as Blynk. In addition, the author also programs the microcontroller so that it can connect to the cloud server and the software and hardware devices used.

The Blynk app provides a large selection of widgets that we can use in the projects we will create. Each widget can be obtained by exchanging “Energy Balance”, for the free service, 2000 energy balances are provided. We can drag and drop the widgets onto the project page. To get the Blynk application can be downloaded from Google Play on a smart phone. After the application has been installed then we create a new account and project on the Blynk application, after that the “auth token” will be sent via email to us, later this “auth token” is used as verification so that our device can connect to the “blynk cloud” server.

In programming the NodeMCU Microcontroller is made with firmware that uses the Arduino IDE on the grounds that the Arduino platform is more widely used and has more support from related communities. Before writing the program, we first prepare the Arduino IDE application so that it can support the NodeMCU board used in this study. after all the settings are complete and the library has been entered, enter the programming code on the arduino ide application page that has been provided then compile / upload the program code that has been entered if there is no error statement then the process of compiling / uploading the program code to the microcontroller on Nodemcu with the Arduino application.

In the workflow of the system after everything is connected to the internet and ready to be used, the program is intended to send input data from the server to the relay driver so that it can turn on and off the lights using a Smartphone and there is a notification feedback from the current sensor to find out the current load on each lamp block and Feedback to find out whether the lamp is off or on by sending an e-mail message to the user. This control and detection will be connected to the Blynk server and will also be connected to an android. In Figure 4 is a flowchart of how the system works.

Figure 4. Flowchart of how the system works

3. RESULTS AND DISCUSSION

In this section, we will explain the process of making equipment from the application of the Internet Of Things (IoT) to control lights using Android-based Arduino which consists of lamp hardware that has been assembled with a wifi shield, Arduino and relay. The developed IoT-based lighting control and monitoring system was tested to evaluate its functionality and performance. The results demonstrate the system's ability to achieve its primary objectives of remote control and real-time monitoring of lights. This section presents the findings in terms of sensor performance, system usability, and the overall effectiveness of the solution, followed by a discussion of the implications and potential improvements.

3.1. Photodiode Light Sensor

The photodiode light sensor integrated into the system showed consistent and reliable performance during testing. It accurately detected the presence or absence of light, ensuring that the system could appropriately determine environmental lighting conditions. This functionality is crucial for scenarios where lights are required to operate only under specific conditions, such as at night or in dim environments.

3.2. Current Sensor

The current sensor proved effective in determining the operational status of the lights. The sensor accurately measured the current flow to detect whether the lights were turned on or off. This feature enables users to monitor the number of lights that are functioning correctly and identify any potential failures. Such real-time insights contribute to efficient maintenance and energy management.

3.3. Usability and Control via Android Application

The Android-based application provided a user-friendly interface for controlling and monitoring the lighting system. Users were able to perform the following tasks seamlessly:

- Remote Switching: Users could turn lights on or off remotely with minimal delay, thanks to the reliable communication facilitated by the Wemos microcontroller and ESP8266 Wi-Fi module.
- Real-Time Monitoring: The application displayed real-time updates on the operational status of the lights, including the number of lights functioning and their conditions.
- Ease of Access: The application's interface was intuitive and easy to navigate, ensuring that even users with limited technical knowledge could interact with the system effectively.

In the initial display of the application Control and monitor lights are presented several buttons to control and monitor lights consisting of: Lamp Button 1, Lamp 2, Lamp 3, Lamp 4 and Current Check Button. In this application the user easily operates the buttons that have been made clearly and easily understood without having to socialize further. as shown in Figure 5 the appearance of the lamp control system application.

Figure 5. Control Application

The first test on the application of Internet Of Things (IoT) for light control using Android-based Arduino is to give input manually by pressing the button on the Blynk application so that the display on the button in Blynk will be the ON button with the lights on and if pressed again the button will turn into OFF lights with off conditions. After that the testing conditions of lamp 1, lamp 2, lamp 3, lamp 4 have run well we can monitor the current load on each lamp with the conditions on, 1 or 2 lights in the on state we can monitor the incoming current by looking at the current notification in the Blynk application.

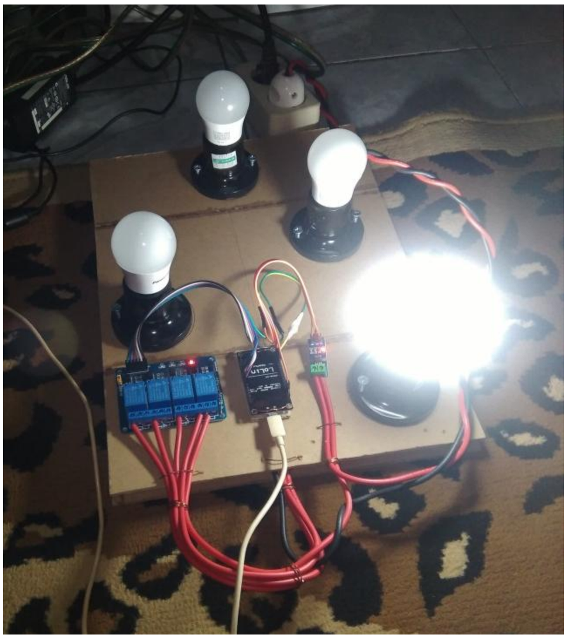

Figure 6. Lamp 1 is ON

3.4. Light Monitoring with Acs712 Current Sensor

In monitoring the ACS712 current sensor which is connected in series to the relay driver and load. ACS712 has an initial value with a current value of 0 and an ACS712 output voltage of 2.5V DC, so it must be processed and converted by the microcontroller program process in order to get the output current amount.

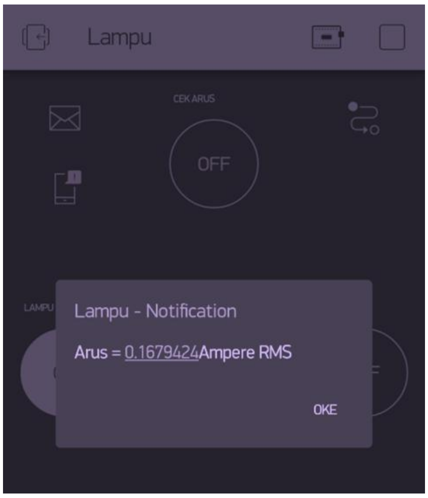

Figure 7. Sensor Current load 1 lamp ON

3.5. ESP8266 Response Time Testing

This test aims to determine the ability of the ESP8266 Wi-Fi module to process incoming commands from smartphones with a distance between the ESP8266 Wi-Fi module and different Wi-Fi. The ESP8266 response time test is shown in Table 1. Based on table 1, data is obtained with a maximum distance of 20 meters (outdoor) with a delay time of 3 seconds.

Table 1. ESP8266 Control Distance and Response Time Testing

Experiment	Control Distance (meter)	Response Time (second)			
		L1	L2	L3	L4
1	3 (indoor)	0.5	0.5	0.5	0.5
2	3 (outdoor)	0.5	0.5	0.5	0.5
3	6 (indoor)	0.5	0.5	0.5	0.5
4	6 (outdoor)	0.8	0.8	0.8	0.8
5	10 (indoor)	0.5	0.5	0.5	0.5
6	10 (outdoor)	1	1	1	1
7	15 (outdoor)	2	2	2	2
8	20 (outdoor)	3	3	3	3

Table 1 summarizes the results of an experiment evaluating the response time of a lighting control system at varying control distances under different conditions. At shorter distances (3 and 6 meters), the response time remains consistent at 0.5 seconds, regardless of whether the environment is indoor or outdoor. As the distance increases (10 meters or more), response times in outdoor conditions become longer than those indoors. For instance at 10 meters, the response time is 1 second outdoors but remains at 0.5 seconds indoors. At 15 and 20 meters, outdoor response times increase significantly to 2 and 3 seconds, respectively. The system performs optimally at distances up to 10 meters under both indoor and outdoor conditions, with response times of 0.5-1 second. Beyond 10 meters, response times increase significantly in outdoor conditions, indicating possible limitations in network communication at greater distances. Response times for all four lights (L1, L2, L3, and L4) are consistent within each experiment, suggesting uniform system performance across the controlled lights.

The results demonstrate that the system is highly responsive at shorter distances, making it suitable for indoor use or small outdoor areas. The increase in response time at greater distances outdoors may be attributed to environmental factors (e.g., signal interference or reduced Wi-Fi range) and highlights a potential area for optimization. For large outdoor areas, improvements such as range extenders or stronger signal protocols may enhance performance.

4. CONCLUSION

This research successfully developed an IoT-based lighting control and monitoring system using an Android application, providing an effective solution to the challenges of traditional manual lighting methods. The system integrates a Wemos microcontroller with an ESP8266 Wi-Fi module, a photodiode light sensor, and a current sensor to enable real-time control and monitoring of lighting systems remotely.

The system demonstrated reliable performance in both indoor and outdoor environments at varying distances.Response times remained optimal (0.5 seconds) for distances up to 10 meters indoors and outdoors, but delays increased for distances beyond 10 meters outdoors, reaching up to 3 seconds at 20 meters. This indicates that the system is well-suited for small to medium-scale applications.

The Android application offered a user-friendly interface, enabling seamless control and real-time monitoring of the lights. Users could effectively manage the operational status of lights and detect failures, contributing to improved convenience and energy efficiency. By allowing remote control and real-time monitoring, the system reduces unnecessary energy consumption and facilitates timely maintenance. This aligns with sustainable technology goals.

The system's performance is dependent on stable internet connectivity, and response times are affected by increased distances in outdoor environments. Potential security concerns in IoT systems highlight the need for robust data protection measures.

Expanding the system's scalability to accommodate larger networks and implementing advanced security protocols can further enhance its functionality. The integration of machine learning to predict lighting needs based on user behavior and environmental factors could optimize energy use. Adding a battery backup to the microcontroller and sensors would ensure system reliability during power outages.

In conclusion, the proposed IoT-based lighting control and monitoring system offers a practical, efficient, and scalable solution for modern lighting applications. By addressing identified limitations and incorporating suggested improvements, this system can further contribute to advancements in smart home and community lighting technologies, paving the way for more sustainable and user-centric innovations.

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