MOTIVECTION
Journal of Mechanical Electrical and Industrial Engineering

Volume: 7, Number: 1, 2025
ISSN: 2655 – 7215 [printed]; 2685-2098 [online]
DOI: https://doi.org/10.46574/motivection.v7i1.424

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Development of an IoT-Based Smart Home Prototype Using the Blynk Application

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ABSTRACT

The advancement of Internet of Things (IoT) technology has enabled the development of smart home automation systems that enhance comfort, security, and energy efficiency. This study aims to design, develop, and evaluate an IoT-based smart home prototype utilizing the Blynk App for remote monitoring and control. The system consists of various components, including an ESP32 microcontroller, relays, and an LDR sensor, which facilitate both automatic and manual light control. A prototype development approach was employed, encompassing system design, implementation, and testing. The experimental results demonstrate that the smart home prototype operates efficiently, with an average response time of 73.4 ms, indicating fast and reliable system performance. The integration of Blynk Cloud security protocols further ensures secure device communication and real-time monitoring. This research provides a functional smart home prototype that can serve as a foundation for future smart home innovations. Moreover, the system's ability to optimize energy usage and improve user convenience highlights its potential impact on sustainable living and smart home advancements.

Keywords
Smart Home, Internet of Things (IoT), Blynk App, Automation, ESP32, Energy Efficiency

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Submitted : February 02, 2025. Accepted : February 24, 2025. Published : February 27, 2025

INTRODUCTION

Technological advancements in the era of globalization continue to evolve rapidly, driving individuals to innovate and develop new technologies. One such advancement is the Internet of Things (IoT), which enables devices to be connected and controlled remotely [1]. Busy schedules and time constraints often make it difficult for homeowners to monitor and manage electrical appliances, potentially leading to energy wastage and fire hazards caused by devices being left on unnecessarily [2][3].

The IoT concept extends the benefits of internet connectivity by keeping devices continuously linked. IoT functions by integrating devices so they can communicate and operate remotely without direct user interaction [4]. Smart homes are a key IoT innovation, where household appliances and systems are transformed into intelligent devices through chip-based technology integration [5]. With the support of the Blynk app, homeowners can remotely control lighting and other devices, offering convenience and efficiency in home automation [6].

The Blynk application features a simple and user-friendly interface [7]. It is compatible with iOS and Android devices and supports various internet-connected modules, making it highly adaptable for different applications [8]. In addition to the app, a microcontroller serves as the central control unit. The NodeMCU ESP-32 microcontroller acts as the system's core, receiving commands from the IoT network and transmitting signals to relays that regulate the

ON or OFF status of electrical devices. When the relay is activated (ON), power flows to the light, turning it on; when deactivated (OFF), the relay cuts power, turning the light off [9]. A high-precision Light Dependent Resistor (LDR) sensor is employed to automatically regulate lighting based on ambient light levels, ensuring efficient energy management [10].

This research is vital as the smart home concept offers multiple advantages, such as heightened convenience, augmented security, and enhanced energy efficiency. Key factors in creating a smart home system encompass accessibility, system adaptability, and streamlined control mechanisms [11]. The swift progression of information and communication technology has led to the widespread availability of numerous smart home products in the market, including Indonesia [12].

A comparison analysis with prior studies is essential to discern the strengths and limits of current smart home systems for this research development. A study entitled "Implementation of Internet of Things (IoT) Web Server for Smart Home" established a web server-based smart home system utilizing a local host and a LAN network for the management of home appliances [13]. A separate study, entitled "Utilization of Blynk Cloud Technology in a Smart Socket Control System for Home Lighting Based on an Android Application," effectively developed an IoT-driven lighting control system utilizing the Blynk application, facilitating both manual and automated operation through scheduled time modifications [14]. The study "Smart Home Application Using NodeMCU IoT for Blynk" introduced a comprehensive room control and monitoring system that includes lighting management, temperature surveillance, motion detection, and gas leak detection. This system employed three sensor types: a PIR sensor for motion detection, a MQ2 sensor for gas leak detection, and an LM35 sensor for temperature monitoring [15].

A smart home is an integrated system where multiple components interact dynamically, enabling devices and systems to communicate intelligently through the Internet of Things (IoT) [16]. IoT is a technological concept that allows devices, machines, and physical objects to connect to the Internet, facilitating autonomous data collection and management using sensors and actuators. This capability enables devices to collaborate and make independent decisions based on newly acquired information [17]. One of the most widely used IoT platforms for smart home applications is Blynk, which allows users to control devices such as Arduino, Raspberry Pi, and ESP32 via a smartphone app on Android or iOS. Blynk operates through three main components: the application, server, and library, with the Blynk server acting as a bridge between the smartphone and hardware to manage communication [18]. The ESP32 microcontroller, developed by Espressif Systems, serves as the core processing unit in many IoT applications due to its built-in WiFi and BLE modules, making it highly suitable for wireless communication and automation [19]. In addition, relay channels function as electronic switches, allowing a low-current signal to control high-power loads. A relay operates based on electrical and mechanical principles, where a magnetized coil moves a spring-loaded contact to open or close a circuit [20]. Meanwhile, an LDR (Light Dependent Resistor) sensor is utilized to detect light intensity by adjusting its resistance based on ambient lighting conditions. The darker the environment, the higher the resistance, whereas brighter light reduces resistance, making it an essential component for automatic lighting control [21].

The suggested smart home system presents a unique benefit above prior studies, since it can be operated both manually by the user and automatically based on sensor-detected data, eliminating the need for direct user participation. Access to the system is available through a website or smartphone via the Blynk platform. Nonetheless, a constraint of the Blynk program is its limited data streams, necessitating a membership for complete access, hence restricting data usage for non-premium users.

METHOD

Research Flow

The initial stage of this research involves a literature review, where references from previous studies are analyzed, as illustrated in Figure 1. Following this, a system needs analysis is conducted to determine the hardware and software requirements. The necessary components include:

1. Laptop (Windows 11)
2. Arduino IDE Software
3. Fritzing
4. Mikrokontroler ESP32 Devkit 01
5. Bread Board
6. Relay 4 channel
7. LDR Sensor

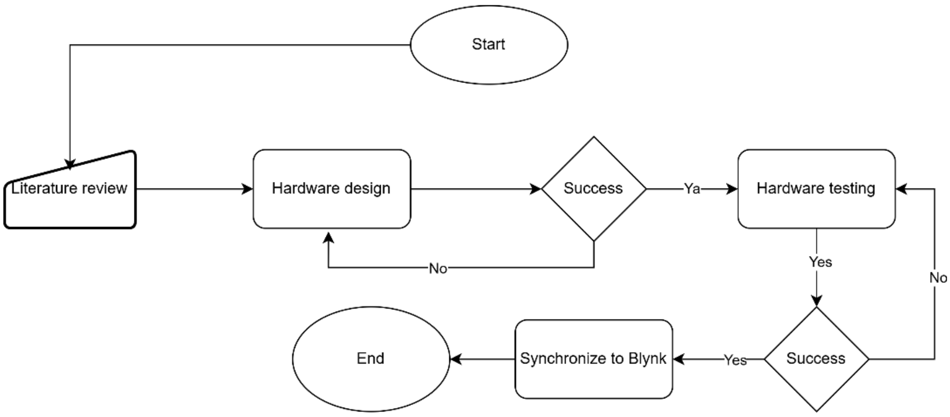

Figure 1. Research Flow

The subsequent phase focuses on system design and development. System testing is conducted over one day, within the time range of 05:00 - 19:00, and is performed in both closed and open room environments. The system is then integrated with the Blynk application, allowing users to remotely operate and monitor the system. Testing procedures include evaluating the LDR sensor performance, measuring response time within the Blynk application, and assessing relay functionality.

Circuit schematic

The circuit schematic that will serve as a reference for assembling the device can be seen in Figure 2.

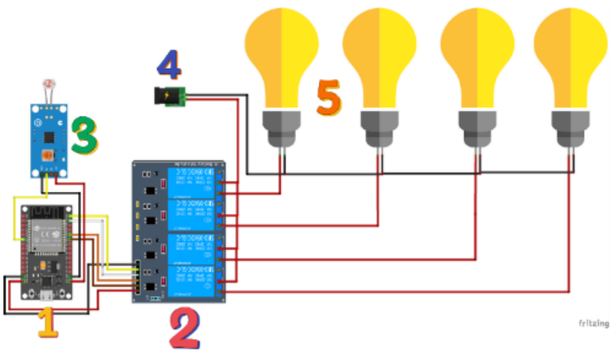

Figure 2. Schematic circuit

Description of the image in Figure 2:
1. ESP32 Devkit 01
2. Relay 4 channel
3. LDR Sensor
4. Power Supply
5. Light Lamps

Wiring

The prototype's circuit is designed according to a schematic diagram that integrates the ESP32 microcontroller, relay, and LDR sensor. Wiring connections detail is describe in Table 1 and Table 2

Table 1. Wiring ESP32 to Relay

ESP32	Relay	Description
GND	GND	Ground connection
VIN	VCC	5V power supply
D23	IN1	Control light 1
D22	IN2	Control light 2
D21	IN3	Control light 3
D19	IN4	Control light 4

Table 2. Wiring ESP32 to Sensor LDR

ESP32	LDR	Description
GND	GND	Ground connection
3V3	VCC	3V power supply
D32	A0	Reads light intensity

Project diagram

Figure 3 illustrates the programming of the ESP32 microcontroller via Arduino IDE, wherein the SSID and internet access password are configured. The Blynk program subsequently connects to the ESP32 via the authentication ID provided during the project's creation in Blynk. Upon successful connection, the components associated with the ESP32 can be remotely managed and observed using the Blynk program.

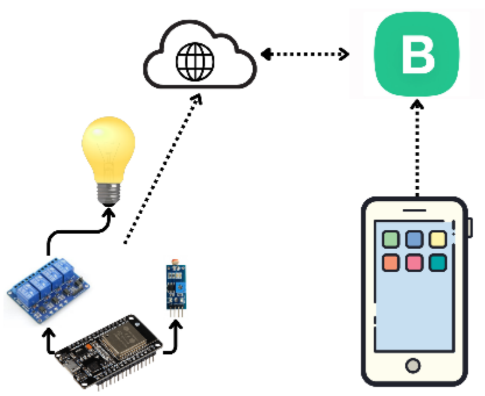

Figure 3. Project diagram

Flowchart System

The workflow of the automatic light control system using the LDR sensor is illustrated in Figure 4. If the LDR sensor detects a light intensity value exceeding 1400, it is classified as the onset of darkness, triggering the automatic activation of the light. All light and sensor conditions can be monitored and controlled remotely through the Blynk application, provided that the ESP32 microcontroller remains connected to the internet.

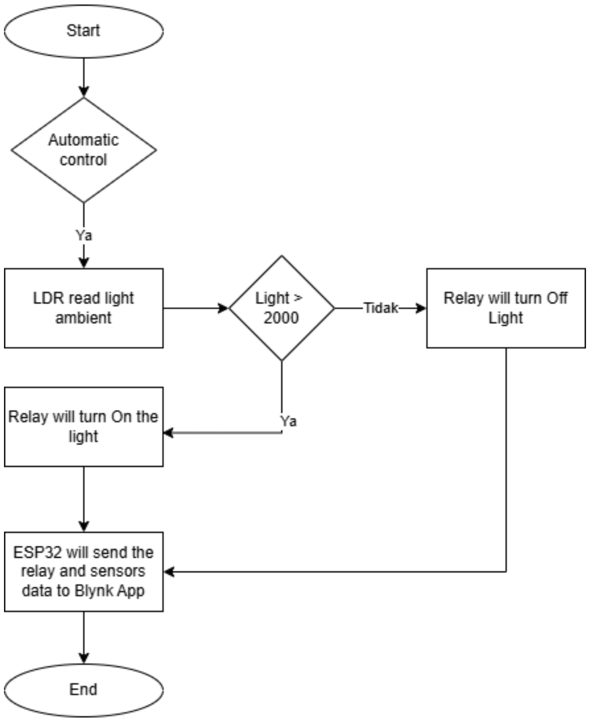

Figure 4. Light Control Using LDR Sensor

System workflow

1. Start
2. Initialize the LDR sensor pin as input.
3. Initialize relay (light) pin as output.
4. Set relay to OFF (HIGH).
5. Continuously repeat the following steps.
   a. Read the LDR sensor value.
   b. If the value < 1400, turn the light ON (set the relay to LOW).
   c. Otherwise, turn the light OFF (set the relay to HIGH)
   d. Display the sensor value and light status on the monitor.
   e. Wait a few milliseconds before reading the sensor again.
6. End

Figure 5 depicts the method for manual light control via the Blynk program. To activate or deactivate the lights, users merely need to tap the appropriate button in the Blynk program. using the "ON" button illuminates the light, whilst using the "OFF" button extinguishes it. The technology changes the light status in real-time, guaranteeing that the Blynk app accurately reflects the current state of the light for effective monitoring and control.

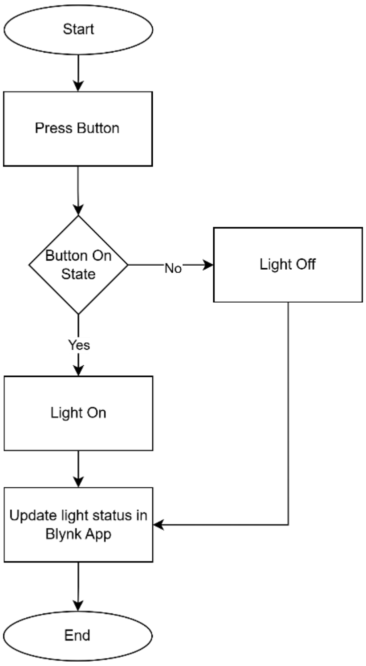

Figure 5. Manual Light Control

Workflow manual Light Control via Blynk App:

1. Start
2. Initialize Wi-Fi connection with SSID and password.
3. Connect to Blynk using an authentication token.
4. Set relay pin as output and turn it OFF by default (HIGH).
5. When a command is received from the Blynk app:
    a. Read the button status on the Blynk application (e.g., virtual button V1).
    b. If the button status is ON, turn the light ON.
    c. If the button status is OFF, turn the light OFF.
6. Continuously run Blynk to process commands.
7. End

RESULT AND DISCUSSION

Hardware implementation

The device assembly follows the configuration shown in Figure 2. Once properly installed, testing is conducted on both hardware and software components to ensure that all elements function correctly. As shown in Figure 6, the back view of the prototype highlights the ESP32 microcontroller, which serves as the system's core, a 4-channel relay responsible for controlling the lamp current, and an LDR sensor used to measure light intensity.

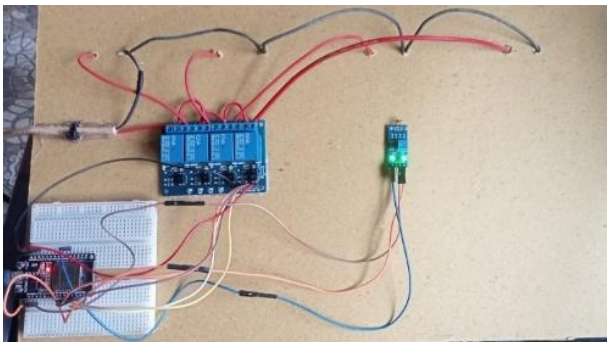

Figure 6. Back view of the Prototype

As shown in Figure 7, the front view of the prototype features four light lamps, which serve as the loads to be controlled. Lamp #1 operates automatically based on input from the LDR sensor; if the sensor detects a light intensity greater than 1400, the lamp turns on, indicating the onset of darkness. Meanwhile, Lamps #2, #3, and #4 are manually controlled via the Blynk application, allowing users to remotely switch them on or off as needed.

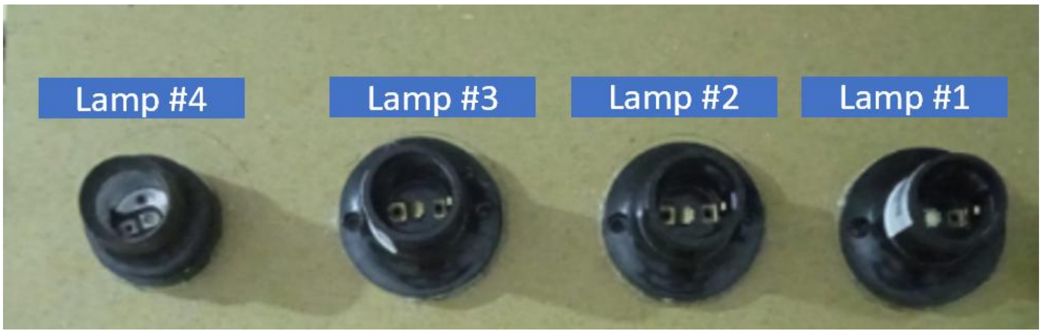

Figure 7. Front view of the Prototype

Software implementation

The Arduino IDE is utilized to program the microcontroller, functioning as the primary system controller. Prior to uploading the code to the microcontroller, it is imperative to install the requisite board and libraries, specifically the ESP32 board and the Blynk library, to guarantee optimal operation. Subsequent to finalizing the programming in the Arduino IDE, more setting is necessary within the Blynk application. This encompasses the configuration of Virtual Pins, facilitating data transmission between the application and the microcontroller through the Blynk server, as depicted in Figure 8.

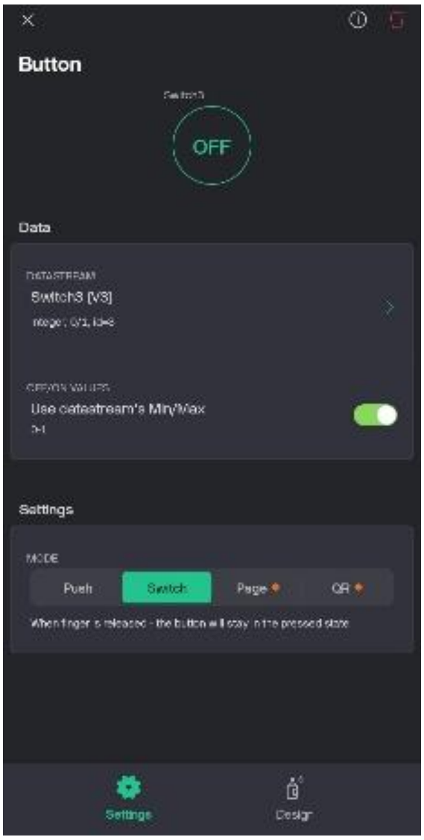

Figure 8. Virtual Pin Configuration in Blynk

A Token is necessary in the microcontroller program code to authenticate the device linked to the Blynk App. This authentication approach guarantees that only devices with a valid token can access and control other connected devices, thereby augmenting system security and thwarting illegal access, as seen in Figure 9.

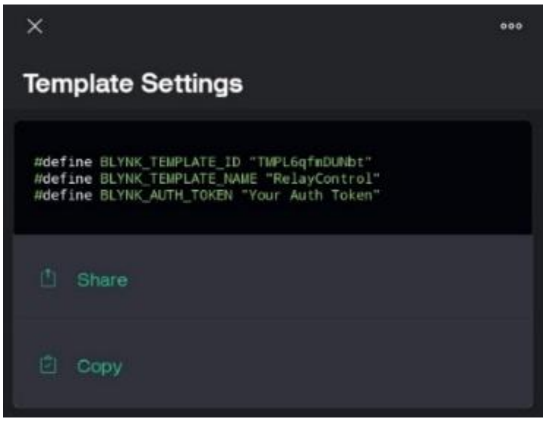

Figure 9. Template Settings Blynk

The regulation and oversight of lighting settings via the Blynk application, as seen in Figure 10, occurs subsequent to the completion of all setup phases. Switch 1 functions as a control for Lamp 1; when activated, the lamp illuminates, and when deactivated, the lamp extinguishes. Likewise, Switches 2, 3, and 4 regulate Lamps 2, 3, and 4, operating in an identical fashion—responding to the user's directive to activate or deactivate the lamps. A Gauge display provides real-time data from the LDR sensor, with a range of 0 to 4095, indicating light intensity values.

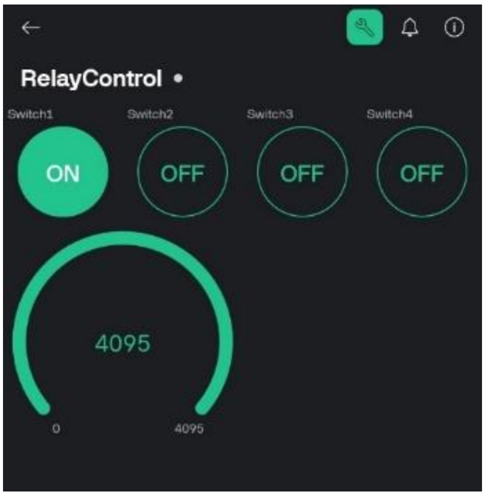

Figure 10. Display in the Blynk Application

Blynk.Cloud ensures security through multiple protective layers, including encrypted and secure messaging (except for hardware without TLS support), granular permissions to regulate device and data access, and mandatory email verification with an integrated authentication process. Its server architecture prevents unauthorized users from accessing devices within an organization's hierarchy. Each device is assigned a unique OAuth token and Product ID, ensuring restricted access within the organization. Additionally, continuous monitoring enables swift detection and response to potential security threats. Blynk primarily utilizes industry-standard security protocols, with TLSv1.3 as the default encryption method or

TLSv1.2 for systems that do not support the latest version. These measures reinforce data integrity, confidentiality, and access control, ensuring a secure and reliable IoT ecosystem.

Testing

System testing involved monitoring hardware functionality to ascertain the proper operation of all components. The conducted tests indicated that the device operated as anticipated, validating its functionality. Table 3 shown response time of the system.

Table 3. Response time system

Number of trials	Sending time	Received time	Response time (ms)
1	23:11:39	23:11:40	100
2	23:11:49	23:11:49	71
3	23:11:59	23:11:59	68
4	23:12:09	23:12:09	67
5	23:12:19	23:12:19	72
6	23:12:29	23:12:29	68
7	23:12:39	23:12:39	69
8	23:12:49	23:12:49	67
9	23:12:59	23:12:59	73
10	23:13:09	23:13:09	67
Average value			**73.4**

The system testing results for data transmission via the Internet of Things (IoT) indicate a minimal time delay. The average data reception speed of the Blynk App from the NodeMCU ESP32 was recorded at under 1 second, which is categorized as very fast, with no noticeable delay in data reception [22].

The ESP32 microcontroller reads ADC (Analog to Digital Converter) values ranging from 0 to 4095, where lower values indicate brighter light conditions, and higher values correspond to darker environments. To accurately determine light intensity levels, the ADC readings from the LDR sensor must be converted into percentage values using Equation 1

$$ADC\% = 1 - \frac{ADC\ Value - ADC\ Min}{ADC\ Max - ADC\ Min}\ x\ 100\% \quad (1)$$

The formula converts the maximum ADC value (4095) to 0% and the minimum value (0) to 100% [23]. Under real-world conditions, a value of 2000 serves as the threshold distinguishing between bright and dark conditions [24]. A light intensity reading above 51% indicates bright conditions, while a reading below 51% signifies darkness.

As shown in Table 4, testing results indicate that between 07:00 and 17:00, light intensity levels range from 96% to 82%, signifying daylight conditions, keeping the light OFF. Meanwhile, between 18:00 and 06:00, light intensity levels range from 63% to 11%, indicating darkness, causing the light is ON automatically.

Table 4. LDR Sensor testing

Time	Sensor value	Lamps condition	Light percentage
05:00	3677	ON	11%
06:00	2879	ON	29%
07:00	404	OFF	90%
08:00	170	OFF	95%
09:00	167	OFF	95%
10:00	159	OFF	96%

Time	Sensor value	Lamps condition	Light percentage
11:00	162	OFF	96%
12:00	153	OFF	96%
13:00	267	OFF	93%
14:00	293	OFF	92%
15:00	174	OFF	95%
16:00	276	OFF	93%
17:00	712	OFF	82%
18:00	1513	OFF	63%
19:00	3514	ON	14%

As shown in Table 5, the Blynk application features four switches, all of which function correctly according to the given commands. Additionally, the Gauge display accurately reflects real-time light intensity values, providing a precise representation of ambient light conditions throughout the day. Figure 11 shown the prototype test result when all the lamps are ON.

Table 5. Testing the Blynk Application's Response to the Device

Testing	Response	Describe
Switch1	Give Lamp #1 Status	Good
Switch2	Controlling Lamp #2	Good
Switch3	Controlling Lamp #3	Good
Switch4	Controlling Lamp #4	Good
Gauge	Show light intensity	Good

Figure 11. Prototype result

CONCLUSION

This study effectively created and developed an IoT-based smart house prototype using the Blynk App, incorporating four bulbs, a 4-channel relay, and an LDR sensor. The trial findings validate that the prototype functions efficiently, enabling both automated and human management of house lighting using the Blynk application. The LDR sensor-driven automation system precisely identifies fluctuations in light intensity, optimizing energy use by operating lights alone when required. Furthermore, manual control via the Blynk App offers customers remote access and monitoring functionalities, hence augmenting ease and flexibility. The system testing findings indicate a rapid response time, with an average data reception latency of under one second, rendering it appropriate for real-time applications. Additionally, the security attributes of Blynk.Cloud, encompassing encrypted communication and access control measures, guarantee the system's dependability and safeguard against unwanted access.

This research successfully designed and developed an IoT-based smart home prototype using the Blynk App, incorporating four lamps, a 4-channel relay, and an LDR sensor. The results demonstrate that the smart home prototype functions effectively, enabling both automatic and manual control and monitoring of home lighting through the Blynk App. For future work, it is recommended that this research be implemented on a larger scale. Additionally, future developments should integrate other IoT features such as voice assistants, security cameras, motion sensors, and other smart home automation technologies to enhance functionality, security, and user convenience.

Future endeavors should involve expanding the implementation to a more extensive smart home setting and investigating supplementary IoT functionalities, like voice assistants, security cameras, motion sensors, and integrated home automation systems. These enhancements would augment functionality, security, and user convenience, rendering the system more adaptable and responsive to contemporary smart home demands.

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