

## Research Article

# Enhancement of Wireless Lighting Control System

Joseph C. Attachie , George Owusu , and Shiphrah O. Adu 

Department of Electrical and Electronic Engineering, University of Mines and Technology, Tarkwa, P. O. Box 237, Ghana

Correspondence should be addressed to George Owusu; gowusu-223@ieee.org

Received 21 July 2021; Accepted 20 September 2021; Published 5 October 2021

Academic Editor: Jit S. Mandeep

Copyright © 2021 Joseph C. Attachie et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The rapid increase in wireless technology has enormously increased wireless control of lighting system in residential, commercial, and industrial settings of many countries across the world. However, this system lacks troubleshooting interface, making it very difficult for the identification of faults in the lighting system. This paper therefore seeks to improve on the wireless lighting system by incorporating into the system two types of sensors such as the current sensor and light dependent resistance (LDR). The current sensor is functioned to determine fault in power supply, whilst the LDR determines fault due to damage in the AC lamp. The proposed system was first simulated with Proteus software to observe the set objectives. A successful simulation resulted in the implementation of the system. The results discussed prove that incorporating wireless technology with current sensor and LDR will make troubleshooting easy and effective when the need arises.

## 1. Introduction

Automation of lighting system has become undoubtedly an essential utility in residential and industrial settings. This type of system enhances the ease in controlling the lighting system. Moreover, automation of lighting system enhances security in residential and industrial settings [1]. The increase in the automation of lighting system is due to the rise in wireless communication technology.

Wireless communication technology is a medium for transmitting information from one device to another [2]. Essential wireless communication technology include microwave radio, Zigbee, Bluetooth, satellite communication, broadcast radio, Wi-Fi, Global Positioning System (GPS), and Global System for Mobile Communication (GSM). Researchers always focus on the cost, efficiency, and the size in choosing the type of communication technology to implement the system.

This research work focuses on enhancing automatic lighting system with sensors. Additionally, light dependent resistor (LDR) and ACS712 current sensors were added to the wireless technology system. These new features of the system enhance effective maintenance when the need arises.

## 2. Theoretical Framework

*2.1. Communication Technology.* This section of the paper discusses the essential communication technologies used in designing an automatic lighting system. The wireless technologies discussed under this section include Zigbee, IoT, Bluetooth, and GSM module.

*2.1.1. Zigbee Technology.* Zigbee is a wireless personal area network (WPANs) technology, which operates on IEEE 802.15.4 at a frequency of 868 MHz, 902–928 MHz, and 2.4 GHz [3]. The Zigbee technology makes use of digital radio to enhance the transmission of information from one device to another. This type of communication technology is usually preferred because of its low cost and low battery consumption. Moreover, it has the ability to create up to 65,000 nodes per network. However, with respect to the Wi-Fi technology, Zigbee is not secured. In addition, this technology has a limited distance compared with the GSM technology. Figure 1 shows an image of Zigbee module.

*2.1.2. Internet of Things.* Internet of Things (IoT) refers to the devices across the world, which are connected to the



FIGURE 1: Image of Zigbee technology module.

Internet for collecting and sharing data [4]. ESP8266 module is usually connected to the Arduino Uno to enable the Internet connection. The use of IoT enhances the storing of information on cloud. However, there is a high risk with privacy and security. There might be a leakage of important data to a third party when using IoT. Moreover, hackers can hack into the cloud to retrieve important data. Figure 2 shows an image of ESP8266 module.

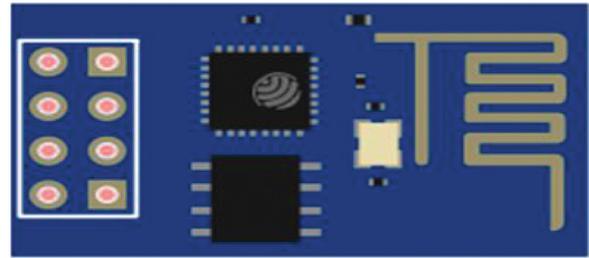


FIGURE 2: Image of ESP8266 module.

**2.1.3. Bluetooth.** Bluetooth is a high-speed short-range technology, which connects phones and other portable equipment together for information transfer [5, 6]. It operates within a frequency band of 2.45 GHz. One main advantage of Bluetooth is that it has low power consumption (at about 0.3 mW). However, the distance needed to control the lighting system is very short compared to other wireless communication technologies. Figure 3 shows an image of a Bluetooth module.

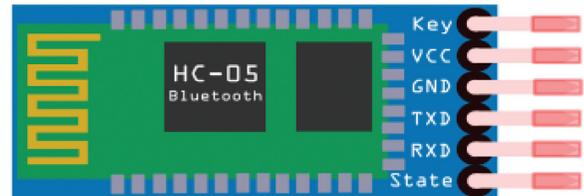


FIGURE 3: Image of Bluetooth module.

**2.1.4. Global System for Mobile Communication Module.** The Global System for Mobile Communication (GSM) is a digital cellular wireless technology, which is used for transmitting mobile voice and data services [7]. This type of technology operates at a frequency band of 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz. Modern GSM technology provides high-speed data transfer. However, this technology uses pulse-based burst transmission which interferes with certain electronics. Therefore, locations such as hospitals, petrol bunks, and airplanes do not encourage the use of GSM-based mobile. Figure 4 shows an image of GSM module.

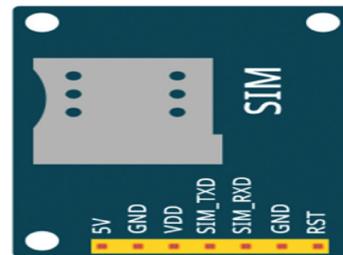


FIGURE 4: Image of GSM module.

**2.2. Related Works.** Taştana and Gökoza implemented an Internet of Things (IoT) based air conditioning and lighting control system for smart homes [8]. The work aimed at providing a comfortable and smart way of controlling air conditioning and lighting system. It was achieved with Arduino Pro Mini, NodeMCU embedded system micro-controller, and Blynk iOS/Android interface developer. This research work succeeded in controlling home appliances and devices with a mobile phone or tablet. However, the system has no interface to diagnose fault condition when the need arises.

A group of researchers designed an efficient smart home management system with IoT [9]. The work focused on

enhancing the security and efficiency of an IoT-based smart lighting system. It was achieved with the Secure Hash Algorithm 256 (SHA-256). The researchers succeeded in contributing to knowledge by implementing the system with a piece of hardware, a server with high security, and a web application. Although the research work was successful, yet there was no interface to diagnose fault condition for easy repair and maintenance.

Swamy et al. also implemented a smart home lighting system [10]. The work aimed at developing a flawless smart home helper to operate home appliances easily through voice command. It was achieved with both hardware and software components possessing a speech recognition module. The speech recognition module was implemented with natural language processing (NLP). Although the system improved wireless lighting system, there was no fault detection interface to diagnose fault in appliance. Hence, diagnosing of fault in appliances becomes difficult when the need arises.

Lee et al. developed a residential lighting control system with Zigbee wireless technology [11]. The work aimed at reducing the power consumption of residential lighting system. It was achieved by integrating Zigbee wireless technology into the lighting control system. The proposed system was able to save the electrical energy up to around 11.81%. However, the system lacked the ability to diagnose fault in appliances.

A team of researchers implemented an automatic lighting and control system for classrooms [12]. The work focused on eliminating the attitude of leaving the appliances in a classroom ON when no one is available. This was achieved using Arduino Uno, Bluetooth module, and a voice-controlled module. The system was implemented and used in a classroom. However, the system has no interface to diagnose faults in appliances during fault condition.

### 3. Methods Used

The proposed system was first designed with Proteus software before its implementation. This was to avoid the waste of money in buying irrelevant electronic components. A block diagram was designed to serve as a guide in simulating the proposed design. Figure 5 shows the block diagram of the proposed design.

Considering Figure 5, as current flows from the AC power supply to the lamp, part of the current is fed to the microcontroller through the current sensor. The light dependent resistor (LDR) sensor also monitors the brightness of the room and sends results in a form of electrical signal to the microcontroller. The microcontroller processes the input signal from the current and the LDR sensor to provide feedback to the user. The feedback to the user is transferred wirelessly through a wireless technology. The microcontroller receives its power supply from a rectified 5VDC output. The user wirelessly controls the state of the relay through the wireless technology and the microcontroller.

**3.1. Selection of Components.** Selection of components was based on cost, efficiency, and availability. Current sensor, LDR sensor, and Atmega328p-pu microcontrollers were among the key components considered for the design.

**3.1.1. ACS712 Current Sensor.** ACS712 current sensor is a fully integrated indirect current sensor that is used in detecting the amount of current flow from an electrical source to a load. The principle of operation of ACS712 current sensor is based on Hall Effect. The Hall Effect sensing method detects the presence of magnetic field as current flows through the sensor. This is followed by the generation of a proportional analog output voltage at the output terminal of the sensor. The output voltage signal is then transferred to a connected microcontroller for processing. Figure 6 shows an image of an ACS712 current sensor module.

**3.1.2. Light Dependent Resistor.** Light dependent resistor (LDR), also known as photocell or photoresistor, is a passive electronic component, which increases or decreases its resistance based on the light intensity. An increase in the light intensity decreases the resistance of the LDR, whilst a decrease in the light intensity increases the resistance of the LDR. The LDR present in the circuit was responsible to transfer a proportional analog current signal to the

microcontroller based on the amount of light intensity detected. Figure 7 shows an image of an LDR.

**3.1.3. Atmega328p-pu Microcontroller.** Atmega328p-pu is an 8-bit RISC processor core microcontroller based on modified Harvard architecture. The main function of the microcontroller is to control the relay based on the input signal from the user. Moreover, it aids in detecting faults by monitoring current flow of the power supply, as well as the light intensity of the lamp. The microcontroller receives proportional analog voltage signal from the current sensor and converts it to a digital signal by the principle of the following equations:

$$V_{p-p} = \frac{ADC_{max} - ADC_{min}}{2^{10}} \times V_{ref}, \quad (1)$$

$$V_{rms} = \left( \frac{V_{p-p}}{2} \right) \left( \frac{1}{\sqrt{2}} \right), \quad (2)$$

$$I_{rms} = \frac{V_{rms}}{R}, \quad (3)$$

where

$V_{p-p}$  = peak-to-peak voltage

$V_{rms}$  = RMS voltage

$I_{rms}$  = RMS current

$V_{ref}$  = analog reference voltage input

$R$  = sensitivity of current measured in ohms

$ADC_{max}$  = maximum ADC value based on the input of the current sensor

$ADC_{min}$  = minimum ADC value based on the input of the current sensor

Concerning the light intensity, the microcontroller converts the analog output voltage of the LDR (ranging from 0 V to 5 V) to digital value ranging from 0 to 1023. The higher the intensity of the light, the higher the digital value of the output voltage of the LDR sensor.

## 4. Results and Discussion

**4.1. Results of Simulation.** The proposed system was simulated with Proteus software to observe its response to the set objective. Figure 8 shows the system's design on the software.

With reference to Figure 8, the design has three main sections, that is, the controller circuit, the main circuit, and the receiver. The main circuit mainly consists of a 220 V/ 50 Hz AC voltage source, which supplies power to a 60 W AC lamp. The power supply flows through a Single Pole Single Throw (SPST) control switch (the control switch is used to introduce fault into the system), the relay, and the current sensor. The controller circuit controls the 5 V input electromagnetic relay to determine the state of the AC lamp. Moreover, it monitors the state of the main circuit by receiving signal from the 20 A current sensor and a 100 mW

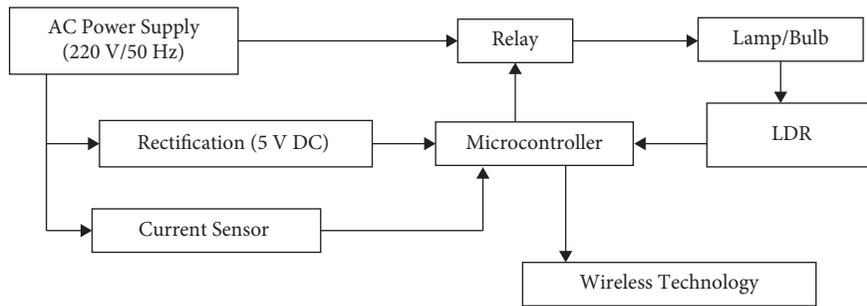


FIGURE 5: Block diagram of the proposed system.



FIGURE 6: Image of an ACS712 current sensor module.

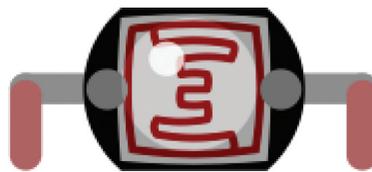


FIGURE 7: Image of an LDR.

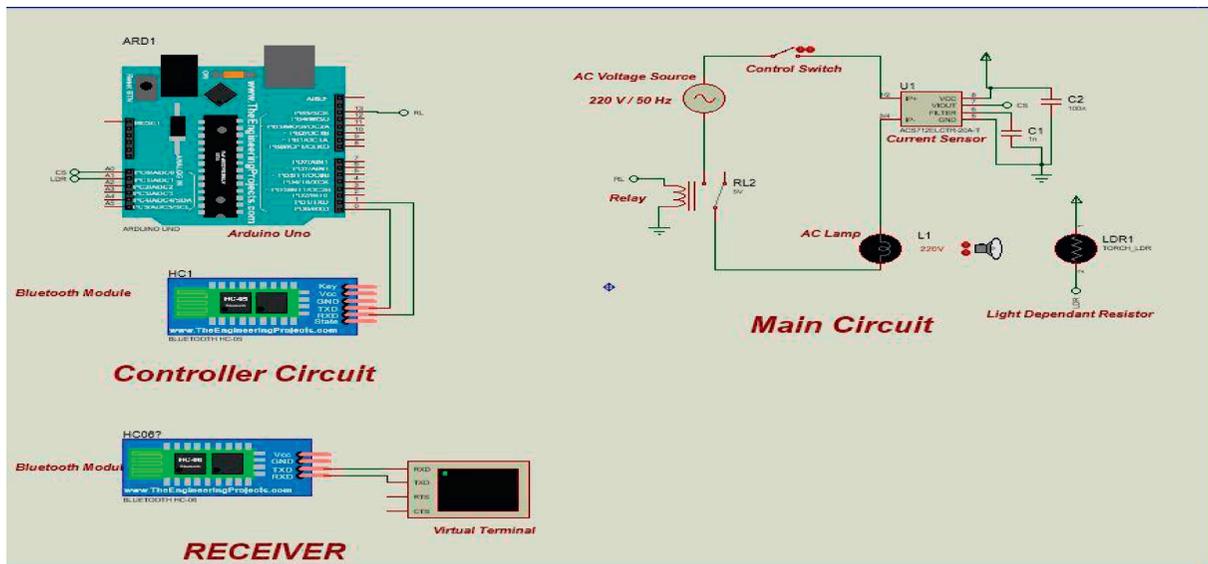


FIGURE 8: Design of the proposed system.

LDR with 540 nm spectral peak value. The “receiver” circuit controls the relay of the main circuit through the controller circuit. During fault condition, the virtual terminal also displays the type of fault in the system based on the communication signal from the control circuit to the “receiver” circuit.

The run button of the software was pressed to begin the observation under normal state condition. After pressing on the run command, the virtual terminal appeared on the screen, as shown in Figure 9. An “ON” command was then input at the virtual terminal dialogue area to turn on the relay.

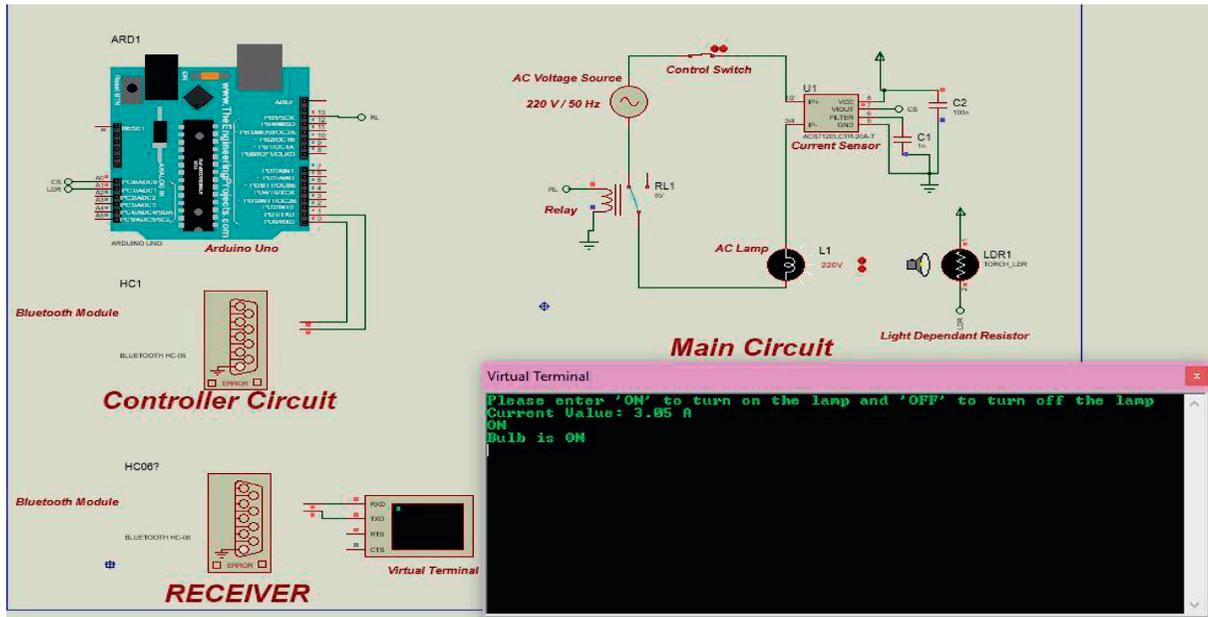


FIGURE 9: Operation of design under normal state condition.

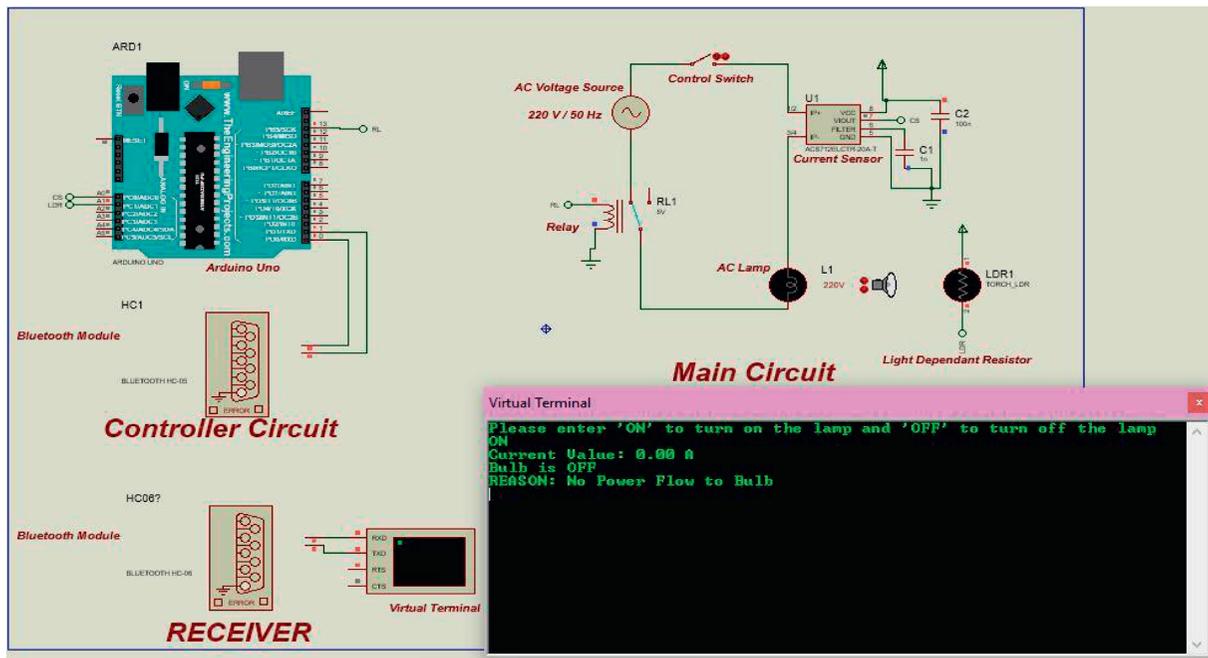


FIGURE 10: State of design with a faulty power supply.

Succeeding the normal state condition, the control switch was opened to indicate a fault in the power supplied to the AC lamp. Figure 10 shows the state of the device during a fault in the power supply.

With reference to Figure 10, after sending the “ON” command, feedback was displayed on the virtual terminal. The feedback displayed on the virtual terminal indicated that current was not flowing from the AC source to the load. Hence, the lamp went OFF.

The control switch was closed again to correct fault in the power supply. However, the resistance of the AC lamp was increased to a very high value to indicate a fault in it. Figure 11 shows the state of the design with a damaged AC lamp.

Although current flowed to the AC lamp, its high resistance caused it to remain OFF. The LDR detected its OFF state and transferred the information to the “receiver” through the controller circuit. This was then displayed on the virtual terminal.

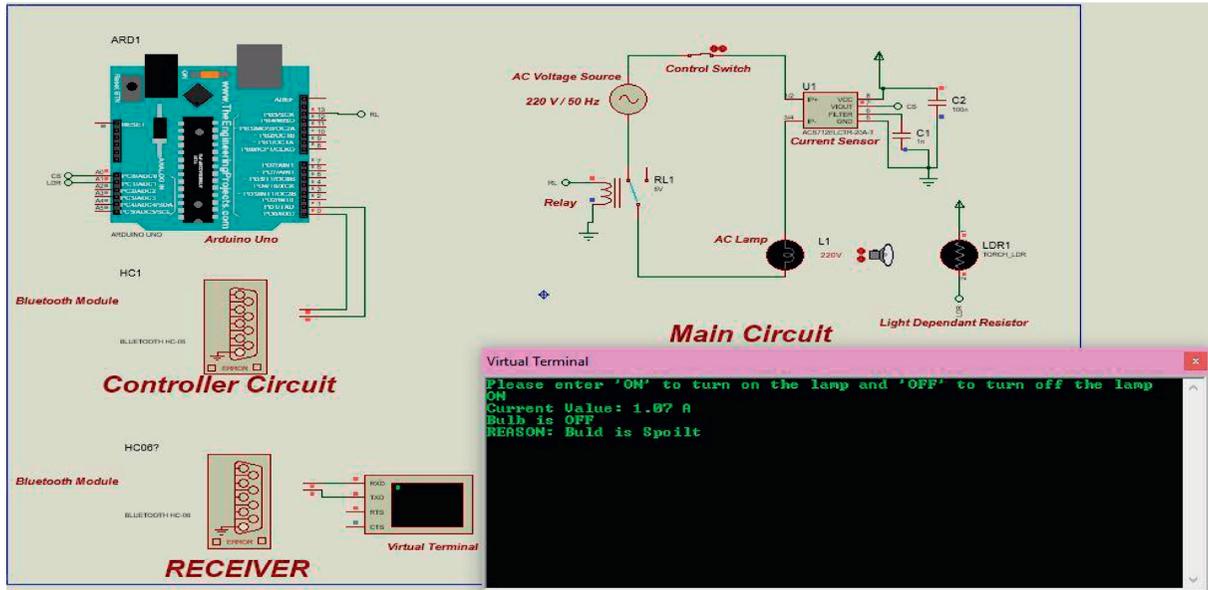


FIGURE 11: State of design with a faulty AC lamp.

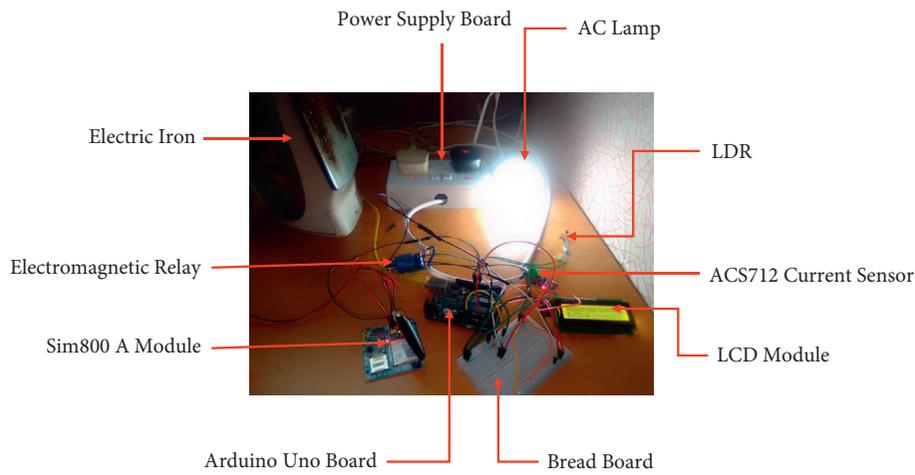


FIGURE 12: Implementation of the proposed system.

TABLE 1: Cost analysis of the proposed system

Quantity	Component	Cost in USD (\$)
1	Arduino Uno board	3.42
1	ACS712 current sensor	1.00
1	Light dependant resistor	0.20
1	16 × 2 LCD module	1.67
1	Sim800A	5.80
1	Electromagnetic relay	1.00
<b>Total</b>		<b>13.09</b>

4.2. *Implementation of Proposed System.* The successful output of the simulation resulted in the implementation of system. A prototype of the system was implemented and tested to observe its response to fault condition. The output of the implementation proved that the system has the ability to notify users during fault condition in home lighting system. Figure 12 shows the process of the implementation.

4.3. *Discussion of Results.* Based on the observed results, it can be deduced that the system has the ability to detect two main types of faults in the wireless lighting system, that is, a fault in the power supply and the AC lamp.

A comparison was made with the reviewed studies at Section 2.2 to determine the novelty of the proposed system [8–12]. The results of the comparison indicate additional

features have been added to the wireless lighting system, that is, the current sensor and the LDR. Moreover, the system's ability to detect fault from the power supply and the AC lamp is distinct. The two additional features of the wireless lighting control system ease troubleshooting fault condition. Hence, there is an ease with corrective maintenance when the need arises.

**4.4. Cost Analysis.** The cost of components that were purchased to realize the implementation of the system was analyzed. Based on the analysis in USD, it can be stated that improving the wireless lighting system will negligibly affect cost. Table 1 shows the output of the cost analysis.

The cost of the proposed system was compared to available wireless systems on sale [13, 14]. The comparative cost analysis proves that the system will be affordable when produced in a large quantity.

## 5. Conclusion

The paper has presented a modified wireless home lighting system for residential buildings. The new approach aids in troubleshooting two main types of faults that usually occur in the system, that is, fault in the power supply and fault due to damage in the AC lamp. This was realized with the aid of a current sensor and an LDR. Modifying the wireless lighting system with these two types of sensors will make troubleshooting easy and effective when the need arises.

## Data Availability

Microcontroller codes for the proposed system can be accessed at <https://github.com/GeorgeOwusu223/Wireless-System>.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

## References

- [1] Master Administrator, "4 Ways to Enhance Your Security with Smart Lighting," Lavishautomation.com, 2020, <https://www.lavishautomation.com/blog/item/4-ways-to-enhance-your-security-with-smart-lighting>.
- [2] Types of wireless communication: advantages and disadvantages," ElProCus-Electronic Projects for Engineering Students, 2014, <https://www.elprocus.com/types-of-wireless-communication-applications/>.
- [3] ZigBee technology: architecture, working and its applications," ElProCus-Electronic Projects for Engineering Students, May 09, 2014, <https://www.elprocus.com/what-is-zigbee-technology-architecture-and-its-applications/>.
- [4] S. Ranger, *What Is the IoT? Everything You Need to Know about the Internet of Things Right Now*, ZDNet, <https://www.zdnet.com/article/what-is-the-internet-of-things-everything-you-need-to-know-about-the-iot-right-now/>, 2020.
- [5] Bluetooth technology: working, advantages and applications," ElProCus-Electronic Projects for Engineering Students, 2015, <https://www.elprocus.com/how-does-bluetooth-work/>.
- [6] How does Bluetooth work?," Scientific American, Nov. 05, 2007, <https://www.scientificamerican.com/article/experts-how-does-bluetooth-work/#:~:text=Bluetooth%20technology%20is%20a%20short,using%20the%20same%20core%20system>.
- [7] GSM-Overview-Tutorialspoint," Tutorialspoint.com, 2021, [https://www.tutorialspoint.com/gsm/gsm\\_overview.htm](https://www.tutorialspoint.com/gsm/gsm_overview.htm).
- [8] M. Taştan and H. Gökozan, "An internet of Things based air conditioning and lighting control system for smart home," *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, vol. 50, no. 1, pp. 181-189, 2018.
- [9] T. A. Khoa, L. M. B. Nhu, H. H. Son et al., "Designing efficient smart home management with IoT smart lighting: a case study," *Wireless Communications and Mobile Computing*, vol. 2020, Article ID 8896637, 18 pages, 2020.
- [10] S. R. Swamy, K. N. Prasad, and P. Tripathi, "Smart home lighting system," in *Proceedings of the 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC)*, pp. 75-81, IEEE, Aurangabad, India, October 2020.
- [11] J. S. Lee, M. J. Chung, and Y. H. Sun, "Development of residential lighting control systems using zigbee wireless technology," in *Proceedings of the 2017 12th IEEE Conference on Industrial Electronics and Applications (ICIEA)*, pp. 133-136, IEEE, Siem Reap, Cambodia, June 2017.
- [12] S. Suresh, H. N. S. Anusha, T. Rajath, P. Soundarya, and S. P. Vudatha, "Automatic lighting and control system for classroom," in *Proceedings of the 2016 International Conference on ICT in Business Industry & Government (ICTBIG)*, pp. 1-6, IEEE, Indore, India, November 2016.
- [13] Amazon.com: Home Automation," Amazon.com, 2021, [https://www.amazon.com/s?k=home+automation&ref=nb\\_sb\\_noss\\_2](https://www.amazon.com/s?k=home+automation&ref=nb_sb_noss_2).
- [14] Home Automation - Buy Home Automation with Free Shipping on AliExpress," Aliexpress.com, 2021, [https://www.aliexpress.com/wholesale?catId=0&initiative\\_id=SB\\_20210917103458&SearchText=home+automation](https://www.aliexpress.com/wholesale?catId=0&initiative_id=SB_20210917103458&SearchText=home+automation).