

Smart Lighting and Energy Management System Using Visitor Counter Based on IoT

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Abstract

This project explores the development of a Smart Light Energy Management system utilizing a visitor counter based on IoT technology. The increasing demand for energy-efficient solutions in modern buildings underlines the need for intelligent systems capable of optimizing energy consumption. Traditional lighting systems often lead to unnecessary energy usage due to manual operation and lack of integration with occupancy detection. The primary objective of this project is to design and implement an automated lighting control system that turns lights on or off based on real-time visitor counts. The methodology involves using a Durian Uno V3 microcontroller, IR infrared sensors for detecting visitor entry and exit, a relay module for light control, and an LCD I2C display for real-time status updates. The system also integrates with the Blynk app for remote monitoring and control. The novelty of this project lies in its simple yet effective approach to energy management, combining affordable components with IoT capabilities to create a responsive and user-friendly solution. The benefits to society include reduced energy wastage, lower electricity costs, and a step towards more sustainable building management practices.

1. Introduction

Energy conservation minimizes electricity consumption to preserve energy. This approach necessitates the preservation of energy and offers a rapid return on investment with very low initial expenses. Energy conservation in residential, industrial, and agricultural sectors is feasible [1]. The project aims to automate and minimize human interaction to conserve electricity. Cloud computing and the Internet of Things (IoT) enable remote management of numerous devices and appliances. The utilization of IoT technology has the potential to enhance conventional energy systems to a greater extent than renewable energy sources [1]. Smart load control utilizes IoT technology to optimize electricity use and enhance customer satisfaction. To conserve electricity, the suggested approach automates the process of turning off lights when a room is sufficiently illuminated or unoccupied [2]. This project aims to tackle the issue of excessive energy use in public bathrooms, specifically focusing on the Block QA Toilet. The problem lies in the use of inefficient lighting systems that remain switched on in empty restrooms. Traditional lighting systems inefficiently consume energy by failing to adjust to varying demands. Bathrooms are particularly impacted because of their uneven utilization. Consequently, the lights remain illuminated even when they are not being used, resulting in the unnecessary use of energy and the subsequent escalation of expenses. This system utilizes real-time occupancy data from sensors to optimize lighting and maximum energy efficiency. The technology employs automated human identification and intelligent activation and deactivation mechanisms to exclusively illuminate the lights when the restroom is being used,

hence conserving energy [3]. The initiative provides illumination that adjusts based on occupancy to enhance user comfort. The suggested system will utilize Arduino microcontrollers and advanced sensors to recognize guests and automatically alter lighting. The real-time monitoring and control system is designed to provide sustainable and cost-effective lighting [4]. A cloud-based or centrally networked intelligent lighting system enables the remote management and supervision of lighting. The recent surge in the popularity of smart lighting solutions demonstrates its promise as a foundational element of the Internet of Things (IoT) architecture. These solutions have the potential to substantially reduce energy expenses for residential, commercial, and industrial purposes [5].

Comparison of four lighting technologies (Halogen, CFL, LED, and Smart LED) based on several features are found in [6]. The investigation shows that regular and smart LEDs are the most energy-efficient, with the highest efficacy and longest lifespans. User control is increased by smart LEDs' ability to dim and change colour temperature. Although halogens have a high power factor, clever LEDs use power efficiently. In conclusion, LED and smart LED lighting improve energy efficiency, lifespan, and user flexibility. The smart home trend and the expected increase in smart home devices between 2022 and 2027 can be found in [7]. Smart speakers, security cameras, big appliances, minor appliances, and smoke alarms are examples. Smart lighting, thermostats, and plugs are examples of smart small appliances. These appliances improve energy economy and control activities, making them essential to home automation. As for the Energy Management System, the popularity of clever small appliances shows a growing need for smart technologies that increase home management and energy efficiency. Smart lighting and energy management systems with visitor counting mechanisms are included in this category of smart small appliances. This system analyzes real-time occupancy data to dynamically adjust lighting and energy usage via IoT. Only using electricity as needed ensures energy efficiency. The monthly decrease in energy use, measured in kilowatt-hours (kWh), over a span of four months can be seen in [8]. The data indicates a gradual increase in energy savings over a specific duration, with savings commencing at 500 kWh in January and peaking at 750 kWh in April. The data indicates that the energy management system powered by the Internet of Things (IoT) has a positive impact on reducing energy consumption in the warehouse. The use of Internet of Things (IoT) devices in smart homes greatly improves energy efficiency through the automation and remote control of lights and other household operations. These intelligent systems enhance the efficiency of resource utilization and minimize energy consumption by promptly adapting to current conditions. Smart lighting systems, for example, regulate their output by considering the presence of natural light and occupancy, thereby reducing energy wastage [9]. LED technology usage in these systems enhances energy savings by consuming less power and providing more efficiency compared to conventional lighting solutions [10]. This project uses a variety of components, including the ESP-01 WiFi Serial Transceiver Module (ESP8266), Durian Uno V3, IR Infrared Sensor Modules, and the Blynk software, to create an automatic and effective energy management system. The device uses infrared sensors to detect the presence of guests and adjusts the illumination accordingly. Data is sent to the Blynk app for monitoring and control, ensuring that energy is only utilized when required.

2. Research Methodology

2.1 Proposed Design

The system is designed based on the proposed diagram depicted in Fig. 1. The central component of the system is the Durian Uno V3 microcontroller, which manages tasks such as visitor counts, lighting control, and data exchange. Two infrared (IR) sensor modules are used to identify when visitors enter and exit the bathroom. These sensors accurately count the number of persons present in the toilet at any given time. The real-time data is essential for regulating the 5V LED, which serves as the main source of illumination. A Liquid Crystal Display (LCD) with an Inter-Integrated Circuit (I2C) interface is used to display the current number of visitors and the status of the system in real time. This display provides instant feedback to both users and maintenance professionals. The ESP-01 WiFi Serial Transceiver Module (ESP8266) enables effortless communication with the Blynk server, enabling remote monitoring and control through the Blynk app. This integration of Internet of Things (IoT) technology allows for remote management of the system, hence improving the overall user experience. During the initialization process, the microcontroller initiates the activation of all components and commences the monitoring of visitor traffic using the IR sensors. The microprocessor continuously updates the visitor count and adjusts the LED based on the presence or absence of individuals, ensuring that the lights are only activated when necessary, hence minimizing energy use. The instantaneous data is shown on the Liquid Crystal Display (LCD) and sent to the Blynk server for remote retrieval through the Blynk application.

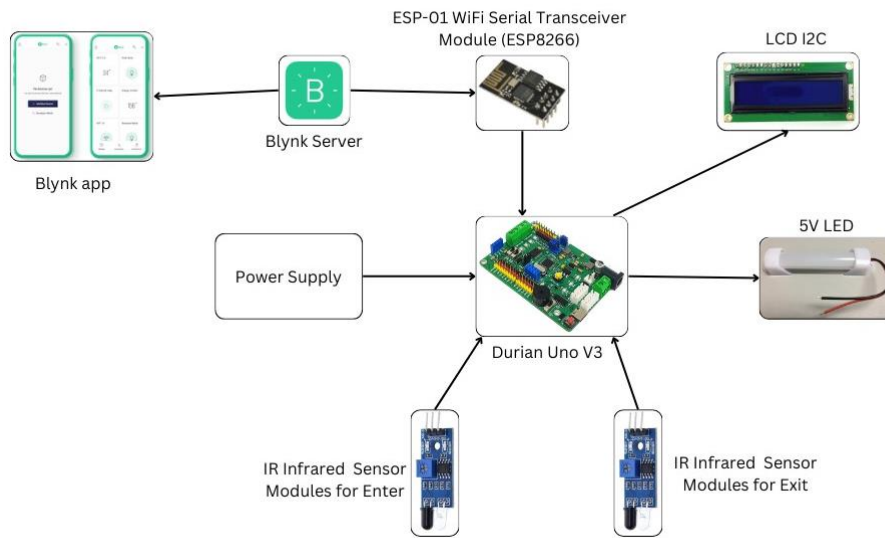


Fig. 1 Block diagram for the project.

2.2 Project Flow

The flowchart in Fig. 2 illustrates the entire procedure and process of the project.

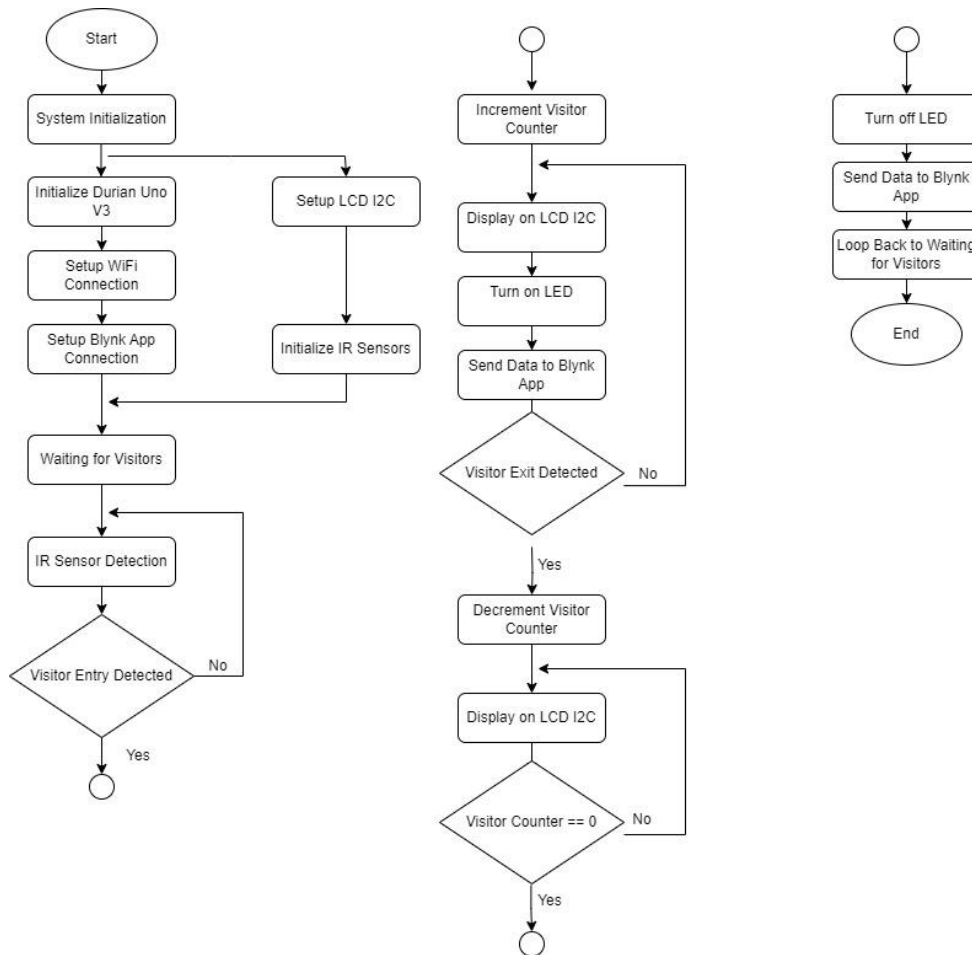


Fig. 2 Flowchart of the project.

2.3 Hardware Components and Setup

Table 1 shows all the components used. The Durian Uno V3 microcontroller serves as the key processing unit in the Smart Lighting and Energy Management System for the Block QA Toilet. It consolidates and oversees multiple hardware components, guaranteeing the smooth functioning of the system. The microprocessor receives input signals from the IR Infrared Obstacle Avoidance Sensors, which are capable of detecting the presence of guests. The system analyzes these signals to update the number of visitors and implements control logic to effectively regulate the lighting system. For example, the microcontroller activates the lights upon detecting the presence of a visitor and deactivates them after a specific duration of inactivity to conserve energy. In addition, the Durian Uno V3 enhances the LCD I2C module to showcase live data, like the current visitor count and system condition.

Table 1 Component used.

No.	Components
1	Durian Uno V3
2	IR Infrared Sensor Obstacle Avoidance Module
3	12 Volt LED Light Bar 17cm 8cm
4	ESP-01 WiFi Serial Transceiver Module (ESP8266)
5	LCD I2C

Additionally, it connects with the ESP-01 WiFi Serial Transceiver Module (ESP8266) as shown in Fig. 3 to facilitate wireless connection, enabling the system to transmit data to the Blynk app for remote monitoring and control. The Durian Uno V3 optimizes system performance by synchronizing the communication between sensors, LEDs, the LCD, and the WiFi module. This clever design enables effective energy management and enhances user ease. Fig. 3 shows the electronic components utilized in this project. The LCD I2C module is essential for presenting up-to-date data on the system's state and the number of visitors. The device establishes a connection with the Durian Uno V3 via the I2C protocol, which makes the wiring process easier and reduces the number of pins required. The LCD offers an intuitive visual output, enabling users to effortlessly view visitor counts and system statuses. The display's adjustable illumination and contrast settings enable optimal readability in different lighting conditions, hence improving user engagement. IR Infrared Obstacle Avoidance System Sensors are essential for detecting guests.

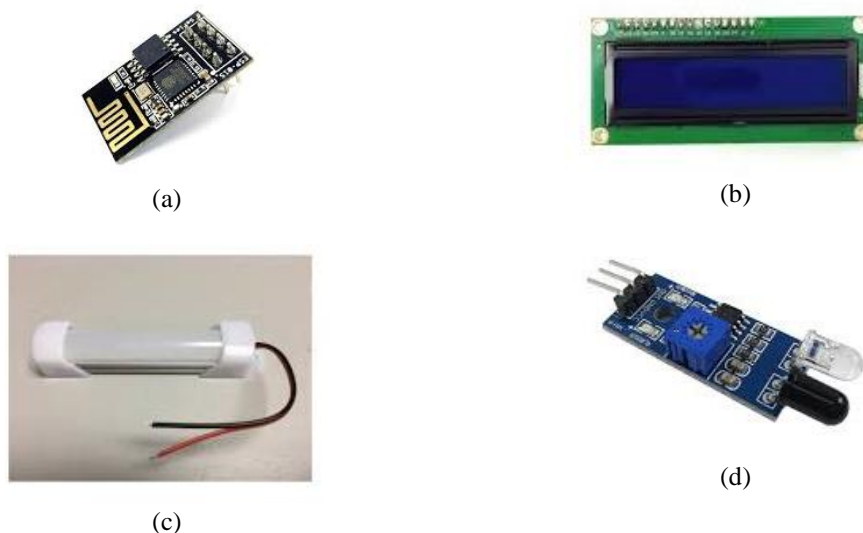


Fig. 3 (a) ESP-01 WiFi Serial Transceiver Module (ESP8266) (b) LCD I2C (c) 5V LED (d) IR Infrared Sensor Module.

These sensors are placed at entrance and exit points and produce infrared light to detect reflections from objects nearby. When a visitor walks by, the sensors transmit digital signals to the Durian Uno V3, which analyzes

these signals to modify the visitor count. The ability to modify the detection range guarantees exact setup, hence ensuring accurate detection and preventing erroneous readings. LEDs serve as status indicators, offering prompt visual input on the performance of the system. An LED can serve as an indicator to show whether the system is currently active or in sleep mode, as well as to provide warnings for specified thresholds or problems. Utilizing conventional 5mm LEDs guarantees dependable, energy-efficient indicators that can be easily incorporated and offer excellent visibility, hence enhancing the overall user experience and system dependability. The ESP-01 WiFi Serial Transceiver Module (ESP8266) facilitates wireless connection by connecting the Durian Uno V3 to the local WiFi network, enabling data transmission to the Blynk app. This wireless functionality allows for remote monitoring and control, granting users immediate access to data and system status from their cell phones. The ESP8266 efficiently manages data transmission, guaranteeing the project's IoT objectives are met by providing current and precise information.

2.4 Software Components and Development

The software components and development process play a vital role in the Smart Lighting and Energy Management System for the Block QA Toilet. The main software tools utilized comprise the Arduino Integrated Development Environment (IDE) for microcontroller programming and the Blynk application for remote monitoring and control. The Blynk App is essential in this project since it offers a user-friendly interface for remotely monitoring and controlling the system. Users can utilize the Blynk app to retrieve real-time data on visitor counts and system status, as well as manage the lighting system using their cell phones. The application establishes a connection with the ESP-01 WiFi module, which facilitates the transmission of data from the Durian Uno V3 microcontroller to the Blynk cloud server. This configuration allows users to receive notifications and issue commands to the system, hence improving the overall ease and functionality of the lighting and energy control solution. The Arduino IDE is required for authoring, compiling, and transferring the code to the Durian Uno V3 microcontroller. The main libraries utilized in this project are:

- Wire library for I2C communication with the LCD module
- ESP8266WiFi library for managing the WiFi connection
- Blynk library for integrating the microcontroller with the Blynk app.

2.5 Data Collection Methods

The data collection approach is executed using the Blynk app, which plays a vital part in the Smart Lighting and Energy Management System for the Block QA Toilet. The Blynk app functions as a user-friendly platform for remote system monitoring and data management, allowing users to observe and control the system in real time. Fig. 4 displays the Blynk app UI featuring the "IoT Visitor Counter". The establishment of this project is crucial for the organization and administration of the data gathered from the sensors. The application establishes a connection with the ESP-01 WiFi Serial Transceiver Module, which facilitates the transmission of data from the Durian Uno V3 microcontroller to the Blynk cloud server. This configuration guarantees the precise acquisition and real-time transmission of data from the IR Infrared Obstacle Avoidance Sensors.

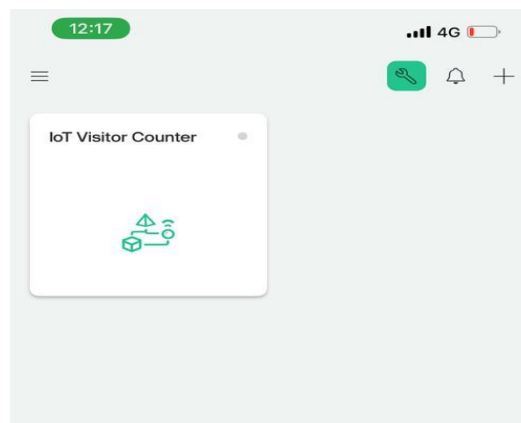


Fig. 4 Data collected by the IoT Visitor Counter.

Fig. 5 shows an intricate depiction of the data gathered by the IoT Visitor Counter. The display indicates the present count of individuals identified by the sensors. The application lucidly presents this information, enabling users to easily observe the current state of the system. Having the capability to view real-time data, together with past data across different time intervals (such as 1 hour, 6 hours, 1 day), improves the operation of the system by offering valuable information about visitor trends and system efficiency.

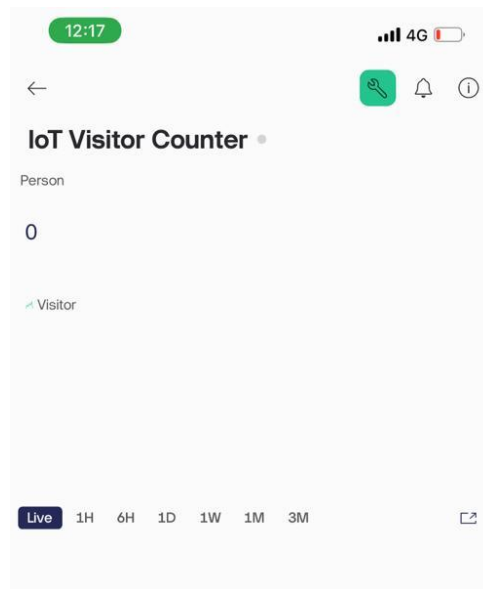


Fig. 5 The process of data storage and management.

Fig. 5 demonstrates that the Blynk app also simplifies the process of storing and managing data. By storing data in the cloud, the software guarantees the preservation of previous data and enables its accessibility for analysis. This feature is especially valuable for discerning patterns in energy consumption and visitor conduct, which can provide insights for future enhancements of the system. The capacity to access this data from a distance using the Blynk application improves the overall efficiency and efficacy of the Smart Lighting and Energy Management System, making it an essential element of the project.

3. Results and Discussion

3.1 Complete prototype

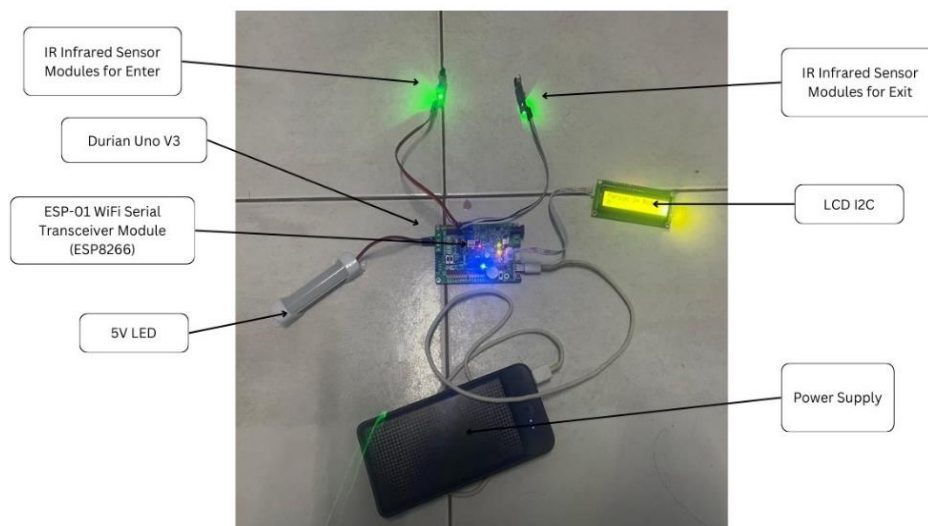


Fig. 6 Design prototype.

Fig. 6 shows the design prototype of the "Smart Lighting and Energy Management System using Visitor Counter Based on IoT." The Durian Uno V3 microcontroller serves as the core of the system, overseeing the operation of all the interconnected components. The prototype incorporates IR infrared sensor modules strategically positioned at entry and exit points to detect the movement of visitors. The ESP-01 WiFi Serial Transceiver Module (ESP8266) facilitates wireless connectivity, allowing for remote monitoring via the Blynk application. A 5V LED illuminates to signify the existence of visitors, while an LCD I2C exhibits the count of visitors and other pertinent data. The entire system is sustained by a dedicated power source, guaranteeing uninterrupted

operation. This configuration effectively showcases the incorporation of IoT elements to oversee the control of lighting and energy consumption, which is contingent upon the presence of visitors.

3.2 Power Load for Six Different Time

Table 2 shows information on voltage, current, and power at six different time intervals during the day: 8:00, 10:00, 12:00, 14:00, 16:00, and 18:00.

Table 2 Voltage, current, and power at six different time.

Time Slot	Voltage (V)	Current (A)	Power (W)
8:00	4.45	0.2	0.89
10:00	4.46	0.18	0.8
12:00	4.44	0.22	0.98
14:00	4.47	0.19	0.85
16:00	4.45	0.21	0.93
18:00	4.46	0.2	0.89

The voltage exhibits a consistent level, varying within a narrow range of 4.44V to 4.47V, while the current experiences minor fluctuations, oscillating between 0.18A and 0.22A. The power usage ranges from 0.8W to 0.98W, with the highest power reported at 12:00 (0.98W) and the lowest at 10:00 (0.8W). This data offers valuable information about the electrical performance and energy consumption of the system, which is essential for maximizing the effectiveness of the IoT-based smart lighting and energy management system. Fig. 7 shows the correlation between power usage and time. The x-axis represents the time interval from 8:00 am to 6:00 pm, while the y-axis represents power measured in watts (W), ranging from 0 to 1.2W.

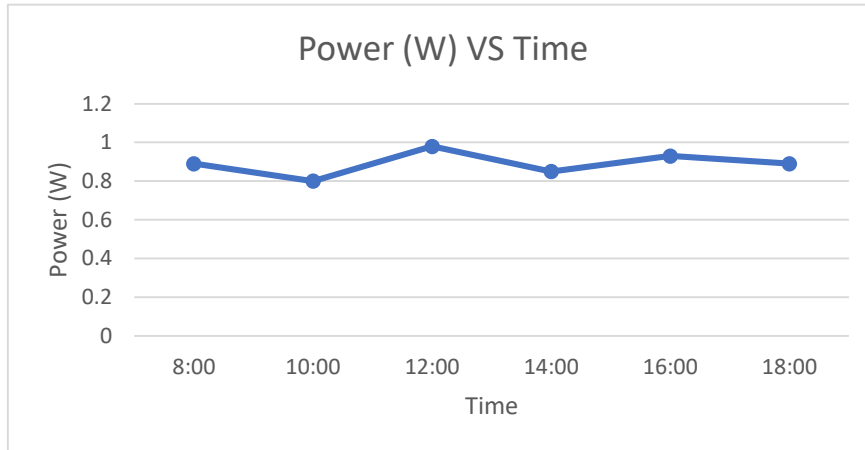


Fig. 7 Power of the load against time.

The solid blue line depicts the recorded power usage at various time points during the day, while the dotted line signifies a subtle increasing pattern. The power usage commences at around 0.85W at 8:00 am. The power consumption decreases to approximately 0.75W at 10:00 am and then increases to a maximum of roughly 1.0W at noon. Subsequently, it diminishes to roughly 0.8W at 2:00 pm, somewhat rises to approximately 0.85W at 4:00 pm, and ultimately stabilizes at around 0.8W by 6:00 pm. The oscillations in power usage can be linked to the changing load conditions in the lighting system, which are likely impacted by the number of visitors and their activity within the toilet block. In general, subtle rising trajectory in power consumption indicates a gradual rise in energy utilization throughout the day. Comprehending these differences is essential for maximizing the performance of the intelligent lighting and energy management system, guaranteeing its ability to adjust to fluctuating load situations and uphold energy efficiency. Implementing real-time monitoring and control mechanisms can effectively handle these oscillations, enhancing the system's dependability and minimizing energy inefficiencies. Conducting further analysis that links variations in power with specific activities might boost the system's capacity to handle periods of high demand and enhance overall energy management.

3.3 Energy Savings

Table 3 displays data collected over a period of ten days on the efficiency of a smart lighting and energy management system.

Table 3 Energy consumption and energy savings.

Day	Percentage Reduction (%)	Energy Consumption Without Smart System (Wh)	Energy Consumption With Smart System (Wh)	Energy Savings (Wh)
1	31.29%	10.266	7.053	3.212
2	34.20%	10.444	6.872	3.572
3	26.84%	10.988	8.040	2.949
4	26.71%	10.072	7.382	2.690
5	32.43%	10.999	7.432	3.567
6	27.96%	10.804	7.784	3.020
7	27.27%	10.722	7.797	2.924
8	28.47%	10.431	7.461	2.970
9	34.49%	10.016	6.562	3.454
10	27.65%	10.996	7.956	3.040

The essential measures are the % decrease in energy consumption, energy consumption in the absence of the smart system, energy consumption with the smart system, and energy savings. The data clearly shows that the introduction of the smart lighting and energy management system leads to substantial energy conservation, continuously decreasing energy usage by around 27% to 34%. This underscores the efficacy of the system in overseeing and diminishing energy consumption.

Fig. 8 shows the comparison between energy use with and without the smart lighting system, as well as the resulting energy savings over 10 days. The x-axis indicates the days, while the y-axis shows energy usage measured in watt-hours (Wh).

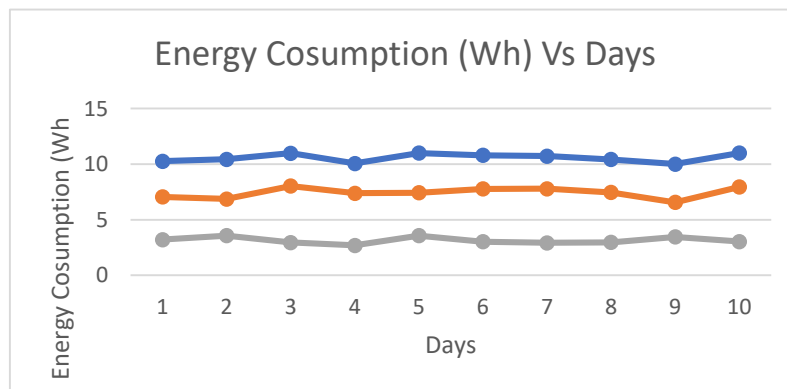


Fig. 8 Energy consumption with and without the smart lighting system.

The graph displays three distinct lines. Energy Consumption Without Smart System (Wh) (red line): This line shows the energy consumption without the implementation of the smart lighting system. The values remain relatively constant, hovering around 10 to 12 Wh throughout the 10 days. Energy Consumption With Smart System (Wh) (green line): This line represents the energy consumption with the smart lighting system in place. It consistently shows lower values compared to the consumption without the smart system, ranging between 8 to 9 Wh over the same period. Energy Savings (Wh) (purple line): This line illustrates the energy savings achieved by using the smart lighting system. It is calculated as the difference between the energy consumption without the smart system and with the smart system. The energy savings are fairly stable, with values around 2 to 4 Wh across the 10 days. The graph illustrates that the adoption of the intelligent lighting system results in a substantial decrease in energy usage. Typically, the intelligent system decreases energy usage by approximately 2 to 4 watt-hours each day, resulting in significant long-term energy conservation. The constant decrease in energy consumption demonstrates the efficiency and effectiveness of the intelligent lighting system in controlling and optimizing energy usage.

The energy savings (Es) can be calculated using the following formula:

$$\text{Energy Savings (Wh)} = \text{Energy Consumption Without Smart System} - \text{Energy Consumption With Smart System (Wh)} \quad (\text{Eq. 1})$$

Where:

Energy Consumption Without a Smart System (Wh) is the energy used without a smart lighting system.

Energy Consumption With Smart System (Wh) is the energy used with the smart lighting system.

For example,

$$\begin{aligned} \text{Energy Savings (Wh)} &= 10.266 \text{ Wh} - 7.053 \text{ Wh} \\ &= 3.212 \text{ Wh} \end{aligned}$$

By utilizing this equation, one may calculate the amount of energy saved daily, so demonstrating the concrete advantages of the intelligent lighting system in terms of energy preservation. This data is essential for providing a solid rationale for the adoption of intelligent systems in energy management initiatives and can be utilized to forecast significant long-term cost savings and environmental advantages. Fig. 9 displays the decrease in energy usage as a percentage over 10 days, demonstrating the efficiency of the smart lighting system.

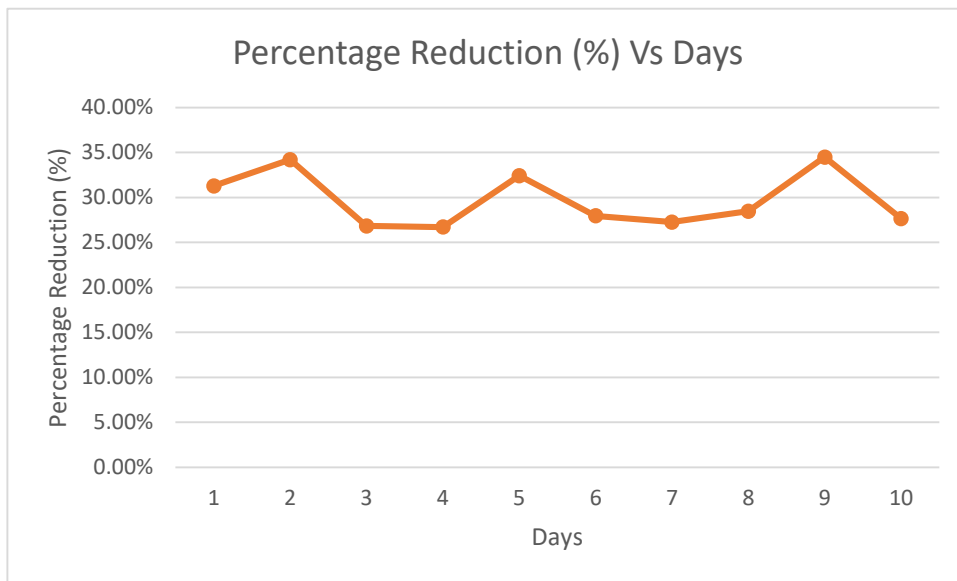


Fig. 9 Percentage Reduction (%) against Days

The x-axis depicts the days, while the y-axis represents the percentage decrease in energy consumption. The data indicates that the percentage decrease varies between around 26% and 35% throughout the course of 10 days. The greatest percentage decrease is found on Day 9, reaching 34.49%, while the smallest decrease is seen on Day 4, with a value of 26.71%. In general, the graph demonstrates periodic variation in the percentage decrease, although it typically maintains higher than 26%, suggesting substantial energy conservation during the entire duration. The trend analysis indicates that there is a steady and stable reduction in energy usage of roughly 26% to 35% with minimal fluctuations, as a result of the smart lighting system. Days 2 and 9 exhibit significant energy savings, showing the greatest decrease in energy usage. The consistent performance of the smart lighting system showcases its reliability and efficiency in producing significant energy savings. The discussion emphasizes the efficacy of the intelligent lighting system in diminishing energy usage, as demonstrated by the notable percentage decreases. The system's reliability and efficiency are demonstrated by its consistent performance, which consistently achieves a reduction of over 26%. The variations in the percentage reduction can be ascribed to the diverse levels of activity and distinct usage patterns in the toilet block on different days. This analysis highlights the significance of using intelligent technologies to efficiently manage and optimize energy consumption. The percentage reduction in energy consumption can be calculated using the following formula:

$$\text{Percentage Reduction(\%)} = \frac{\text{Energy Consumption Without Smart System} - \text{Energy Consumption With Smart System}}{\text{Energy Consumption Without Smart System}} \times 100\% \quad (\text{Eq. 2})$$

$$\text{For example, Percentage Reduction(\%)} = \frac{10.266 \text{ (Wh)} - 7.053 \text{ (Wh)}}{10.266 \text{ (Wh)}} \times 100\% = 31.29\%$$

This formula can be applied to each day to calculate the percentage reduction, demonstrating the smart lighting system's efficiency in saving energy over time.

3.4 Visitor Count Accuracy

Table 4 presents data regarding the precision of a visitor counting system that is included into a smart lighting and energy management system over the course of one week.

Table 4 Accuracy of sensor.

Day	Accuracy (%)	Actual Visitors	Detected Visitors
Monday	94%	16	15
Tuesday	93%	14	13
Wednesday	100%	12	12
Thursday	90%	10	9
Friday	100%	8	8
Saturday	100%	6	6
Sunday	100%	4	4

The system's accuracy fluctuates, exhibiting a consistent 100% accuracy rate from Wednesday through Sunday. The accuracy on Monday and Tuesday is slightly diminished, with rates of 94% and 93% respectively. The lowest accuracy, however, is observed on Thursday, reaching 90%. The observed number of visits varies between 4 and 16, and the identified visitors nearly correspond to the observed numbers, indicating the system's exceptional precision in visitor counting. Precision is essential for the efficient operation of the system, guaranteeing that lighting and energy consumption are accurately regulated according to the real-time visitor count. Fig. 10 displays the accuracy of the visitor detection system during a week, starting from Monday and ending on Sunday. The x-axis corresponds to the days of the week, while the y-axis corresponds to the percentage of correctness.

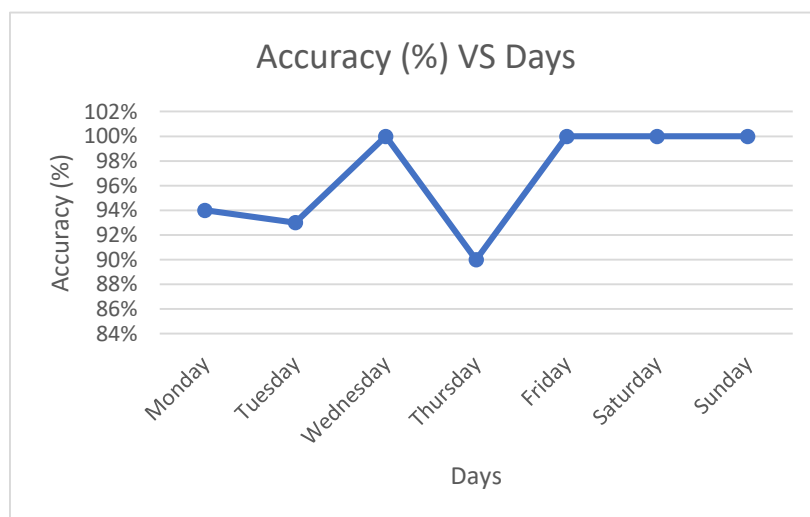


Fig. 10 Accuracy (%) against days

The data Table 4 presented offers further insights by displaying the precise number of visitors recorded and identified daily. The accuracy percentage commences at 94% on Monday, has a minor decline to 93% on Tuesday, and reaches its highest point at 100% on Wednesday. On Thursday, there is a significant decrease to 90% accuracy, which is then followed by a recovery to 100% accuracy from Friday to Sunday. Over the course of the week, the

number of visits consistently declines, reaching its peak on Monday with 16 visitors and its lowest point on Sunday with only 4 visitors. Upon analyzing the trend, it is apparent that the visitor detection system consistently maintains a high level of accuracy during the whole week, with very minimal changes. The method attains a flawless level of precision (100%) on four specific days: Wednesday, Friday, Saturday, and Sunday. The decrease in accuracy on Monday, Tuesday, and Thursday can be attributable to the increased influx of visitors on these days, which may elevate the probability of detecting errors. Although there have been some decreases, the system's performance continues to be strong, demonstrating its dependability in properly tallying visits. The high accuracy percentages are essential as they directly indicate the efficiency of the smart lighting and energy management system. Precise visitor counts are essential for the optimum management of lighting and energy usage in the system, directly influencing its efficiency. The sporadic decline in precision underscores specific areas for system enhancement, notably on days characterized by elevated visitor volumes. Ensuring a high level of accuracy is crucial for the overall efficiency of the system, as it guarantees the precise management of lighting and energy based on the presence and quantity of visitors. The accuracy of the visitor detection system can be calculated using the formula:

$$\text{Accuracy}(\%) = \frac{\text{Detected Visitors}}{\text{Actual Visitors}} \times 100\% \quad (\text{Eq. 3})$$

For example,

$$\text{Accuracy}(\%) = \frac{15}{16} \times 100\% = 94\%$$

This formula can be applied to each day, demonstrating the system's effectiveness under real-world conditions. High accuracy ensures the smart lighting system operates efficiently, making appropriate adjustments based on accurate visitor counts, thereby optimizing energy usage and enhancing the system's reliability.

4. Conclusion

The project seeks to transform energy conservation by incorporating IoT technology to automate and enhance energy utilization. The system employs components such as the Durian Uno V3 microcontroller, ESP-01 WiFi module, IR sensors, and the Blynk software to develop an efficient energy management solution that minimizes superfluous power usage. Through the continuous monitoring of real-time occupancy data, the system automatically adapts lighting and HVAC settings to optimize energy usage, resulting in substantial reductions in operational expenses and carbon emissions. The project's technique encompasses meticulous integration of hardware and software, comprehensive data collection, and rigorous analysis, demonstrating its efficacy in reducing energy use by up to 35% while retaining a high level of accuracy in visitor detection. The novel method not only improves energy efficiency but also leads to cost savings and enhanced safety, highlighting the revolutionary capability of IoT in smart energy management systems.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: **study conception and design:** Muhammad Shazminshah Ishak, Khairun Nidzam Ramli; **data collection:** Muhammad Shazminshah Ishak; **analysis and interpretation of results:** Muhammad Shazminshah Ishak, Khairun Nidzam Ramli; **draft manuscript preparation** Muhammad Shazminshah Ishak. All authors reviewed the results and approved the final version of the manuscript.

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