An IoT Smart Lighting System for University Classrooms

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***Abstract*—This research is the development of an IoT based controller device with a cloud-based system to switch, manage, and monitor the lights of university classrooms. The project output shall aid the problem in the operation of lights from unnecessary energy consumption to save energy. The researchers used a NodeMCU V3 with Wi-Fi capabilities together with a Passive-Infrared Sensor to detect room occupancy and a Relay Switch to operate the switching of lights to create the controller device. The controller device can run using the web and mobile applications over the internet using AJAX. The developed applications not only serve as a controller but a management system to set appropriate schedules for class hours, a monitoring system that indicates the length of usage and the total amount of energy consumed from lights. The management can set class schedules to allow the room to operate the lights on a given period if there are occupants in the room. Failure to occupy the room even with a set schedule, the lights will not turn ON, thus reducing excess energy consumption. Furthermore, lights can still be controlled over a separate remote network through the applications even beyond the given schedule.**

Keywords—Internet of Things, Smart Lighting Systems, Management System, Microcontroller, Sensors

I. Introduction

The internet of things (IoT) traversed the world to a new paradigm of having daily-used objects connected to the internet. Devices are now able to use sensors, communication hardware, and other forms of network technologies to yield better information and enhanced capabilities for users. The demand for IoT is considerably increasing and can grow even further by having more than 50 million devices connected on the internet by the year 2020 and beyond [1]. The trend of IoT shows an evident change in how we live our daily lives, increasing the interaction through the internet. Using devices like mobile phones, personal computers, or even wireless sensors to operate daily tasks can reduce time consumption and human effort. An IoT system allows the exchange of data through a vast network, providing users control over connected and even wireless devices. Data can be captured as input through different interfaces for communication and stored in a computer system, processed, and used by other applications. Wireless connected devices provide flexibility for people to operate over a remote network having more control to increase overall efficiency and capability [2].

Today, modern technology had played a significant role in educational institutions providing solutions like computer systems for control and management due to the increasing demand for modernization. This technology, however, had the initiative to reinvent the design of how lighting systems are to be in future university classrooms and to re-examine new ways of promoting good practices to conserve energy [3]. More universities are investing in IoT systems, devices applications, and services as it can dramatically change its operations. However, with a massive cost required, some potentially had the hindrance of moving over to a new leap [4]. Cisco envisioned that complexity in universities arises as the population bulks up, increase of energy as consumption, and utilization are affected. These, however, can be reduced through the application of IoT applications such as Energy Monitoring and control systems to support the decrease of cost in operations and energy [5].

In this research, indicates the development of a Smart Lighting System using IoT concepts for a university classroom. The main objective is to develop a low-cost lighting control system that allows the user to control the operations of the lights through a cloud-based system. The cross-platform applications provide the display of the excess energy consumption, management, and even monitoring capabilities to lessen the university endeavors to cope up with the increasing energy cost. The scope of this paper covers the device principles, the development process of the device, software workflow, and installation. This research also intends to streamline an easily adaptable smart lighting systems for any buildings to reinvent the way universities in the Philippines manage their energy from lights.

II. Recent Related Works

This section provides excerpts of other studies that conducted a similar path to reduce energy wastage. The researchers of this article intend to show how this research can provide further improvements to existing works. Several studies conducted on Smart Lighting Systems offered new ways to increase efficiency in energy consumption. IoT integration in modern buildings had been an increasing trend for energy management but still lacks the component of the actual application of IoT-based control systems for university classrooms [6]. These new control systems are solutions capable of reducing energy consumption not just for households but can also be in a University setting. Previously published research projects applied several solutions to pave a way to solve the increasing problem in energy waste. Zeebaree, S.R.M. and Yasin, H.M., developed a Short Message System (SMS) based control using Global System for Mobile Communications (GSM) modules to interact with the lighting system. The users can send commands through text messages to control the lights and even the sensors. However, the given method may not be so efficient, especially in the case of having to use credits. The device itself requires the same to allow transmission of messages back to the sending device [7]. Passive Infrared (PIR) sensors can detect room occupancy. Automatically turning ON and OFF the lights, in the study of Suresh, S. et al. created a mobile application to control lights using the Transmission Control

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Protocol/Internet Protocol (TCP/IP) that connects to a webserver to communicate with the lighting control device. However, the final output needs further improvement to become a more stable lighting system for implementation. Also, the study had no management and monitoring capabilities implemented to support the need for admins to facilitate energy use [8]. Mahalakshmi, G., and Vigneshwaran improved the automation of homes using different Arduino components. The study can also work for various universities. The included lights can operate over the internet via a relay switch. An application allows the users to manipulate every device to connect to the relay to lessen physical interaction. However, the outcome did not reach the actual installation to households and can still improve for future applications. Also, the controllability only stays within the mobile app, and a cross-platform application may generate better management and flexibility for this research [9].

The following studies conducted did not have a fully developed and deployed system of their lighting management and monitoring that can operate on the application layer using cross-platform apps. Also, better prototype design to create a more effective implementation; thus, yielding further improvements in the future for energy conservation.

III. PRINCIPLES AND MATERIALS

A. *Javascript Object Notation*

The JSON (JavaScript Object Notation) specified by Douglas Crockford is a light and simple formatting used widely today for exchanging data between servers and other internet technologies. The format provides a simple text format made available for multiple different programming languages to use. Users of JavaScript objects can efficiently utilize through native applications created in various platforms using a built-in function for converting strings. In this research, JSON provides the capability for the Lighting system to transmit and receive data from a cross-platform application by using a JavaScript call function. The JavaScript call function creates the XMLHttpRequest Object that can be read by the server to transmit a reply to the controller in JSON format. The exchange of data over the applications using JSON provides the carrying of data from one node to another [10].

B. *Asynchronous Javascript and XML*

AJAX (Asynchronous JavaScript and XML) provides the interactivity with the controller device through the cross-platform applications using JavaScript [11]. AJAX allows the transmission of data from the cloud server to the controller device continuously and asynchronously in the background. This concept happens due to the XMLHttpRequest object that is constructed on both the web and mobile applications to retrieve data using JavaScript language. The concept of AJAX provides a seamless bi-directional transfer across the internet without the assistance of any user input in this research. AJAX works within a TCP/IP network model, allowing it to execute dynamically with webpages and other related applications simultaneously [12]. Fig. 1 provides a detailed view of how AJAX works for both the application server and the lighting system to provide the needed task for the overall system.

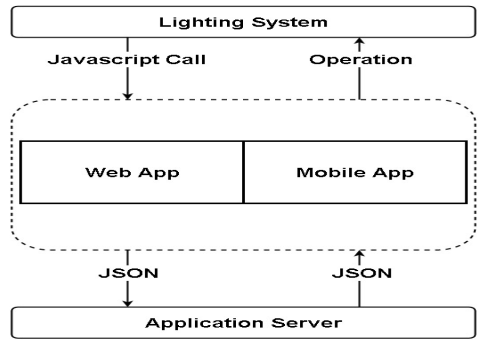

Fig. 1. Lighting System Framework with AJAX

C. *Microcontroller Unit*

Based on Fig. 2, NodeMCU V3 ESP8266 represents as the main component on the light controller device to provide over-all centralization of the system. The device comes with a firmware made for open-source use and a development kit that lessens the tedious configuration for developing IoT products. The NodeMCU also has a built-in WIFI module for the accessibility of the lighting system to allow wireless controllability and access [13]. The microcontroller is programmed using the Arduino Integrated Development Environment (IDE), allowing it to send and receive a request from the application server to toggle the lights. It is also programmed to send data from the PIR sensor and Relay Switch to record the logs and duration of use for computing its energy consumption.

Fig. 2. NodeMCU ESP8266 Microcontroller

D. *Motion Sensor*

As shown in Fig. 3, the PIR Sensor is a motion-sensing device integrated with the controller and detect occupants in the room by sensing infrared fluctuations to trigger the lights from turning ON and OFF. The sensor consists of crystalline material that produces electrical charges to detect infrared radiation with a maximum range of six meters. The use of PIR sensors had been commonly used in recent studies to detect human presence to monitor classroom occupation [14], prevent the occurrence of theft [15], and to save energy wastage in an office setting [16].

Fig. 3. PIR Sensor

E. *Relay Switch*

Relay Switch, in Fig. 4, is the central switching mechanism of the control system that permits the exchange of information for the MCU using voltage and current. The hand-off shields every segment on the circuit from any form of electrical damage on the original wiring, ensuring itself [17].

Fig. 4. Relay Switch

F. System Workflow

System Workflow indicates how the PIR sensor and controller will work together based on the set schedule and occupancy of the classroom. If the device is ON, it will first check the schedule set on the back-end system. Having an occupied room on a set schedule will turn ON the lights. However, if the room was scheduled and had no occupants, the lights will remain in OFF status. Fig. 5 illustrates the system workflow of the lighting system.

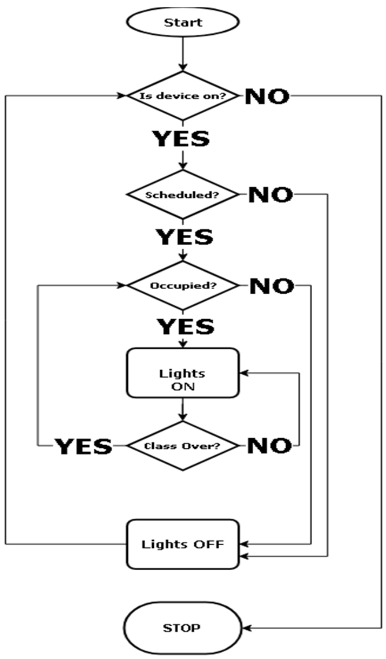

Fig. 5. System Workflow

G. Cloud Server Infrastructure

A cloud server infrastructure provides the use of the applications with the controller device across the globe. The app placed in the cloud application servers, the servers then communicate with the controller device and the cross-platform apps, and not directly with each other. Currently, the target University has its cloud servers that can accommodate the deployment of the system. The applications are stored in the cloud application server together with its database to store the logs and activities. This method allows the users to access the controller device (NodeMCU V3 ESP8266) anywhere in the world using the internet without the need of physical presence or interaction. After each request, the apps communicate with the servers to trigger the NodeMCU using AJAX for the relay switch to toggle the lights. The current light status passes back to the servers to display the updated light status on the application's user interface. The cloud server lies on the Internet and not on a LAN network, as shown in Fig. 6.

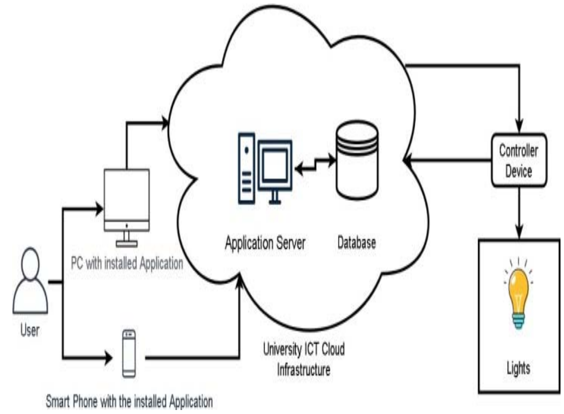

Fig. 6. Cloud Infrastructure

IV. Prototype Development and Installation

A. Lighting Control Circuit Design

Circuit Design in Fig. 7 indicates the connectivity of the device to process yield desired results simultaneously. The researchers maximized the small space for the chosen microcontroller. With the compact circuit design, the device shall not consume much space, making it easy to transfer. The circuity connection involves the PIR Sensor Data OUT Pin connects to the microcontroller, ESP8266 Pin marked D7. The LED has a pin connected and marked as D1 on the MCU. The LED shows if the current light status corresponds to ON or OFF. The IN1 pin of the relay switch connects to the pin marked as D2 on the MCU, IN2 relay pin module connects to pin marked as D3 of the MCU. The Relay1 Normally Open (NO) pin is connected to the control wire of Light Set 1 while the Relay2 NO pin is connected to the control wire of Light Set 2. Relay1 and Relay2 COM pins connect to the AC supply line. This design allows the components to work all together according to the desired functionality of the overall system. The final design itself can work in any form of lighting setup in any building.

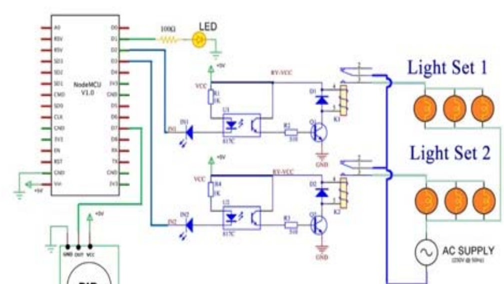

Fig. 7. Lighting Device Circuit Diagram

B. Final Prototype Outcome

The Final prototype is composed of a NodeMCU (Microcontroller Unit) V3, PIR sensor, Relay Switch, and a power supply. The different components pack together using an adhesive material secured in a plastic enclosure. The PIR peaks out of the cover to receive efficient inputs to make the device works appropriately without reduced functionality. Fig. 8 displays our output with and without its protective cover.

Fig. 8: Final Prototype with Enclosure

C. Installation

A typical classroom of the identified University consists of six fluorescent lamps connected in two light switches with three lights per single switch. The developed device will have a PIR sensor to detect occupants in the room with a max range of six meters, and a controller device that will replace the conventional light switches in the classroom. The following figures will indicate the steps taken to install the controller device in the classroom.

Firstly, determining the location for the device installation. Fig. 9 defines the chosen location, which lies beside the doorway as entering students or faculty in a set schedule can effectively trigger the PIR sensor compared to any other site in the room.

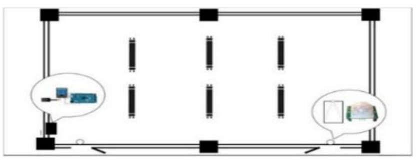

Fig. 9. Room Location

Secondly, Fig. 10 shows the device attached to the light switch of the classroom by using the old wiring setup and replacing the mechanical switch. Line 1 connects to the COM of the first relay and the jumper wire on the COM of the second relay. The light set 1 attached to the NO of relay one and the Light set 2 on the NO of relay 2, allowing light control by using the relay switches at command. The method prevented any significant destruction of the wall and plate that may consume additional cost.

Fig. 10. Switch Replacement with Controller Device

Lastly, Fig. 11 displays the device with proper enclosure installed to cover the bare equipment for added protection and security. This protective cover made the device installation looked clean and seamless, preventing any distractions to the entering occupants. The prototype design may still vary according to the desired look of the user.

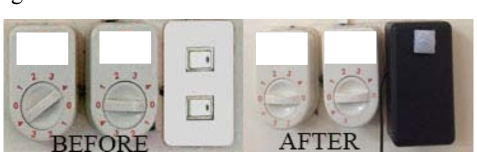

Fig. 11. Lighting Device Installed

V. Cross-Platform Applications

The Smart Lighting device developed does not only operate to toggle the lights from ON to OFF. The system also provides management and monitoring capability for the university. Components of the web application consist of dashboard management, scheduling, activity logs, and energy consumption. The mobile app is to support the control of the lights over a remote network.

A. System Management Dashboard

The dashboard illustrated in Fig. 12 indicates the rooms with the installed devices and current light status. The panels with red color signify that the lights are OFF, while green color indicates that its ON. The Design template proceeds to Bootstrap.

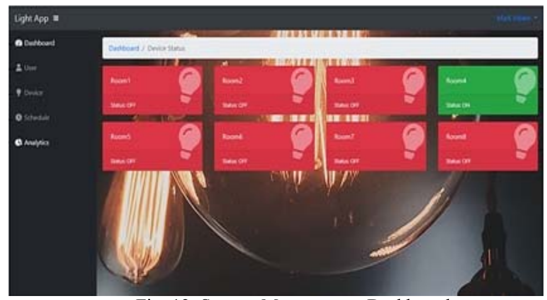

Fig. 12. System Management Dashboard

B. Reports Monitoring

Fig. 13 presents the log of actions together with the amount of electricity consumed per hour. The computed consumption of power relies on the number of hours and the wattage of the lights.

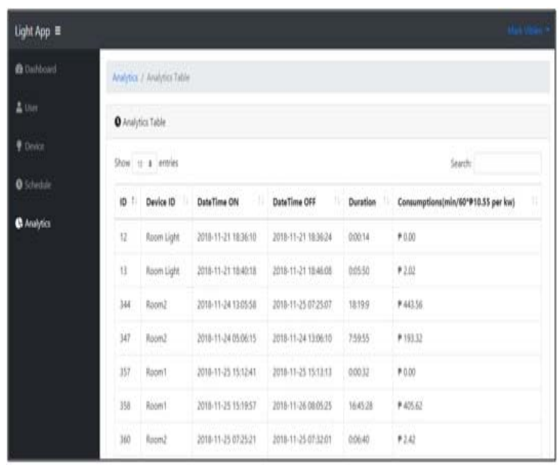

Fig. 13. Reports Monitoring Module

C. Light Scheduler

Fig. 14 provides the scheduling module that allows the creation of the desired light schedule by the user. The user should indicate the room number and date together with the beginning and end of class. The assigning of the controller device requires a room number done by inputting it on the system. Users can add new schedules, add new light devices for scalability and expansion. Other lighting devices can also be removed or moved to different locations without much worry. The web application can be accessed using any desired web browser. The design is responsive using the Bootstrap styling sheet framework.

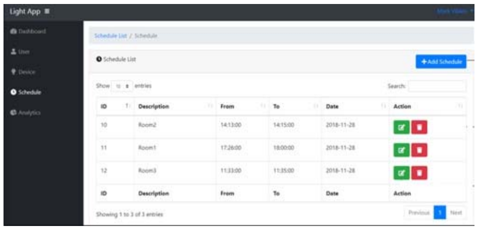

Fig. 14. Light Scheduler Module

D. *Lighting Device Controller App*

To further improve flexibility, the researchers also developed a mobile application to take control of the lights remotely, even on separate networks if needed. The capability of the mobile app is currently limited only to turning ON and OFF lights. Fig. 15 displays the actual controlling of the lights using both the web and mobile apps. However, a simple solution by the app could initially solve the problem of going over rooms. Having large buildings can complicate the issue in case of the light left turned ON without occupancy.

Fig. 15. Cross-Platform Applications

VI. Conclusion and Future Works

The use of IoT for universities can be highly beneficial due to its capability to be flexible and accessible anywhere. This research provides an undeniably cheap solution compared to expensive reconstruction and installation of modern lighting systems. Such a concept could help universities to move into new methods of operating utilities even without much-needed cost and effort. Even with a prototype, the lights were able to be controlled from a remote network by accessing the web portal. Automation with the use of a PIR sensor helped in preventing the lights from being left turned ON if the room had no occupants in the set schedule. The overall design is slick, compact, durable, and lightweight. The final look makes the device highly transferrable from one room to another without consuming too much space.

Further improvements are still possible through the application of machine learning and AI concepts [18], less reliance on the sensor and more on the patterns generated from the day to day activity can be used for future improvements in automating the operation of the lights. Lastly, a study on the acceptability can also provide better insights for further adaptation.

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