

## Green switch: an IoT based energy monitoring system for mabini building in De La Salle Lipa

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### Article Info

#### Article history:

Received Jan 13, 2021

Revised Aug 30, 2021

Accepted Sep 7, 2021

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#### Keywords:

Building management systems

Grafana

InfluxDB

Internet of things

NodeMCI

Node-red

Raspberry Pi

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### ABSTRACT

Building energy management systems (BEMS) are critical tools for managing and controlling a facility's technical systems and services, such as lighting, ventilation, heating, and air conditioning, to ensure that the building operates at peak efficiency while decreasing energy waste. The Mabini Building at De La Salle Lipa has nearly a hundred rooms, 70 of which are used by college students for lecture and laboratory classes. From 7:30 a.m. to 9:00 p.m., these rooms are available. In a daily class schedule, air conditioning units and lights are used an average of 10 hours per day, while fans and power outlets are used an average of 5 hours. Even when no classes are being held, the aforementioned equipment is frequently left open in these rooms. The researchers created and constructed an IoT-based energy monitoring system to monitor and control the lights and outlets in a room. The system will also record the number of kilowatt-hours (kWh) consumed. The system employs NodeMCU, current, and voltage sensors, a Raspberry Pi 3, and the school's existing network to send and receive data from the server. The building administrator will use the collected data to give consumption statistics and reduce the carbon footprint.

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## 1. INTRODUCTION

The internet of things (IoT) is a system that includes connected devices that gather data, are connected to the Internet or local networks, generate analytics, and (in some cases) adapt behavior/responses based on the generated data through the network. It is made up of three components: sensors, networks, and analytics. Sensors are electronic devices that generate useful data that is then transmitted over a network. Networks connect devices to data centers or servers. Analytics assists in the interpretation of meaningful data in order to optimize and improve the operation of a specific infrastructure [1].

De La Salle Lipa (DLSL) is a Philippine educational institution located in Lipa City, Batangas. Within the 10-hectare lot, there are over 15 buildings, the majority of which are occupied by Integrated School and College facilities. Around 70% of the rooms in one of DLSL's buildings, the Mabini Building, are used by college students for lecture and laboratory classes. These rooms are available from 7:30 a.m. to 9:00 p.m. In a typical class schedule, air conditioners and lights are used for an average of 10 hours per day, while fans and power outlets are used for an average of 5 hours per day. Even when there are no classes, the above-mentioned equipment is frequently left open in these rooms.

Table 1 shows the energy consumption in kilowatt-hour (kWh) of a lecture room in the Mabini building. The total kWh consumption of a lecture room per month is 678.56 kWh. With 70 classrooms and an electric utility company price per kWh of 8 pesos per kWh (according to the De La Salle Lipa General Services Department), the lecture rooms of the Mabini building consumed 47,499.2 kWh, resulting in an energy cost of 379,993.6 pesos.

Table 1. kWh consumption of a lecture room in mabini building

Equipment	Qty	kW rating	Hours	kWh per day	kWh per month
Airconditioning units	2	1.4914	10	29.828	596.56
Lights	8	0.01	10	0.8	16
Ceiling fans	4	0.075	5	1.5	30
Power outlets	2	0.18	5	1.8	36
				Total kWh	678.56

In line with this, the researchers created an IoT-based energy monitoring system that tracks kWh consumption and controls the lights, fans, air conditioning, and outlets in a room. The system uses the WiFi network to transmit and receive information to and from the server. The stored data will be used by the building administrator to improve energy waste reduction. It specifically seeks to accomplish the following:

- 1) To prepare the project plan of the study:
  - User and hardware requirements for the specifications of the system that will determine the architecture of the system
  - Block diagrams and schematic diagrams
  - Electrical layouts of the system
- 2) To construct and assemble the hardware of the project.
- 3) To create the database and software application that will control and monitor the energy consumption of the electrical equipment in the room.
- 4) To test the system and evaluate the results.

Figure 1 shows the operational framework of the study. The energy management system shown in the figure has server and the utility monitoring and control web application acted as the data logger and repository in which client devices such as smartphones and computers attempt to access the devices in the rooms to track and control them. The control module houses the sensors and relays that have acquired the appliance's power consumption and control switch. Many of the peripherals are connected to the room's access point.

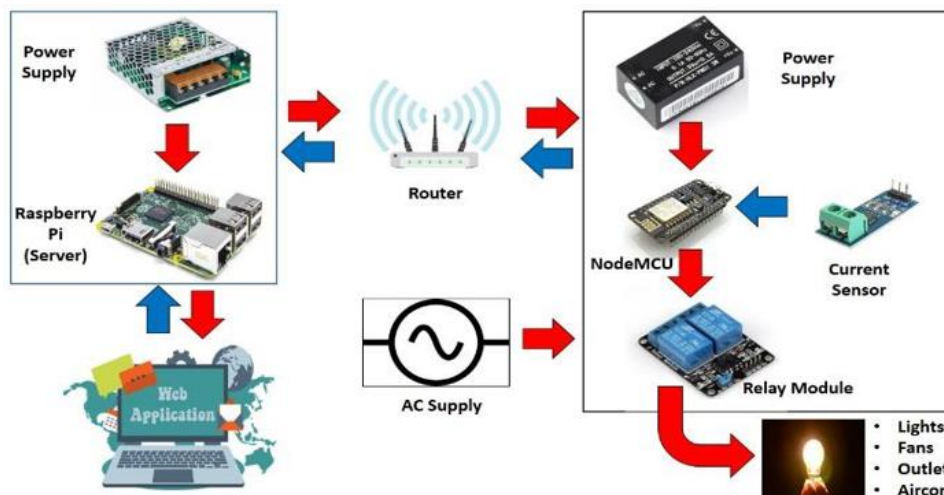


Figure 1. Operational framework

Message queuing telemetry transport (MQTT) [2] is a protocol used in the "internet of things". It's a simple publish/subscribe messaging system. It is used to connect networks with remote locations where a small footprint code is required, or network bandwidth is limited. Node-RED, developed by the emerging technology services team at international business machines (IBM) Corporation and now part of the JS foundation, is a flow-based programming tool. It is a way of defining the functions of an application as a black-box network, or 'nodes' as they are called in Node-RED. Each node has a function that is well defined [3].

The study of Mowad *et al.* [4] used Android smartphones to control devices and monitor the security at home wirelessly using Bluetooth. David *et al.* [5] incorporated both internet and Bluetooth communication protocol to manipulate appliances remotely from home. It uses hypertext transfer protocol (HTTP) to interact from the Arduino microcontroller installed with WiFi module which is the micro-server where the smartphone or polycarbonate (PC) can connect. Al-thobaiti *et al.* [6] discussed on using WiFi communication where the user uses his smartphone or PC to interact to a server where the Arduino microcontroller communicating via Serial means. With this, the user controls the appliances at home. Hasan *et al.* [7] used ATMEGA16 microcontroller, Bluetooth protocol to control appliances and GSM module which also used in the study of Rana *et al.* [8] and Anandan *et al.* [9] to monitor the security at home. Narrowband power line communication (N-PLC) was utilized by Bautista *et al.* [10] to connect the server to the service node where the utilities are connected. Astier *et al.* [11] have adapted the Malte concept [12] to Ippolito's technological management systems and control logics [13]. They discussed the use of Modbus/TCP, HTML/JavaScript and structured query language (SQL) as alternative and cost-effective solution in the deployment of an IoT based building management system. It also provides a uniform supervision across all connected devices from building control equipment and data acquisition devices.

Kashyap *et al.* [14] used the MQTT protocol, which was also implemented for data transmission in the Atkomo *et al.* study [15] and the use of WiFi interface in the study of Nasrin and Radcliffe [16]. It's a publisher and subscriber-based communication protocol that enables many devices to communicate with one another across a wireless network. Jaloudi [17] discussed the use of the MQTT protocol for the IoT in a Smart City application. The system uses components such as Arduino, which was used in the data acquisition of Diao and Mahmood [18], ESP8266 and Raspberry Pi. Discussed in the study, the MQTT, which is in the discussion of Lohokare [19], is suitable for small-to-medium IoT-based business applications that use cloud-based servers and for medium-to-big business applications that rely on LANs and Intranet. Tabaa *et al.* [20] used Modbus protocol to connect industry-based sensors and controller to a single on-board computer and wirelessly connect to the network using MQTT and Node-RED application which was also used in Hajovsky *et al.* [21]. The study of Yokotani and Sasaki [22] discusses the advantages of and MQTT network over Http on the rate of sending and receiving transmission to devices due to its lightweight in nature of publishing and subscribing to a particular topic which the Http does not have. Suparman and Jong [23] research employs an Arduino with an ESP 8266 shield and a MQ-2 sensor enclosed in a 3D printed enclosure. To send notifications to the Fire Rescue Department, the uses the cloud IoT platform Favoriot. Hussein and Shujaa [24] research on vehicle-to-vehicle voice chat employs the MQTT protocol for central monitoring and tracking of ambulances, thereby alleviating traffic congestion and avoiding the use of traditional sirens.

## 2. RESEARCH METHOD

The engineering planning and design research method was used in this study. It is a methodical approach that entails conducting technical research to solve a problem, solving the problem by developing a model to achieve the desired solution, and testing the effectiveness of the solution. The Energy Management in De La Salle Lipa, Mabini Building is divided into two (2) components:

- Design and development of the hardware which consist of the data acquisition and controls.
- Design and implementation of the software application that will be used for building administration.

Table 2 shows the system hardware requirement. The power supply will turn on the entire system. It will convert a standard 220-volt AC supply to 5 volts DC to power the hardware's components. The microcontroller will be the system's brain, converting the signal from the sensor, transmitting data via WiFi, and controlling the room's lights and outlets. The current sensor will measure the current flowing through the lights and outlets. Depending on the microcontroller instructions, the relay will switch the lights and outlets.

Table 2. Hardware requirements

Hardware	Description
AC-DC Power Supply	Power source of the data acquisition device
Microcontroller	Serves as the controller and will connect to the server wirelessly
Current Sensor	Used to measure current
Relay	Used to switch the light and outlets

Figure 2 show the connection diagram of the hardware and the lectrical layout in which the hardware is installed in an outlet or a switch. The current sensor is connected to one line of the outlet to calculate the current. The 5 volt power supply is used to power the ESP8266 microchip-based opensource microcontroller, NodeMCU [25]. The sensor output is connected to the NodeMCU's analog A0. The relay module is

connected to Pin D2 of the microcontroller. The NodeMCU microcontroller's function is to acquire data from the device's sensor control via WiFi communication. The electrical layout uses a two-wire configuration to make the connection more convenient. To power the system, an existing outlet with a 220 volt AC source is connected to the hardware's L1 and L2. T1 and T2 output terminals are connected to the load.

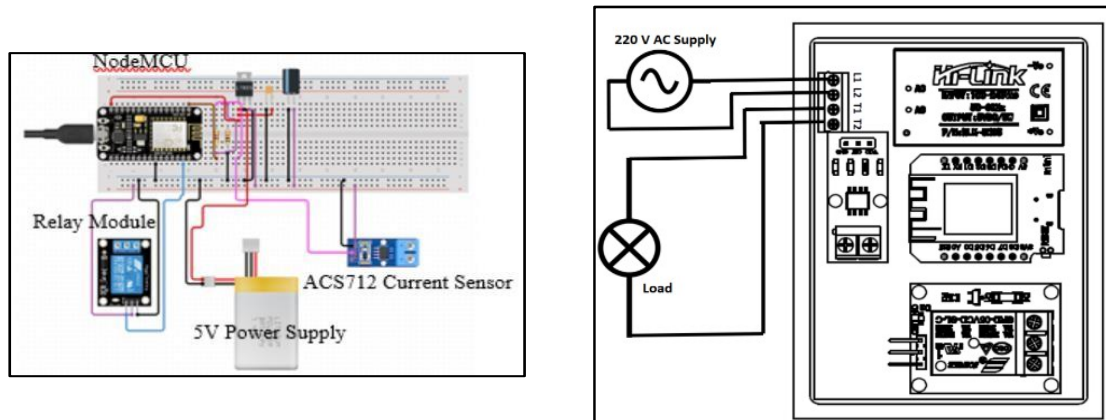


Figure 2. Connection diagram of the control node and electrical layout

Figure 3 shows the actual node hardware of the system. The dimension of the hardware is 95mm x 70mm x 35mm. It comprises the electronic components inside the enclosure. The enclosure of the hardware is 3D printed using printer plastic (PLA) plastic. The electronic components are soldered together on the printed circuit board. The board then is installed inside the enclosure.

Table 3 shows the software requirements in building the web application. The Arduino integrated development environment (IDE) is open-source programming software for microcontrollers [23]. Node-red is a node-based programming language used to create web-based applications. InfluxDB is a free and open-source time series database for archiving and storing data [26]. Grafana is an open-source monitoring solution that provides graphical data for a project [27]. The Node-red framework is written on the Raspberry Pi 3 server, a credit-card-sized single-board computer [28] that also serves as the system's MQTT broker. Each MQTT topic node is intended to keep track of each server-controlled appliance. Influx DB and Grafana, which serve as the database and web-based visualization, are also installed on the Raspberry Pi. Figure 4 shows the system architecture. In the system architecture, the hardware nodes, which are made up of sensors, relays, and a microcontroller, collect power data from the lights and fans and act as a switch for the appliances. WIFI was used to transmit the data, which was then routed to the server. The software application collected data on the power consumption of the appliances on an hourly basis.



Figure 3. Node hardware

Table 3. Software requirements

Software	Description
Arduino IDE	Programming software for the Microcontroller
Node-red	Web-based programming software
InfluxDB	Database
Grafana	Web-based monitoring solution

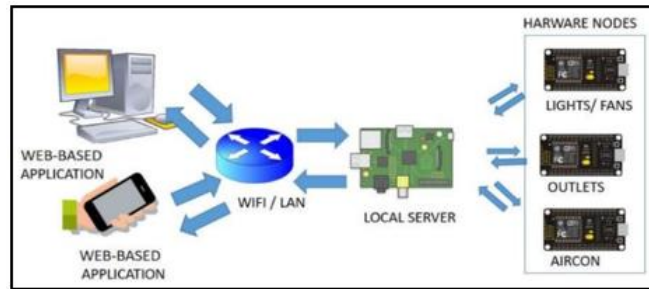


Figure 4. System architecture

### 3. RESULTS AND DISCUSSION

Figure 5 shows how the node hardware is installed in the simulation board. The hardware module is installed to the simulation board's respective lights and outlets, as shown in the Figure 5. Each hardware module is linked to a light or outlet and can be individually controlled. All of the node hardware is wirelessly connected via a wireless router, and each node subscribes to a different MQTT topic.



Figure 5. Installed hardware module on simulation board

The web-based interface is shown in Figure 6. The web-based application displays control for the hardware nodes, real-time power, and a graph of the power trend. The web application is accessible from any device with a browser, such as Microsoft Edge, Safari, Firefox, or Google Chrome.

Historical trend is shown in Figure 7. The Grafana interface displays the amount of power consumed per hour by a specific appliance. This provides the user with an overview of how much they spent per day on a specific appliance. Figure 8 shows the hardware node connection in to the network. The hardware nodes can be seen in the dynamic host configuration protocol (DHCP) list, and the connection to the server can be seen. The web application responds in 1 to 2 seconds to control and monitor the hardware nodes.

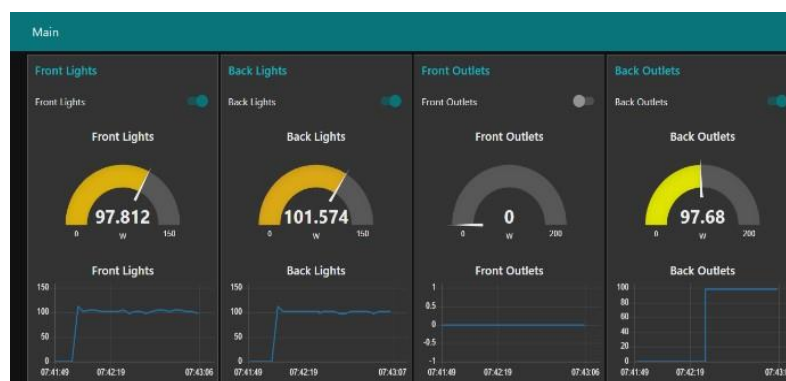


Figure 6. Web-based application

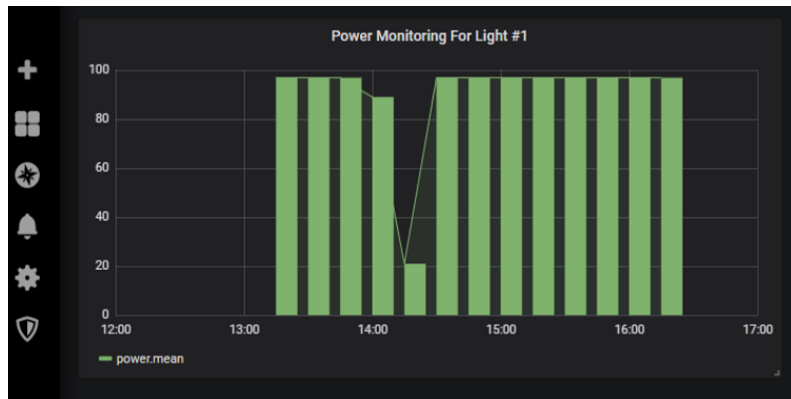


Figure 7. Grafana interface for historical data

Network band:	2.4 GHz	
<input type="button" value="Edit"/>		
Devices connected:	4 of 8	
Device name	IP address	Physical address (MAC)
Unknown	192.168.137.205	cc:50:e3:08:6f:e3
ESP_0870BD	192.168.137.122	cc:50:e3:08:70:bd
Unknown	192.168.137.79	80:7d:3a:58:fc:d0
ESP_5D352F	192.168.137.86	80:7d:3a:5d:35:2f

Figure 8. Connection of the hardware node to the network

Table 4 was made to compare current structures based on the project was made to validate the solution. Current devices use Bluetooth, which limits the ability of devices to be monitored outside the home. Each appliance must be paired with a smartphone in order to be monitored. Others use a PC server that consumes at least 200 watts of power, which is excessive given the control of appliances. The use of Arduino as an HTTP webservice limits versatility to external functions such as the database due to its limited memory. It can be seen that using a single data protocol, such as MQTT, simplifies and improves the system, especially for microcontrollers. Using Node-red provides an easy-to-use web-based user interface with no device installation for both smartphones and PCs.

Table 4. Table of comparison based on related literature

IoT Systems	Protocols	Controller Node and Server	Application	Accessibility
Mowad, Ahmed and Ahmed (2014) [4]	Bluetooth and RF	Arduino with Bluetooth module and PIC with RF Module	Phone Application	Local
David, Chima, Ugochukwu and Obinna (2015) [5]	WiFi/ Bluetooth	Arduino with Bluetooth module and PC	Web Application	Local/ LAN
Al-thobaiti, Abosolaiman, Alzahrani, Almalki, and Soliman (2014) [6]	WiFi/ USB	Arduino and PC	Web Application	Local/ LAN
Hasan, Monirujjaman, Asaduzzaman, Israt and Rumpa (2015) [7]	Bluetooth/GSM	ATMEGA16 with Bluetooth and GSM Module	Phone Application	Local
Bautista, Ong, Pineda, Urbano, Uy and Dulay (2015) [10]	Powerline Communication	PLC and PC	PC Application	Local
Astier, Zhukov, and Murashov (2017) [11]	Modbus/ LAN	RTU and Server PC	PC/ Server Application	Local/ Internet
Project	WiFi/ Internet	ESP8266 and Raspberry Pi	Web Application	Local/ Internet

#### 4. CONCLUSION

The conclusions were derived from the data and results. In the development of hardware, it is appropriate to determine the user and hardware requirements for specifications, block diagrams, flowcharts, schematic diagrams, and electrical layouts. The hardware is simple to assemble and implement because it makes use of the setup's existing wiring connections. The web application was designed to be user-friendly



on both PCs and smartphones. The test provided precise measurements as well as a satisfactory response to control and monitor the appliance.

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