Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 8, Issue 2, 2024, Page 72-82
ISSN: 2616-1192

(www.ujesr.org)

IoT Based Bi-directional Guest Enumerator with Smart Light Control

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Abstract
In this era of smart technologies, the integration of Internet of Things (IoT) in various applications has become increasingly prevalent. This work presents an innovative solution for efficient visitor counting and automatic light control using Blynk IoT. The system incorporates IR sensors for accurate bidirectional counting of visitors, providing real-time data on occupancy. The methodology used in this work is the Waterfall Model. The core functionality of the system relies on an IoT enabled microcontroller that communicates with Blynk, a popular IoT platform. The designed system consists of two major units; the visitor counter unit and the energy saving unit, with the later depending on the result of the visitor counter unit. The bidirectional sensors of the counter unit are strategically placed to detect the movement of individuals entering or leaving a specified area. The gathered data is seamlessly transmitted to the Blynk cloud, allowing users to monitor visitor traffic remotely through a user-friendly mobile application, thus preventing overcrowding. The energy saving unit incorporates an automatic light control mechanism based on the occupancy data collected. When the visitor count is at least one (1), the system turns ON the AC light bulb in the monitored area. Likewise, when the visitor count is zero (0), the AC light bulb in the monitored area is turn OFF. This is validated through the test conducted in a room where this system was deployed and a 50% reduction in cost of electrical energy due to efficient consumption of energy was achieved.

Keywords: *IoT, Digital Counter, LCD, Sensors, Arduino*

Received: 4th February, 2024 *Accepted: 3rd April, 2024*

1. Introduction

Nowadays, modern technology has witnessed an epidemic rise. It makes human life much easier by simplifying our way of life. It changed the methods of communication, products manufacturing, method of transportation, knowledge and thoughts of people. Through the application of vision technology, monitoring the environment becomes easy and feasible. This has many benefits, for example, management of resources, security, urban planning, and advertising. From a point of view of technology, computer solutions of vision always consist of detecting, transmitting and analysing persons using a CPU (Carvalho et al., 2016).

Visitor counting is simply a measurement of the visitor traffic entering and exiting conference rooms, malls, sports venues, etc. With the increase in standard of living, there is a sense of urgency for developing circuits that would ease the complexity of life. A digital bi-directional counter system is considered a smart system. It is capable of detecting and calculating number of moving objects, like cars or individuals that passes through an area such as doors, gates, an intersection or a tunnel. Also, this system is capable of analysing the direction of an individual (entering or exiting) passing through an enclosed place, thus it is termed bidirectional (Jafrul et al., 2018). There are many examples of these applications such as: in shopping malls or markets where the number of customers that are entering or leaving malls or markets during a period of time are tracked; financial institutions such as banks may need to remotely track number of customers entering, exiting or currently inside a banking hall within a specific period of time; also garage owners need to know the number of vehicles that entering, exiting or inside their garage to control parking capacity. In Baghdad for example or any other big city that suffers traffic jam all time, knowledge of the number of people and moving cars in streets and blocks can help determine how to control the traffic, thus preventing traffic jams (Vivekananth et al., 2017).

This work develops an IoT based bi-directional visitors' counter with automated control of electronic appliances such as light bulbs. It is Internet of Things (IoT) based since the system can be connected to other systems through Wi-Fi and information obtained from the counter system can be transmitted for processing through various channels to get the accurate number of visitors at different periods, thus making available the option of remote monitoring, and additionally ensuring efficient electrical energy consumption.

2. Materials and methods

2.1 Materials

The IoT based visitor counter is designed to respond to the flaws in the operations of the existing counters. The design consists of four (4) main units. These include the Power Supply Unit, Processing Unit, Input/Detection Unit (IR sensor circuitry), and the Output Unit (OLED display, Relay and AC light bulb). The open-source Arduino Software (IDE) version 1.8.19 was used to write control code for the Node-MCU using C programming language, and to upload the written code to the microcontroller board. Blynk IoT was used to facilitate communication and data exchange between IoT devices as well as storage of traffic data to cloud database for further analysis and real-time/remote monitoring. Proteus 8.6 was used to create schematics and electronic prints for manufacturing printed circuit boards of the system. It was used to simulate the work prior to implementation, to avoid damaging the components during construction due to wrong connection. Since the major hardware components in the Input (IR Sensors), Output (LCD, single channel relay) and Process (Node-MCU ESP8266) sub-units require 5V DC, the Power Supply Unit shown in figure 1 below supplies a voltage of 5V DC.

Fig. 1: 5V power supply adapter

The Node-MCU ESP8266 Development Board as shown in Figure 2 is the brain box of this system because it controls the entire behaviour of the system such as obtaining input from the sensor, displaying data on the OLED, signaling the relay to control the load and automatically upload visitors traffic data to Blynk IoT cloud database using the NodeMCU ESP8266 WiFi Module. This Microcontroller Unit was programmed using Arduino IDE with C programming language.

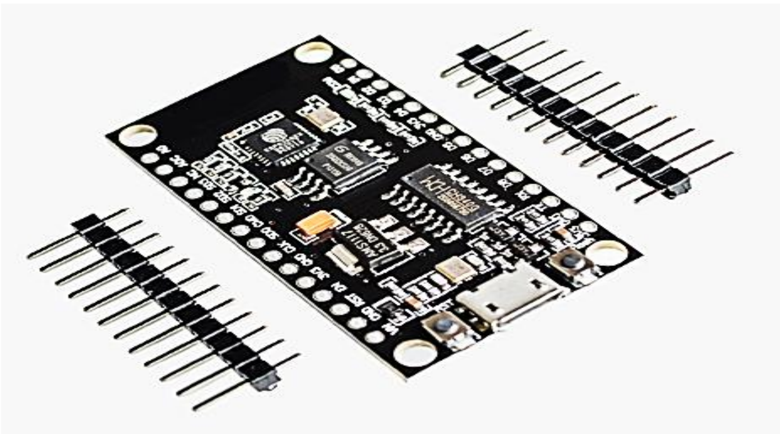

Fig. 2: Node-MCU ESP8266 development board

2.2 Connection of major components to the Node-MCU

The I2C Pins (SDA & SCL) of the 0.96″ OLED Display were connected to the D2 and D1 Pins of the Node-MCU. The output pin of the pair of IR Sensors was connected to D5 and D6 pins of the Node-MCU. Depending on the desired layout, one of the IR Sensors acts as the incoming visitor counter and the other as the outgoing visitor counter. Similarly, a 5V Relay Module is connected to the D4 Pin of Node-MCU. Both the IR Sensors and Relay Module works at 5V VCC. You can supply 5V from Amica Node-MCU Vin pin or Lolin Node-MCU VU Pin.

2.3 System block diagram

As shown in Fig. 3, the system consists of four units which include:

a. Power supply unit: A 5V Power Supply Adapter supplies power to the major components of the system through the control unit (Node-MCU) VIN port.
b. Processing unit: The Node-MCU ESP8266 module controls the operation of the input and output units.
c. Input unit: A pair of Infrared Sensor modules serves as sensing devices which detects entry or exit of a person and send input signal to the control unit.
d. Output unit: The output unit of the system consist of three sub-units:
   i. A single channel relay module which controls the load (light bulb) depending on the command of the control unit.
   ii. An Organic Light Emitting Diode which serves as a physical display unit of the system.
   iii. Blynk IoT serves as a cloud database for storing visitors' traffic data and for real-time/remote monitoring of the traffic.

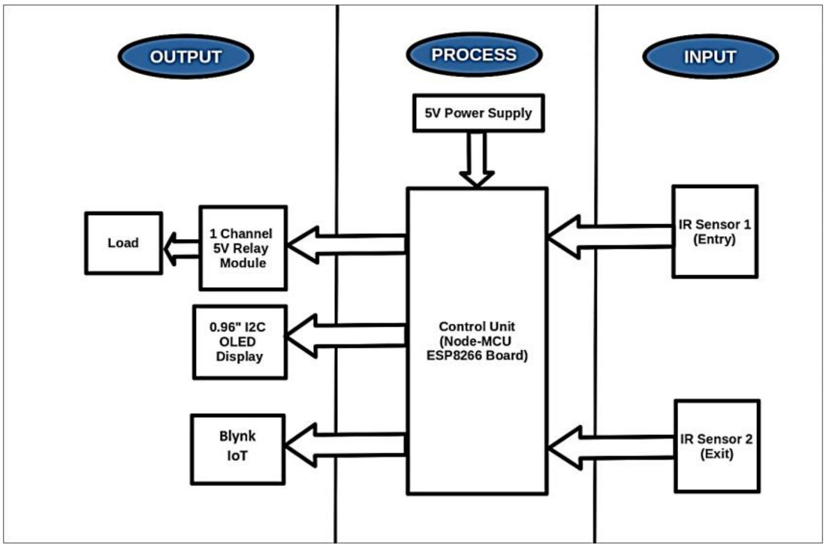

Fig. 3: Block diagram of the system

2.4 Circuit diagram and schematic of the system

The circuit diagram entails the connections and interfacing of each component device to each other. The IR sensors, OLED and relay are connected to the Node-MCU (Micro-Controller Unit), while the light bulb (load) is connected to the relay pins. As shown in Fig. 4, the I2C Pins (SDA & SCL) of 0.96″ OLED Display are connected to the Node-MCU D2 and D1 Pins. The output pin of the pair of IR Sensors are connected to D5 and D6 pins of the Node-MCU. Similarly, the 5V Relay Module is connected to the D4 Pin of Node-MCU. Since 5V IR Sensors and Relay Modules are used in the system, a 5V Power is supplied from Amica Node-MCU Vin pin or Lolin Node-MCU VU Pin. The circuit diagram and schematic of the system are show in Fig. 4 and 5, respectively.

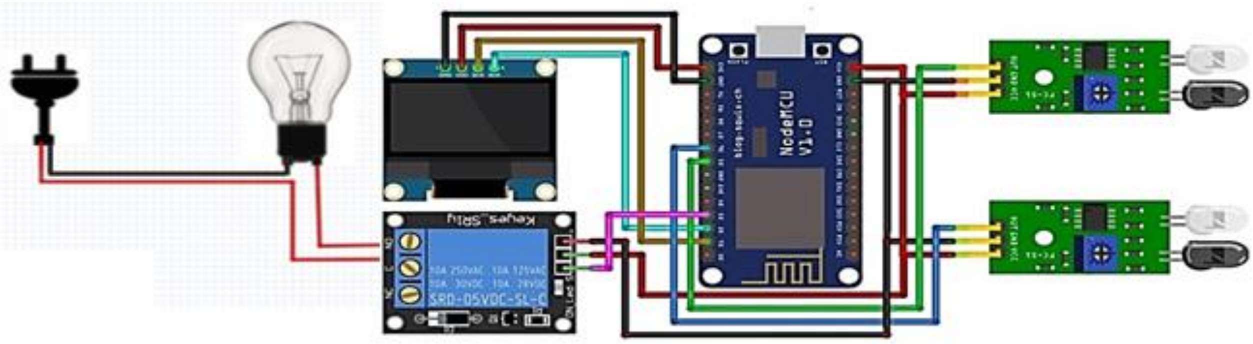

Fig. 5: Circuit diagram of the system

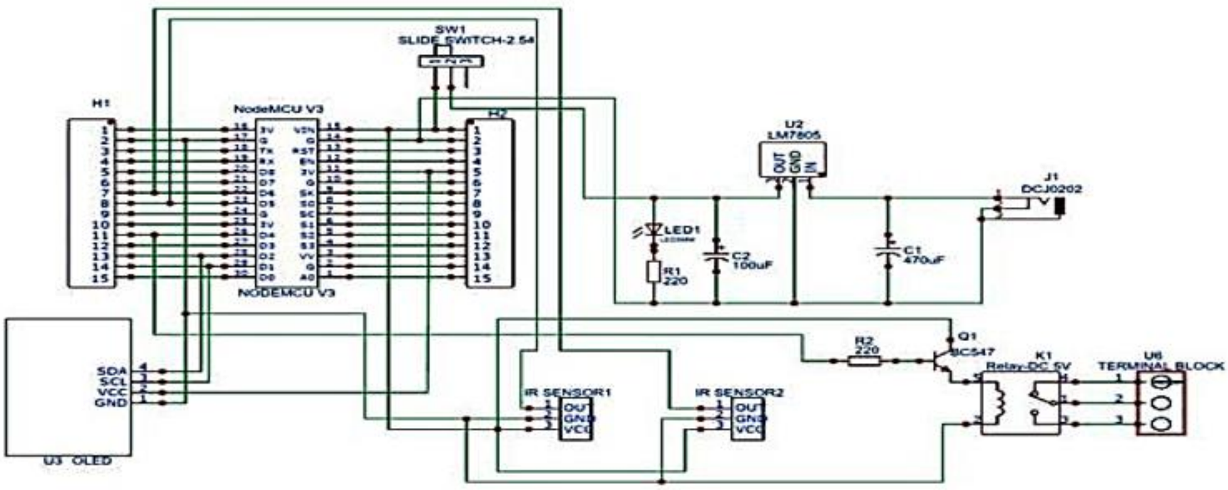

Fig. 6: Schematic of the system

2.5 System flow chart

The flowchart of the IoT based Bi-Directional Visitor Counter with automated light control is shown in Fig. 7. A single entrance is used to model the system. A person entering the room must first pass through IR Sensor 1 before IR Sensor 2. Once the microcontroller has finished reading the data, it will increase its count and switch ON the relay which in turn activate the light. A person leaving the room must first pass through IR Sensor 2 before IR Sensor 1. As soon as the microcontroller has finished reading the data, it will decrement its count by one. If the value of count is less than or equal to zero, that means there is no person in the room and the microcontroller will switch OFF the relay which in turn deactivates the light. Finally, traffic data is constantly updated in both the LCD and the Blynk IoT cloud database.

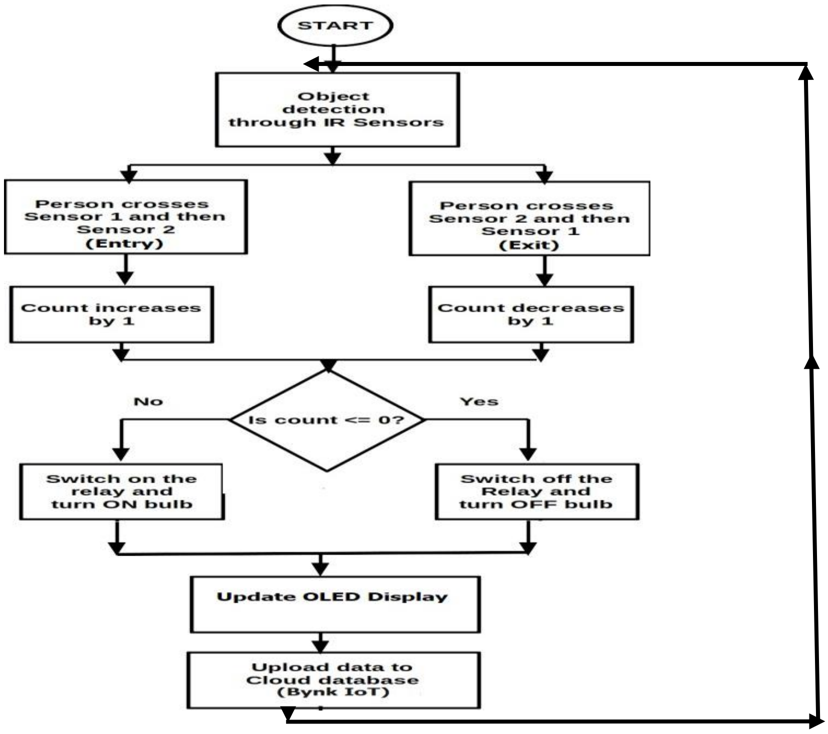

Fig. 7: Process flow chart

2.6 Software implementation of the system

As shown in Fig. 8, Arduino Software (IDE) was used to write control code for the Node-MCU using C programming language, based on the flowchart of the system in figure 7. With Arduino IDE, the sketch (code) was upload to the Node-MCU ESP8266.

2.6.1 Integrating with Blynk IoT

Blynk IoT protocol offer real-time and remote monitoring of the system. The web dashboard of the Blynk IoT is shown in Fig. 9.

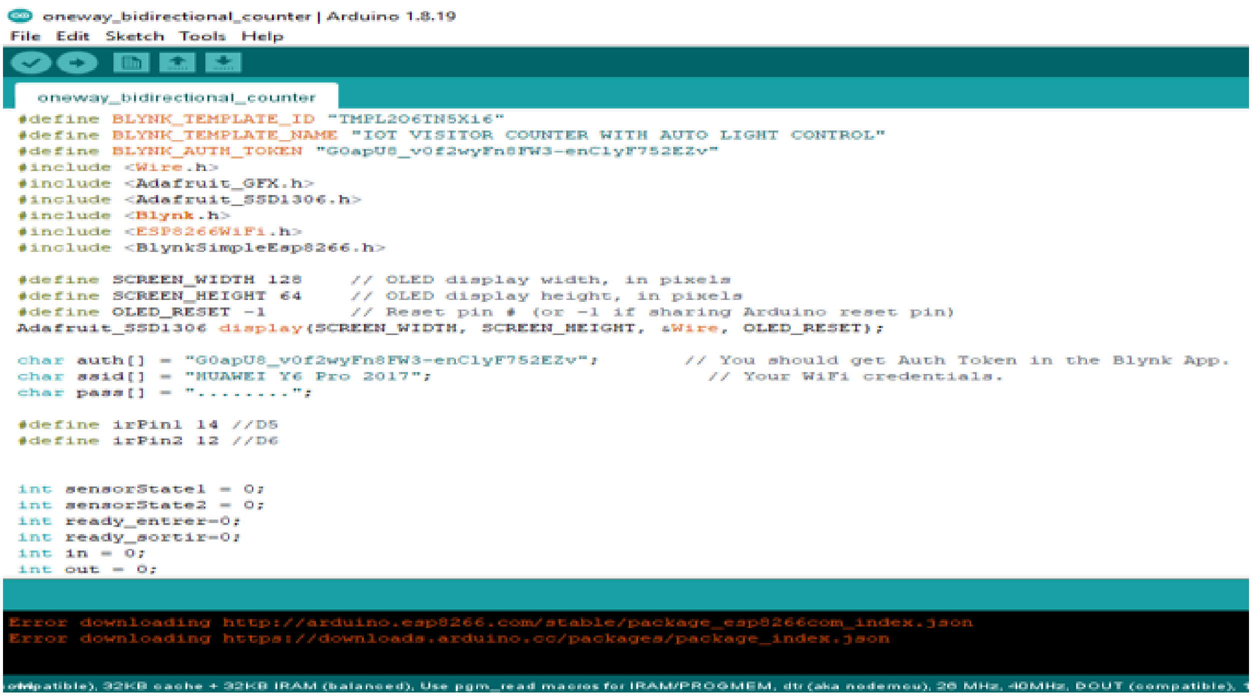

Fig. 8: Writing the control program with Arduino IDE

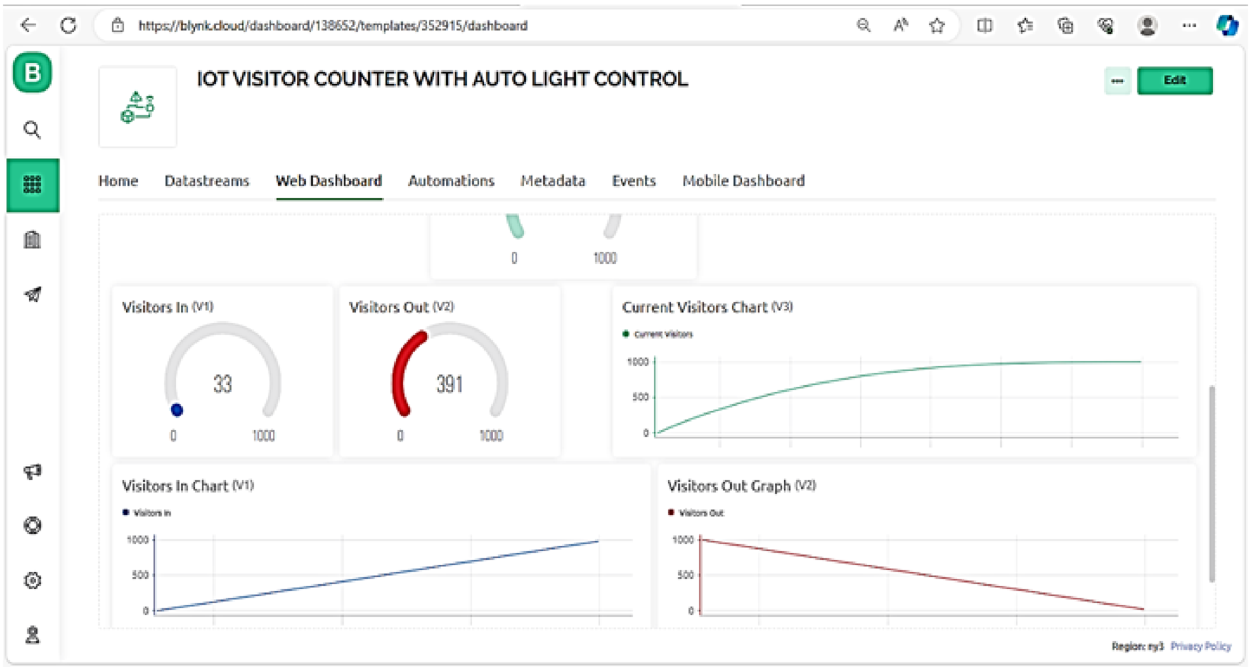

Fig. 9: Blynk IoT dashboard

2.7 Hardware implementation

2.7.1 Designing of the counter circuit

This entails the connections and interfacing of each component device to each other. From Fig. 10, the IR sensors and OLED are connected to the Node-MCU (Micro-Controller Unit). The I2C Pins (SDA & SCL) of 0.96″ OLED Display are connected to the Node-MCU D2 and D1 Pins. The output pin of the pair of IR Sensors are connected to D5 and D6 pins of the Node-MCU. Since 5V IR Sensors is used in the system, a 5V Power is supplied from Amica Node-MCU Vin pin or Lolin Node-MCU VU Pin.

2.7.2 Designing of the electrical power saving circuit

The relay is connected to the Node-MCU (Micro-Controller Unit), while the light bulb (load) is connected to the relay pins. As shown in Fig. 11. The 5V Relay Module is connected to the D4 Pin of Node-MCU.

2.7.3 Interconnection of the above circuits.

The above counter and energy-saving circuits are interconnected into a single system as shown in system circuit diagram in Fig. 5.

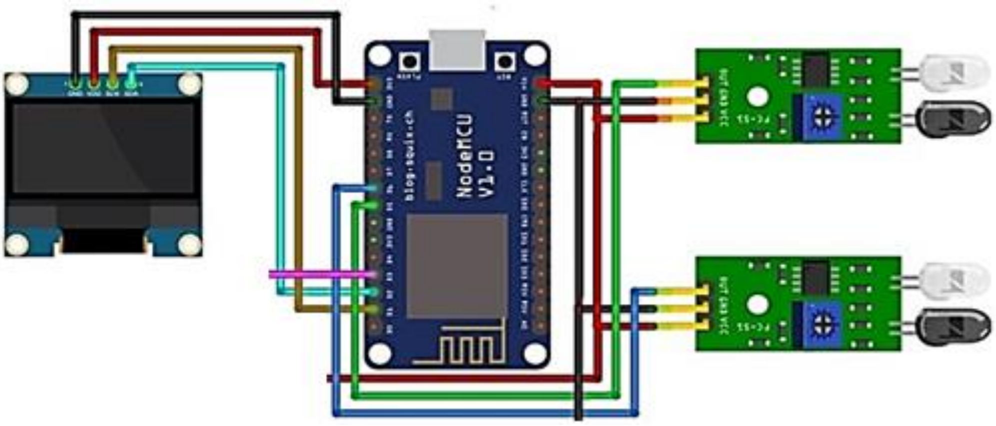

Fig.10: Circuit diagram of the counter unit

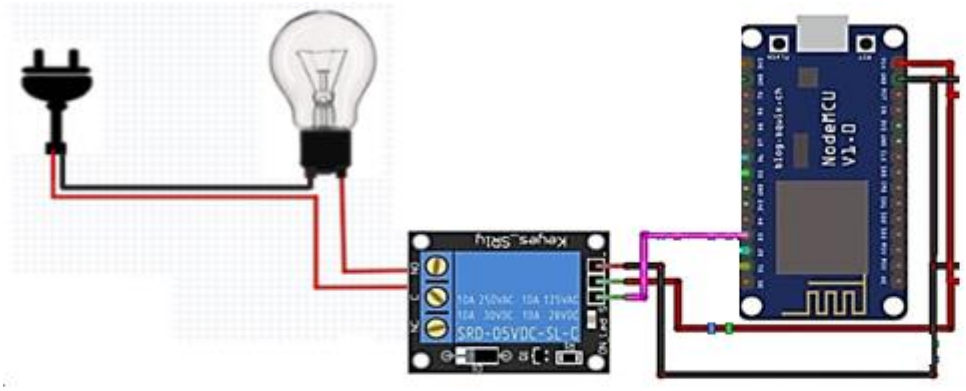

Fig. 11: Electrical power saving circuit

3. Results

3.1 Analysis

A. Case I: The room appliances are in off state, if there is nobody in the room which implies that energy is getting conserved instead of wasting. The Fig. 12 gives a pictorial representation of the Blynk IoT charts for Current Visitors, Visitors In and Visitors Out. As shown in Fig. 13, the light widget is white indicating that lights have been turned off.

B. Case II: The room appliances are switched on as the person enters the room. The Fig. 14 gives a pictorial representation of the Blynk IoT charts for Current Visitors, Visitors In and Visitors Out. As shown in Fig. 14, the light widget is green indicating that lights have been turned on. Through incorporation of real-time remote tracking/monitoring into the system, accurate data for various research and analytical purposes are made available, as it generates live, hourly, daily, monthly, and yearly report, as shown in Fig. 15.

Fig. 13: Visitors report (room empty)

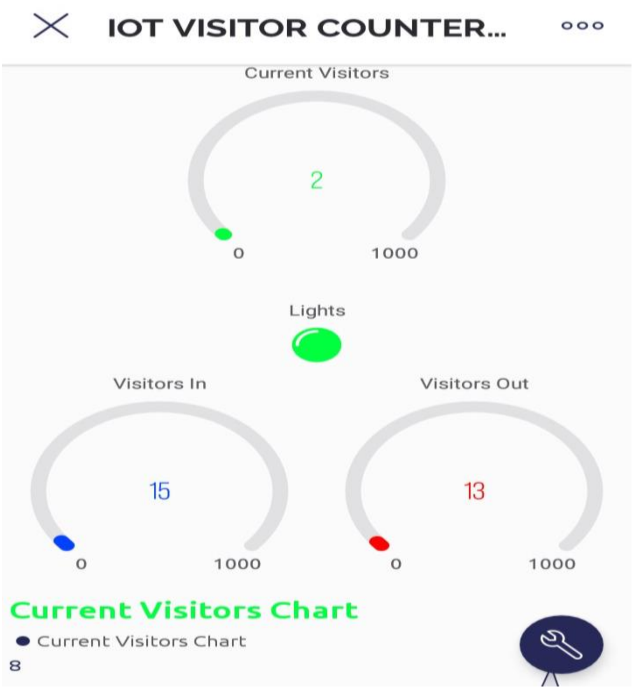

Fig.14: Visitors report (room occupied)

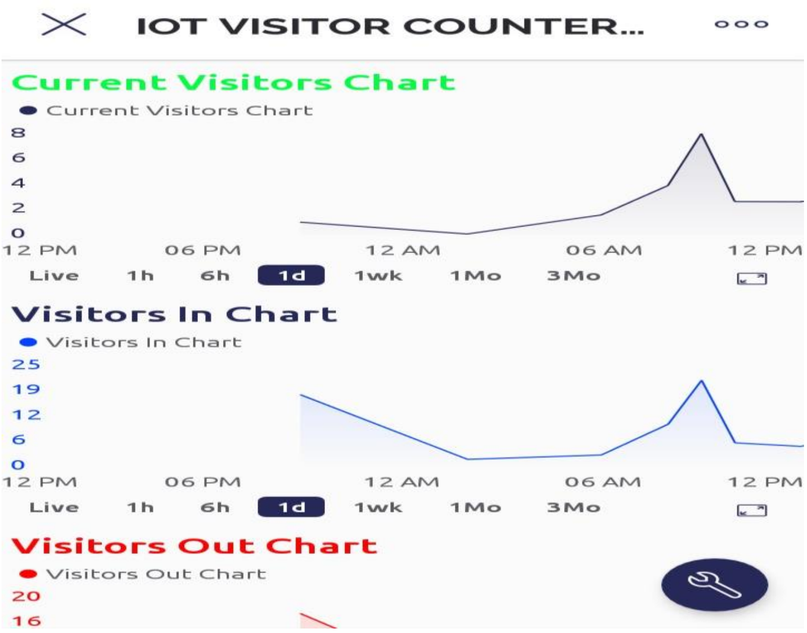

Fig. 15: Chart of current visitors, visitors in/out

3.2 Energy saving calculations

The load in this project is a single 10 Watts AC light bulb which is automated by the designed system. To establish energy saved by this system, two assumptions was made:

1. Say tariff rate is ₦46.15k per unit of energy consumed per hour.
2. At least one person is present in the room/hall where this system is installed for 12 hours per day.

CASE A: Energy units consumed in kilowatts hour when room is occupied for 12 hours per day is calculated as follows:

Energy units consumed for 12 hours is (10watts * 12 hours)/1000 = 0.12KWh

Energy charged is (₦46.15k * 0.12KWh) = ₦5.54k
Energy charged per month is (₦5.54k * 30 days) = ₦166.20k
Energy charged per year is (₦166.20k * 12 months) = ₦1,994.20k

CASE B: To calculate the energy units consumed in kilowatts hour when the system is not installed in the room, thus the AC light bulbs are constantly ON for 24 hours per day,

Energy units consumed for 24 hours is (10watts * 24 hours)/1000 = 0.24KWh
Energy charged is (₦46.15k * 0.24KWh) = ₦11.08k
Energy charged per month is (₦11.08k * 30 days) = ₦332.40k
Energy charged per year is (₦332.40k * 12 months) = ₦3,988.80k

From the above calculations, the value of energy saved per year/efficiency of the system can be calculate as follows:

From CASE A, let E24 be cost of energy per year when this system is not installed in a room and the AC Light bulb is ON for 24 hours per day.

From CASE B, let E12 be cost of energy per year when this system is installed in a room and the AC Light bulb is ON for 12 hours per day.

$$\text{Efficiency} = \frac{E24-E12}{E24} \quad (1)$$

$$\text{Efficiency} = \frac{₦3,988.80k - ₦1,994.20k}{₦3,988.80k}$$

$$\text{Efficiency} = \frac{₦1,994.60k}{₦3,988.80k}$$

$$\text{Efficiency} = 0.5$$

From the calculation above, it is evident that this system saved 50% of the cost of electrical energy in a year when deployed because the AC light bulbs are only turned ON when the room is occupied. The electrical energy saved is dependent on how long the room is occupied per day. Therefore, when this system is installed in a room, the user can be rest assured that they only pay for the energy units consumed. Furthermore, this system will reduce national budget for power generation allocated to a country since electrical energy wastage will be minimized.

From CASE A when the system is not installed in a room with a single 10 watts AC light bulb, energy is charged at ₦166.20k per month which cumulates to ₦1,994.4k after 12 months as shown in Table 1. From CASE A when the system is not installed in a room with a single 10 watts AC light bulb, energy is charged at ₦332.40k per month which cumulates to ₦3,988.80k after 12 months as shown in Table 2.

Fig. 16 compares total amount in Naira charged for 10 watts of AC light bulb when this automated system is installed and when it is not. From the graph, we can see that more cost of electricity is incurred when this system is not deployed (CASE B), as compared to when it is deployed (CASE A). Thus, the cost of electricity is cut down by 50%, depending on the number of hours spent per day in the room where the system is deployed.

Table 1: CASE A - cumulative cost of energy for 12 months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cumulative cost of energy (₦)	166.2	332.4	498.6	664.8	831.0	997.2	1,163.4	1,329.6	1,495.8	1,662.0	1,828.2	1,994.4

Table 2: CASE B - cumulative cost of energy for 12 months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cumulative Cost **OF ENERGY (₦)**	332.4	664.8	997.2	1,329.6	1,662	1,994.4	2,326.8	2,659.2	2,991.6	3,324.0	3,656.4	3,988.8

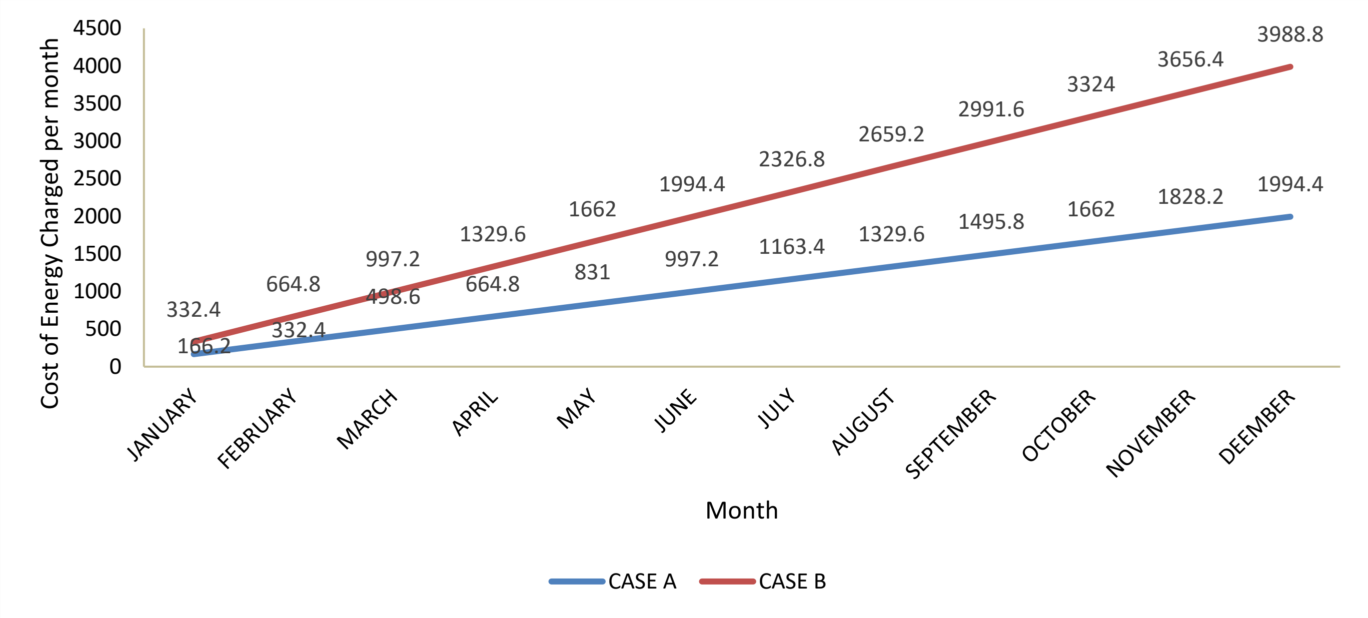

Fig. 16: Case A vs Case B

4. Discussion

The IoT based Bi-Directional Counter with Automatic Light Control System offers a host of benefits by leveraging its technologies to do considerably more than merely "count heads." People counting systems can provide statistics that is useful for both fundamental business metrics like gross margins and more complex insights into areas like staff deployments, marketing program effect measurement, and energy conservation and control. These benefits include:

a. Deploying staff more effectively: It is important to understand not only the cumulative number of workers at any given time in large companies and institutions with different divisions, but also where they'll have the greatest impact on customer service and sales. This becomes a simple task with the ability of bidirectional visitor counters to investigate traffic flows and identify concentration patterns.
b. Keeping a detailed record of the number of people in a particular area: From a business standpoint, bidirectional people counters allow you to calculate how many people are in an environment from the start of the business day to closing time. It is important for gathering conversion rate data that can be linked to specific times of the day or activities, rather than the relatively uninformative periodic or weekly averages. Retailers can also calculate the optimum number of customers in a given location by measuring fluctuations in total people counts. More customers are definitely a plus, but too many customers can cause clogged aisles, an inadequate number of employees to serve them, and a higher risk of out-of-stock scenarios.
c. Energy Saving: When this automated system is deployed, users can be rest assured of paying only for the energy units used. This also translates to reduction in the high cost incurred in electrical power generation as power wastage is drastically reduced.
d. Real-Time and Remote Monitoring of visitors entering and exiting an enclosed area.

5. Conclusion

The designed IoT-based bidirectional visitor counter with automatic light control has proven to be a successful and innovative solution for efficiently managing and optimizing lighting in various spaces. The integration of Internet of Things (IoT) technology has enabled real-time monitoring and data analysis, providing valuable insights into visitor traffic patterns. The bidirectional counting system ensures accurate and reliable tracking of individuals entering and exiting a space, contributing to a more precise understanding of occupancy. The automatic light control feature, triggered by the visitor count, enhances energy efficiency by ensuring that lighting is only active when necessary. This not only reduces energy consumption but also aligns with sustainable practices and contributes to cost savings. The project has effectively addressed the need for intelligent systems capable of adapting to dynamic environmental conditions, promoting a more efficient use of resources. Hardware components of the system were tested and were in good working condition. The Node-MCU ESP8266 was then independently interfaced and implemented with each unit. Each unit of the system was tested separately. After the visitor counter unit yielded the expected result, the energy saving unit was put to the test. After all units were found to work as expected, they were interconnected and the system was tested as a whole. The entire program was written in C language and compiled with Arduino IDE platform.

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