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An Eco-Friendly and Low Cost IoT based Room Temperature Control by Fan Speed Regulation for Tropical Use

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Abstract:- This work presents an Internet of Things (IoT) based room temperature monitoring and control system by fan speed regulation developed for use in rooms of tropical regions of West Africa. In this work, cutting-edge technologies were integrated, including IoT, and cloud-based monitoring to create a system capable of dynamically remote controlling fan speed based on real-time temperature data. The Dallas DS18B20 Waterproof Temperature Sensor serves as the cornerstone for accurate temperature monitoring. A Microcontroller (Node MCU ESP8266) with Wi-Fi Module facilitates IoT connectivity, allowing users to remotely monitor and control the system through the Blynk Cloud and the Blynk App. A 12V DC table fan, driven by a MOSFET which is being controlled through Pulse Width Modulation (PWM) by the microcontroller, enables fine-tuned speed adjustments. A 16x2 LCD display provides real-time feedback on current temperature and fan speed percentage, enhancing user awareness. The microcontroller programming involves the implementation of an adaptive algorithm for dynamic fan speed control based on the room temperature, user settings and some preset parameters conditioned for tropical region of West Africa. By dynamically adjusting fan speed based on real-time temperature data, the system optimizes energy consumption, providing sustainable and eco-friendly solutions. The circuit was designed and simulated in Proteus software, the code was written in Arduino IDE, tested on breadboard, implemented finally on Veroboard and all fitted inside a suitable box. After testing the system, it worked as expected and it was observed that the fan speed increases as the room temperature increases and vice versa. Also, the fan speed depends both on the room temperature and the set threshold value. It was also observed that the speed of the fan is at its maximum when the temperature is above 40°C. Thus, the developed system is good for room temperature control in the tropical region of West Africa.

***Keywords:-** Temperature Control; Fan Speed Regulation; Sensor; Microcontroller; IoT.*

I. INTRODUCTION

Systems that monitor the environment have become important components of modern lives and sustainable smart living realization. They have evolved from simple sensors to sophisticated, interconnected networks. The integration of diverse sensor technologies, real-time data analytics, and Internet of Things (IoT) connectivity represents the current terrain of modern environmental monitoring such as in meteorology, agriculture, transportation, space, etc. [1]-[4].

In today's smart living, the combination of cutting-edge technologies of embedded systems with cloud-based technologies in everyday appliances, particularly those related to environmental control has become a focal point of innovation. The modern residential living and cities have evolved significantly with the integration of smart technologies for diverse purposes. Also, the advent of the IoT has played a significant role in this evolution, offering solutions that bring more convenience, smartness and comfort [5]-[7]. The integration of the IoT and mobile apps enhances user accessibility and convenience by enabling users to be able to remotely monitor and control the system from anywhere with internet connectivity. This especially provides convenience for scenarios where physical presence is impractical or impossible.

Traditional methods of temperature control, especially those reliant on ON-OFF fan control methods and/or fixed-speed fan mechanisms, lack the precision needed to adapt to subtle changes in ambient conditions, and cater for individual preferences dynamically thereby contributing to energy inefficiency. The abrupt transitions between fan states often result in unnecessary power consumption leading to increased utility costs. In the developing world, the inability of most existing temperature-controlled living spaces to adapt dynamically to changing environmental dynamics, such as sudden temperature spikes or drops, hampers their efficacy. This lack of adaptability compromises the systems' ability to provide consistent comfort and environmental control.

There are limited studies on thermal comfort of living buildings such as homes in the tropical sub-Sahara Africa. For example, in the tropical climate of Nigeria, thermal discomfort is a problem because of high indoor temperature. Thermal comfort is the feeling of well-being or satisfaction that an individual experiences in a living space which is influenced by various parameters such as temperature, humidity, air quality, etc. It is the condition of the mind expressing subjective satisfaction with the thermal environment [8].

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Room temperature or indoor temperature varies within the tropics depending among several factors, on the surrounding climate, the type of building, and the season of the year. Thermal comfort survey conducted in three locations in Lagos, Nigeria between July 1996 and June 1997 showed a comfortable temperature range of 26 °C – 28 °C, comfortably cool 24 °C – 26 °C and comfortably warm 28 °C – 30 °C [9].

Reference [10] empirically studied the thermal comfort of Igbo traditional residential buildings in Nigeria. The Igbos are in the Southeast region of Nigeria, with warm humid tropical climate. Five locations were studied from February to April (hottest season of the year). The results showed that the average thermal sensation experienced by the occupants of the buildings varies from cool to slight warm. Mean thermal comfort room temperature is around 28 ^{0}C. Mean indoor temperature in the morning varies from 27.9 ^{0}C - 29.86 ^{0}C, while mean indoor temperature in the afternoon varies from 29.46 ^{0}C - 31.82 ^{0}C. Two of the locations which are not so far from the ocean have morning mean indoor temperature from 25.3 ^{0}C - 25.75 ^{0}C; and afternoon mean indoor temperature from 25.7 ^{0}C - 26.04 ^{0}C.

Reference [11] conducted an empirical thermal comfort study in Jos Nigeria which is a city in the tropical savannah region of Africa between July and August 2006. The recorded indoor-air temperature ranged from 21.96 °C to 29.98 °C across the different locations.

A field study was conducted to understand the conditions of thermal comfort in low-income residential buildings in Abuja, Nigeria. Measurements taken in both air-conditioned and naturally ventilated buildings showed that the average and maximum temperatures in the air-conditioned buildings were 31 °C and 34 °C; and 33 °C and 36 °C for the naturally ventilated buildings [12].

Reference [13] examined the perception of occupants on thermal comfort in Jimeta, Nigeria where the temperature is high, with hot and dry weather. Indoor thermal comfort and room temperature survey of thirty occupants' living rooms were taken using thermometers. Results showed that the average temperature of buildings ranged from 31.86 ºC to 32.18 ºC.

A field study conducted in Hyderabad in India revealed a comfort band of 26 °C – 32 °C with a mean of 29 °C [14]. Studies from Indonesia showed that the range of comfortable temperature falls between 24 °C – 29 °C for residents [15].

Reference [16] investigated the thermal comfort of an enclosed transitional space in tropical buildings in University of Putra, Selangor, Malaysia from August to November 2008. The result showed that the air temperature as measured ranged 23 °C – 32 °C, with a mean value of 28.1 °C.

Reference [17] examined indoor-outdoor correlations of temperature, relative humidity (RH), and absolute humidity (AH) over a 1-year period in seven of the tropical cities of the world. They found out that indoor AH and RH were linearly correlated with outdoor AH when the air conditioning (AC) was off. All indoor measurements were more strongly correlated with outdoor measurements as distance from the equator increased. They also found out that the correlations were weaker during the wet season, especially when AC was in operation. However, one insufficiency of their work is that none of the seven tropical cities studied involved the whole continent of Africa except Madagascar.

A team of researchers from UC Berkeley, Nanyang Technological University in Singapore and Stanford University conducted experiments in the tropical city-state of Singapore [18]. They concluded from their research that increasing the indoor temperature to values in the range of 26 °C – 29 °C with personally controllable fans for the occupants is a sustainable, energy-efficient and cost-effective option for providing thermal comfort.

In the realization of an optimal living environment, comfort management is paramount. The ability to regulate indoor temperatures efficiently and effectively enhances physical well-being as well as contributes to overall quality of life. The integration of smart technologies plays a pivotal role in revolutionizing comfort management within residential spaces [19]. The integration of temperature sensors, and temperature-based dynamic fan speed control mechanisms, often employing IoT technologies, has gained prominence to achieve precision and adaptability in temperature regulation. Precise fan speed control is significant and crucial especially in spaces where a narrow temperature range is essential.

There is increasing need for energy-efficient and sustainable cooling solutions in the developing countries in the tropics such as Nigeria. House/room fans are popular among homeowners to cool their homes cost-effectively. Unlike traditional air-conditioning systems, house/room fans provide a natural and efficient way of cooling that can reduce indoor temperatures and energy consumption. They help maintain a fresh and healthy indoor environment by continuously circulating the air through the room. They also reduce the buildup of pollutants, and prevent stale air, thereby providing better air quality when in use [20].

There has been works on IoT-based temperature monitoring and automatic fan control systems involving diverse components such as LM35 and DHT11 temperature sensors, ESP8266 Wi-Fi module, ESP32 Wi-Fi module, Blynk cloud platform, transistor-based control, TRIAC-based control, relay-based control, etc. [21]-[25]. Some are for demonstration of proof of concept, while some are for demonstration of the suitability of the components/devices chosen. Some work with simple linear algorithms for control while some are to demonstrate complex algorithm or machine learning based.

The aim of this work is to design and implement an IoT based room temperature monitoring and control system that regulates the speed of fan that blows air into a room or living space with user-centric control to provide comfort and energy

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efficiency in residential buildings in the tropical regions of West Africa, especially Nigeria. To achieve this aim, a waterproof temperature sensor, DS18B20 renowned for its accuracy and reliability, was used. A microcontroller ESP8266 with Wi-Fi Module programmed with an algorithm that drives a MOSFET that dynamically adjusts the fan speed in response to changes in room temperature serves as the system's communication hub, allowing for both local and remote monitoring and control of the system via a Blynk IoT App. For real-time feedback, an LCD Display was incorporated into the system. This display unit offers a visual representation of the current room temperature and the corresponding fan speed percentage.

Furthermore, the work integrates with Blynk Cloud IoT platform. Users can remotely view real-time fan speed and temperature data, and exercise control over the system settings. The application's interface allows users to set threshold values, dictating at what temperature the fan should be activated or adjusted, thus granting a high degree of personalization and adaptability to individual preferences.

II. TEMPERATURE CONTROL SYSTEMS

➢ *Fan Speed Modulation*

Fan speed modulation is a critical aspect of temperature control systems, influencing not only the comfort of occupants but also the energy efficiency of the entire system. Pulse Width Modulation (PWM) has emerged as a prominent technique for fan speed control due to its efficiency and adaptability. Traditional on-off mechanisms often result in abrupt transitions between fan states, leading to spikes in power consumption. PWM allows for more fine control of the fan speed. The ability to precisely adjust the duty cycle allows for a seamless transition between fan speeds, and adjusting the duty cycle based on temperature requirements minimizes energy wastage.

Hybrid approaches combining PWM with other control techniques have been used such as integration of fuzzy logic control with PWM to improve the adaptability of the control system for enhanced speed regulation. The fuzzy logic handles uncertainties and variations in the environmental conditions.

➢ *Adaptive Temperature Regulation*

Adaptive temperature regulation systems aim to provide a proactive response to changing environmental conditions. The adaptive approach enables the system to anticipate temperature changes and adjust fan speed in advance, ensuring a smoother and more controlled transition between states. By dynamically modulating fan speed based on predictive algorithms, the system optimizes energy usage, avoiding unnecessary peaks in power consumption associated with abrupt changes in fan speed.

Adaptive systems go beyond temperature sensing but integrating multiple sensors for comprehensive context awareness such as temperature, humidity, air quality, occupancy, solar radiation, motion, etc. Multi-sensor approach creates a comprehensive environmental monitoring system and enables the system to consider a broader range of environmental factors when making adaptive adjustments [26].

➢ *IoT Integration in Temperature Control Systems*

The integration of the Internet of Things (IoT) into temperature control systems has ushered in a new era of connectivity, providing remote monitoring, control capabilities, and data-driven insights. There is a growing interest in leveraging IoT technologies to enhance the adaptability, accessibility, and overall intelligence of temperature control systems [27], [28].

Also, there is a trend towards leveraging cloud-based platforms for data storage and analytics in IoT-enabled temperature control systems. Cloud integration has advantages in collecting and analyzing large volumes of data generated by temperature sensors [29], [30]. Cloud platforms provide scalable and secure storage, enabling the application of advanced analytics and machine learning algorithms for predictive temperature control.

The integration of IoT also extends to user interfaces, contributing to a more user-centric design. IoT platforms, such as Blynk, provide users with a visual interface for monitoring temperature data and adjusting control parameters, ensuring a seamless and user-friendly experience [31]. While the potential benefits of IoT integration are substantial, there are still challenges. Ensuring the security and privacy of IoT-enabled systems remains a concern. Additionally, the interoperability of diverse IoT devices and platforms poses challenges, particularly in heterogeneous environments with multiple vendors and protocols.

III. MATERIALS AND METHODS

A. System Overview and Principle of Operation

The developed system operates on a principle that involves real-time temperature sensing, dynamic fan speed modulation, and Internet of Things (IoT) integration for room temperature control. It uses ESP8266 Wi-Fi Module and observes the data on IoT Blynk mobile app & web platform, and LCD display. The system's block diagram is shown in Fig. 1.

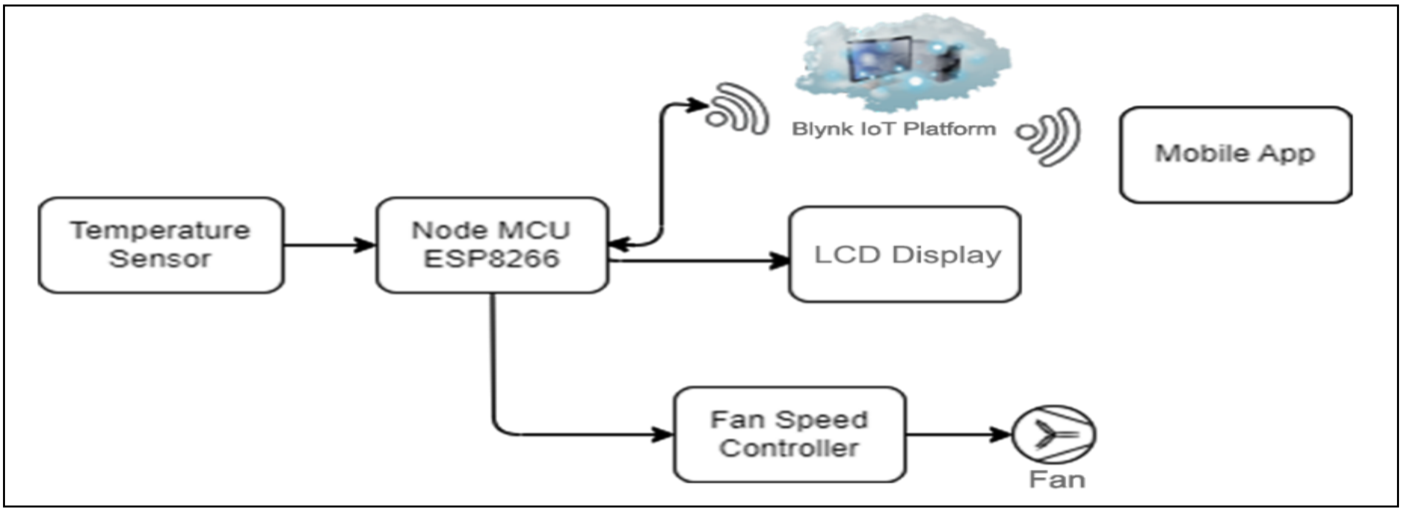

Fig. 1 The System's Block Diagram

- *Temperature Sensing:*

To sense the room temperature, a Dallas Waterproof Temperature Sensor DS18B20 was used [32]. The DS18B20 is a digital temperature sensor that provides accurate and reliable temperature readings. Its waterproof design allows it to be deployed in various environmental conditions. The sensor communicates temperature data digitally to a microcontroller. It features 3V – 5.5V input voltage, -55ºC to +125ºC temperature range, +/- 0.5ºC accuracy from -10ºC to +85ºC, and unique 64-bit ID burned into chip. The probe is 7 mm in diameter and about 26 mm long.

The temperature sensor continuously monitors the ambient temperature and provides precise and instantaneous temperature readings to the microcontroller. It communicates with the microcontroller using a single data wire and a ground wire as shown in Fig. 2. The data wire is used to both transmit and receive data, using a unique serial number that identifies each sensor on the one-wire bus. The sensor also has a built-in 12-bit analog-to-digital converter (ADC) that converts the analog voltage output from the sensor into a digital value that can be read by the microcontroller.

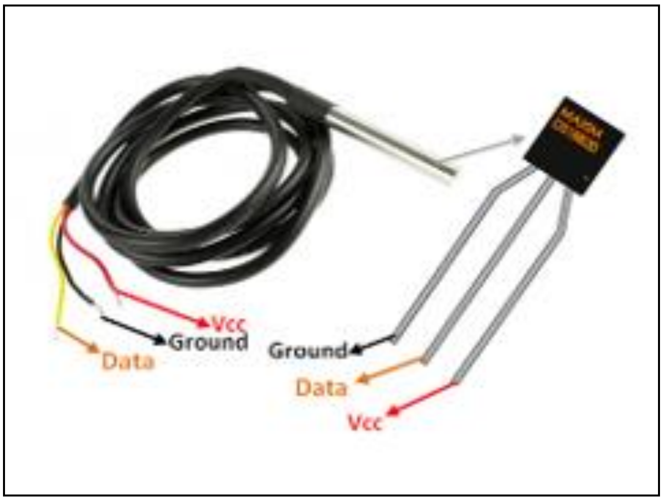

Fig 2 The DS18B20 Temperature Sensor

- *Microcontroller (Node MCU ESP8266) and IoT Integration:*

The microcontroller ESP8266 acts as the brain of the system, executing programmed algorithms [33]. It receives the temperature data from the DS18B20 sensor, executes programmed algorithms to analyze the temperature readings and determine the appropriate fan speed, adjusts the fan speed through PWM control, manages IoT communication with the ESP8266 Wi-Fi module, and controls the display on the 16x2 LCD. It orchestrates the overall functionality of the system. The ESP8266 Wi-Fi module enables IoT connectivity and connects the system to the Blynk App and cloud, allowing users to monitor and control the system remotely.

The Node MCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor as shown in Fig. 3(a). Its high processing power with in-built Wi-Fi/Bluetooth and Deep Sleep Operating features make it ideal for IoT projects. The ESP8266 Node MCU has 17 GPIO pins that can be assigned different functions by programming the appropriate registers as shown in Fig. 3(b) and Table I respectively [34].

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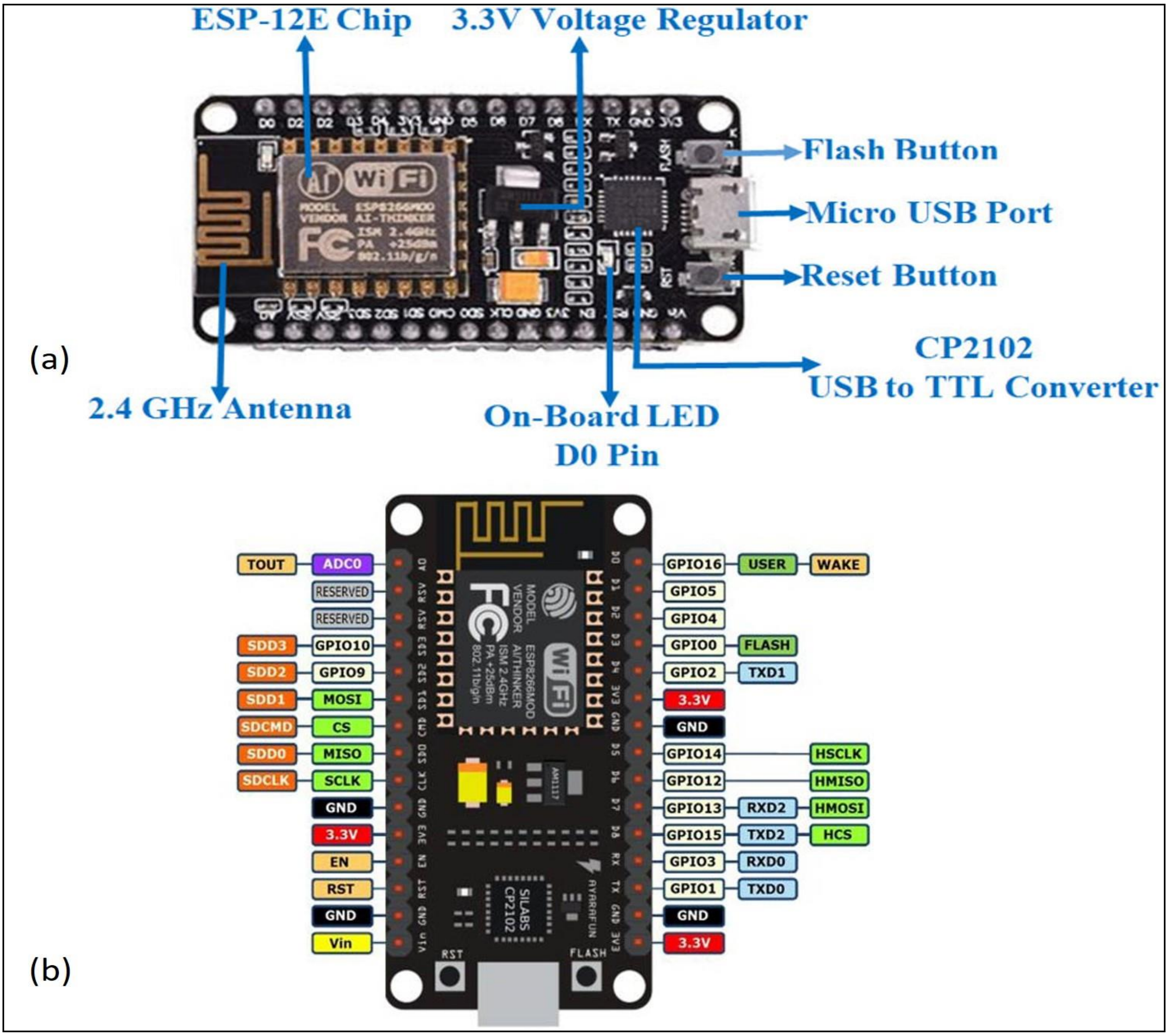

Fig. 3 The Node MCU ESP8266 with Wi-Fi module (a) Physical Outlook, (b) Pinout Configuration.

Table 1 Node MCU ESP8266 Pinout Description

Pin Category	Name	Description
Power	Micro-USB	Micro-USB: NodeMCU can be powered through the USB port.
	3.3V, GND, Vin	3.3V: Regulated 3.3V can be supplied to this pin to power the board. GND: Ground pins. Vin: External Power Supply.
Control Pins	EN, RST	The pin and the button reset the microcontroller.
Analog Pin	A0	Used to measure analog voltage in the range of 0-3.3V
GPIO Pins	GPIO1 to GPIO16	NodeMCU has 16 general purpose input-output pins on its board.
SPI Pins	SD1, CMD, SD0, CLK	NodeMCU has four pins available for SPI communication.
UART Pins	TXD0, RXD0, TXD2, RXD2	NodeMCU has two UART interfaces, UART0 (RXD0 & TXD0) and UART1 (RXD1 & TXD1). UART1 is used to upload the firmware/program.

Source: [34]

- ➢ *Mode of Communication between Sensor and MCU:*

The Dallas Temperature sensor (DS18B20) does not provide a direct analog voltage reading like some other types of sensors. Instead, it communicates using digital signals, i.e. sequences of digital pulses. The sensor communicates with the microcontroller (the NodeMCU ESP8266) using the OneWire communication protocol. The OneWire protocol is a simple and efficient serial communication protocol

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designed for communication with devices over a single data wire. Each device on the OneWire bus has a unique 64-bit address and communicates using this address. The OneWire bus is connected to GPIO pin 12 of the ESP8266.

To request temperature data from the sensor, the microcontroller sends a series of commands to the sensor using the OneWire protocol. The sensor responds by sending the temperature data as a sequence of digital bits. The digital temperature data received by the microcontroller is then converted into a human-readable temperature value in degrees Celsius.

- *Fan Speed Control by PWM Based on Sensor Temperature:*

An electric table fan was used to serve the purpose of providing ventilation and cooling, as is typical in many rooms in Nigeria. In this work, for the sake of reducing power consumption and ease of control, a 12V DC table (desktop) fan was chosen for this application as it is easy to control the speed with Pulse Width Modulation (PWM) signal. The 12V DC fan is an electric fan with a 12V DC motor. There are desktop types and standing types, and some are with rechargeable batteries within. The speed of the fan can be adjusted by the level of voltage supplied to the fan DC motor, and/or also by PWM. It is better and easier to adjust the speed of the fan motor by PWM, as it determines the average voltage supplied to the fan motor without altering the voltage supplied across the fan motor. The PWM control allows the microcontroller to be able to adjust the fan speed dynamically based on the real-time temperature data from the temperature sensor, thus optimizing energy usage. As the temperature increases, the fan speed is incrementally adjusted to optimize cooling efficiency.

In a PWM signal, the ON time is a percentage of the total period. The ON-OFF timing is determined by the duty cycle. So, the duty cycle is directly related to the percentage of the total period the signal is ON. The duty cycle (in %) of the PWM signal is used to control the speed of the fan. A duty cycle of 0% means the fan is off, and a duty cycle of 100% means the fan is running at maximum speed. To use PWM for the DC motor in the table fan, the frequency of the pulses must not be too high to avoid excessive heating arising from high reactance of the motor coils and must not be too low to avoid inertia issues and mechanical jittery or motor chatter.

In this work, the PWM frequency is set at 10 kHz. This frequency provides the best balance between the motor torque and chatter throughout the desired speed range for the table fan that was used. For a duty cycle of 50%, the PWM signal will be ON for 50 µs and OFF for 50 µs, and this pattern repeats at a frequency of 10 kHz. Table II shows the fan speed (in %) with duty cycle (in %) and their respective ON-OFF times.

Table 2 Fan Speed (%) with Duty Cycle (%)

Duty Cycle (%)	0	25	50	75	100
OFF (µs)	100	75	50	25	0
ON (µs)	0	25	50	75	100
Fan Speed (%)	0	25	50	75	100

In controlling the fan speed by temperature, five parameters of interest were decided to be used: the input room temperature from the sensor, t; the threshold temperature (set by the user), T_h; the maximum allowable room temperature, T_m; the initial fan speed (%), F_c; and the maximum fan speed (100%), F_m. Bearing Nigeria which is in the tropical region of West Africa in mind, 40 ^{0}C was chosen as the maximum allowable room temperature for this application. Also, to overcome the mechanical inertia of the table fan at low speed when the fan is ON, an initial fan speed of 10% was chosen whenever the fan is first turned ON.

If the room temperature, as sensed by the sensor is greater than or equal to the specified 'threshold`, the fan is turned ON, otherwise it is turned OFF. For the fan speed determination, the temperature range (`threshold` to 40 ^{0}C) is mapped to the fan speed range (10% to 100%) by the expression in (1)

$$F_s = F_m\left(\frac{t - T_h}{T_m - T_h}\right) + F_c\left[1 - \left(\frac{t - T_h}{T_m - T_h}\right)\right] \quad (1)$$

Where F_s is the fan speed (%), F_m is the maximum fan speed or full speed (100%), F_c is the initial fan speed necessary to overcome inertia of the motor (10% for the table fan used), t is the room temperature from the sensor, T_h is the threshold temperature set by the user, and T_m is the maximum allowable temperature (40 ^{o}C).

In the expression in (1), the fan speed range is mapped linearly to the temperature range. If the room temperature is equal to the specified `threshold`, the fan is turned ON at fan speed of F_c, and for all room temperatures equal to or above T_m, the fan speed adjusts automatically to F_m.

For the table fan used, while the fan speed range is still mapped linearly to the temperature range, the initial fan speed was also made to vary or be dependent on the threshold temperature, instead of being constant for all threshold temperature values. The initial fan speed was programmed to vary non-linearly with the threshold temperature according to a power law as expressed in (2). Here, maximum and minimum allowable threshold temperature values (T_{hmin} and T_{hmax}) were pre-determined, i.e. the user is restricted to threshold values within T_{hmin} and T_{hmax}.

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$$F_s = F_m\left(\frac{t-T_h}{T_m-T_h}\right) + F_{c\max}\left(\frac{T_h}{T_{h\max}}\right)^b\left[1-\left(\frac{t-T_h}{T_m-T_h}\right)\right] \quad (2)$$

Where

$$b = \frac{\log_{10}\left(\frac{F_{c\max}}{F_{c\min}}\right)}{\log_{10}\left(\frac{T_{h\max}}{T_{h\min}}\right)} \quad (3)$$

$F_{c\max}$ is the value of F_c at $T_{h\max}$, and $F_{c\min}$ is the value of F_c at $T_{h\min}$. Still considering Nigeria's case, these values were selected $F_{c\max}$ (30%), $F_{c\min}$ (10%), $T_{h\max}$ (35 ^oC), and $T_{h\min}$ (10 ^oC). With the above parameters, Fig. 4 shows the expected variation of the fan speed with threshold values and room temperature values from 5 ^0C to 55 ^0C.

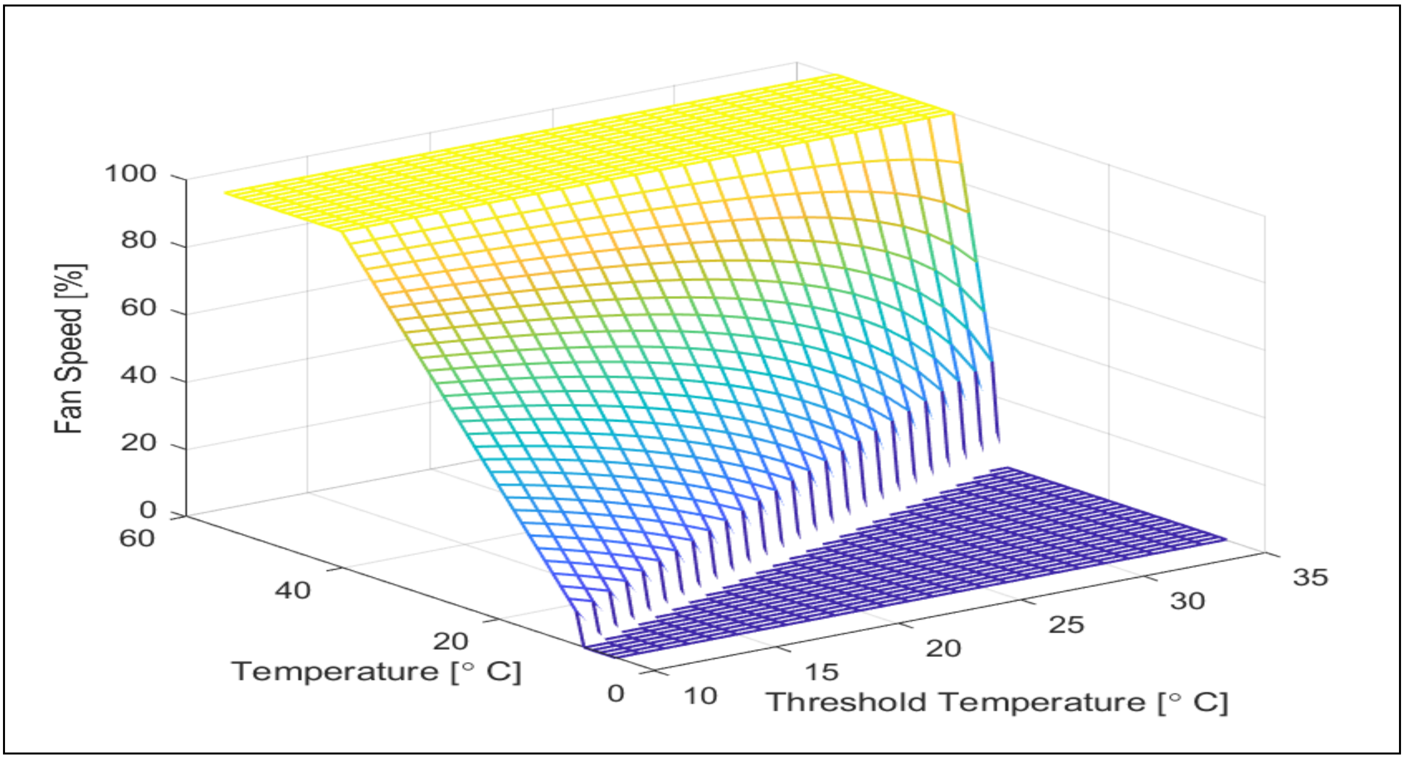

Fig 4 Expected Variation of the Fan Speed (%) with threshold Temperature values and Room Temperatures.

➢ *Local User Interface:*

A 16x2 LCD display is a liquid crystal display used to display content in the form of texts and images. It is cheap, available and programmer friendly. Hence it is commonly used in embedded projects. It has 16 columns and two rows. The 16x2 LCD Display serves as the local user interface as it displays both the instantaneous temperature and fan speed at the same time, thus providing real-time feedback on the current temperature and fan speed. Users can monitor the system's status on the display in the absence of the external Blynk App interface. The user-friendly interface of the display enhances the overall accessibility of the system, providing users with immediate insights into the environmental conditions.

➢ *Blynk IoT Cloud Platform, Blynk App and Interaction:*

The Blynk IoT platform is a fully integrated suite of IoT software. It is a user-friendly platform. Blynk platform allows connection of almost any electronic hardware to the Internet, collect data from devices, monitor and control them remotely from anywhere in the world. Data from devices can be stored, aggregated, and visualized in easy-to-build mobile and web applications [35].

The Blynk app allows real-time monitoring and logs historical data on the Blynk IoT platform. For this work, the Blynk app was configured to display real-time temperature data and current fan speed in percentage; and users can interact with the system through the app. The app's intuitive interface allows users to set fan speed preferences and temperature threshold values, dictating at what temperature the fan should be activated or adjusted, thus granting a high degree of personalization and adaptability to individual preferences. Users can review past temperature trends and system performance through the app.

B. *System Operational Circuit Diagram and Flow Chart*

The system's main circuit diagram is shown in Fig. 5.

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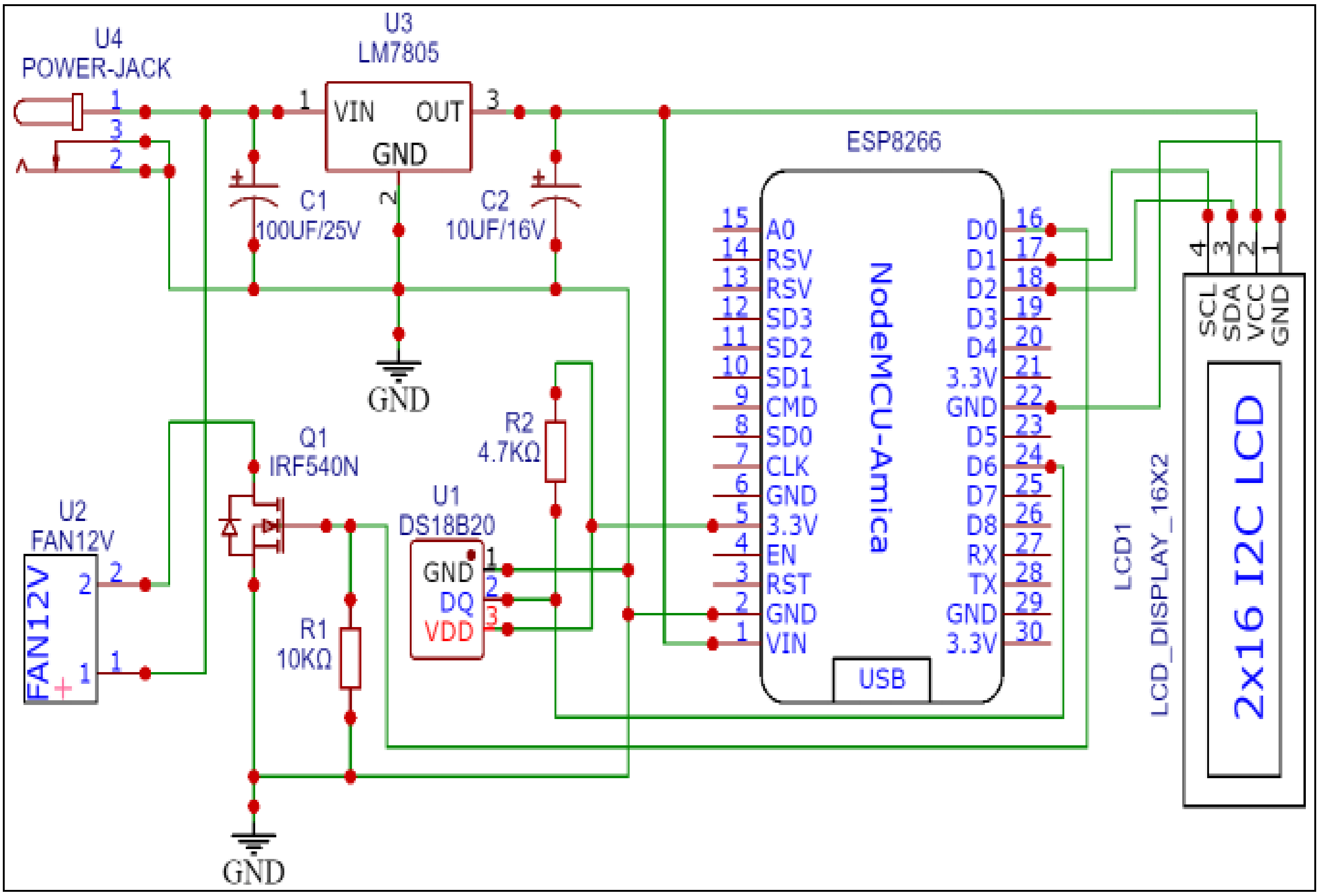

Fig 5 The System’s Circuit Diagram.

The entire circuit is powered by a 12V DC power supply. The DC table fan requires 12V for its operation, while the rest of the components take 5V as input from the 7805 fixed positive voltage regulator IC. Because of the high current requirement of the DC table fan, a commercial 220V/12V 2200mA AC-DC adapter was used to serve as the external 12V DC power supply.

The DS18B20 waterproof temperature sensor is connected to the D6 pin of Node MCU ESP8266. The DS18B20 VCC and GND are connected to 3.3V and GND of Node MCU. The output pin of DS18B20 is pulled high with a 4.7 kΩ resistor. The 16×2 I2C LCD Display is for displaying the temperature and the fan speed. The VCC, GND, SDA & SCL pins of the LCD Display are connected to 5V, GND, D2 & D1 pins of the Node MCU ESP8266 respectively.

The digital pin of the Node MCU is not capable of directly driving the 12V table fan alone because of its maximum current sourcing capability which is far lower than the current requirement of the DC table fan. Therefore, an IRF540 MOSFET is used to drive the fan, while the MCU controls the MOSFET. The output of the Node MCU pin D0 goes to the Gate terminal of the IRF540 MOSFET. The MOSFET works as a voltage-to-current amplifier, which controls a large amount of current (flowing through the table fan) by applying a small amount of voltage at the Gate Terminal. The system’s operational flowchart is shown in Fig. 6.

The flowchart starts by checking if the temperature is greater than the set threshold value. If the temperature is not greater than the threshold value, then the fan remains OFF, but if the temperature is greater than the threshold value, then the fan is turned ON at a speed based on the temperature. The temperature is then monitored. If the temperature falls below the threshold value, then the fan is turned OFF. Otherwise, the fan is kept on.

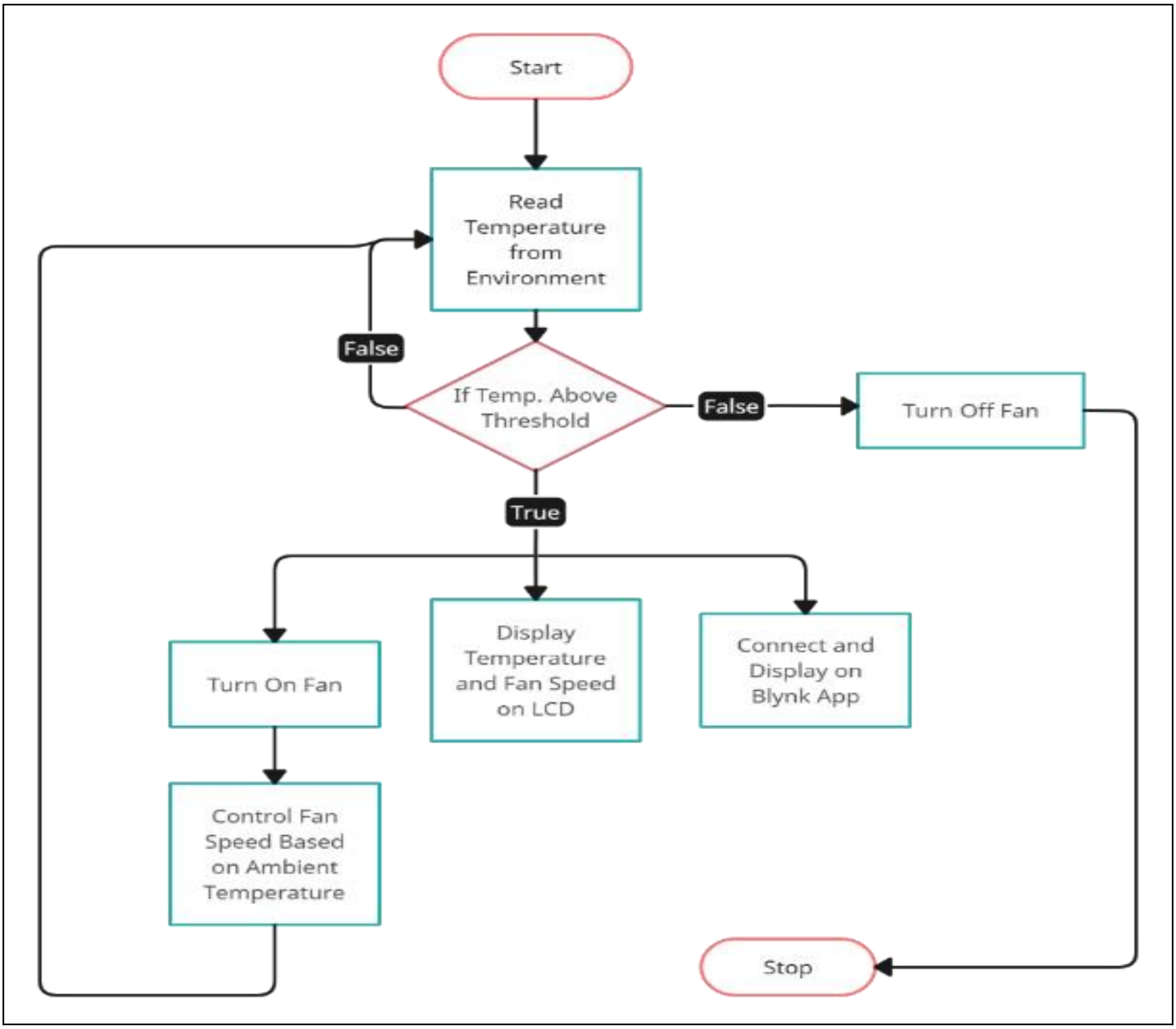

Fig 6 System's Operational Flowchart

C. Blynk 2.0 Web and Mobile Dashboard Setup

The The Blynk Web Dashboard was first created. To do this, Blynk site was visited, and sign-up process was performed using an email ID. On the site, a New Template was created. On the New Template, 'Name' (IoT App), 'Hardware' (ESP8266) and 'Connection Type' (Wi-Fi) were assigned.

From the Web Dashboard, 4 widgets were created: Gauge, Label, LED and Slider. For the Gauge setting, Virtual pin V4 was chosen. This is used for displaying the fan speed in percentage. For temperature display in label, virtual pin V3 was selected and Data Type as Integer. For the slider, the virtual pin was assigned as V7. The slider is used to set up the threshold value at which the fan would turn on. For LED setting, the variable was renamed as Fan, as this will indicate the fan ON/OFF status. The virtual pin assigned to the fan is V0.

Apart from the Web Dashboard, the associated Mobile App Dashboard was also set up using the same settings and pin configurations. For that, the Blynk application was downloaded from AppStore. Using the Mobile dashboard, the same observation as the web dashboard was obtained.

D. Writing of Code in Arduino IDE

The code for the system using ESP8266 was written in Arduino IDE. It was written in C++ programming language. A function is used to request temperature readings from the Dallas Temperature sensor. The actual temperature is then obtained using another function and stored in the `temp` variable.

For the fan speed control, if the temperature is greater than or equal to the specified `threshold`, the fan is turned ON, and the fan speed is calculated using a `map` function. The `map` function scales the temperature range (`threshold` to 40) to the fan speed range (10% to 100%). A fan speed

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control function sets the PWM output to the fan based on the calculated fan speed percentage. This value represents the duty cycle of the PWM signal. So, the translation from temperature readings to PWM is achieved by mapping the temperature range to the desired fan speed range. The PWM duty cycle is then set based on this mapping, controlling the fan speed proportionally to the temperature.

Some snippets of the code are shown in Fig. 7.

Fig 7 Some Code Snippets in Arduino IDE.

E. Software Simulation and Breadboard Implementation

The circuit was simulated on Proteus software. However, the Wi-Fi capabilities could not be simulated in the Proteus software, but other functions like PWM, I/O control etc. were successfully simulated and carried out.

After simulation on Proteus, the next step was implementing the circuit on a breadboard. A breadboard (protoboard) is a construction base for prototyping. It does not require soldering, and it is reusable. This makes it easy to create temporary prototypes and experiment with circuit design. Before embarking on the final circuit implementation on Vero board, each circuit design was breadboarded using jumper wires to interface components. The circuit was tested, and it worked as expected. During this stage, the circuit was temporarily tested with Century table fan.

F. Components Soldering, Assembly and Packaging

Following the prepared layout, the circuit components were carefully transferred from the breadboard to a Vero board and soldered. The interconnection was achieved by laying the soldering lead beneath the Vero board. The circuit's components and associated wires were secured firmly on the board with the aid of a lead-tin alloy compound through soldering.

After soldering, appropriate tests were carried out to ensure that there was no error in the circuit implemented and that they functioned as expected. All the circuit boards were packed and secured firmly inside a white pattress box. The front cover was then covered with black tape. Fig. 8 shows the system unit during the packaging process.

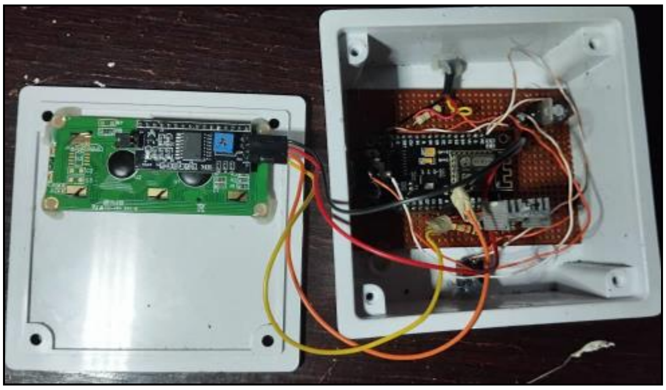
Fig 8 The System Unit during the Packaging Process

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IV. RESULTS AND DISCUSSION

A. Results and Observations

After the circuit was successfully implemented on a Veroboard, packaged and tested, the following were observed: accurate and real-time temperature monitoring; dynamic and responsive fan speed control; instantaneous display of temperature and fan speed on the LCD; successful integration with the ESP8266 Wi-Fi Module for IoT connectivity; proper functioning of the Blynk app for remote monitoring and control; and user-configurable threshold values.

Fig. 9(a) shows the LCD and the Blynk App showing the same value for the room temperature (29 ^{0}C) and the fan speed at the same time when the value is below the threshold temperature (30 ^{0}C). The fan remains switched OFF at this stage. Fig. 9(b) shows the LCD and the Blynk App showing the same value for the room temperature (26 ^{0}C) and the fan speed at the same time when the value is above the threshold temperature (11 ^{0}C). The fan is switched ON at this stage and the fan speed is at 41%. The entire system setup on a table including the control box, the fan, mobile and web dashboards in a typical standard room in Nigeria (3.6m by 3.6m by 3.6m) are shown in Fig. 10. The external 220V/12V AC-DC adapter is shown plugged to the wall socket. The black cord in front of the control box is the temperature sensor probe.

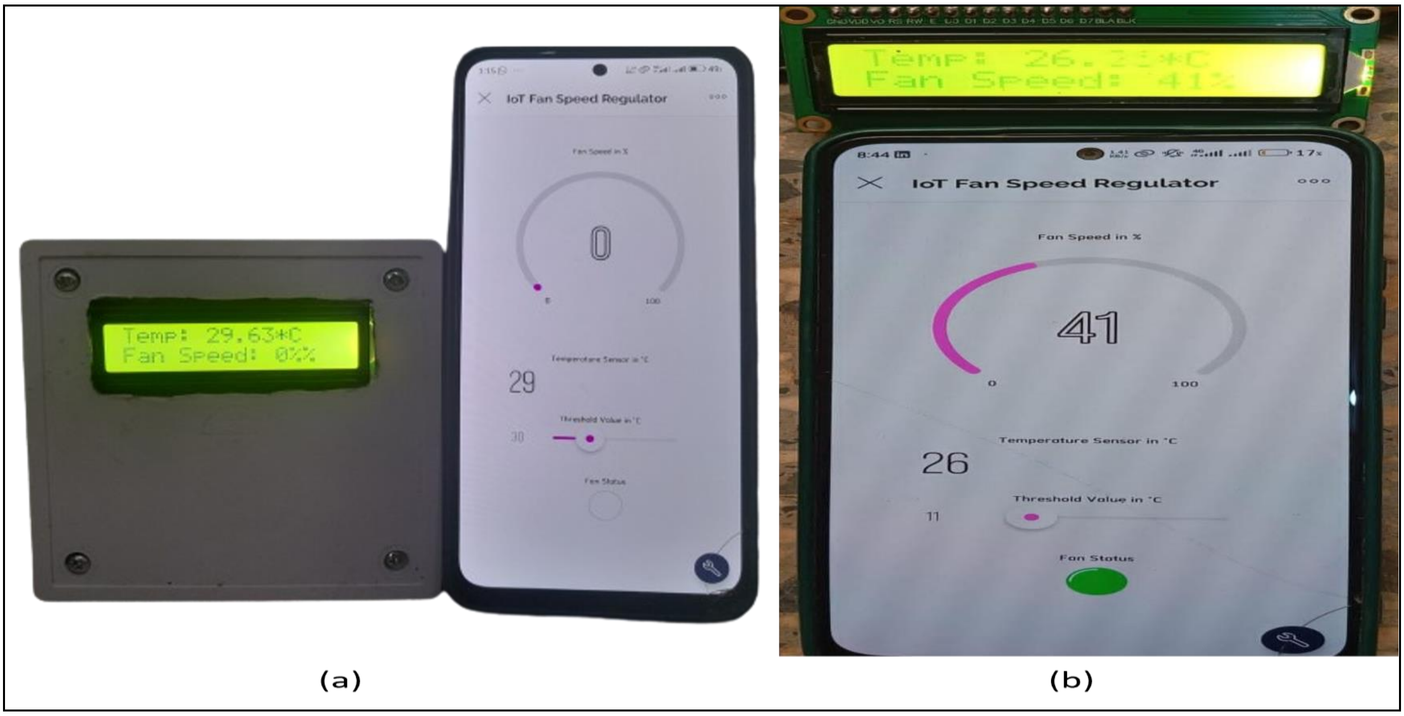

Fig 9 LCD and Blynk App Displaying the Temperature and Fan Speed (a) when below Threshold. (b) when above the Threshold.

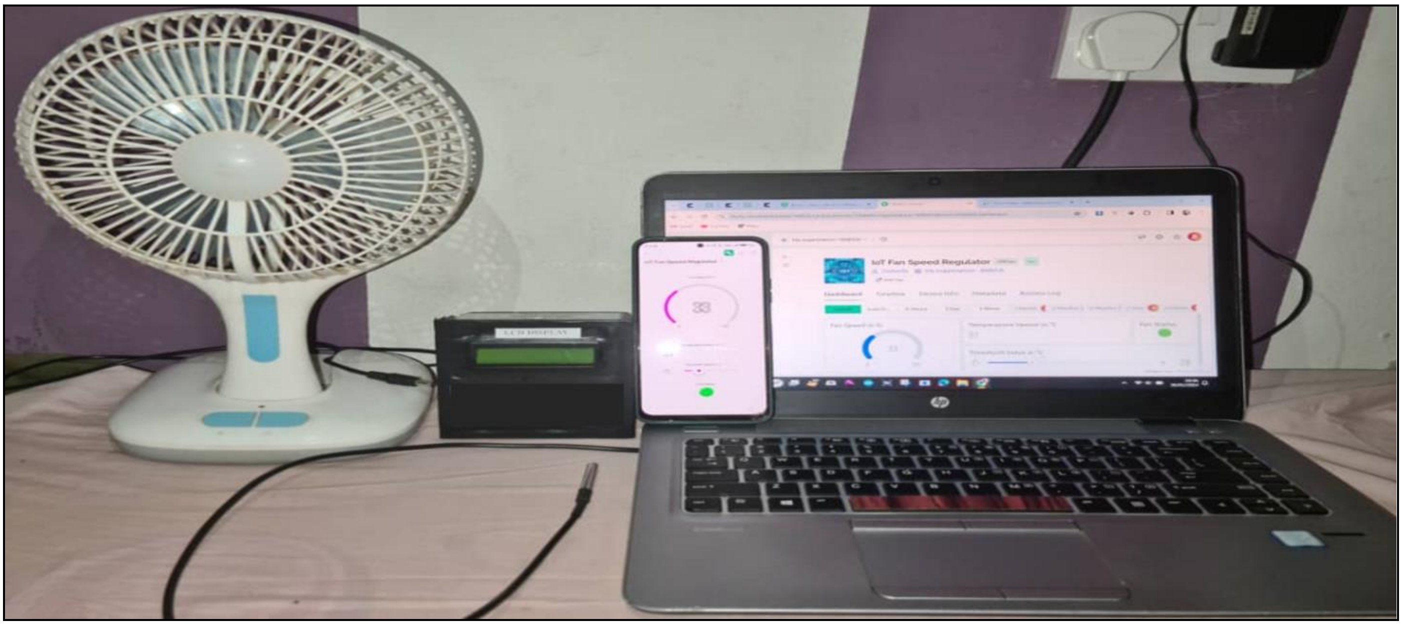

Fig 10 The System Setup showing the Control Box, a Table fan, the Mobile and Web Dashboards.

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B. Discussions

> *LCD and Mobile App Temperature Reading:*

The temperature display on the mobile app and the web dashboard was designed to display the sensor temperature values in integers while the LCD displayed up to two decimal places of the sensor temperature reading. Table III shows some sensor temperature readings by the mobile app/web dashboard, and the corresponding display by the LCD.

Table 3 LCD and Mobile App/Web Temperature Reading Display

Mobile App/Web Reading (°C)	**LCD Reading (°C)**
26	26.31
28	28.38
29	29.63
33	33.33

From the table, it can be observed that the mobile app/web dashboard displays only the integer part of the temperature reading. So, if the app displays a temperature reading of XX, the actual reading can be a value anywhere from XX.00 °C to XX.99 °C.

> *Threshold, Temperature and Fan Status:*

Table IV shows some preference thresholds, sensor temperature readings, corresponding fan speeds and fan status when the system was tested in the room of Figure 10. When the system was in operation, the actual fan speed was measured using a laser digital tachometer and expressed as a % of the maximum value (full speed).

Table 4 Thresholds, Room Temperature, Corresponding Fan Speeds and Fan Status

Threshold Temperature (°C)	**Room Temperature (°C)**	**Expected Fan Speed (%)**	**Measured Fan Speed (%)**	**Fan Status**
11	26	63	63	ON
21	26	48	47	ON
27	30	41	39	ON
28	17	0	0	OFF
28	28	24	20	ON
28	31	43	41	ON
30	29	0	0	OFF
30	33	48	47	ON

It is clear from the table that the fan is OFF whenever the room temperature, as sensed by the sensor, is lower than the set threshold value, and is turned ON whenever the room temperature is higher than the set threshold value. It can also be observed from the table how the fan speed (%) adaptively adjusts to the sensor temperature and the threshold value. The value of the fan speed (in %) at any point in time does not depend only on the sensor temperature but as well as on the threshold values. For the same sensor temperature, the value of the fan speed is different for different threshold values.

It can also be observed from the table that for some speed values, the measured values are slightly different from the expected (display) values. Also, it seems that at higher speeds, both the expected and the measured values are the same, but at lower speeds, the measured values are slightly lowered than the displayed values, with the difference increasing with lower speeds. This might have to do with the PWM frequency and the nature of the motor in the table fan that was used, and not due to any program error.

C. Temperature and Fan Readings above the Threshold

Since the fan is OFF for any temperature below the set threshold, therefore it is also of interest to observe how the fan speed varies with temperature above a set threshold. Linear behavior is expected. The following results for fan speed at some room temperatures above the set threshold of 10 °C were obtained and are as shown in Fig. 11.

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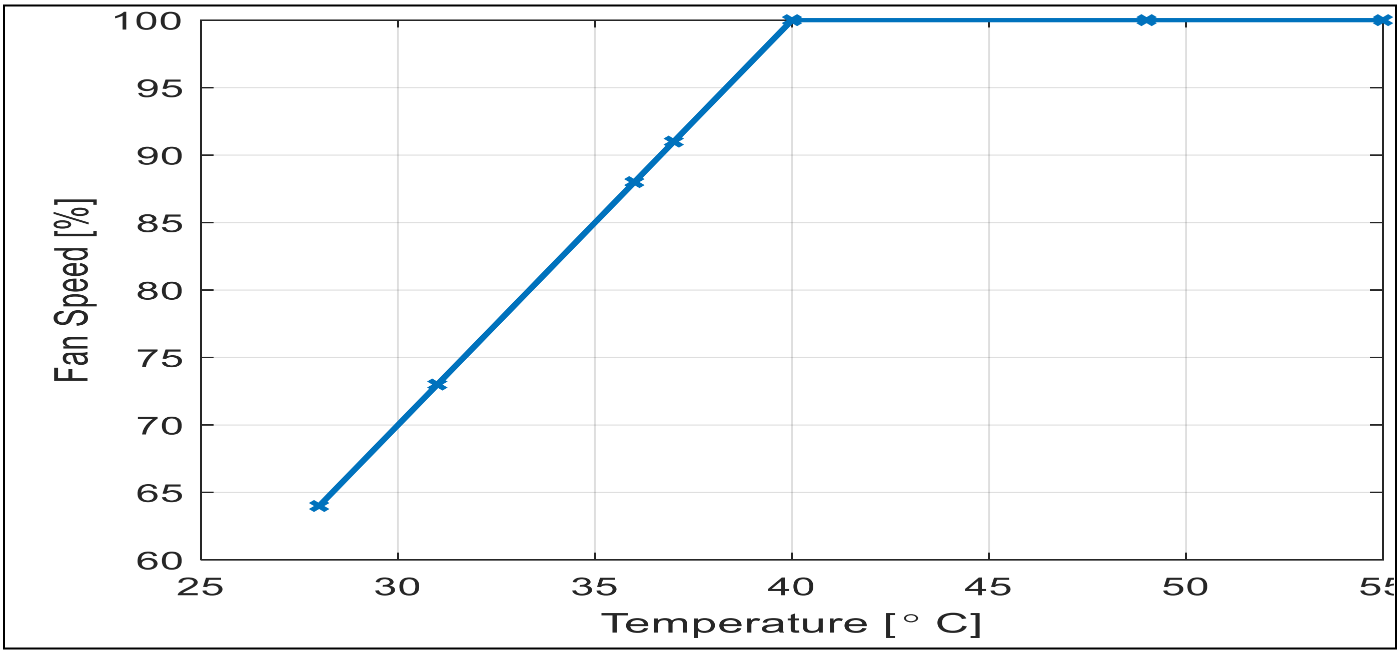

Fig 11 Fan Speeds (%) with Room Temperature for a set Threshold of 10 °C.

The fan speed increases in a linear fashion with the room temperature until it reaches 40 °C at which the fan speed is at full speed and remains so with further increase in temperature. The system was programmed to make the fan reaches 100% full speed at a temperature of 40°C given its use for Nigeria and other similar tropical/equatorial regions.

V. CONCLUSION

The developed low cost IoT based room temperature monitoring and control system by fan speed regulation for tropical use combines real-time data, adaptive algorithms, and IoT connectivity to offer a seamless experience where users can monitor, control, and customize their living environment based on the principles of energy efficiency, sustainability and user comfort. The adaptive fan speed control ensures that the system responds dynamically to changing environmental conditions. This adaptability optimizes energy consumption, providing an efficient and sustainable solution.

The primary application of the developed system lies in residential spaces in the tropical region of West Africa but would also find application in diverse settings where precision temperature control, energy efficiency, and user-centric features are paramount. Homeowners can deploy the system in bedrooms, living rooms, or home offices, ensuring optimal comfort by dynamically adjusting fan speed based on the room's temperature. Hotels and hospitality establishments can also deploy the system in guest rooms to provide personalized comfort for occupants. The ability to remotely monitor and control the system adds a layer of convenience for both guests and management.

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REFERENCES

[1]. A. Kumar, H. Kim and G. P. Hancke, "Environmental monitoring systems: A review," in *IEEE Sensors Journal*, vol. 13, no. 4, pp. 1329-1339, April 2013, doi: 10.1109/JSEN.2012.2233469.

[2]. A.A. Okandeji, M.B. Olajide, A.A. Ponnle and D.S. Kuponiyi. “Design analysis of a microcontroller-based irrigation system”. Nigerian Journal of Technological Research (NJTR), vol. 15, no. 2, pp. 96 – 101, 2020. Doi: http://doi.org/10.0.16.218/njtr.v15i2.3

[3]. K. Sekaran, M.N. Meqdad, P. Kumar, S. Rajan, and S. Kadry. “Smart agriculture management system using internet of things”. TELKOMNIKA (Telecommunication Computing Electronics and Control), vol. 18, no. 3, pp.1275-1284, 2020.

[4]. T. Lakshmi Narayana, C. Venkatesh, A. Kiran, C. Babu J, A. Kumar, S. B. Khan, A. Almusharraf, and M. T. Quasim, “Advances in real time smart monitoring of environmental parameters using IoT and sensors”, Heliyon, vol. 10, no. 7, pp. 1-22; e28195, 2024, ISSN 2405-8440, https://doi.org/ 10.1016/j.heliyon.2024.e28195.

[5]. A.E. Akin-Ponnle, and N.B. Carvalho. “Energy harvesting mechanisms in a smart city—A review”. *Smart Cities*, vol. 4, no. 2, pp. 476-498, 2021. https://doi.org/10.3390/smartcities4020025

[6]. R. Apanavičienė, and M.M.N. Shahrabani, “Key factors affecting smart building integration into smart city: Technological aspects”. Smart Cities, vol. 6, pp. 1832-1857, 2023. https://doi.org/10.3390/smartcities 6040085

[7]. A. Ullah, S.M. Anwar, and J. Li, “Smart cities: the role of Internet of Things and machine learning in realizing a data-centric smart environment”, Complex Intelligent Systems, vol. 10, pp. 1607–1637, 2024. https://doi.org/10.1007/s40747-023-01175-4.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG921

[8]. ANSI/ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy.

[9]. L. K. Komolafe, and F.O.A. Akingbade. "Analysis of thermal comfort in Lagos, Nigeria". Global Journal of Environmental Sciences. Vol. 2: pp. 59–65, 2003. doi:10.4314/gjes.v2i1.2407. Retrieved 4 March 2021.

[10]. M.D. Nwalusi, C.B. Chukwuali, M.U. Nwachukwu, and H.C. Mba (2019), "Analysis of thermal comfort in traditional residential buildings in Nigeria", Journal of Recent Activities in Architectural Sciences, vol. 4, no. 2, pp. 28 – 39, 2019, e-ISSN: 2581-9046.

[11]. A.C. Ogbonna, and D.J. Harris, "Thermal comfort in sub-Saharan Africa: Field study report in Jos-Nigeria", Applied Energy, vol. 85, pp. 1–11, 2008.

[12]. M. Adaji, R. Watkins, and G. Adler, "An investigation into thermal comfort in residential buildings in the hot humid climate of Sub-Saharan Africa: A field study in Abuja-Nigeria". In: Proceedings of 31st International PLEA Conference, Passive Low Energy Architecture: Architecture in (R)Evolution, 2015.

[13]. A.C. Haruna, U.D. Muhammad, and O.M. Oraegbune," Analysis of indoor thermal comfort perception of building occupants in Jimeta, Nigeria". Civil and Environmental Research, vol.10, no.4, pp 11-20, 2018. ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online).

[14]. M. Indraganti. "Using the adaptive model of thermal comfort for obtaining indoor neutral temperature: Findings from a field study in Hyderabad, India". Building and Environment. Vol. 45, no. 3, pp. 519–536, 2009. doi:10.1016/j.buildenv.2009.07.006.

[15]. T.H. Karyono. "Predicting comfort temperature in Indonesia, an initial step to reduce cooling energy consumption". School of Architecture, Tanri Abeng University, Jalan Swadarma Raya, Jakarta 12250, Indonesia, 2015, pp. 802–813. doi:10.3390/buildings5030802.

[16]. Q.J. Kwong, N.M. Adam, and S.H. Tang, "Effect of environmental comfort factors in enclosed transitional space toward work productivity", American Journal of Environmental Sciences, vol. 5, no. 3, pp. 315 – 324, 2009. *https://doi.org/10.3844/ajessp.2009.315.324*

[17]. J. Pan, J. Tang, M. Caniza, J-M. Heraud, E. Koay, H.K. Lee, C.K. Lee, Y. Li, A.N. Ruiz, C.F. Santillan-Salas, and L.C. Marr, "Correlating indoor and outdoor temperature and humidity in a sample of buildings in tropical climates". Indoor Air, vol. 31, no. 6, pp. 2281–2295, 2021. *https://doi.org/10.1111/ina.12876*

[18]. S. Schiavon, B. Yang, Y. Donner, V. W-C. Chang, and W.W. Nazaroff, "Thermal comfort, perceived air quality, and cognitive performance when personally controlled air movement is used by tropically acclimatized persons". Indoor Air, vol. 27, no. 3, pp. 690-702, 2017. *https://doi.org/10.1111/ina.12352*

[19]. J. Kim, and C. Yang, "Smart environmental control for energy efficiency in buildings." Energy and Buildings, vol. 220, pp. 112-125, 2020.

[20]. Synergy Companies. "How effective are whole house fans?" https://www.synergycompanies.com/post/how-effective-are-whole-house-fans accessed May 2024.

[21]. N. N. Prince, A. Theophilus, O. D.A. Onwuzulike, and N. Vincent. "Design and implementation of microcontroller based automatic fan speed regulator (using temperature sensor)". International Journal of Engineering Research and Management (IJERM), vol. 1, 2014, p. 205.

[22]. S. Gupta. "IoT based smart fan control using ESP8266 and Blynk". Circuit Digest, August 2021. Available online: https://circuitdigest.com/microcontroller projects/iot-based-smart-fan-control-using esp8266-and-blynk.

[23]. A. Jain, A. Sarkar, D. Ather, and D. Raj. "Temperature based automatic fan speed control system using Arduino". Proceedings of the Advancement in Electronics & Communication Engineering, 2022, Available at SSRN: *https://ssrn.com/abstract=4159188* or *http://dx.doi.org/10.2139/ssrn.4159188*

[24]. V. Nagababu, M. N. Y. P. Kumar, C. S. Pravallika, and N.A. Sundari. "Temperature based fan speed controller using IoT". International Journal of Creative Research Thoughts. vol. 11. pp.1-6, 2023. Available: https://ijcrt.org/papers/IJCRT2304566.pdf.

[25]. J-C. M. Resquites, M. A. Parrocho, N. Vinegas, and V. H. Oquiño. "IoT-based temperature monitoring and automatic fan control using ESP32", Iconic Research and Engineering Journals (IRE) Journals, vol. 7, no. 5, pp. 35-44, 2023. ISSN: 2456-8880.

[26]. C. Stolojescu-Crisan, C. Crisan, and B.P. Butunoi, "An IoT-based smart home automation system". Sensors, vol. 21, 3784, 2021. https://doi.org/10.3390/s21113784

[27]. S. Gutiérrez, E. Barrientos, J. Alvarez, and M. Cardona. "An integrated architecture for monitoring and controlling the temperature of different platforms based on Internet of things". In 2018 IEEE 38th Central America and Panama Convention (CONCAPAN XXXVIII), pp. 1-5, 2018.

[28]. J.A. Hassan, and B.H. Jasim. "Design and implementation of internet of things-based electrical monitoring system". Bulletin of Electrical Engineering and Informatics, vol. 10, no. 6, pp. 3052-3063, 2021.

[29]. S. Sharma, V. Chang, U.S. Tim, J. Wong, and S. Gadia. Cloud and IoT-based emerging services systems. Cluster Computing, vol. 22, pp.71-91, 2019.

[30]. J.B. Awotunde, R.G. Jimoh, R.O. Ogundokun, S. Misra, and O.C. Abikoye. "Big data analytics of iot-based cloud system framework: Smart healthcare monitoring systems". In Artificial intelligence for cloud and edge computing. Cham: Springer International Publishing, 2022, pp. 181-208.

[31]. Blynk IoT Platform. "Blynk: a low-code IoT software platform for business and developers". *https://blynk.io/*. Accessed May 2024.

[32]. Dallas Semiconductor: "DS18B20 Programmable Resolution 1-Wire Digital Thermometer". *www.dalsemi.com; https://www.analog.com/media/en/technical-documentation/data-sheets/ds18b20.pdf.*

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG921

[33]. ESP8266 Technical Reference. *https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf*
[34]. https://components101.com/development-boards/ nodemcu-esp8266-pinout-features-and-datasheet
[35]. What is Blynk 2.0. https://github.com//blynkkk/ docs/blob/main/What-is-Blynk-2.0.md