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Temperature and Humidity Monitoring System

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Abstract

This technical paper presents a comprehensive smart temperature and humidity monitoring system designed for diverse industries such as food manufacturing, agriculture, and construction. The system utilizes Internet of Things (IoT) technology to capture real-time temperature and humidity data in rooms, contributing to enhanced safety, equipment protection, and product quality control. The core components of the system include a nodeMCU microcontroller with ESP8266 Wi-Fi capabilities, enabling seamless data transmission to the Arduino IoT Cloud. The system employs the DHT11 temperature and humidity sensor to accurately detect environmental conditions. The Arduino IoT Cloud serves as the central platform, displaying captured data on a user-friendly dashboard. Additionally, the Arduino IoT Cloud Remote mobile application provides users with convenient access to monitor temperature and humidity readings on-the-go. To further enhance user awareness, the system integrates IFTTT (If This Then That) functionality, triggering notifications when environmental conditions deviate from predefined acceptable ranges. The prototype implementation involves a room scenario to validate the effectiveness of the temperature and humidity monitoring system. The results showcase the system's capability to safeguard workers, equipment, and products by preventing spoilage and mold growth. This paper contributes to the growing field of IoT applications in industrial settings, offering a scalable and adaptable solution for organizations requiring real-time environmental monitoring.

1. Introduction

In various industries such as food manufacturing, agriculture, construction, and real estate, the need for precise temperature and humidity monitoring has become increasingly critical. The sensitivity of climate-controlled environments to even minor fluctuations in these parameters underscores the importance of a robust monitoring system. This system serves as a safeguard for workers, equipment, and products, particularly in food manufacturing where quality control is essential to prevent spoilage, foodborne illnesses, and shrinkage. Moreover, in construction zones, where the setting of concrete is pivotal, close monitoring ensures that humidity and temperature variations do not compromise the structural integrity. Additionally, the system aids in preventing mold growth by constantly assessing conditions in mold-prone areas, thereby protecting occupant health and facilitating the identification of root causes [1]. Climate-controlled environments, including food manufacturing facilities and server rooms, are equipped with air conditioning systems to maintain optimal conditions. However, the absence of a mechanism to detect AC damage poses a significant challenge. Damaged AC units may result in increased room temperature and humidity, posing risks to stored materials and equipment. To address this gap, there is a crucial need for additional tools, such as sensors, capable of detecting changes in temperature and humidity. Furthermore, a real-time monitoring system is essential to provide timely information on the environmental conditions, enabling the maintenance of standard temperature and humidity levels.

This project aims to achieve several key objectives. Firstly, to design a temperature and humidity monitoring system that allows users to access real-time reports from any location. Secondly, to develop a system that provides timely notifications to users in the event of temperature or humidity deviating from acceptable ranges. Lastly, to evaluate the performance of the developed system, ensuring its capability to minimize material downtime due to environmental factors affecting critical materials in storage. To fulfill the stated objectives, the project focuses on detecting temperature and humidity readings through dedicated sensors. Real-time monitoring is achieved through the integration of Internet of Things (IoT) cloud technology and a mobile application. The system is designed to promptly notify users or designated personnel if the temperature and humidity levels fall outside the acceptable range. With these scopes, the project aspires to create a comprehensive solution that not only detects environmental variations but also proactively addresses potential risks, thereby enhancing the stability and resilience of climate-controlled environments.

2. Background research

The monitoring and control of environmental conditions play a crucial role in various applications, ranging from data centers to industrial settings. In this context, a monitoring system serves as a fundamental tool for system administrators to oversee the hardware, software, and traffic of an infrastructure. Protocols such as SNMP, WMI, HTTP, MQTT, and OPC UA enable devices and applications to connect with monitoring systems, allowing real-time tracking and immediate alerts in case of errors or disturbances [2]. This centralized approach enables efficient management of network devices, servers, routers, switches, bandwidth, and applications. Temperature monitoring systems, utilizing devices like resistance temperature detectors (RTDs), thermistors, and thermocouples, focus on converting temperature measurements into readable forms. These systems are essential for monitoring critical temperatures in areas such as server rooms and data centers. The DHT11 sensor, for instance, is commonly used to measure both temperature and humidity, providing valuable insights into environmental conditions. These monitoring systems are instrumental in proactively addressing temperature-related issues [3].

Several previous projects have explored temperature and humidity monitoring systems. Examples include the use of IoT devices like NodeMCU microcontrollers, DHT11 sensors, and online platforms such as ThingSpeak for real-time temperature monitoring. Additionally, projects have employed GSM networks for remote monitoring and SMS alerts. The integration of IoT with platforms like Blynk and the utilization of sensors like DHT-11 in industrial settings further demonstrate the versatility of temperature and humidity monitoring systems. Smart monitoring systems extend beyond temperature and humidity, encompassing a wide range of applications. Projects involving NodeMCU ESP8266 microcontrollers have been implemented for live weather monitoring [4], plant monitoring [5], patient health monitoring [6], industrial security control [7], air quality monitoring [8], and even smart pet care [9]. These projects leverage the capabilities of IoT to enhance automation, remote monitoring, and data visualization.

Electronic components such as NodeMCU ESP8266 and sensors like DHT11 are fundamental building blocks for these projects. The NodeMCU, an open-source hardware and software development environment, provides a cost-effective solution for IoT applications. The DHT11 sensor, with its capability to measure temperature and humidity, is widely adopted for environmental monitoring. The software components integral to these projects include the Arduino IoT Cloud, providing a platform for IoT project development with features such as data monitoring, variable synchronization, and over-the-air uploads. The Arduino IDE serves as the programming environment for writing and uploading code to Arduino modules. Additionally, software tools like Proteus aid in electronic design automation, simulation, and PCB layout. The integration of platforms like IFTTT further enhances automation possibilities by connecting different web applications and services.

3. Methodology

The methodology employed in this research encompasses various facets of data collection and analysis, elucidated comprehensively in this chapter. Key components such as room temperature and humidity, project flowchart, system block diagram, system flowchart, project circuit diagram, and associated explanations, along with lists detailing hardware and software components, are integral to the investigative process. To establish a standardized environment, the room temperature and humidity parameters were rigorously defined. Drawing from The Department of Standards Malaysia's 2007 guidelines, which advocate maintaining indoor temperatures between 23°C and 26°C for Malaysian climates [10], the selected room temperature for this project was set at 25°C. Additionally, room humidity was established at 50%, aligning with recommended home humidity levels ranging between 45% and 50%, as exceeding 50% is deemed excessive, while falling below 30% is considered excessively dry [11]. This holistic approach to data collection and analysis, encompassing environmental parameters, visual representations, and circuit schematics, lays the foundation for a robust and comprehensive exploration of the research objectives.

Fig.1 illustrates the detailed block diagram of the microcontroller NodeMCU ESP8266, a pivotal component in the system architecture. The diagram delineates the inputs, consisting of the power supply and the DHT11 sensor, and the corresponding outputs, which encompass the IoT cloud, mobile application cloud, and notifications, along with a Liquid Crystal Display (LCD). In this schematic representation, the microcontroller NodeMCU ESP8266 serves as the central processing unit, integrating crucial elements of the system. The power supply and the DHT11 sensor are identified as key inputs, contributing essential data to the microcontroller. On the output side, the system interfaces with the IoT cloud, facilitating connectivity and data exchange with the broader Internet of Things network. Simultaneously, the integration of the mobile application cloud signifies the system's capacity to interact with mobile platforms, broadening its accessibility and usability. The inclusion of notifications enhances the system's communicative capabilities, notifying users of pertinent information. Additionally, the incorporation of an LCD provides a tangible interface for local monitoring and feedback.

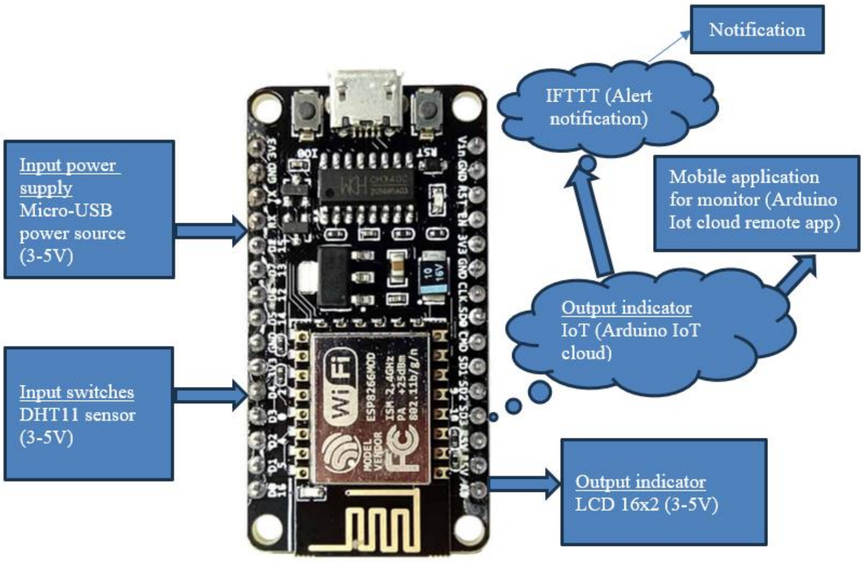


Fig. 1 *Detail System Block Diagram*

Fig.2 delineates the circuit diagram integral to this project, encompassing three essential components: the microcontroller NodeMCU V3, the DHT11 temperature and humidity sensor, and the LCD 16x2 with I2C interface. The circuit design is orchestrated to facilitate seamless interaction among these components, with the NodeMCU V3 serving as the central microcontroller orchestrating overall circuit operations. Within this circuit framework, connectivity is established between the microcontroller NodeMCU V3 and two primary components: the DHT11 sensor responsible for capturing ambient temperature and humidity data, and the LCD 16x2 with I2C interface employed for displaying the recorded readings from the DHT11 sensor. The collaborative functioning of these components is integral to the project's overarching objectives. Specifically, the DHT11 sensor is designated to collect precise temperature and humidity data from the surrounding environment. This information is then transmitted to the NodeMCU V3, which functions as the primary control unit, overseeing the circuit's operations. Subsequently, the NodeMCU V3 directs the processed data to the LCD 16x2 with I2C interface for clear and accessible display.

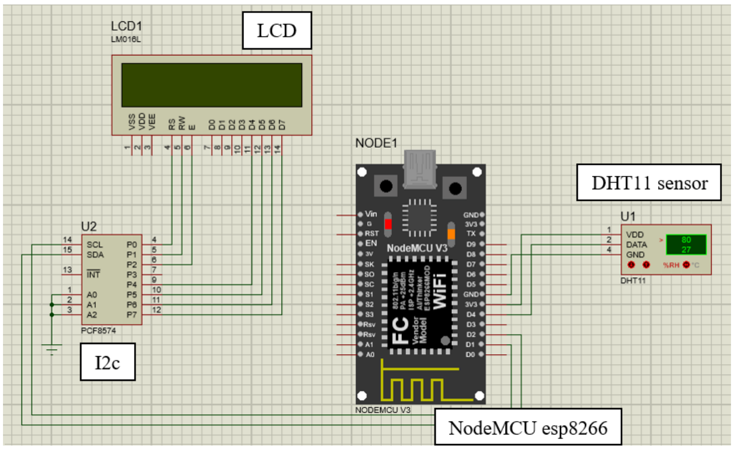
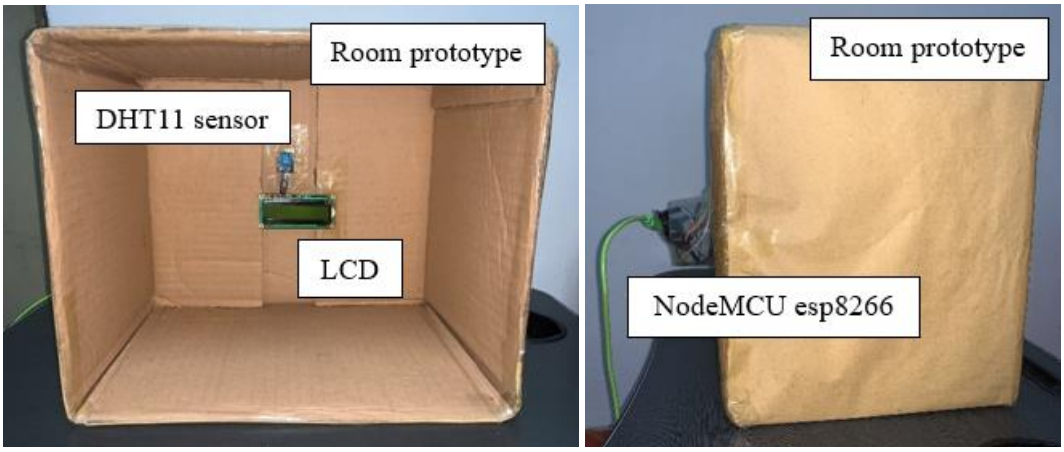


Fig. 2 *Circuit Design and Simulation*

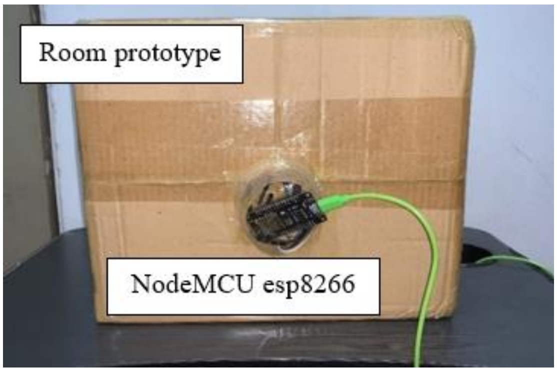
4. Result and Analysis

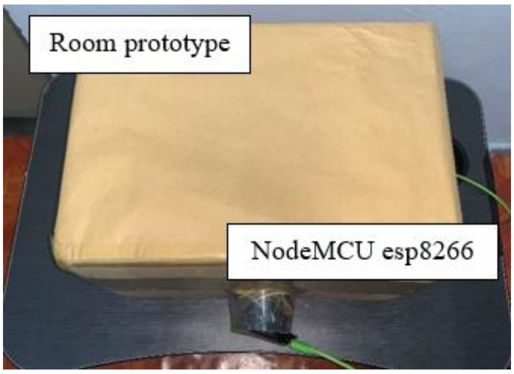
This part delves into the data derived from conducted studies and experiments, elucidating the subsequent analysis based on the methodology. The objective is to ascertain the efficacy of the Smart Temperature and Humidity Monitoring system in collecting and monitoring data on the cloud. The analytical process is oriented towards gauging the system's performance, specifically in terms of its ability to fulfill the outlined objectives and scope. To assess the monitoring functionality pertaining to temperature and humidity, the initial step involves a comprehensive understanding of the Smart Temperature and Humidity Monitoring system's core functions. This analysis aligns with the project's overarching goals and objectives. Performance evaluation is conducted to gauge the system's capability in effectively monitoring temperature and humidity readings within a room environment, where both variables are pre-set at 25°C and 50%, respectively. The practical implementation of the system utilizes a room prototype to simulate real-world conditions. The analysis is geared towards discerning how well the Smart Temperature and Humidity Monitoring system aligns with the stipulated parameters, shedding light on its practical utility in accurately monitoring and reporting temperature and humidity metrics within the designated room.

Fig.3 unveils the project layout, presenting a comprehensive depiction of the prototype from various vantage points, encompassing front, side, back, and top views. The visual representation of these diverse perspectives serves to offer a holistic understanding of the project's physical prototype configuration. Each view is strategically captured to provide insights into the structural attributes and design considerations from multiple dimensions, contributing to a comprehensive overview of the project's physical layout and form. This detailed exploration of the prototype layout aims to facilitate a nuanced comprehension of the project's external features and spatial arrangement.



(a) (b)





(c) (d)

Fig. 3 *View of prototype (a) Front View (b) Side View (c) Back View (d) Top View*

Fig. 4 and Fig. 5 delineate the procedural sequence of the project prototype. The process begins with the DHT11 sensor recording temperature and humidity data within the designated room prototype. Subsequently, this recorded data is transmitted to the microcontroller NodeMCU ESP8266. The microcontroller serves as a pivotal hub for data aggregation and forwarding. Once collected, the data undergoes a dual transmission process. Firstly, it is sent to the cloud for visualization on the Arduino IoT Cloud dashboard. Concurrently, the data is relayed to the Arduino IoT Cloud Remote application, facilitating mobile access to the recorded information. The inclusion of these cloud-based functionalities underscores the project's emphasis on remote monitoring and accessibility. Simultaneously, the data gathered by the NodeMCU ESP8266 is directed to the Liquid Crystal Display (LCD) component integrated into the prototype. This real-time display on the prototype offers an immediate visual representation of the recorded temperature and humidity metrics. Notably, the project operates on a power supply mechanism to sustain the prototype and its system functionalities. This systematic approach ensures a synchronized flow of data acquisition, processing, and dissemination, underscoring the comprehensive nature of the Smart Temperature and Humidity Monitoring system.

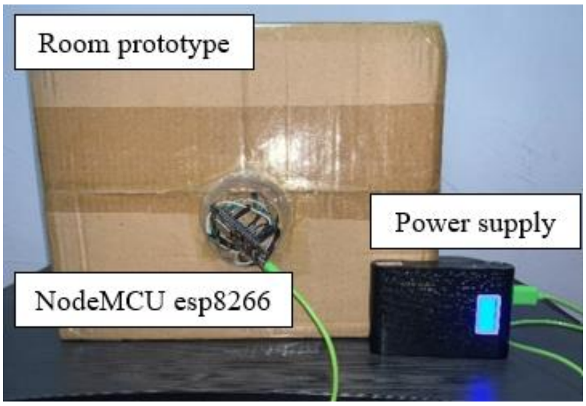


Fig. 4 : *Connection of NodeMCU esp8266 to power supply*

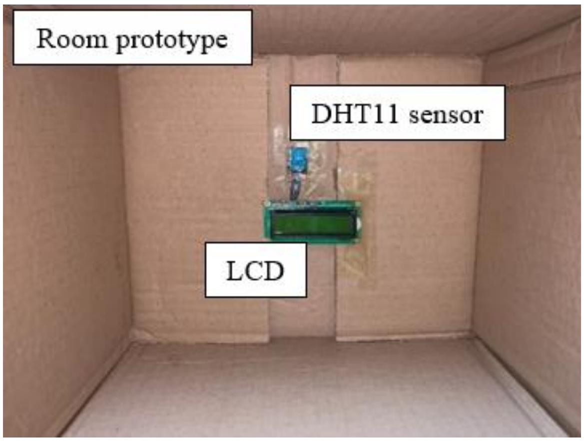


Fig. 5 *Temperature and humidity readings in the room prototype is collected by DHT11 sensor and send the data to NodeMCU esp8266 to send to cloud and LCD to display readings*

As illustrated in Fig.6, the Smart Temperature and Humidity Monitoring system seamlessly updates and displays real-time temperature and humidity data on the Arduino IoT Cloud. The comprehensive information relayed includes the current temperature reading, a graphical representation of temperature trends, the present humidity reading, a humidity graph, and a detailed message encapsulating the temperature and humidity readings. This synchronized data presentation on the Arduino IoT Cloud ensures a dynamic and up-to-date visualization of environmental conditions. In concurrence, Fig.7 showcases the real-time temperature and humidity data acquired by the system, presented on the Arduino IoT Cloud Remote application. The displayed information encompasses the instantaneous temperature reading, a graphical representation of temperature fluctuations, the current humidity reading, a humidity graph, and a detailed message conveying the specific temperature and humidity readings. This application is designed to enable users to conveniently monitor the system's dashboard from their mobile devices.

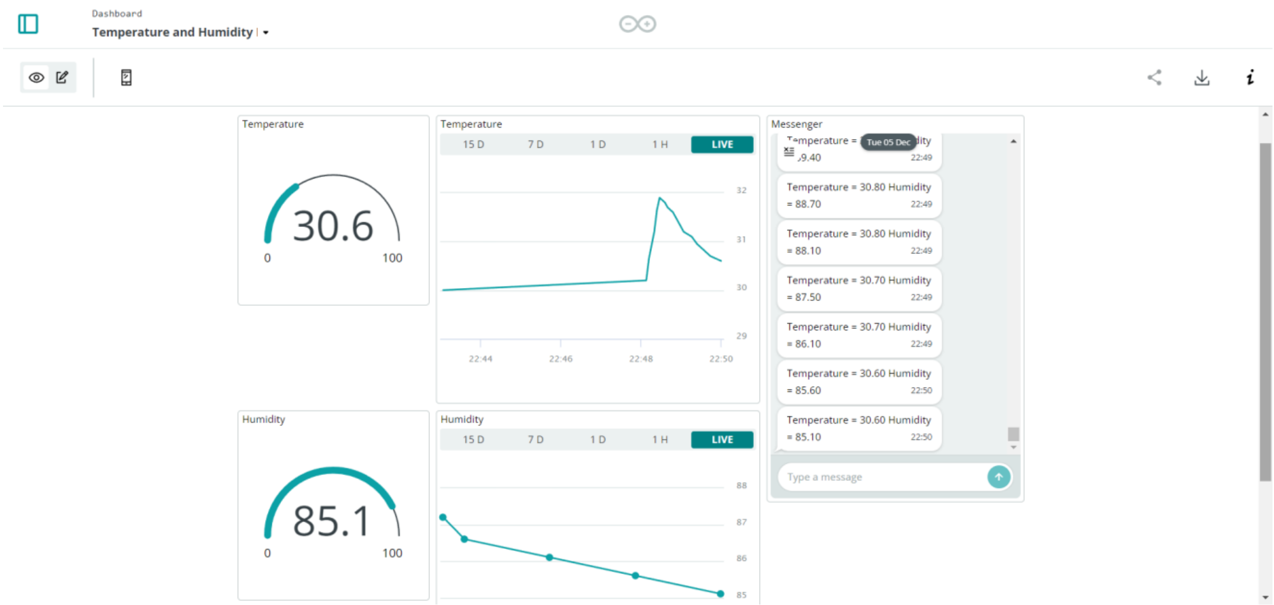


Fig. 6 *Dashboard of Arduino IoT Cloud with temperature and humidity data*

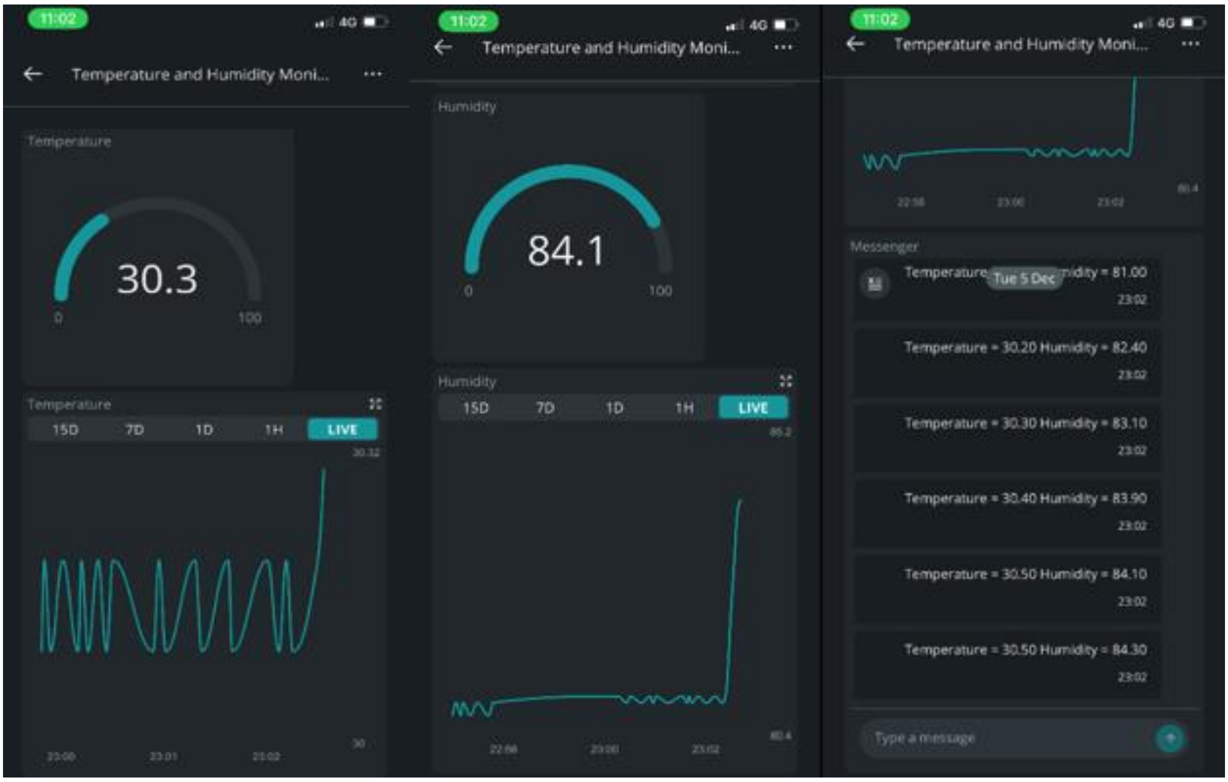


Fig. 7 *Dashboard of Arduino IoT Cloud Remote App with temperature and humidity data*

IFTTT (If This Then That) is employed to convey notifications and alerts to users in instances where temperature and humidity readings surpass the predefined acceptable range, namely the set room temperature of 25°C and room humidity of 50%. This notification system serves as a crucial element in ensuring timely user awareness of environmental conditions. IFTTT applet is configured to establish the parameters for notification alerts. These applets are designed to trigger alerts when the recorded temperature and humidity readings deviate beyond the specified room conditions. The precise setup of these applets is instrumental in tailoring the notification system to the project’s requirements. Fig. 8 further elucidates the practical outcome of this configuration, showcasing notifications received by users through the IFTTT mobile application. These notifications serve as alerts, promptly notifying users when environmental conditions exceed the designated thresholds. Notably, notification alerts are activated when temperature and humidity readings surpass the room temperature and humidity settings, providing a proactive mechanism for users to stay informed about variations in the monitored environment.

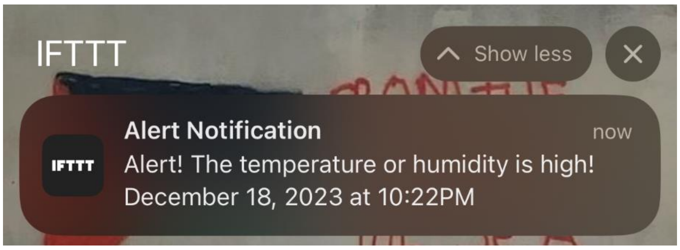


Fig. 8 *IFTTT notification sent to mobile application*

The accuracy of temperature and humidity readings was subjected to a rigorous testing regimen, with each test conducted five times within a controlled environment. The testing environment was a singular room configured to maintain a consistent room temperature of 25°C and room humidity of 50%. The purpose of these tests was to evaluate the precision and reliability of the Smart Temperature and Humidity Monitoring system in capturing and reflecting the designated environmental conditions. Table 1 provides a comprehensive breakdown of the temperature readings recorded during each of the five testing instances in the controlled room. Similarly, Table 2 details the humidity readings captured during the repeated testing sessions. The average percentage difference in temperature between the measured value and the developed monitoring system is calculated as -0.48%, indicating a slight underestimation by the monitoring system. Conversely, for humidity, the average percentage difference is 0.06%, demonstrating a minimal deviation between the measured humidity and the values recorded by the monitoring system. These results suggest that the developed monitoring system exhibits a high level of accuracy in capturing both temperature and humidity measurements, with discrepancies well within acceptable margins.

Table 1 *The Temperature Readings*

Testing	First	Second	Third	Fourth	Fifth
Temperature (monitoring system)	24°C	24.8°C	25.4°C	26°C	25.8°C
Room Temperature (measurement)	25°C	25°C	25°C	25°C	25°C

Table 2 *The Humidity Readings*

Testing	First	Second	Third	Fourth	Fifth
Humidity (monitoring system)	49.9%	50%	50.2%	50.1%	51%
Room Humidity (measurement)	50%	50%	50%	50%	50%

5. Conclusion

The Smart Temperature and Humidity Monitoring System has successfully achieved its goals, providing users with real-time access to temperature and humidity reports from any location. This system allows users to monitor room conditions and detect changes in temperature or humidity promptly. Additionally, it includes a notification feature that alerts users via the IFTTT mobile application if readings exceed acceptable limits. The system's performance has been optimized to minimize material downtime due to environmental factors for critical storage. Users can effectively control room temperature and humidity to prevent spoilage of stored materials. For the temperature parameter, the recorded measurement was 25°C, while the developed monitoring system reported values of 24°C, 24.8°C, 25.4°C, 26°C, and 25.8°C, resulting in percentage differences of -4%, -1.6%, +1.6%, +4%, and +3.2%, respectively. Regarding humidity, the measured value was 50%, whereas the monitoring system registered percentages of 49.9%, 50%, 50.2%, 50.1%, and 51%, yielding percentage differences of -0.1%, 0%, +0.2%, +0.1%, and +1%, respectively.

To enhance the system, consider implementing Wireless Sensor Networks (WSN), which use multiple wireless sensors to measure and transmit temperature and humidity data to a central hub. WSNs are flexible and suitable for applications in warehouses, data centers, and greenhouses. Another improvement is the integration of Smart Thermostats, Wi-Fi-enabled devices that automatically adjust temperature settings for optimal performance, with remote control capabilities. Lastly, consider using Data Loggers, portable devices that record temperature and humidity readings at set intervals, commonly used in transportation, laboratories, and food storage facilities. These recommendations will contribute to a more versatile and efficient Smart Temperature and Humidity Monitoring System.

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