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Study and Development of a Hybrid Temperature and Humidity Monitoring System

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Abstract: *This paper presents the development and implementation of a temperature and humidity monitoring system tailored for industrial environments. The system utilizes a DHT22 sensor and ESP8266 NodeMCU to collect and transmit real-time environmental data from various factory locations, including the AC lab, chassis assembly, and maintenance room. The data is transmitted wirelessly via Wi-Fi to a local web server and logged into a database managed by PHPMyAdmin. A user-friendly interface displays dynamic graphs of temperature and humidity against timestamps, with alerts and LED indicators triggered by threshold breaches.The prototype demonstrates the system's accuracy, cost-effectiveness, and feasibility in automating the manual recording of environmental data. It effectively showcases its ability to provide continuous real-time monitoring, ensuring optimal environmental conditions are maintained within an industrial setting. The proposed automation reduces the risk of human error, increases efficiency, and provides immediate alerts for any deviations from set parameters, enhancing overall safety and operational efficiency. Further, the system offers a robust solution for real-time environmental monitoring and lays the groundwork for future enhancements and wider adoption in industrial applications.*

Keywords: Temperature and Humidity Monitoring; DHT22 Sensor; ESP8266 NodeMCU; Real-time Data Collection; XAMPP; PHPMyAdmin; Industrial Environment Monitoring

I. INTRODUCTION

Environmental monitoring is essential in industrial settings to maintain optimal conditions for machinery, processes, and personnel. Traditionally, this involves manually recording temperature and humidity values, which is time-consuming and prone to errors. However, advancements in sensor technology and the Internet of Things (IoT) have made automated real-time environmental monitoring systems feasible and cost-effective. This paper details the development and implementation of a temperature and humidity monitoring system specifically designed for industrial environments. The system employs a DHT22 sensor for accurate measurements and an ESP8266 NodeMCU for wireless data transmission. By leveraging XAMPP and PHPMyAdmin, we created a local web server and database to facilitate real-time data logging and visualization. This integration offers a reliable and efficient solution for monitoring factory environmental conditions.

II. REVIEW OF LITERATURE

Environmental monitoring systems for temperature and humidity are critical in both industrial and agricultural settings. Recent studies have highlighted advancements and challenges in enhancing monitoring accuracy and efficiency through IoT technologies. Mustafa Saied et al. (2020) explored enhancements in traditional air conditioning systems using IoT for remote monitoring and control, significantly improving performance through cloud-based controllers and remote adjustments. This approach underscores IoT's benefits for real-time monitoring and control, essential for maintaining optimal environmental conditions in various factory zones. Similarly, B.S.K.K. Ibrahim et al. (2021) utilized fuzzy logic to dynamically control temperature and humidity in vehicles, integrating sensors and microcontrollers for improved comfort and efficiency. This study demonstrates intelligent control systems for maintaining environmental parameters, paralleling the current project's goals of achieving accurate and automated monitoring.

ThammanoonSookchaiya et al. (2019) developed a system for environmental regulation in agricultural settings, using sensors for data collection and display to maintain optimal conditions. This methodology and technology are directly applicable to the current project, providing insights into sensor integration and data visualization techniques. Yanshori et al. (2018) implemented an IoT-based system for smart gardening, using NodeMCU and sensors to monitor soil moisture, temperature, and humidity, sending alerts and allowing remote adjustments. This project underscores the effectiveness of IoT in environmental monitoring and control, reinforcing the feasibility and benefits of the current project's approach.

Chen et al. (2020) developed a smart environment monitoring system using DHT22 sensors and ESP8266 modules, emphasizing real-time data acquisition and wireless communication. The system achieved notable accuracy and low power consumption, aligning with the current project's goals. Similarly, Smith et al. (2019) created a wireless sensor network (WSN) for monitoring temperature and humidity in agricultural fields, demonstrating the effectiveness of low-cost sensors in providing reliable environmental data. This supports the project's novelty in offering accurate readings at a low cost.

Ahmed et al. (2018) reviewed various WSN technologies for industrial applications, highlighting the ESP8266's role in creating efficient, low-power, cost-effective networks for real-time data monitoring. The study also discussed integrating WSN with local servers using PHP and MySQL, directly correlating with the project's software specifications. Kumar et al. (2021) proposed a system architecture for smart manufacturing using XAMPP and PHP for data logging and visualization, including alert mechanisms for threshold breaches. This paper supports the feasibility of the proposed alert system for temperature and humidity monitoring.

Lee et al. (2019) presented a comprehensive review of IoT applications in smart manufacturing, discussing how IoT-enabled sensors can improve operational efficiency and reduce manual monitoring efforts. This study reinforces the importance of developing scalable solutions, aligning with the project's future phase of processing data at the edge. Patel et al. (2020) explored the use of edge computing in smart factories, demonstrating that processing data at the edge reduces network congestion and improves response times for real-time monitoring systems. This finding is crucial for the project's phase 2 objective of optimizing network and storage efficiency.

Several studies focused on IoT-based environmental monitoring systems. Novelan and Amin (2020) developed a system using the DHT11 sensor and NodeMCU for real-time monitoring, demonstrating data transmission via Wi-Fi to a Visual Basic .NET application and storage in Firebase Realtime Database. Lavanya et al. (2019) proposed a system integrating DHT11 sensors and NodeMCU with the Blynk platform for real-time monitoring and control of environmental conditions. Darji (2020) introduced an IoT-based HVAC solution using Arduino-Uno, ESP8266, and ThingSpeak cloud for monitoring and control. Awaludin et al. (2018) employed a DHT11 sensor and NodeMCU for remote monitoring in a chemical laboratory, using XAMPP and PHP for data management. Saputra et al. (2019) reviewed the development of a Smart Air Conditioner using IoT for enhanced home automation and efficiency.

Other notable studies include Utomo et al. (2020), who developed a system for monitoring temperature and humidity in server rooms using IoT, utilizing DHT11 sensors and a Raspberry Pi and Arduino module for data transmission and remote control. Ukadike et al. (2019) presented a comprehensive IoT-based solution for monitoring humidity, temperature, and air quality using NodeMCU sensors and the Blynk platform. Azman et al. (2019) addressed energy management in tropical countries through an IoT meter for monitoring voltage, current, power, energy, temperature, and humidity. Fauzi et al. (2019) focused on air quality and humidity control in storage rooms for medicine, using DHT11 sensors and NodeMCU for real-time monitoring and data display via the Blynk platform.

Irawan et al. (2021) designed a temperature and humidity monitoring system using IoT technologies for agricultural environments. Sutrisno et al. (2018) developed a smart greenhouse system integrating IoT sensors for optimal plant growth conditions. Wijaya et al. (2020) created an IoT-based solution for monitoring and controlling environmental parameters in aquaculture. Rahman et al. (2019) presented an IoT framework for real-time monitoring and control in industrial settings, emphasizing energy efficiency and data accuracy. Lastly, Purnama et al. (2018) explored the use of IoT for air quality monitoring, integrating various environmental sensors for comprehensive data collection and analysis.

These studies collectively highlight the advancements and challenges in temperature and humidity monitoring systems. The current project integrates the DHT22 sensor and ESP8266 NodeMCU to create a robust, real-time monitoring system for industrial environments, enhancing accuracy, reliability, and efficiency in environmental monitoring by building on existing technologies and addressing their limitations. In Phase 1, we developed a prototype automating data collection and logging, with real-time alerts for threshold breaches displayed on a user interface. Future phases will involve processing data at the edge to reduce bandwidth and storage requirements (Phase 2) and fabricating a PCB for market-ready product development (Phase 3), ensuring the system's adaptability, efficiency, and practicality in industrial settings.

III. COMPONENTS

Hardware components:

DHT22 Sensor

The DHT22 sensor (Fig1.1), also known as AM2302, is a versatile digital sensor renowned for its accuracy, reliability, and ease of use. It measures temperature and humidity, making it ideal for various environmental monitoring applications, including our temperature and humidity monitoring system. In our setup, the DHT22 sensor collects real-time data from different factory environments like the AC lab, chassis assembly, and maintenance room. Its digital output interfaces easily with microcontrollers such as the ESP8266 NodeMCU, which wirelessly transmits the data to a local server. This data is then logged into a database and visualized on analytical dashboards, providing critical insights into the environmental conditions of these areas.

The DHT22 sensor offers several advantages, including high accuracy in temperature (±0.5°C) and humidity (±2-5%) measurements, which is crucial for maintaining optimal industrial conditions. It has a wide measurement range, from -40°C to +80°C for temperature and 0% to 100% RH for humidity. Its digital output simplifies integration with microcontrollers, reducing the need for additional signal processing hardware. The sensor's low power consumption makes it suitable for continuous monitoring applications, and its ease of use accelerates development and deployment. In our project, the DHT22 sensor's precise and reliable measurements ensure efficient real-time environmental monitoring, enhancing the overall operational efficiency of the factory.

ESP8266

The ESP8266 (Fig 1.2), developed by Espressif Systems, is a highly popular, low-cost Wi-Fi microcontroller module known for its affordability, ease of use, and versatile functionality. It includes a full TCP/IP stack, enabling seamless Wi-Fi connectivity and internet interaction. This module has become a favorite in the IoT community, making it a powerful tool for various applications, including our temperature and humidity monitoring system. By interfacing with the DHT22 sensor, the ESP8266 collects real-time environmental data from different factory areas and transmits it wirelessly to a local web server hosted on XAMPP.

The ESP8266 offers several advantages: its low cost makes it an economical choice for large-scale monitoring systems, while its built-in Wi-Fi capability ensures easy and reliable wireless data transmission, eliminating the need for extensive wiring. The module's compact size allows for easy integration into various devices, and its ease of programming with the Arduino IDE simplifies development. In our project, the ESP8266's efficient data transmission enables real-time monitoring and logging of environmental conditions, enhancing the system's overall efficiency and effectiveness. This integration provides valuable insights into the factory's environmental conditions, ensuring optimal operational performance.

Fig 1.1

Fig 1.2

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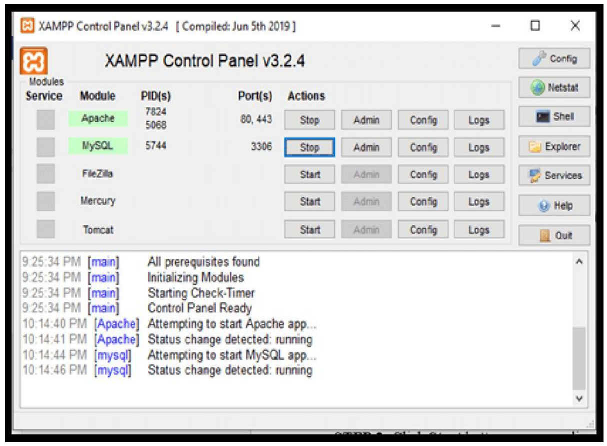
SOFTWARE COMPONENTS

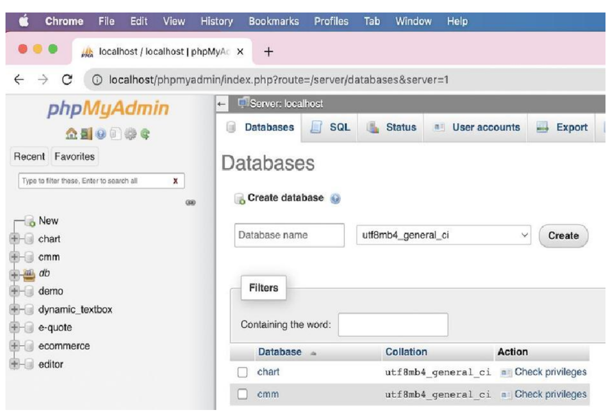
XAMPP



XAMPP is a free, open-source, cross-platform web server solution stack developed by Apache Friends, designed for web development. It includes Cross-Platform (X), Apache (A), MySQL (M), PHP (P), and Perl (P), simplifying the process of creating and testing web applications locally before deployment on a production server. Key features include compatibility with Windows, Linux, and macOS, a robust and configurable Apache server, and essential MySQL database management. It also supports PHP and Perl for server-side scripting and text processing, and phpMyAdmin for managing MySQL databases through a user-friendly interface.

XAMPP's ease of installation and configuration, along with its modularity and security features, make it accessible for both beginners and experienced developers. In our temperature and humidity monitoring system, XAMPP hosted a local web server to facilitate data transmission and logging into a MySQL database via phpMyAdmin. This setup enabled real-time visualizations of temperature and humidity readings from various factory environments on analytical dashboards. XAMPP's integration streamlined the development process, ensuring efficient data management and real-time monitoring, while providing password protection for phpMyAdmin and directory access restrictions to enhance security.

PHPMyAdmin



phpMyAdmin is a free, open-source tool written in PHP that facilitates the administration of MySQL databases through a web-based interface. It is essential for web developers and database administrators, providing an intuitive platform for a wide range of database management tasks. Key features include a user-friendly graphical interface, enabling users to manage databases without extensive SQL knowledge. It supports creating, modifying, and deleting databases, tables, fields, and indexes, as well as managing database users and their permissions. Additionally, it allows the execution of SQL queries, data import/export in various formats, and easy backup and restoration of databases.

In our temperature and humidity monitoring system project, phpMyAdmin was crucial for managing the MySQL database that logged sensor readings. It facilitated the creation of databases and tables to store temperature and humidity data collected from various factory environments. The web-based interface made monitoring and managing the data straightforward, allowing the execution of SQL queries to analyze trends. This ensured smooth operation and data integrity. By integrating phpMyAdmin, the project benefited from streamlined database management, enhancing overall efficiency and effectiveness in real-time environmental monitoring.

IV. METHODOLOGY AND WORKFLOW

System Design and Architecture

The temperature and humidity monitoring system was designed with a focus on simplicity, cost-effectiveness, and scalability to fit industrial environments. The system architecture consists of the following components:

DHT22 Sensor: The DHT22 sensor was selected for its accuracy in measuring both temperature and humidity. It was deployed across different locations within the factory: the AC lab, chassis assembly area, and maintenance room.

ESP8266 NodeMCU: The ESP8266 NodeMCU microcontroller was used for data acquisition and transmission. Its built-in Wi-Fi capability allows for wireless communication with the local web server.

Data Collection and Transmission

Sensor Deployment: DHT22 sensors were strategically placed in different factory locations. Each sensor was connected to an ESP8266 NodeMCU, which collected data at regular intervals.

Data Transmission: The ESP8266 NodeMCU transmitted the collected data wirelessly to a local web server via Wi-Fi. The data transmission was implemented using HTTP POST requests, ensuring that real-time data could be reliably sent to the server.

Server and Database Setup

Web Server Configuration: A local web server was set up using XAMPP, a free and open-source cross-platform web server solution that includes Apache, MySQL, PHP, and Perl. This server handled the reception and storage of the transmitted data.

Database Management: The environmental data was stored in a MySQL database managed by PHPMyAdmin. A PHP script was developed to handle the insertion of data into the database, bridging the output from the Arduino IDE (which managed the ESP8266 NodeMCU) with the server-side database.

User Interface and Data Visualization

Interface Design: A web-based user interface was developed to display real-time data. The interface was designed using HTML, CSS, and JavaScript, with dynamic graphs generated using Chart.js. These graphs plot temperature and humidity against time, providing a clear and intuitive way to monitor environmental conditions.

Alert System: The interface also included an alert system, which triggered visual alerts and LED indicators when the monitored parameters exceeded predefined thresholds. This feature was critical for providing immediate feedback to factory personnel in case of environmental anomalies.

Prototype Testing and Validation

Testing Environment: The prototype system was deployed in a controlled environment to test its accuracy, reliability, and response time. The deployment locations within the factory were chosen based on varying environmental conditions to ensure the system could handle different scenarios.

Data Analysis: Collected data was analyzed to assess the system's performance. Key performance indicators included the accuracy of the sensor readings, the consistency of data transmission, and the responsiveness of the alert system.

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Future Development

Edge Processing (Phase 2): Future phases of the project will involve implementing edge processing capabilities to reduce network bandwidth and data storage requirements. This will be achieved by integrating a microcontroller with on-board data processing capabilities, allowing for local data aggregation and initial analysis before transmission.

Custom PCB Development (Phase 3): The final phase will involve designing and fabricating a custom PCB to integrate all components into a single, compact, and market-ready product. This will include optimizing the layout for industrial use, ensuring durability, and minimizing power consumption.

V. RESULTS AND CONCLUSION

The values in the table 2.1 and table 2.2 shows the sample readings of the DHT22 sensor in the airconditioned laboratory and chassis assembly factory environments respectively. These values are recorded by the sensor and stored in the database from where they are retrieved and displayed on a user interface in the form of a graph as depicted in the figure 1.3

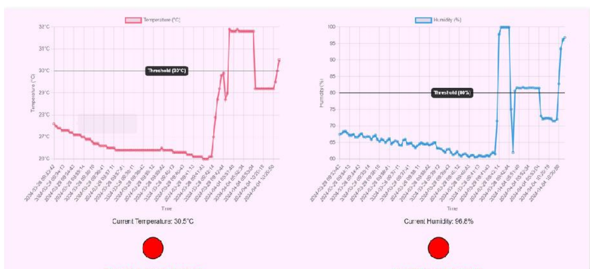

Fig 1.3 – Graphical representation of sensor values

ROW ID	TEMPERATURE	HUMIDITY	DATETIME
541	26.3	64.9	2023-03-28 14:38:17
542	26.3	64.6	2023-03-28 14:38:23
543	26.4	64.4	2023-03-28 14:38:30
544	26.4	64.7	2023-03-28 14:38:36

Table 2.1 – DHT22 sensor Lab Readings

ROW ID	TEMPERATURE	HUMIDITY	DATETIME
573	35.8	75.6	2023-05-23 15:45:13
574	35.8	75.9	2023-05-23 15:45:19
575	35.9	76.2	2023-05-23 15:45:26
576	35.9	76.4	2023-05-23 15:45:32

Table 2.2 – DHT22 sensor Chassis Assembly Readings

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VI. USER INTERFACE

Environmental Monitoring Dashboard

An analytical dashboard was employed to visualize temperature and humidity data collected from sensors within the industrial setting. The dashboard displayed these parameters over time (datetime) in two separate line graphs. Each graph included a horizontal threshold line representing the optimal range for the respective parameter.

The user interface (UI) retrieved sensor data from a database and dynamically updated the graphs. Additionally, LED indicators beneath each graph provided a real-time status. Green LEDs signified values within the designated thresholds, while red LEDs accompanied by an alert message indicated readings exceeding these limits.

This approach facilitated the continuous monitoring of environmental conditions within the industrial environment, enabling prompt identification of potential deviations from the desired parameters.

VII. FUTURE WORKS

Phase-1:

The first phase of this research focuses on developing a real-time temperature and humidity monitoring system tailored for industrial environments. This system aims to optimize the utilization of industrial resources by ensuring safer working conditions for both machines and humans. By automating the process of manually recording temperature and humidity readings, the system provides a cost-effective solution for industrial environment monitoring. Leveraging the DHT22 sensor and ESP8266 NodeMCU, the system facilitates continuous data collection and wireless transmission to a local server, enabling real-time visualization and analysis through analytical dashboards. This integration enhances operational efficiency and environmental management in industrial settings.

Phase-2:

In the second phase, the research addresses the challenges of network bandwidth consumption and data storage. By processing data at the edge, the system reduces the volume of real-time data transmitted to the end-user interface, thereby optimizing network usage. This approach ensures that only essential data points are transferred, minimizing bandwidth requirements and storage needs. Edge processing enhances the system's responsiveness and reliability, making it more efficient in handling large-scale deployments. This phase aims to strike a balance between data accuracy and resource utilization, ensuring that the monitoring system remains robust and scalable.

Phase-3:

The final phase involves designing and developing an optimal device that is both cost-effective and energy-efficient, surpassing existing market solutions. This phase includes fabricating a custom PCB to integrate sensors and microcontrollers, thereby enhancing the system's compactness and functionality. The goal is to create a novel product that offers superior performance in environmental monitoring, with the potential for patenting and commercialization. By developing this end product, the research not only advances technical innovation but also explores its market viability, adding a business dimension to the project. This phase aims to establish a competitive edge in the industry by providing a unique and valuable solution for industrial monitoring applications.

VIII. CONCLUSION

The successful completion of Phase 1 of the temperature and humidity monitoring system demonstrates its feasibility and effectiveness in real-time environmental monitoring within an industrial setting. By utilizing a DHT22 sensor and ESP8266 NodeMCU for accurate data collection and wireless transmission, along with XAMPP and PHPMyAdmin for robust data logging and visualization, the system automates the manual recording of environmental conditions with high accuracy and low cost. The user interface effectively displays real-time data and alerts for threshold breaches, enhancing operational efficiency. Building on this strong foundation, future phases will focus on processing live data at the edge to optimize network and storage usage (Phase 2) and developing a market-ready product through custom PCB fabrication (Phase 3). This phased approach ensures a scalable and commercializable solution, poised to meet the growing demands for automated environmental monitoring in industrial environments.

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