Smart Lecture Hall Management: Integrating IoT for Monitoring and Controlling Environmental Conditions

MDCD CHAMATHKA(21268)-
mdcdchamathka@students.nsbm.ac.lk

RMIS RATHNAYAKA(20456)-
rmisrathnayaka@students.nsbm.ac.lk

KMMH RAJAKARUNA(21243)-
kmmhrajakaruna@students.nsbm.ac.lk

BHKL DAYAWARDANA(21871) -
bhkldayawardana@students.nsbm.ac.lk

MADU PRABASHWARA(21631)-
maduprabashwara@students.nsbm.ac.lk

Abstract— **This proposed Smart Lecture Hall Management system presents the development and implementation of a smart environmental monitoring and control system for lecture halls, leveraging Internet of Things (IoT) technology. The system aims to optimize learning environments by automating the regulation of temperature, humidity, and lighting conditions. A NodeMCU microcontroller, coupled with sensors like BMI 680, LDR, and PIR, collects real-time data to control air conditioning, humidification, and lighting systems. By prioritizing energy efficiency, student comfort, and system adaptability, the research investigates the system's impact on learning outcomes and energy consumption. The study also explores the system's potential for remote monitoring, early fault detection, and integration into broader campus sustainability initiatives.**

Keywords— smart environmental monitoring, IoT, energy efficiency, student comfort, climate control, lighting control

I. INTRODUCTION

The educational landscape in both Sri Lanka and the whole world is undergoing a profound transformation, driven by technological advancements and a growing emphasis on sustainability. The conventional lecture hall, often characterized by static environments and suboptimal conditions, presents a significant opportunity for innovation. This research paper delves into the development of a "Smart Environmental Monitoring and Control System" for lecture halls, harnessing the potential of the Internet of Things (IoT) to create a more intelligent, responsive, and eco-friendly learning environment.

By integrating a network of sensors and actuators, the proposed system automates the regulation of critical environmental factors, including temperature, humidity, and lighting. The system's core component, a NodeMCU microcontroller, orchestrates the collection of real-time data from sensors such as the BMI 680 environmental sensor, LDR, and PIR sensor. This data is then processed to make informed decisions about adjusting air conditioning, humidification, and lighting levels accordingly.

A key innovation of this system lies in its holistic approach to environmental management. By intelligently managing lighting through light-dependent resistors and occupancy sensors, the system significantly reduces electricity usage without compromising student comfort. Similarly, the automated control of air conditioning and humidity levels contributes to energy efficiency while maintaining a pleasant classroom atmosphere. This dual focus on student well-being and environmental sustainability positions the system as a compelling solution for educational institutions seeking to reduce their carbon footprint and operational costs.

Beyond environmental control, the system incorporates advanced monitoring and diagnostic capabilities. Real-time data on temperature, humidity, and occupancy is accessible through an online platform, empowering administrators to track environmental conditions and make informed decisions remotely. Furthermore, the system's proactive approach to maintenance is exemplified by its ability to detect anomalies and generate alerts, such as those indicating AC blower failures or humidifier malfunctions. This early warning system ensures timely intervention, preventing disruptions to the learning process and minimizing downtime.

The versatility and scalability of the system are key strengths. Its modular design facilitates easy installation and configuration in diverse classroom settings, making it adaptable to various educational institutions. Additionally, the system's architecture allows for future expansion, potentially integrating additional sensors, actuators, or functionalities to meet evolving requirements. For instance, the system could be expanded to incorporate air quality monitoring, CO2 level detection, or integration with building management systems.

II. RELATED WORK

The integration of Internet of Things (IoT) technology into educational settings has garnered increasing attention in recent years. While research has explored a broad spectrum of applications[1], from enhancing student engagement to optimizing administrative processes, the specific focus on leveraging IoT to optimize lecture hall environments remains relatively understudied.

A substantial body of research has unequivocally established a correlation between the physical learning environment and student outcomes[2]. Factors such as temperature, humidity, lighting, and air quality significantly influence student comfort, focus, and overall well-being. Studies have consistently demonstrated that suboptimal environmental conditions can lead to decreased cognitive function, reduced attention spans, and increased fatigue, ultimately hindering academic performance. These findings underscore the imperative need for creating learning spaces that prioritize student health and comfort.

Traditional lecture halls often fall short in providing adequate environmental control. The static nature of these spaces, coupled with limited monitoring capabilities, frequently results in suboptimal conditions that can negatively impact student learning. The advent of IoT technology presents an opportunity to revolutionize lecture hall environments by enabling real-time monitoring, control, and optimization of critical environmental factors.

While there is a growing body of research exploring the application of IoT in various educational settings[3], such as classrooms, libraries, and campus-wide infrastructures, the specific focus on lecture halls requires further investigation. A key challenge in designing IoT-based systems for lecture halls lies in the need to balance multiple, often competing, objectives. Maintaining optimal temperature and humidity levels for student comfort is paramount, but it must be reconciled with energy efficiency and cost-effectiveness considerations. Additionally, ensuring adequate lighting without compromising energy consumption is another critical aspect. Furthermore, the system must be user-friendly, facilitating easy monitoring and control for both students and faculty.

To effectively address these challenges, a comprehensive approach is necessary. This entails not only the development of advanced sensor technology but also the creation of intelligent algorithms capable of analyzing sensor data and making real-time adjustments to environmental conditions. Moreover, integrating user feedback into the system design is crucial [4] to ensure that it aligns with the specific needs and preferences of occupants. By adopting a holistic approach that considers the interplay between technology, human factors, and environmental sustainability, researchers can contribute to the development of IoT-based systems that truly optimize the lecture hall environment.

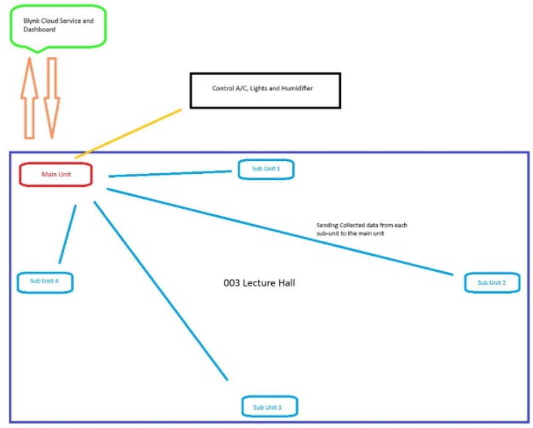
III. ARCHITECTURE DESIGN APPROCH

To effectively implement the smart environmental monitoring and control system, a modular architectural approach is adopted. The system is divided into two primary components: the main unit and the sub-units. This modular structure enhances system flexibility, scalability, and maintainability.

The system's core functionality is realized through a judicious selection of hardware components. A NodeMCU microcontroller serves as the central processing unit, orchestrating data acquisition, processing, and control decisions. To monitor environmental conditions, DHT11 sensors provide real-time temperature and humidity readings, while LDR sensors detect ambient light levels. Occupancy detection is initially handled by PIR sensors, although alternative fire detection methods will be explored. Actuators such as PWM A/C blower controllers and humidifiers enable precise control over temperature and humidity levels. An SSD1306 OLED display offers a local interface for visualizing real-time data and system status.

The system's operation involves continuous data collection from sensors, which is then analyzed to determine necessary adjustments. Predefined thresholds for temperature, humidity, and light levels trigger corresponding actions, such as activating or deactivating the A/C blower, adjusting humidifier output, or controlling lighting. To facilitate remote management and monitoring, the system incorporates a web interface that provides access to real-time data and control parameters.

The Smart Lecture Hall Management system are divided into two segments as the main unit and sub unit, which will be explored further below.



A. Main Unit

The main unit serves as the central nervous system of the smart environmental monitoring and control system. Its role is pivotal in orchestrating the system's functions, from data acquisition to control execution. Equipped with a WeMos NodeMCU ESP8266 microcontroller, the unit acts as the intelligent core, processing data from various sensors and making informed decisions.

To ensure system autonomy, a 1000mAh battery provides power backup, guaranteeing uninterrupted operation for at least six hours in the event of a power outage. The system's power input is facilitated through a USB-C port for convenient charging.

A comprehensive suite of sensors and modules enhances the main unit's capabilities. An ultrasonic sensor meticulously monitors the water level in the humidifier's tank, preventing water shortages and ensuring optimal system performance. An SSD1306 OLED display provides real-time feedback on temperature, humidity, air quality, and system status, enabling users to monitor environmental conditions at a glance. To control external devices, an SSR 3 channel relay module is employed, allowing for precise activation and deactivation of connected appliances. A buzzer serves as an audible alert system, signaling low water levels, nighttime occupancy, system failures, or sensor malfunctions.

Beyond hardware components, the main unit's intelligence lies in its software. Programmed in C++, the microcontroller executes algorithms to analyze sensor data, compare it against predefined thresholds, and initiate appropriate control actions. The system's decision-making capabilities extend to regulating air conditioning, lighting, and humidifier operation based on real-time environmental conditions and occupancy patterns.

To enhance system accessibility and remote management, the main unit integrates with the Blynk cloud platform. This integration enables users to monitor environmental parameters, adjust system settings, and receive notifications through a dedicated mobile application. Key notifications include low water levels, nighttime occupancy, air quality deviations, humidity fluctuations, temperature anomalies, and lighting system failures. This remote monitoring capability empowers users to stay informed about the lecture hall environment and take corrective actions as needed.

B. *Sub Unit*

The sub-units form the sensory backbone of the smart environmental monitoring system, diligently collecting and transmitting environmental data to the main unit. Strategically placed throughout the lecture hall, these units ensure comprehensive coverage of the learning space. Each sub-unit houses a specific set of sensors and a microcontroller to process the gathered information.

A WeMos NodeMCU ESP8266 serves as the microcontroller for each sub-unit, providing computational power for data acquisition and preliminary processing. To capture environmental parameters, a DHT11 sensor accurately measures temperature and humidity levels, while an MQ-135 sensor detects air quality, specifically CO2 concentration. An LDR sensor monitors ambient light conditions, determining whether the classroom lights are on or off.

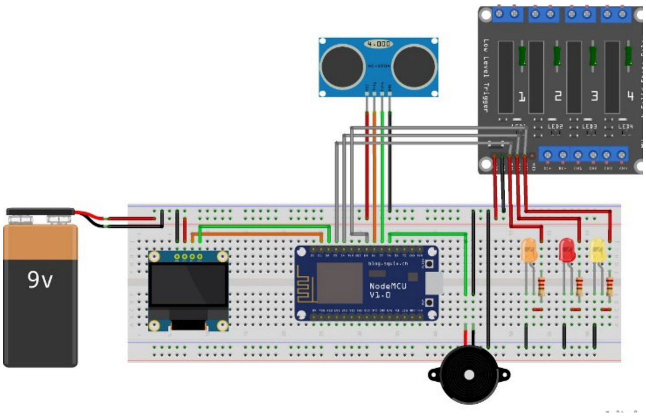
To provide visual feedback on environmental conditions, each sub-unit incorporates sets of red, green, and blue LEDs. These LEDs dynamically display color combinations corresponding to different environmental parameters, offering users an intuitive understanding of the classroom's state. A 1000mAh battery ensures the sub-unit's operation during power outages, guaranteeing uninterrupted data collection.

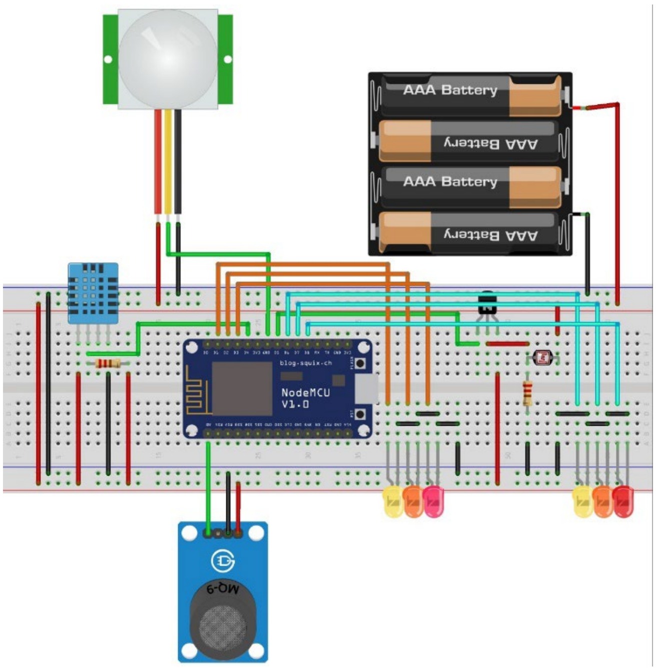
The sub-units operate within a coverage range of 8 to 12 meters, allowing for flexible deployment in various classroom sizes. By strategically positioning multiple sub-units, it is possible to achieve comprehensive environmental monitoring across the entire lecture hall. The collected data, including temperature, humidity, air quality, and light levels, is transmitted to the main unit for further analysis and control decisions.

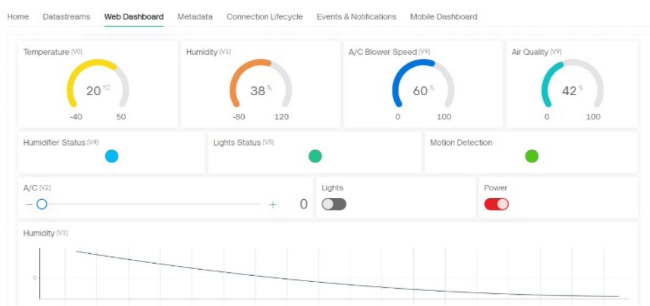
The collaborative efforts of the main unit and sub-units create a synergistic system that effectively monitors and regulates the lecture hall environment, ultimately enhancing the learning experience.

IV. Demonstration

The following images demonstrate the implementation of the proposed system as well as the readings from the dashboard.







V. CONCLUSION

The development and implementation of a smart lecture hall management system, as presented in this research, represents a significant step forward in creating intelligent and sustainable learning environments. By harnessing the power of IoT technology, the system effectively addresses the challenges posed by traditional lecture halls, where static conditions often hinder student comfort, focus, and overall well-being.

The integration of a network of sensors, including temperature, humidity, light, and air quality sensors, coupled with a robust microcontroller-based architecture, enables real-time monitoring and control of environmental factors. The system's ability to autonomously adjust temperature, humidity, and lighting conditions based on predefined thresholds and occupancy patterns significantly enhances student comfort and well-being. Moreover, by incorporating energy-efficient practices, such as optimizing lighting usage and controlling HVAC systems based on occupancy, the system contributes to reduced energy consumption and environmental sustainability.

A key strength of the proposed system lies in its modular design, allowing for easy installation, configuration, and scalability. The division of the system into main and sub-units facilitates flexible deployment in various classroom sizes and configurations. Additionally, the integration of a user-friendly web interface empowers administrators to remotely monitor environmental conditions, make adjustments, and receive notifications, enhancing system management and responsiveness.

While this research presents a promising approach to smart lecture hall management, further exploration and refinement are necessary. Future studies could focus on expanding the system's capabilities to include additional environmental parameters, such as noise levels and air particulate matter, and investigating the integration of advanced machine learning algorithms for predictive modeling and optimization. Furthermore, conducting comprehensive user studies to evaluate the system's impact on student performance, satisfaction, and learning outcomes is crucial for validating its effectiveness.

In conclusion, the development of a smart lecture hall management system signifies a paradigm shift in educational infrastructure. By prioritizing student well-being, energy efficiency, and technological innovation, this research contributes to the creation of more conducive and sustainable learning environments. As IoT technology continues to evolve, the potential for further advancements in smart lecture hall management is immense, promising to shape the future of education.

REFERENCES

[1] Gaëlle Guyot, M. S. I. W. J. D. C., 2017. *Residential smart ventilation: a review,* s.l.: hal-01670527.

[2] Nishant Raj Kapoor, P. B. S. K. K. A. K., 2021. A Review on Indoor Environment Quality of Indian School Classrooms. *Sustainability ,* Volume 13 (21).

[3] Priyanka Thirumugam, Z. R. D. H., 2022. IoT-based Air Pollution Monitoring System for Surrounding Environments in Private Education Institute using MQ135 and MQ7 Sensors. *Journal of Engineering Technology.*

[4] Wael Alsafery, C. P. O. F. R., 2023. Sensing within Smart Buildings: A Survey. *ACM Computing Surveys,* 55(13), pp. 1-35.