# An Extended IoT Model for Smart Temperature and Humidity Control and Monitoring System: A Case Study of University of Kigali Classrooms

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Publication Date: 2025/04/12

**Abstract: This study presents an advanced IoT model for managing and monitoring temperature and humidity in classrooms at the University of Kigali. The system addresses two critical issues: reducing unnecessary energy consumption caused by human error (such as forgetting to turn off fans) and creating an optimal learning environment by maintaining ideal temperature and humidity levels. By automating temperature control and providing real-time monitoring through IoT technologies, the system ensures both accuracy and reliability. The setup includes several components, with the NodeMCU microcontroller serving as the central processing unit. It connects to a DHT sensor for temperature and humidity readings, a fan, and a 220V heater through a relay module, enabling efficient control. An LCD screen displays current environmental data, while the Blynk app allows for remote management and monitoring of sensor values. The system operates automatically based on class schedules stored in a MySQL database, ensuring it runs only during class hours. An SMS gateway (Mista.io) alerts operators to any potential system failures when temperature or humidity exceeds predefined thresholds. Sensor data is collected in real-time and sent to the MySQL database via the NodeMCU. Operators can manage class schedules, monitor system performance, and view environmental data through a web interface. The platform provides an intuitive way to analyze trends in sensor data, allowing for well-informed decisions regarding temperature control. The system not only ensures a productive learning environment but also reduces operational costs, offering a sustainable solution for classroom comfort and energy management. It demonstrates how IoT technologies can enhance traditional systems to create smarter, more effective solutions for educational settings.**

***Keywords:*** *IoT (Internet of Things), Temperature with humidity, NodeMCU, MySQL Database and Mista.io SMS Gateway*.

**How to Cite:** Ndayishimiye Ismael; Dr. Wilson Musoni. (2025). An Extended IoT Model for Smart Temperature and Humidity Control and Monitoring System: A Case Study of University of Kigali Classrooms. *International Journal of Innovative Science and Research Technology*,10(3), 2669-2680. https://doi.org/10.38124/ijisrt/25mar1697.

## I. INTRODUCTION

This study explores an advanced IoT model designed for smart temperature and humidity regulation in classrooms at the University of Kigali. The chapter outlines the background and significance of the research, addressing the issues of energy wastage and discomfort in classrooms. It also presents the objectives aimed at resolving these problems. Additionally, the scope of the study is discussed, including the time frame, content, and geographical focus, along with the potential benefits the system offers to the community, researchers, and academic scholars. Lastly, the organization of the study is outlined to provide a clear structure for the research.

➢ *Problem Statement*

Classrooms at the University of Kigali often experience uncomfortable temperature and humidity levels, which negatively affect students' focus and learning outcomes. Additionally, manual ventilation systems, such as fans, are frequently left running when classrooms are empty, leading to unnecessary energy consumption and higher operating costs. This inefficient practice not only increases expenses but also creates an undesirable learning environment.

The proposed IoT-based smart temperature and humidity control system addresses these challenges by automating the management of classroom conditions. The system ensures optimal indoor environments during study hours, improving student concentration and overall academic performance. Moreover, it prevents energy waste by automatically turning off fans and heaters when classrooms are unoccupied, including during nights, holidays, and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1697

breaks. The technology also supports proactive maintenance by notifying university staff of any system malfunctions through real-time monitoring and fault detection features. This innovative solution provides a cost-effective, energy-efficient way to enhance educational environments while reducing energy consumption.

## II. METHODOLOGY AND RESEARCH

### *A. Research Design*

This study employs a descriptive research design to explore the practices, challenges, and opportunities in the classrooms of the University of Kigali. It combines both quantitative data (such as maintenance response times) and qualitative insights from relevant stakeholders, providing a well-rounded understanding of the technical, operational, and communication issues. This approach also assesses the impact of proposed solutions, such as automation and training, and offers valuable insights to improve system efficiency, reliability, and satisfaction.

### *B. Study Population*

The population of this study includes 1,563 individuals associated with the University of Kigali, consisting of students (1,517), teachers (36), cleaners (4), lab technicians (1), and administrative staff (4). A sample size of 318 respondents was calculated using Yamane's formula, with a 5% margin of error, ensuring representative participation across all groups. Participants were selected using random sampling to minimize bias.

### *C. Sampling*

The study utilizes a combination of stratified and purposive sampling methods. Stratified sampling divides the population into distinct subgroups (e.g., students, staff), while purposive sampling targets specific experts, such as technicians and operators. This dual approach ensures both broad representation and in-depth insights from key stakeholders.

### *D. Data Collection Methods and Instruments*

Various data collection methods—interviews, observations, and surveys—are used to gather both qualitative and quantitative data. These methods provide a thorough understanding of how the IoT-based system is functioning in classrooms. Interviews offer in-depth perspectives on challenges, observations document real-time practices, and surveys provide broader statistical trends related to system performance.

### *E. Interviews*

Structured and semi-structured interviews are conducted with important stakeholders, such as technicians, operators, and students, to understand the practical challenges of operating temperature and humidity control systems. Semi-structured interviews offer flexibility, allowing participants to share detailed insights and experiences that may not emerge from more structured methods.

### *F. Observation*

Observational visits to cooling facilities and operator sites allow for a practical assessment of system functionality. These visits help identify maintenance practices, operational efficiency, and user interactions with the technology, further enriching the analysis by cross-checking data gathered from interviews and surveys.

### *G. Surveys*

Surveys are distributed to a range of stakeholders to collect data on the system's adoption, user satisfaction, and operational challenges. Both closed-ended questions (for quantitative data) and open-ended questions (for qualitative feedback) are included to capture a comprehensive view of system performance and impact.

### *H. Data Processing*

Data processing involves cleaning, coding, and entering real-time sensor data into a MySQL database. The data is then analyzed to identify trends, anomalies, and correlations. Data visualization tools, such as charts and graphs, summarize the findings, making the information accessible for decision-making. This ensures accurate and timely insights to optimize energy management and classroom conditions.

### *I. Data Analysis*

Both descriptive and inferential statistics are applied to analyze the collected sensor data. Descriptive statistics summarize key trends (e.g., average temperature and humidity levels), while inferential statistics help predict future performance and examine correlations between variables. The analysis ensures that the system adapts to maintain ideal conditions and generates alerts when thresholds are exceeded.

### *J. Limitations Encountered During the Study*

During deployment, several challenges may arise, such as hardware issues (e.g., connectivity problems, sensor failures), software difficulties (e.g., integration of the MySQL database, web interface bugs), environmental factors (e.g., power fluctuations), and user-related constraints. Budget limitations could also affect the scalability and enhancement of the system. These challenges will require continuous testing and refinement to ensure the system operates efficiently.

## III. CONCEPTUAL FRAMEWORK

The conceptual framework for the IoT-based smart temperature control and monitoring system illustrates the relationships between independent and dependent variables. Independent variables, such as temperature, humidity, and moisture content monitoring and regulation, are supported by devices like an LCD screen and a cloud platform. System efficiency is ensured through automated processes, including relay switching, occupancy tracking in classrooms, and scheduled settings, along with real-time fault detection and notifications sent via SMS alerts, web interfaces, and the Blynk app. The dependent variable is the extended IoT-based smart air conditioning system model designed to optimize classroom conditions at the University of Kigali, promoting

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both energy efficiency and an improved learning environment. All these components collectively influence the performance of the system.

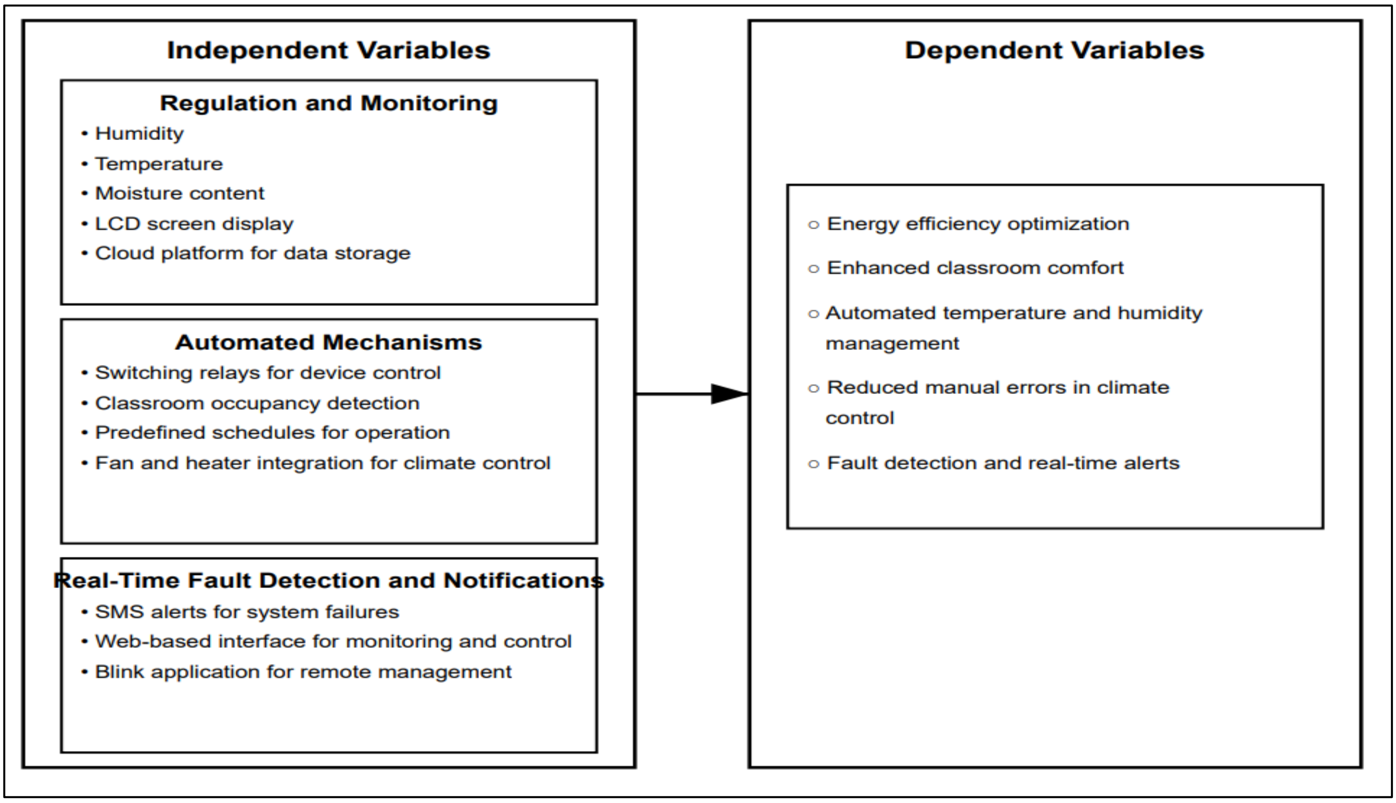


Fig 1: Conceptual Framework

## IV. PRESENTATION AND ANALYSIS OF RESEARCH FINDINGS

### *A. Existing System*

Manually operating fans and air conditioning can help the University of Kigali address three key challenges in managing classroom conditions. Firstly, extreme humidity or temperature levels often disrupt students' ability to focus and learn effectively. A manual air conditioning system can help by activating fans with adjustable speed settings during study hours, ensuring a more comfortable learning environment. Secondly, fans in unoccupied classrooms are often left running, resulting in unnecessary energy consumption. This can be avoided by implementing a simple manual process to turn off the fans after study sessions.

Lastly, the current approach, which is inefficient, leads to higher operational costs and poor classroom environments. A structured manual method for controlling fans and air conditioning can reduce energy costs while maintaining a comfortable atmosphere, ultimately improving both academic outcomes and the institution's financial efficiency.

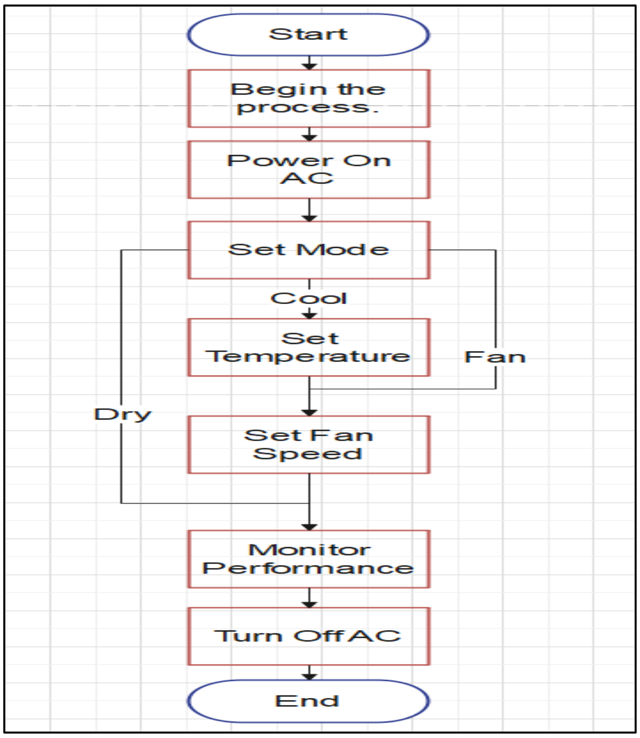


Fig 2: Existing Flowchart

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1697

The manual temperature control process is illustrated through a flowchart. The user begins by turning on the air conditioning unit using the power button. Next, the user selects the desired operation mode (Cool, Fan, Dry, or Heat). Depending on the chosen mode, the user can adjust additional settings, such as fan speed and temperature. The system then operates according to these parameters, providing heating, cooling, dehumidifying, or air circulation as required. To ensure comfort, the user monitors the system's performance and makes adjustments as necessary. The process concludes when the user switches off the system.

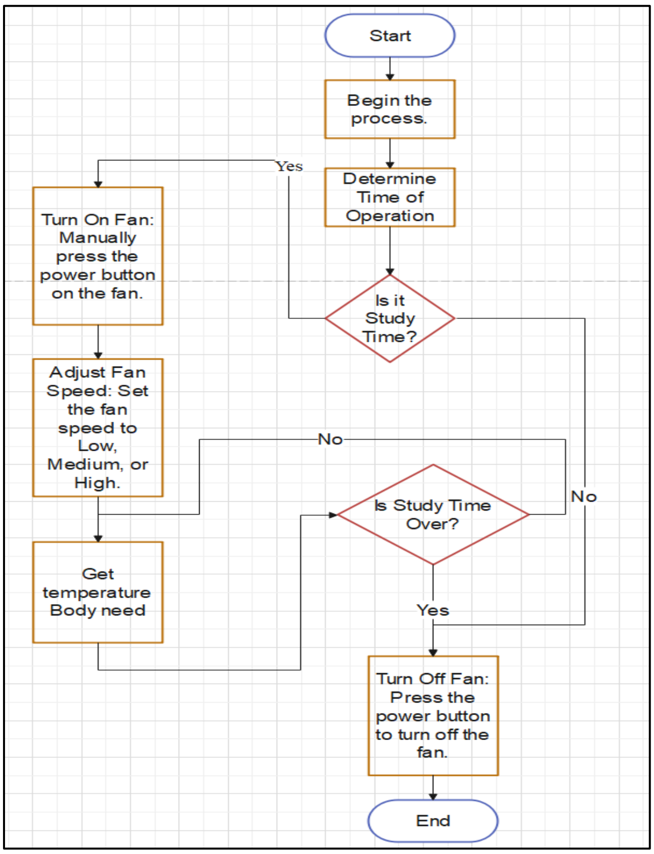


Fig 3: Flowchart of Existing System in UOK
Source: research owner Drawn in Edraw max Software application in computer, 2025

The flowchart outlines the manual operation of a fan in University of Kigali classrooms, considering both study and non-study periods. The first step is to determine if it is study time. During study sessions, the fan is manually activated using the power button, and its speed can be adjusted to low, medium, or high based on the comfort of the students. The fan operates according to the room's temperature to maintain a pleasant environment for learning. Once study time concludes, the next step is to manually turn off the fan. This prevents unnecessary energy consumption by ensuring the fan is switched off after classes. This method ensures efficient fan use by maintaining classroom comfort during lessons and conserving energy when the room is not in use.

### *B. Microcontroller (NodeMCU ESP8266)*

The NodeMCU ESP8266 acts as the system's central processing unit, responsible for collecting sensor data, processing commands, and controlling connected devices. It enables communication between the temperature and humidity sensor, relay module, LCD display, and MySQL database. The microcontroller's built-in Wi-Fi capability allows it to connect to the internet, supporting real-time monitoring and remote control via the Blynk app and web dashboard. Its low power consumption and ease of programming make it an ideal choice for IoT-based automation in classroom settings.

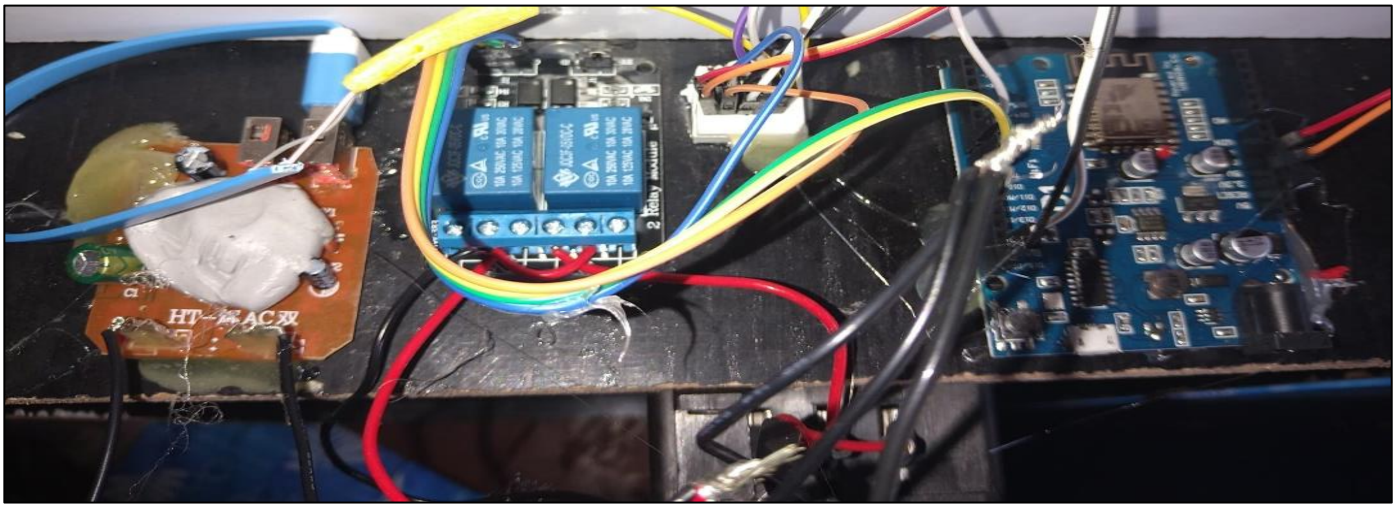

Fig 4: NodeMCU Connection with Hardware's

Volume 10, Issue 3, March – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1697

### *C. Relay Module and Actuators (Fan and Heater)*

The relay module is responsible for switching the fan and heater on or off based on the sensor readings and system logic. When the temperature exceeds a set limit, the relay activates the fan to cool the classroom, and when the temperature drops too low, the heater is turned on to provide warmth. The relay acts as an electronic switch that enables the NodeMCU to control high-voltage appliances safely. This integration ensures that the classroom maintains an optimal temperature without requiring manual intervention, reducing energy waste caused by human error.

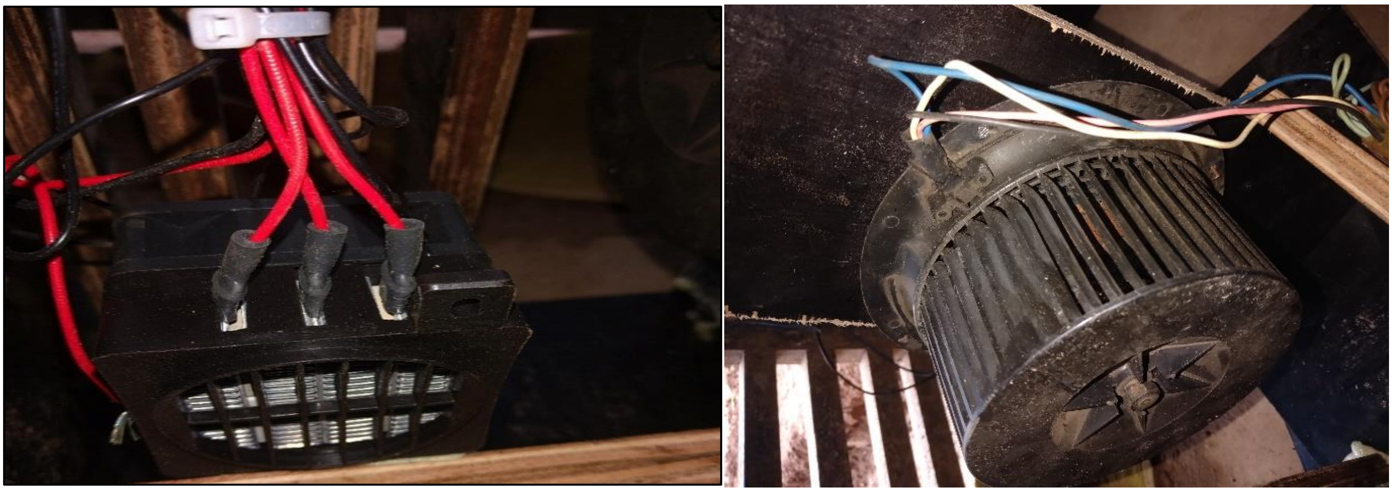

Fig 5: Fan and Heater

### *D. Embedded System Programming*

The embedded system programming is responsible for controlling the hardware components of the system. The NodeMCU ESP8266 is programmed using Arduino IDE and C++ to read data from the DHT sensor, process the temperature and humidity values, and activate the fan or heater accordingly. The firmware also enables communication with the MySQL database and the Blynk app for remote monitoring. This ensures seamless automation and efficient operation of the system.


Fig 6: Arduino IDE

### *E. Database Management (MySQL)*

A MySQL database is utilized to store sensor information, class schedules, and system logs. It plays a key role in managing classroom schedules by ensuring the air conditioning system operates only during designated class hours. Additionally, the database tracks historical temperature and humidity data, enabling administrators to analyze trends and make data-driven decisions to improve energy efficiency. The database is structured to be scalable and reliable, supporting both real-time data storage and retrieval.

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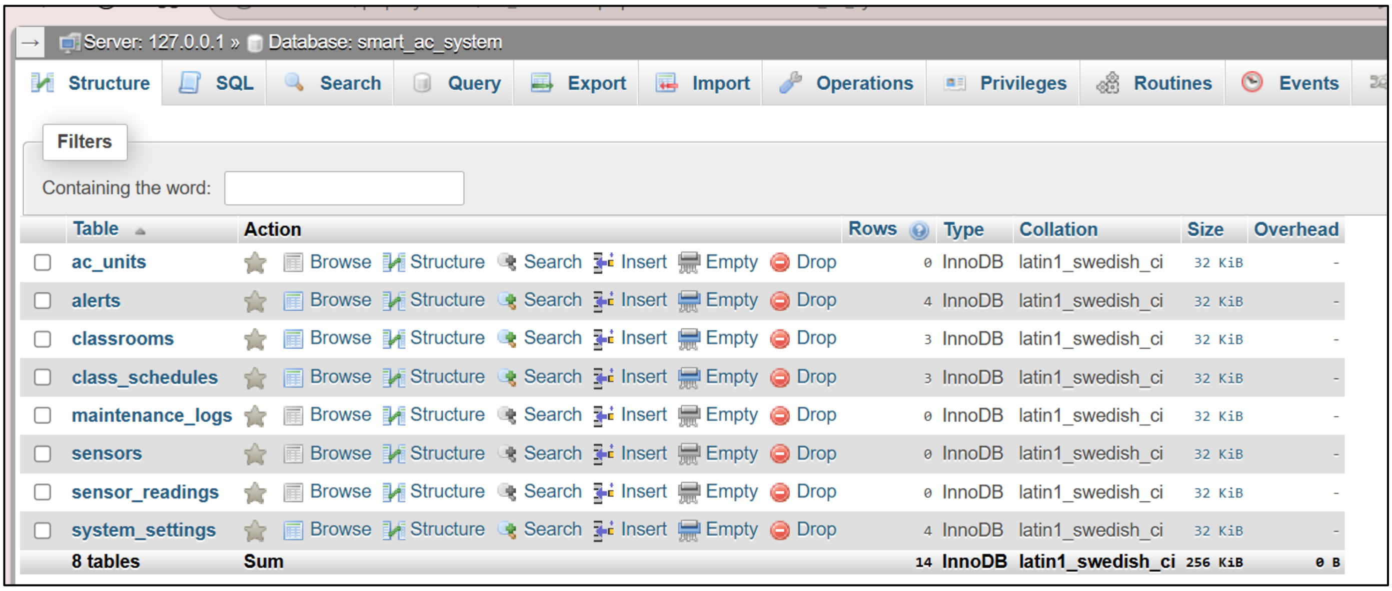


Fig 7: SQL Data Base

### *F. Web-Based User Interface*

The web-based interface enables administrators to track real-time sensor data, manage class schedules, and access system logs. Developed using HTML, CSS, JavaScript, and PHP, the platform offers an interactive dashboard for managing the system. Users can set temperature limits, activate or deactivate automation features, and receive notifications about system malfunctions through this platform. The interface streamlines system operation and improves accessibility for university personnel.

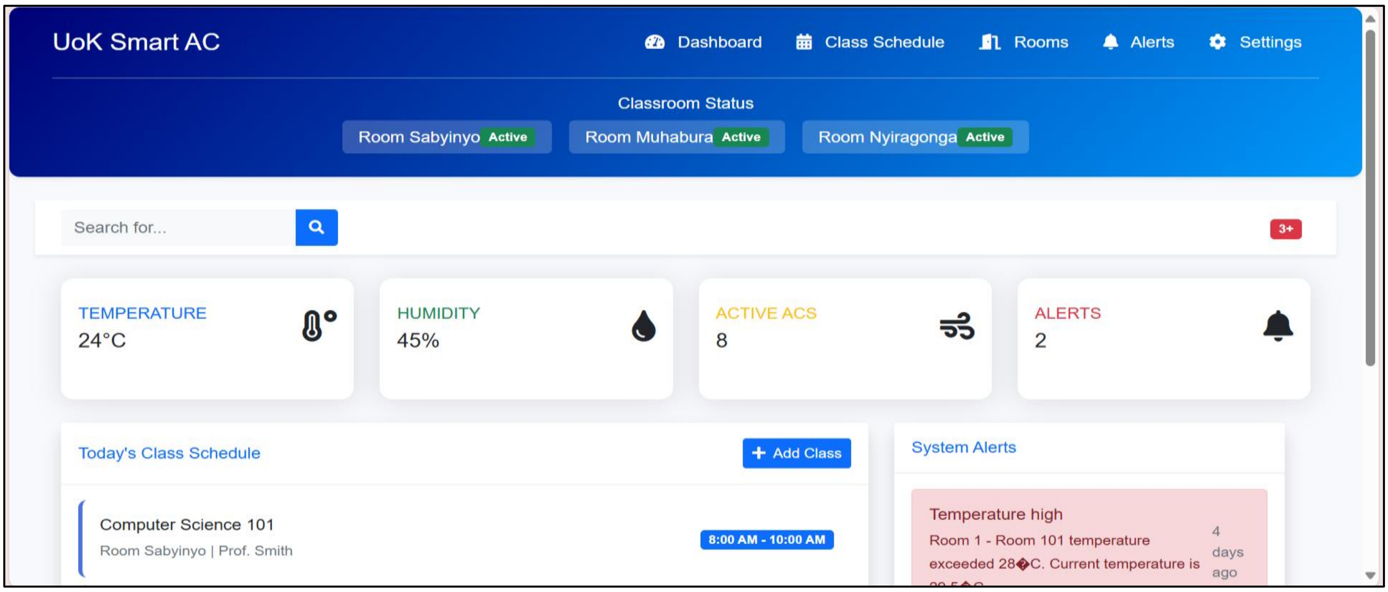


Fig 8: Website Dash board

The image displays the dashboard of the "UoK Smart AC" system, an IoT-based platform designed for environmental monitoring and control in classrooms at the University of Kigali. The dashboard showcases key metrics, including temperature (24°C), humidity (45%), the number of active air conditioners (8), and system alerts (2). The design features a navigation bar with options like Dashboard, Class Schedule, Rooms, Alerts, and Settings, providing easy access to various functions. It also shows the real-time status of classrooms, indicating whether "Room Sabinyiro," "Room Muhabura," or "Room Nyiragongo" are in use.

Additionally, the system includes a search function, a class schedule section with upcoming classes listed (e.g., "Computer Science 101" in "Room Sabinyiro" from 8:00 AM to 10:00 AM), and a system alerts section that highlights important issues, such as temperatures exceeding 29°C.

The dashboard is intended to assist administrators, technicians, and faculty members in monitoring classroom conditions, automating AC management, and receiving warnings for scheduled maintenance, hence enhancing energy efficiency and the overall learning environment.

Volume 10, Issue 3, March – 2025 International Journal of Innovative Science and Research Technology
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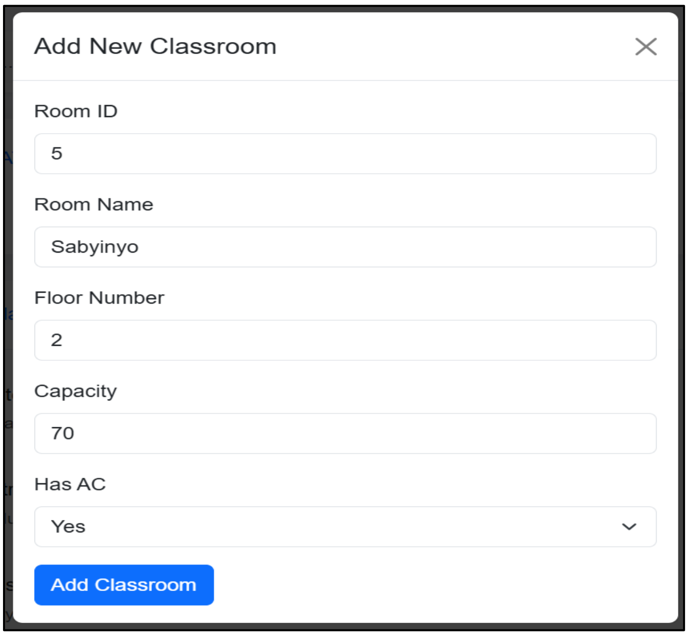


Fig 9: Register Classes

### G. *Mobile Application (Blynk Integration)*

The system is integrated with the Blynk app, allowing for remote monitoring and control through smartphones. The app presents real-time temperature and humidity data, enabling users to check classroom conditions from any location. It also offers a feature for manually switching the fan or heater on and off when needed. Blynk improves the system's functionality by providing an easy-to-use and intuitive mobile control interface.

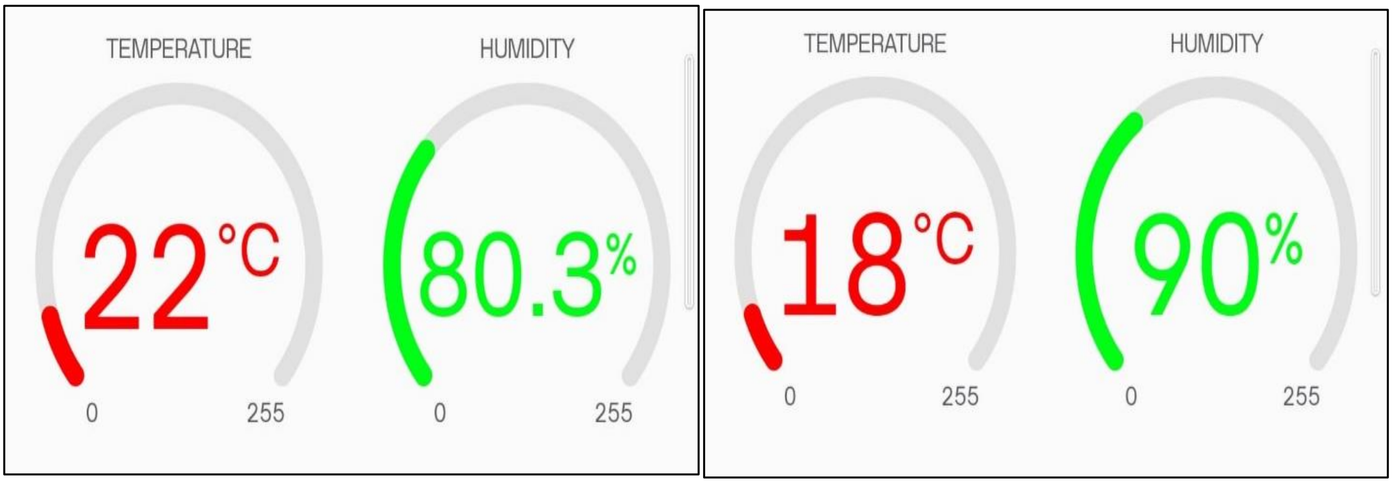


Fig 10: Blynk App

### H. *SMS Alert System (Mista.io API)*

The system integrates the Mista.io SMS gateway to notify university operators when temperature or humidity levels surpass set limits. When an anomaly is detected, an automatic SMS alert is triggered, enabling operators to take immediate corrective action. This feature ensures quick resolution of issues, preventing discomfort in classrooms and minimizing energy waste. The SMS alert system enhances the overall reliability and responsiveness of the implementation.

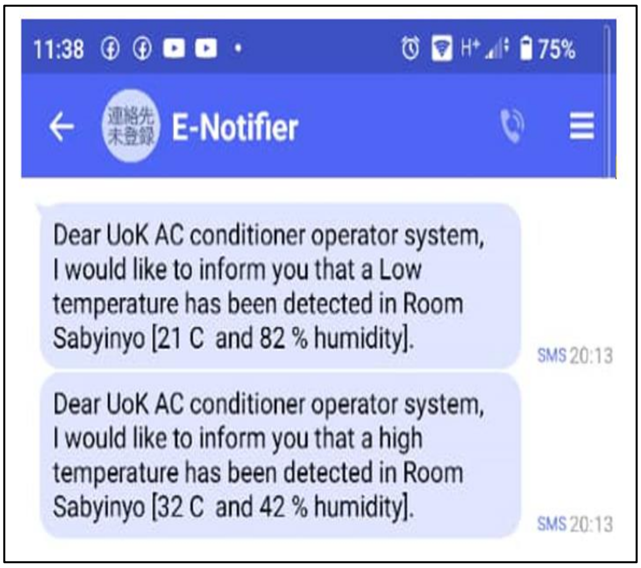


Fig 11: SMS Notification

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1697

### *I. System Security and Access Control*

safeguard against unauthorized access, the system includes authentication protocols for the web-based interface, SMS API, and mobile app. User roles and permissions are controlled through the MySQL database, ensuring that only authorized individuals can adjust system settings. Security features such as encryption, secure API access, and login credentials are implemented to protect sensitive information and prevent tampering with the system. These measures help maintain the integrity and dependability of the IoT-based air conditioning control system.

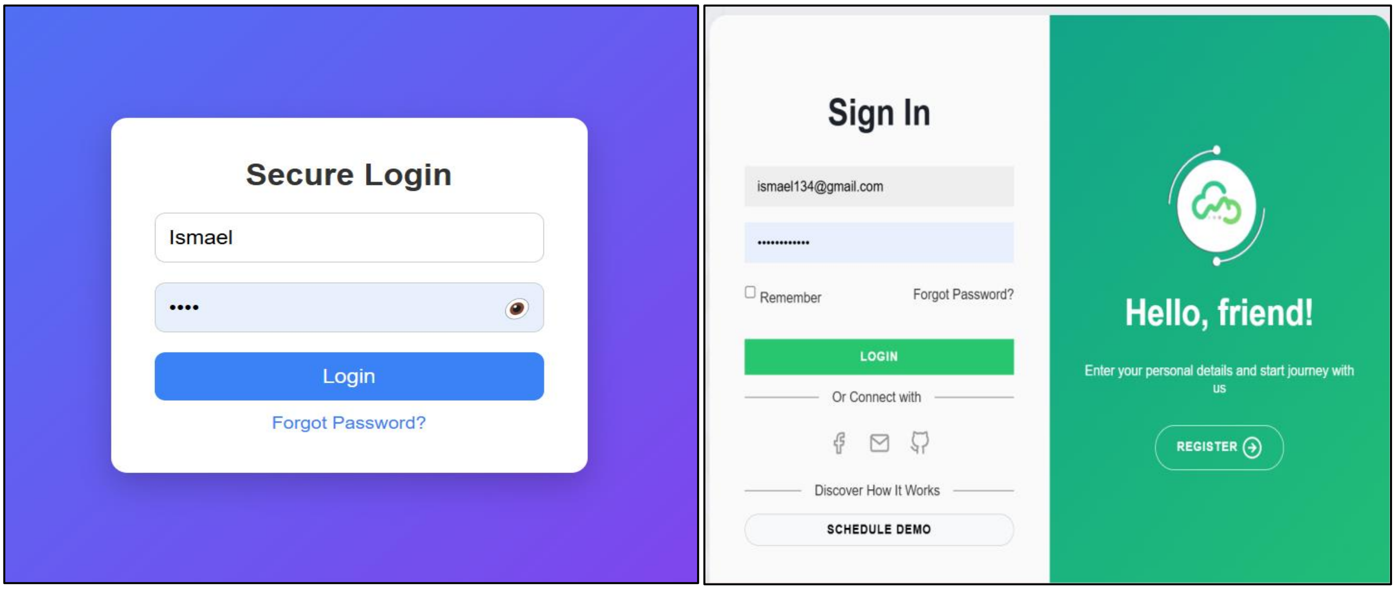


Fig 12: Login Security

### *J. System Testing and Results*

The system underwent extensive testing to ensure its usefulness, accuracy, and dependability. Temperature and humidity sensor values were compared to conventional measurement instruments to ensure their accuracy. The relay module was tested to ensure that it properly operated the fan and heater when needed.

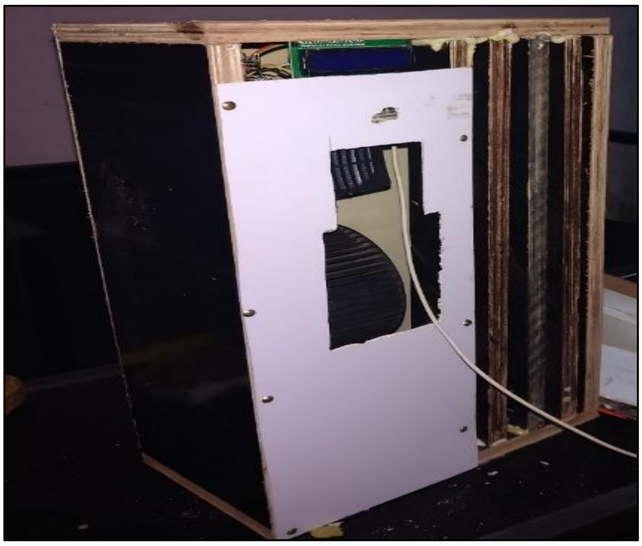

Fig 13: System Case Enclosure

The web dashboard and Blynk app were evaluated for real-time updates and seamless remote control functionality. The database was assessed for its efficiency in storing and retrieving data, ensuring accurate adherence to class schedules. The SMS alert system was also tested for its response time and reliability in notifying administrators about abnormal environmental conditions. The results demonstrated that the system effectively maintained classroom temperature and humidity within the desired parameters, conserving energy and providing timely alerts when intervention was needed.


Fig 14: Sensor Values in LCD

## V. DISCUSSION OF RESULTS

The results indicate that the IoT-based smart temperature and humidity control system enhances classroom comfort and energy efficiency. By automating temperature regulation, the technology eliminates human errors, such as

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forgetting to turn off fans and heaters after classes. The integration of remote monitoring via the Blynk app and web dashboard offers ease and flexibility in managing classrooms. The SMS alert system boosts the system's reliability by ensuring operators receive immediate notifications of potential issues or unusual environmental changes. The use of the MySQL database ensures the system operates according to class schedules, minimizing unnecessary power consumption. Overall, the findings highlight the system's effectiveness in improving learning environments while reducing operational costs through intelligent automation.

*A. Circuit Diagram*

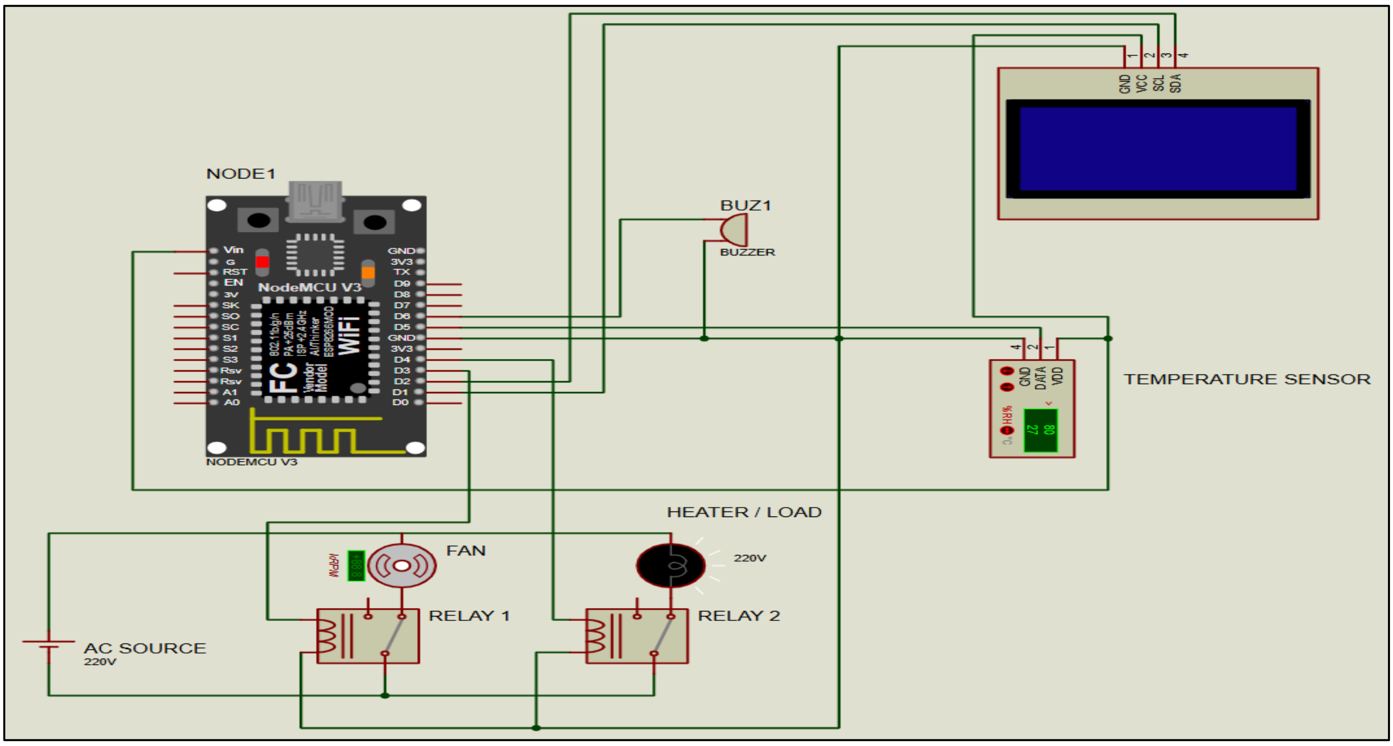


Fig 15: Circuity Diagram

*B. Physical Infrastructure*

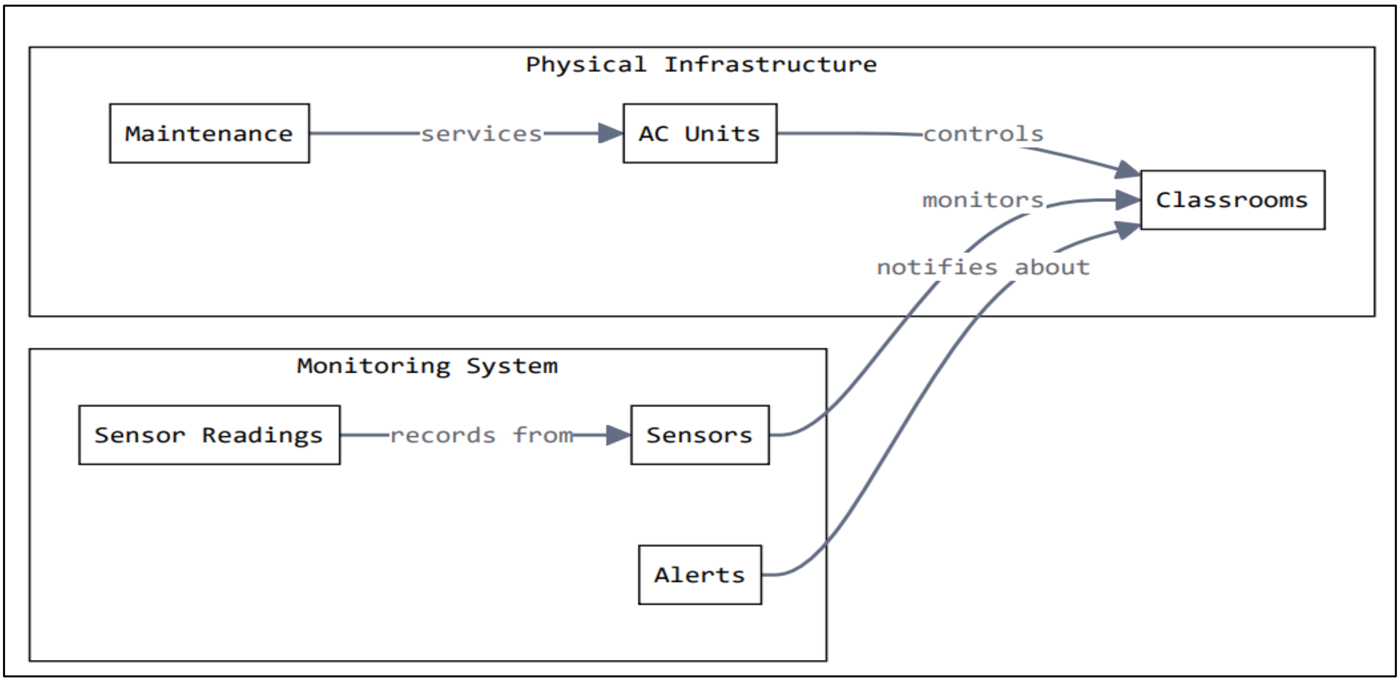


Fig 16: Physical Infrastructure

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This diagram illustrates the overall architecture of the Smart AC Control System, which is composed of two main components: the Physical Infrastructure and the Monitoring System. The Physical Infrastructure includes the maintenance of the AC units, which are responsible for managing, monitoring, and providing notifications about classroom environmental conditions. The Monitoring System consists of sensors that detect ambient conditions and provide real-time sensor data. If any discrepancies are detected, the system triggers alerts. The monitoring system continuously supplies input to ensure proper functionality and timely notifications, maintaining an ideal classroom environment.

*C. User Case Diagram*

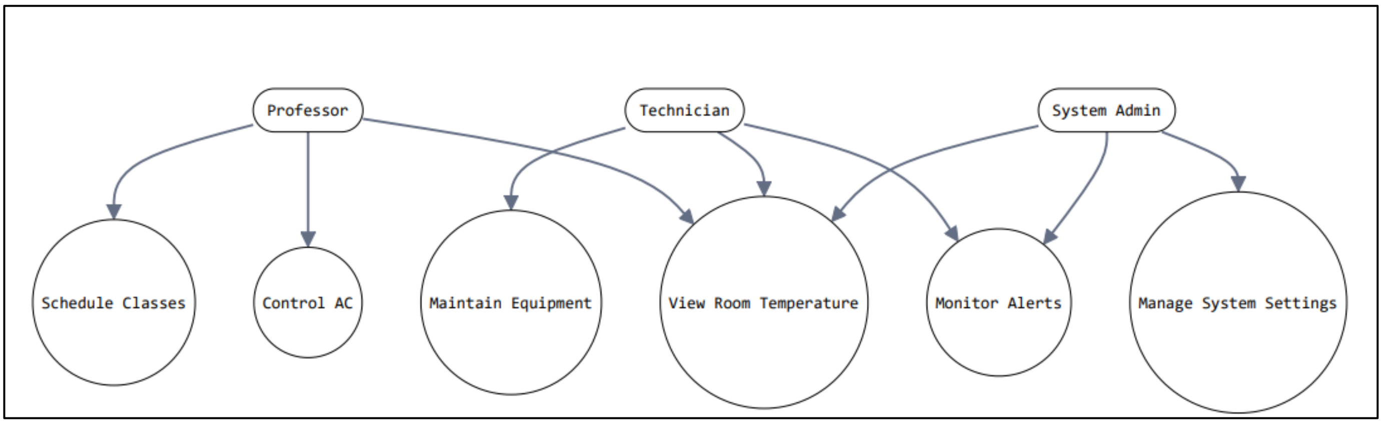


Fig 17: User Case Diagram

The diagram illustrates a role-based system where each user is assigned specific responsibilities. Professors are responsible for scheduling lessons and controlling the air conditioning (AC) in classrooms. Technicians handle the maintenance of equipment and monitor room temperatures to ensure ideal conditions. System administrators have a wider scope, overseeing system alerts and adjusting settings to ensure the system runs smoothly. Each role is connected to key tasks, showing how various users interact with the system to maintain its effectiveness and efficiency.

*D. Dfd Level 0*

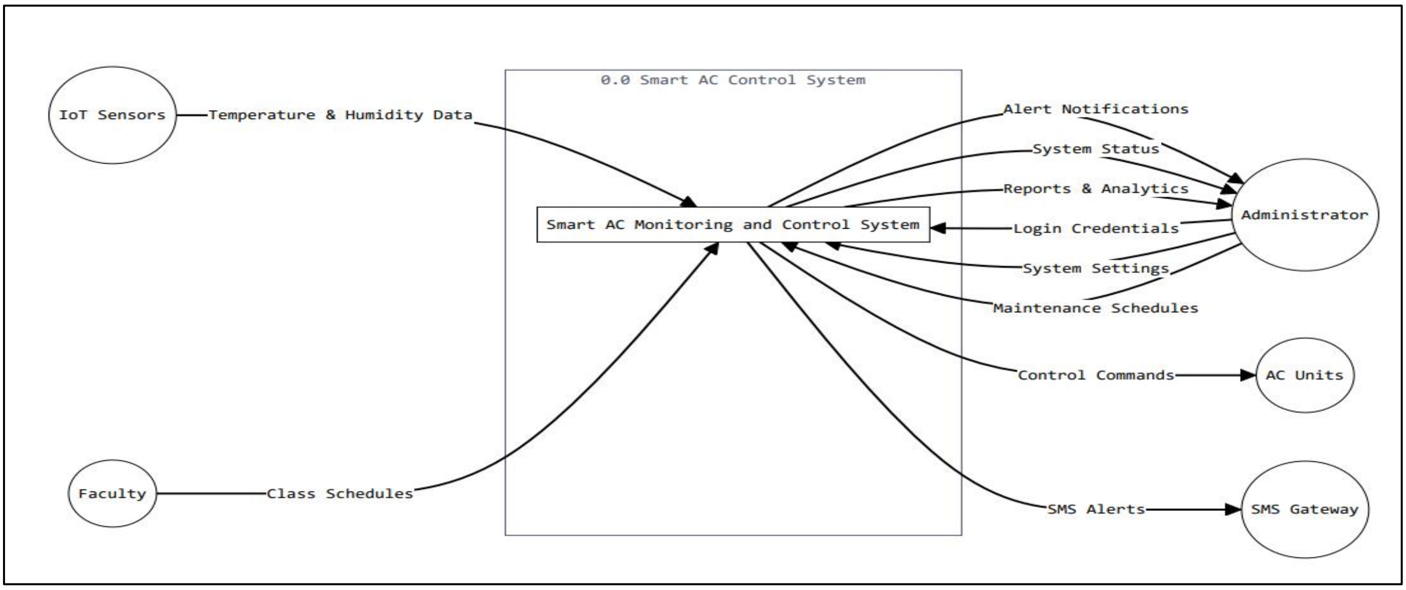


Fig 18: DFD Level 0

The Level 0 Data Flow Diagram (DFD) illustrates a Smart AC Control System that integrates IoT sensors and class schedules to enhance classroom climate management. IoT sensors gather temperature and humidity data, while instructors provide their class schedules. This information is processed by the Smart AC Monitoring and Control System, which interacts with various entities. It sends control commands to air conditioning units for heating or cooling and communicates with an SMS Gateway to issue notifications. Administrators receive alerts, system status updates, reports, analytics, login details, system configurations, and maintenance schedules for managing the system. This centralized control system guarantees efficient climate regulation, remote monitoring, and automated alerts.

*E. Dfd Level 1*

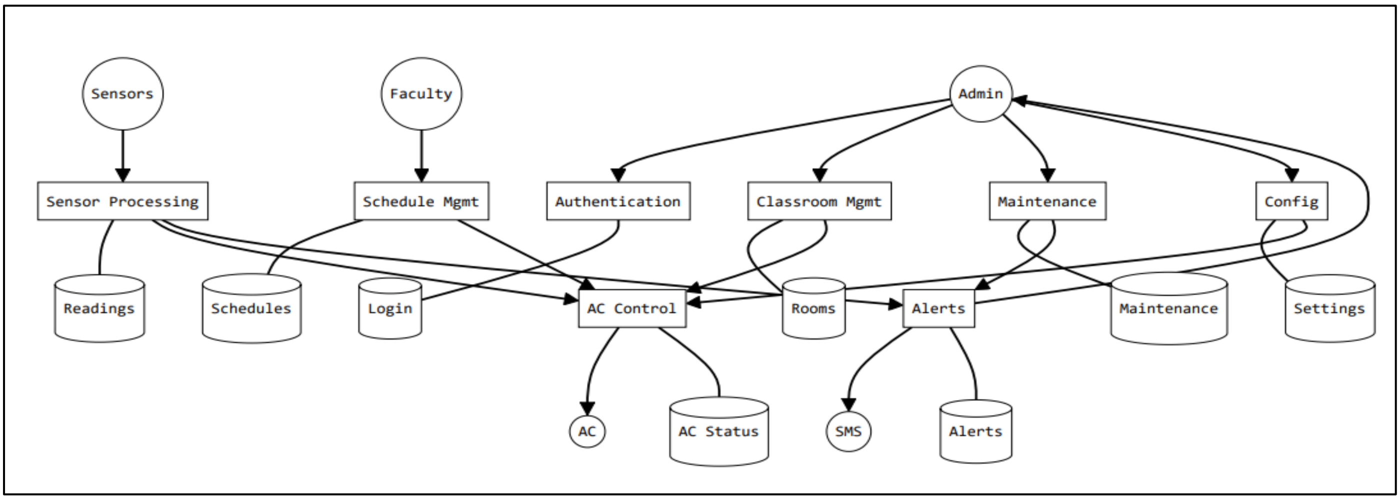


Fig 19: DFD Level 1

The Level 1 Data Flow Diagram (DFD) of the Smart AC Control System outlines its core processes and data exchanges. The sensor processing module gathers temperature and humidity data, while faculty members input class schedules using the schedule management module. Authentication protocols ensure secure user access, allowing only authorized individuals to control the AC system. The AC control module oversees and regulates the air conditioners' operations. The classroom management module links AC control to specific rooms, triggering alarms via SMS when necessary. Administrators track maintenance tasks, adjust system settings, and receive alerts and reports to assist in decision-making.

## VI. CONCLUSIONS

This research demonstrated the practicality and effects of an IoT-powered system for monitoring and adjusting classroom temperature and humidity at the University of Kigali. By incorporating sensors, automated controls, and real-time notifications, the system has successfully fostered a better learning environment, ensuring comfort for students and instructors. Additionally, automating fans and heaters based on class schedules and room occupancy has led to notable reductions in energy use, resulting in cost savings and contributing to sustainability efforts. The real-time fault detection and SMS notifications have proven effective in enabling prompt repairs, minimizing downtime, and avoiding long-term system failures.

The findings emphasize the transformative potential of IoT in educational settings, enhancing efficiency and developing a responsive, energy-conscious infrastructure. The study showed that implementing IoT-based environmental control systems in classrooms can boost student focus, reduce operational challenges, and create a progressive approach to facility management. Future enhancements and scalability could make these systems more robust and adaptable for wider use in educational institutions.

## RECOMMENDATIONS

*A. For the University of Kigali (UoK):*

Fully deploy and extend the IoT environmental monitoring system across all classrooms to ensure consistent optimal learning conditions.

Schedule regular maintenance and sensor calibration to maintain system accuracy and reliability.

Investigate the integration of renewable energy sources like solar power to complement the automated heating and cooling systems, optimizing energy efficiency.

Offer training for faculty and technical staff to ensure proper system operation, troubleshooting, and maintenance.

*B. For the Environmental and Sustainability Committee:*

Consider adding CO2 and air quality sensors to provide a comprehensive assessment of indoor air quality, promoting student comfort and health.

Partner with industry specialists and encourage ongoing research to enhance the system and keep it aligned with the latest IoT innovations and sustainable building practices.

*C. For the IT Department and System Developers:*

Incorporate AI-driven predictive analytics to improve the system's efficiency by anticipating environmental shifts and proactively adjusting controls.

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