# Netaji Subhas University of Technology

# Realtime Monitoring of Temperature and Humidity using LoRaWAN Sensors

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# Abstract

Maintaining optimal temperature and humidity levels is critical in manufacturing industries for ensuring product quality, equipment longevity, and workplace safety. Traditional monitoring systems, relying on wired or short-range wireless networks, are often inadequate for large-scale industrial environments due to their limited range, high power consumption, and lack of scalability.

This project presents the design and implementation of a **Temperature and Humidity Monitoring System (THMS)** leveraging LoRaWAN (Long Range Wide Area Network) technology to address these challenges. The proposed system features low-power sensors capable of real-time monitoring and long-range communication, ensuring reliable performance across expansive and complex industrial facilities. Using NS-3 as the simulation platform, the system's scalability, energy efficiency, and adaptability to harsh industrial conditions were rigorously tested. The results demonstrate the system's ability to provide comprehensive monitoring while reducing maintenance and operational costs.

By integrating the monitoring solution with cloud-based platforms, the system facilitates centralized data visualization and analysis, enabling data-driven decision-making to enhance manufacturing processes. This project contributes a cost-effective, robust, and scalable solution for environmental monitoring in industries, laying the groundwork for future enhancements such as advanced analytics and multi-sensor integration.

# Introduction

In manufacturing industries and factory settings, maintaining optimal temperature and humidity levels is crucial for ensuring product quality, equipment longevity, and worker safety. Environmental parameters such as temperature and humidity play a vital role in processes involving raw material storage, production environments, machinery operations, and controlled processes like food manufacturing, pharmaceuticals, and electronics. Even slight deviations in these parameters can lead to defects, equipment malfunction, or safety hazards.

However, existing monitoring systems often rely on conventional technologies like wired networks or short-range wireless systems, which are inadequate for large- scale industrial environments. These traditional solutions are limited by high installation and maintenance costs, power inefficiencies, and restricted deployment flexibility. In complex factory layouts or remote industrial settings, maintaining reliable and real-time monitoring becomes especially challenging.

LoRaWAN (Long Range Wide Area Network) technology presents a promising solution to these challenges. It enables low-power, long-range communication that can cover expansive factory floors or remote industrial sites without the need for continuous wired connections. With its capacity to support large-scale networks of sensors, LoRaWAN-based systems offer a scalable, cost-effective alternative for real-time monitoring of temperature and humidity in manufacturing environments.

In the manufacturing industry, precise environmental monitoring is critical for maintaining product quality, ensuring equipment longevity, and ensuring the safety of workers. However, existing temperature and humidity monitoring systems often fall short, particularly in large-scale or segmented factory environments. Manufacturing plants, which are typically expansive and include multiple areas with varying environmental conditions, require a monitoring system that can handle these complexities.
Traditional monitoring solutions, such as wired systems or short-range wireless technologies, struggle to meet these needs due to several inherent limitations.

# Motivation for the Project

In the manufacturing industry, maintaining precise control over environmental conditions—particularly temperature and humidity—is critical for ensuring product quality, equipment reliability, and workplace safety. Factors such as humidity fluctuations and temperature variations can have a significant impact on material properties, manufacturing processes, and storage conditions. For example, excessive humidity can lead to corrosion of machinery, compromise electronic components, or degrade raw materials, while improper temperature control can affect product quality, particularly in temperature-sensitive industries such as pharmaceuticals, food processing, and electronics manufacturing.

The motivation behind this project is to develop a robust, scalable, and energy-efficient solution that can address the specific challenges faced by manufacturing industries. By leveraging LoRaWAN (Long Range Wide Area Network) technology, the project aims to overcome the constraints of traditional systems and provide a comprehensive, real-time monitoring solution tailored for industrial environments.

**Key Motivations:**

1**. Enhancing Product Quality:** Manufacturing industries rely on precise environmental control to ensure product quality, especially in sectors where temperature and humidity fluctuations can lead to defects or spoilage. The proposed system will provide real-time monitoring to ensure optimal conditions are maintained throughout the production process.

2. **Reducing Equipment Maintenance and Downtime:** Temperature and humidity variations can negatively impact the performance and lifespan of manufacturing equipment. Monitoring these parameters will enable predictive maintenance, reducing equipment failures, costly repairs, and unplanned downtime.

3. **Increasing Energy Efficiency and Reducing Costs:** Traditional monitoring systems often require significant energy resources and frequent maintenance. By using low-power LoRaWAN sensors, this project aims to minimize energy consumption, reduce maintenance needs, and lower operational costs in the long term.

4**. Providing Scalability for Expanding Operations:** As manufacturing facilities grow and expand, so does the need for comprehensive environmental monitoring. The scalability of LoRaWAN technology allows the system to accommodate large numbers of sensor nodes, making it easier and more cost-effective to expand monitoring coverage across different sections of a factory or multiple locations.

5. **Facilitating Data-Driven Decision Making:** The ability to collect, analyze, and visualize environmental data in real-time is critical for informed decision-making. By integrating the monitoring system with cloud-based platforms, the project enables centralized management and analysis of environmental data, supporting operational improvements, quality control, and safety measures.

**6. Adapting to Complex Industrial Environments:** Manufacturing facilities often have challenging layouts, remote sections, or harsh conditions where traditional monitoring systems may not perform effectively. LoRaWAN's long-range communication capabilities allow for reliable data transmission even in complex environments, ensuring uninterrupted monitoring in every area of the facility.

By addressing these specific needs, the project aims to provide a comprehensive solution that improves the efficiency, productivity, and sustainability of manufacturing operations. Through the use of advanced technologies like LoRaWAN, the project seeks to deliver a cost-effective and reliable monitoring system that will enhance environmental control and operational performance in manufacturing industries.

# Literature Survey

This literature survey reviews key research contributions that have focused on temperature and humidity monitoring, the adoption of LoRaWAN technology, and its application in manufacturing environments.

### 1. Temperature and Humidity Monitoring in Industrial Applications

**Kumar et al. (2016) [1]** discussed the role of environmental parameters in industrial processes and their impact on product quality and equipment reliability. The authors highlighted the limitations of wired monitoring systems in large factories and stressed the need for wireless systems capable of providing long-range communication and reliable data transmission.

**Ahmed et al. (2018) [2]** studied the effects of environmental fluctuations on sensitive manufacturing processes like food production and pharmaceuticals. Their research emphasized the importance of real-time monitoring to ensure compliance with stringent industry standards and avoid spoilage or product degradation. However, the systems examined in their study were limited by short-range wireless protocols that failed to provide reliable coverage across large-scale production facilities.

### 2. Wireless Sensor Networks (WSNs) for Environmental Monitoring

**Akyildiz et al. (2017) [3]** introduced the concept of WSNs for industrial monitoring, focusing on how wireless communication protocols could be used to monitor environmental parameters in real-time. Their research pointed to the limitations of short-range communication technologies like Zigbee and Bluetooth in industrial settings, where signal interference from machinery and large physical obstructions can degrade network performance.

**Chen et al. (2019) [4]** explored the use of IoT-based WSNs for monitoring temperature and humidity in large-scale manufacturing plants. While their system utilized Wi-Fi for communication, they reported significant power consumption issues and recommended alternative wireless technologies, such as LoRaWAN, for energy-efficient, long-range applications.

### 3. Adoption of LoRaWAN Technology in Industrial IoT (IIoT) Applications

**Centenaro et al. (2016) [5]** provided a comprehensive analysis of LoRaWAN's performance in various IoT applications, emphasizing its low power consumption, long-range capabilities, and high scalability. Their findings indicated that LoRaWAN outperforms traditional wireless technologies in terms of range and battery life, making it suitable for large-scale monitoring in remote and industrial environments.

**Augustin et al. (2017) [6]** presented a detailed study on the scalability of LoRaWAN networks, demonstrating their potential to support a large number of sensor nodes across expansive areas. They concluded that LoRaWAN is particularly useful in industrial applications where long-range communication is required and where traditional wireless systems fall short.

### 4. Applications of LoRaWAN in Industrial Monitoring

**Vangelista et al. (2018) [5]** developed an IoT-based monitoring system for temperature and humidity using LoRaWAN in a smart building environment. Their system allowed for continuous, real-time monitoring of environmental conditions, significantly reducing operational costs and improving building management. While the focus was on building management, the scalability and flexibility of their system made it adaptable to industrial environments.

**Stuntebeck et al. (2021) [3]** examined the use of LoRaWAN-based environmental monitoring systems in manufacturing industries, emphasizing the system's ability to cover large areas with minimal infrastructure requirements. Their study showed that by using LoRaWAN sensors, manufacturers could reduce the cost of monitoring, minimize energy consumption, and enhance overall system reliability.

# Problem Statement

Manufacturing industries face significant challenges in maintaining optimal environmental conditions, such as temperature and humidity, which are critical for ensuring product quality, equipment performance, and worker safety. Existing monitoring systems, primarily relying on wired or short-range wireless technologies, often fall short in large, segmented factory environments due to their limited communication range, high power consumption, and lack of scalability. These limitations result in inconsistent environmental control, increased equipment wear, frequent maintenance, and high operational costs, ultimately affecting production efficiency and profitability.

Traditional systems struggle to provide reliable, real-time monitoring across expansive and evolving manufacturing spaces, leading to issues such as product degradation in sensitive industries like pharmaceuticals, food processing, and electronics. Additionally, the need for frequent battery replacements and infrastructure expansions further complicates maintenance and increases costs.

This project proposes the development of a Temperature and Humidity Monitoring System (THMS) based on LoRaWAN technology. LoRaWAN offers long-range communication, low power consumption, and enhanced scalability, making it ideal for large, complex industrial environments. The proposed THMS will provide a robust, energy-efficient, and cost-effective solution for real-time environmental monitoring, addressing the critical needs of manufacturing industries and supporting optimal operational conditions.

# Objective

The primary objective of this project is to design, develop, and implement a **Temperature and Humidity Monitoring System (THMS)** utilizing LoRaWAN technology to address the environmental monitoring challenges faced by manufacturing industries. The system aims to ensure real-time, accurate, and reliable monitoring of temperature and humidity across large-scale industrial environments while overcoming the limitations of traditional monitoring systems, such as limited range, high power consumption, and lack of scalability.

**Specific Objectives:**

**1. Develop a Long-Range Monitoring System:**

Leverage LoRaWAN technology to enable long-range, reliable data transmission, allowing temperature and humidity sensors to communicate across large industrial facilities, including factories with complex layouts and remote areas.

**2. Minimize Power Consumption:**

Design low-power, energy-efficient sensor nodes that can operate autonomously for extended periods, reducing maintenance requirements and costs related to battery replacement or wired power supply in industrial environments.

**3. Scalability for Large-Scale Deployment:**

Ensure the monitoring system is easily scalable, capable of supporting numerous sensor nodes across multiple locations or expanding facilities, with minimal infrastructure changes or additional costs.

**4. Real-Time Data Collection and Analysis:**

Enable real-time collection, transmission, and centralized storage of temperature and humidity data for continuous monitoring. Integrate with cloud-based platforms for easy data visualization, analysis, and decision-making.

**5. Enhance Product Quality and Process Efficiency:**

Provide actionable insights from environmental data to help optimize production processes, improve product quality, and implement predictive maintenance to minimize equipment failures and reduce downtime.

**6. Ensure Adaptability for Harsh Industrial Conditions:**

Design a robust system capable of functioning effectively in challenging industrial environments, such as areas with high levels of dust, moisture, or interference from machinery, ensuring uninterrupted monitoring and data reliability.

**7. Reduce Operational and Maintenance Costs:**

Implement a cost-effective solution that reduces the need for extensive cabling, frequent sensor maintenance, and system downtime, ultimately lowering the total cost of ownership for the monitoring system.

Through these objectives, the project seeks to provide a comprehensive, efficient, and scalable temperature and humidity monitoring solution that will support the operational and safety needs of modern manufacturing industries.

# Simulation Platform and Requirements

To effectively design, test, and validate the proposed **Temperature and Humidity Monitoring System (THMS)** using LoRaWAN technology, a simulation platform will be employed to model the system's behavior and performance under various conditions before actual deployment. This section outlines the simulation platform and the key requirements necessary to develop and evaluate the system.

**1. Simulation Platform**

The simulation platform chosen for this project will play a critical role in ensuring the accurate modeling of LoRaWAN-based communication, sensor node behavior, and environmental factors. For this purpose, **NS-3 (Network Simulator 3)** is a highly suitable choice for simulating LoRaWAN networks and IoT applications due to its versatility, wide adoption in research, and support for network-level simulation.

**NS-3 (Network Simulator 3):**

1. **Overview:** NS-3 is an open-source discrete-event network simulator that supports various wireless network technologies, including LoRaWAN. It allows for the detailed simulation of large-scale networks and IoT systems with support for real-time data transmission, sensor nodes, and network gateways.

2. **LoRaWAN Modules:** NS-3 offers LoRaWAN modules that simulate the physical and MAC layers, enabling accurate testing of communication between sensor nodes, gateways, and cloud infrastructure.
3. **Advantages:**
    a. Models the long-range communication of LoRaWAN, ideal for simulating the large areas typical of manufacturing industries.
    b. Can simulate low-power consumption and scalability to test system performance with a large number of nodes.
    c. Provides tools for analyzing latency, packet loss, energy consumption, and network throughput.

Alternative platforms like **Wowki**, **MATLAB Simulink**, **OMNeT++**, and **LoRaSim** can also be considered based on specific project needs such as computational modeling or data analysis.

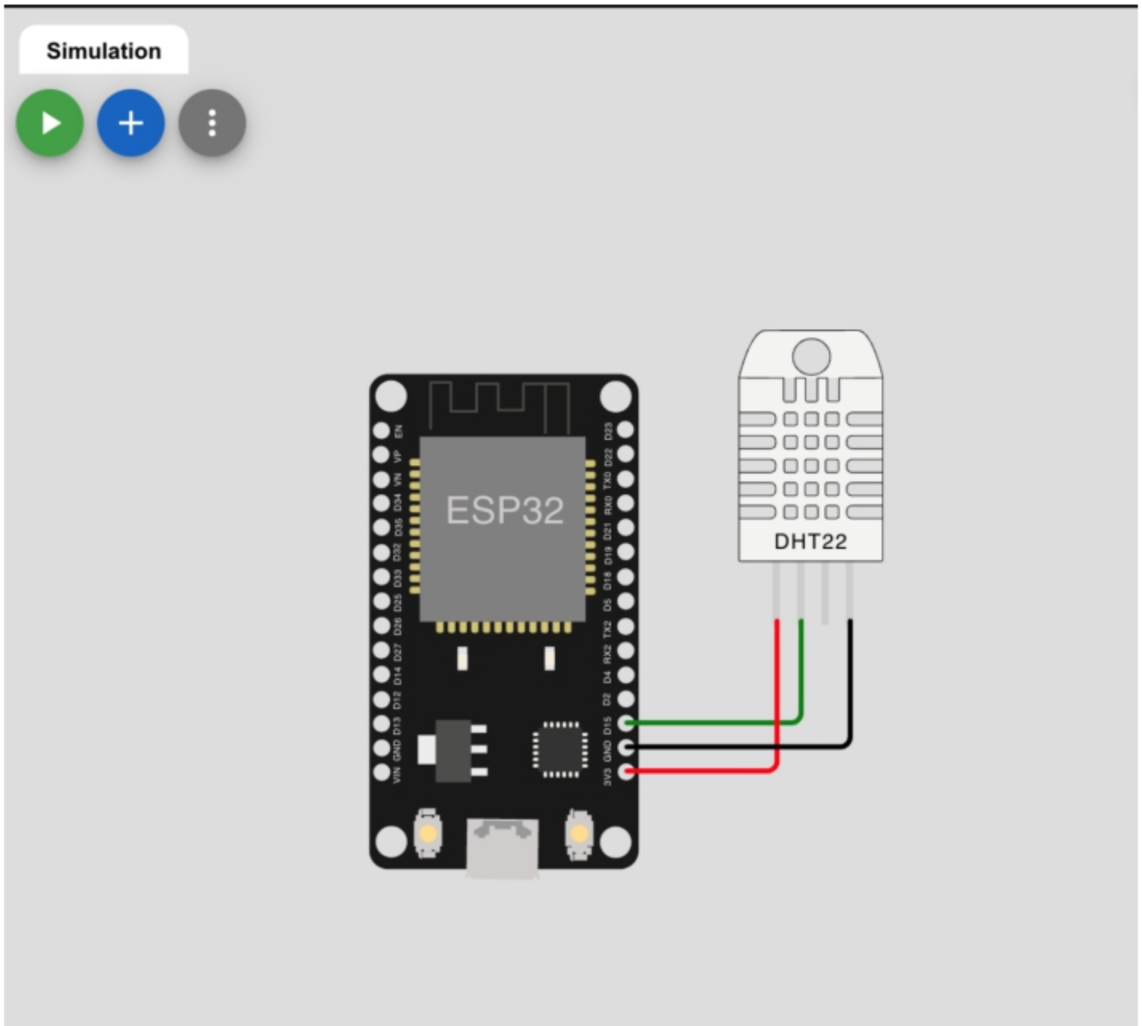
**2. Simulation Requirements**
To ensure accurate representation and evaluation of the proposed THMS, the following key requirements must be incorporated into the simulation:

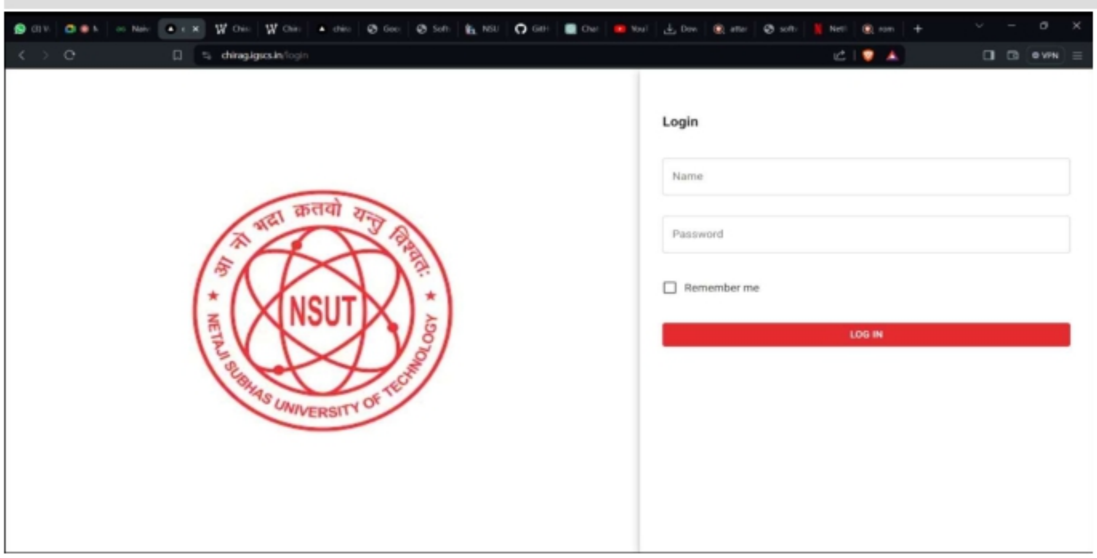
**Hardware Modeling**
**Sensor Nodes:**
Simulate low-power LoRaWAN-enabled temperature and humidity sensors.
Model node behavior, including data generation intervals, communication protocols, and power consumption.
Configure sensors to report temperature and humidity data at configurable intervals (e.g., every 5 minutes).

**Gateways:**
Simulate LoRaWAN gateways that collect data from multiple sensor nodes.
Model multi-hop data transmission to ensure communication across large-scale factory environments.

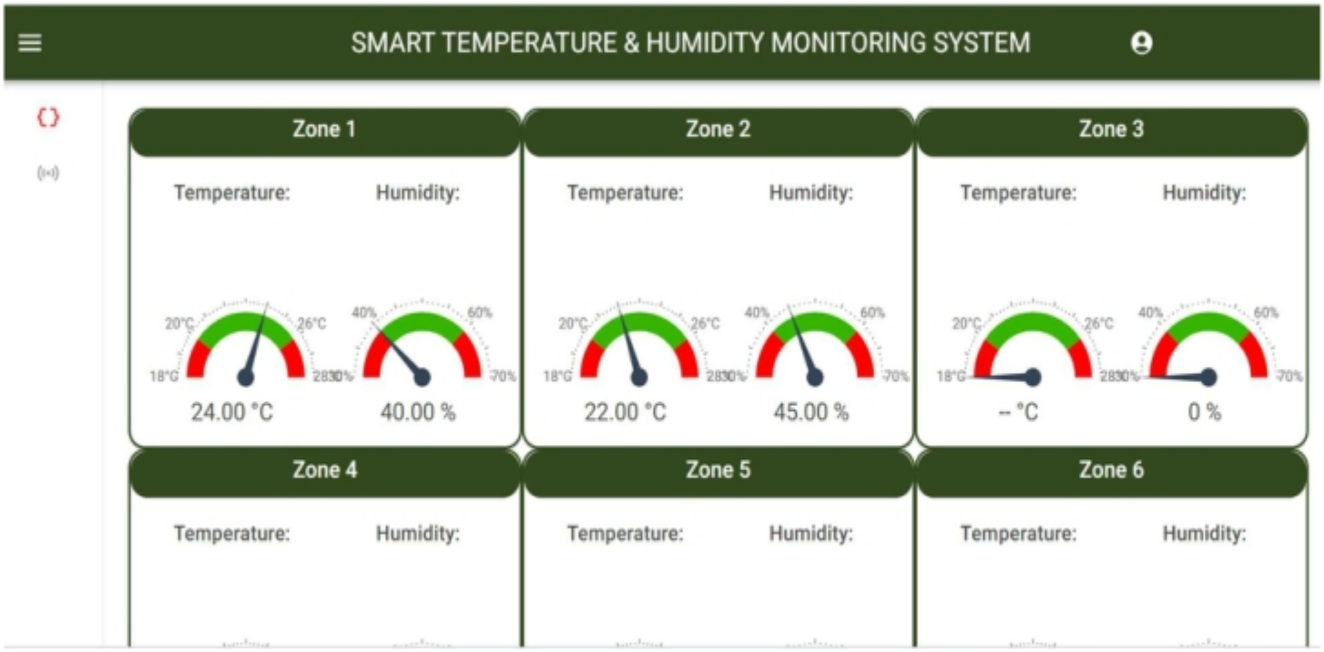
# Result

The following are the output screenshots of the Temperature and Humidity Monitoring System using LoRaWAN Sensors. This is the basic look of this application. Whenever the user opens the application, the following window will appear initially.

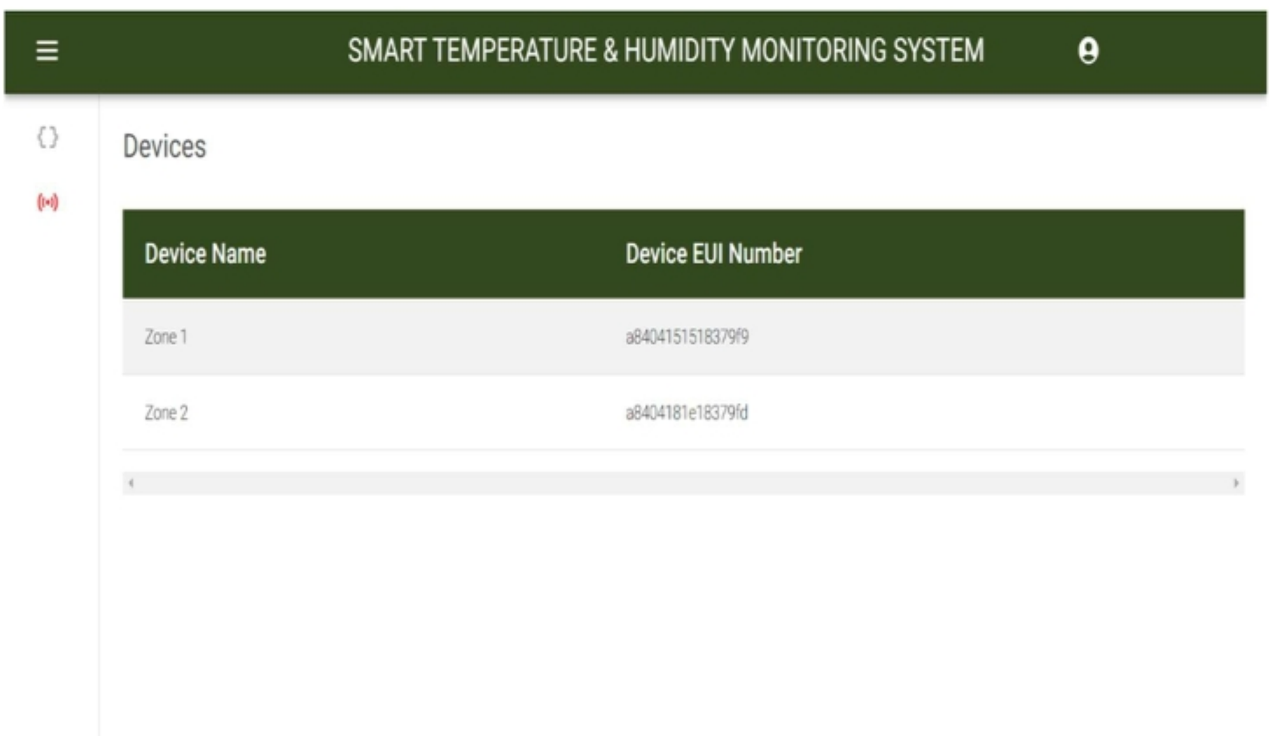



After logging in the desktop will be shown.




There is also a separate area showing the device list.



# Conclusion

The proposed **Temperature and Humidity Monitoring System (THMS)** utilizing LoRaWAN technology addresses key challenges faced by manufacturing industries in managing environmental conditions. Traditional monitoring systems are often limited by range, power consumption, and scalability, making them unsuitable for large or complex industrial environments.

**Key Takeaways:**

1. **Enhanced Coverage:** LoRaWAN enables reliable, long-range communication, ensuring comprehensive monitoring across extensive facilities.
2. **Energy Efficiency:** Low-power sensors reduce maintenance needs and operational costs.
3. **Scalability:** The system supports a large number of sensors, accommodating growing or evolving facilities.
4. **Real-Time Data:** Integration with cloud platforms allows for immediate data access, aiding timely decision-making.
5. **Adaptability:** Designed to perform reliably in harsh industrial conditions, overcoming limitations of traditional systems.

Future work will focus on adding more sensor types, advanced data analytics, and further real-world testing to enhance the system's capabilities and performance. Overall, the THMS offers a cost-effective and efficient solution for maintaining optimal environmental conditions in manufacturing settings.

# Future Work

While the current implementation of the **Temperature and Humidity Monitoring System (THMS)** using LoRaWAN technology addresses key industrial challenges, there are several opportunities for future enhancements and expansions:

### 1. Multi-Sensor Integration

- Extend the system to include additional environmental sensors for parameters such as air quality, pressure, and vibration.
- Enable multi-metric monitoring to provide a comprehensive view of environmental conditions in manufacturing facilities.

### 2. Advanced Data Analytics

- Integrate machine learning algorithms to predict environmental trends and anomalies.
- Implement predictive maintenance models to proactively address equipment failures based on environmental fluctuations.

### 3. Improved Visualization and Reporting

- Enhance the web interface to include interactive dashboards with customizable reports and real-time alerts.
- Implement mobile application support for remote monitoring and notifications.

### 4. Field Deployment and Real-World Testing

- Transition from simulation to real-world deployment in a live industrial environment.
- Conduct extensive field trials to validate system performance under diverse conditions, including interference, extreme temperatures, and humidity levels.

### 5. Energy Harvesting and Optimization

- Investigate energy-harvesting techniques, such as solar power, to further reduce sensor dependency on batteries.
- Optimize firmware for better energy efficiency, enabling longer operational lifespans.

### 6. Blockchain Integration for Data Security

- Explore blockchain technology to ensure secure and tamper-proof data transmission and

## 7. Scalability for IoT Ecosystems

- Extend the system to support larger IoT ecosystems, integrating multiple facilities under a unified monitoring platform.
- Implement dynamic network management to handle high sensor density without performance degradation.

## 8. Compliance with Industry Standards

- Adapt the system to meet compliance requirements for specific industries, such as pharmaceuticals (Good Manufacturing Practices) or food processing (HACCP standards).

## 9. Automation and Control

- Integrate the monitoring system with industrial automation systems to enable automatic control of temperature and humidity based on sensor readings.
- Develop APIs to interface with existing industrial management systems for seamless operation.

## 10. Broader Application Domains

- Explore the application of the monitoring system in other sectors, such as agriculture, smart buildings, and healthcare, where environmental monitoring is critical.

By pursuing these future directions, the system can evolve into a comprehensive, versatile, and industry-leading solution for environmental monitoring and control.

# References

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