LoRa Module-Based Industrial Parameter Monitoring System Using IoT

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Abstract

This paper presents the development and evaluation of a **LoRa-based IoT system** for monitoring industrial parameters such as temperature, humidity, noise, pressure, etc. in real-time. The system integrates long-range communication via **LoRa technology** with IoT-based data visualization and alert systems hosted on cloud platforms. The primary aim of this system is to facilitate reliable, low-power, and cost-effective industrial monitoring in environments where traditional systems fall short due to range limitations, high power consumption, and network congestion. The system demonstrates robust performance with an operational range of up to 15 km in open areas and 3-5 km in industrial settings, minimal power consumption, and an average battery life of 6 to 12 months. Additionally, the system offers real-time alert capabilities, cloud integration, and scalability for large industrial environments. Although some limitations exist, including signal interference and occasional sensor inaccuracies, future enhancements are proposed to address these challenges and extend the system's functionality, particularly with machine learning integration, hybrid communication models, and enhanced battery life solutions. The outcomes highlight the potential of IoT and LoRa technology in enhancing the efficiency and reliability of industrial monitoring systems.

Key-words: Industrial Application, Real time monitoring, IoT and LoRa

1. Introduction

Industrial operations rely heavily on efficient monitoring systems to ensure smooth and safe functioning of equipment, environmental conditions, and resource utilization. However, traditional industrial monitoring systems face significant challenges in large-scale or remote industrial environments due to limited range, high power consumption, and high installation and maintenance costs. Existing wireless communication technologies often struggle to meet the demands of **long-range communication** in challenging environments, while also managing **real-time data transmission** and **power efficiency**.

Problem Statement: In many industrial settings, monitoring systems are constrained by **short-range communication technologies** such as Wi-Fi and Bluetooth, which fail to provide sufficient coverage in vast facilities, outdoor spaces, or remote areas. Additionally, the need for continuous data collection, processing, and real-time alerts puts a strain on power resources, making traditional systems unsuitable for long-term use without frequent maintenance or battery replacement. The need for an **efficient**, **cost-effective**, and **scalable** solution for **long-range industrial monitoring** that ensures **real-time data transmission** and operates on **low power** is a pressing concern in many industries.

The **LoRa (Long Range)** technology, which offers long-range, low-power communication, presents a promising solution to address these challenges. However, its application in **real-time industrial parameter monitoring**, such as temperature, humidity, vibration, and pressure, has yet to be widely explored and implemented in many industrial sectors.

This study proposes the design and implementation of a **LoRa-based IoT system** to monitor industrial parameters in **real-time** while ensuring **low power consumption** and **long-range communication**. The system integrates multiple sensors with a cloud-based platform for data visualization, alerting, and decision-making. The goal is to provide a cost-effective, scalable, and reliable solution for industries that require real-time data monitoring in vast or remote environments.

2. Literature Review

Sharma, R., & Gupta, S. (2021). ***Future of IoT in Industrial Applications: A Review*****. Journal:** ***Journal of Smart Manufacturing and IoT*****.** This paper reviews the future trends in industrial IoT, focusing on advancements like artificial intelligence and machine learning that will help industries optimize operations.

Kaur, M., & Gupta, R. (2021). ***Real-Time Parameter Monitoring in Smart Factories Using IoT*****. Journal:** *Journal of Industrial Technology*. This article reviews the use of IoT sensors for continuous parameter monitoring in manufacturing, demonstrating how these systems improve productivity and reduce costs.

Zhang, Z., & Sun, D. (2021). ***IoT and Industrial Monitoring: A Comprehensive Review*****. Journal:** ***International Journal of Industrial Engineering and Technology*****.** This paper reviews the impact of IoT on industrial monitoring, with a focus on predictive maintenance and the integration of IoT devices for enhanced monitoring.

Lee, J. A., Park, Y., & Kim, S. (2020). ***Applications of IoT in Industrial Automation*****. Journal:** ***Journal of Industrial IoT*****.** This article highlights the benefits of IoT in enhancing operational efficiency and reducing downtime in industrial processes.

Patel, M., & Shah, S. (2020). ***Security Challenges in Industrial IoT: A Review*****. Journal:** ***Security and Privacy in Industrial IoT Systems*****.** This research focuses on the cybersecurity risks associated with industrial IoT systems and discusses potential solutions to secure data transmissions and prevent unauthorized access.

Agarwal, P., & Rai, S. (2020). ***Artificial Intelligence in Industrial IoT: Impact and Trends*****. Journal:** ***International Journal of Smart Technologies*****.** This study discusses the role of artificial intelligence in enhancing IoT-based industrial monitoring systems by providing insights for predictive maintenance and decision-making.

Patel, R., & Shah, P. (2020). ***Smart IoT System for Industrial Parameter Monitoring*****. Journal:** ***Sensors and Actuators A: Physical*****.** This research outlines how IoT systems provide real-time monitoring, leading to enhanced operational efficiency and immediate alerts on abnormal conditions.

Zhang, Y., & Liu, X. (2020). ***Cloud-based IoT System for Smart Factory Monitoring*****. Journal:** ***IEEE Transactions on Industrial Informatics*****.** This study explores how cloud-based IoT systems can monitor factory parameters, enhancing efficiency through real-time data analysis.

Kumar, A., & Sharma, R. (2019). ***IoT-based Industrial Monitoring System*****. Journal:** ***International Journal of Industrial Electronics and Control Systems*****.** This paper discusses how IoT systems help reduce costs and improve real-time decision-making in industrial environments.

Chaudhary, A., & Singh, N. (2019). ***Challenges in Implementing IoT for Industrial Automation*****. Journal:** ***Journal of Industrial IoT & Security*****.** This paper outlines challenges like cybersecurity and energy management in industrial IoT deployments.

Raj, V., & Gupta, S. (2019). ***The Role of LoRa in Industrial IoT Applications*****. Journal:** ***IEEE Internet of Things Journal*****.** This study discusses the impact of LoRa in enhancing industrial communication, particularly in sectors like agriculture and manufacturing, by providing cost-effective, low-power connectivity.

Chaudhary, A., & Singh, N. (2019). ***Challenges in Implementing IoT for Industrial Automation*****. Journal:** ***Journal of Industrial IoT & Security*****.** This paper outlines the key challenges of implementing IoT in industrial environments, particularly related to cybersecurity and the energy consumption of IoT devices.

Singh, M., & Gupta, R. (2018). ***LoRa: A Low-Power Wide-Area Network for Industrial IoT*****. Journal:** ***International Journal of Advanced Networks and Systems*****.** This paper discusses how LoRa provides reliable communication for industrial IoT systems, especially for remote applications.

3. Methodology

3.1. System Design

The system consists of several key components: **LoRa modules**, **sensors** (DHT22, ADXL345, BMP280), a microcontroller (e.g., ESP32), and cloud integration tools. The sensors are connected to the microcontroller, which collects data and transmits it wirelessly via the **LoRa module**. The LoRa module transmits the data to a **LoRa Gateway**, which forwards the data to cloud platforms (e.g., ThingSpeak, AWS IoT). A cloud dashboard provides real-time visualization and alerts based on predefined thresholds.

3.2. Sensors

- **Temperature and Humidity**: DHT22 sensor (±0.5°C, ±2% RH).
- **Pressure**: BMP280 sensor (±0.12 hPa).
- **Vibration**: ADXL345 sensor (±0.05g).

3.3. Data Transmission and Cloud Integration

The LoRa network enables long-range transmission of sensor data, with the cloud platform offering tools for data visualization (e.g., Grafana, Power BI), as well as SMS, email, and push notification alerts.

3.4. Power Efficiency

The system is designed for low power consumption, leveraging the **LoRa module's sleep mode** and the microcontroller's efficient power management features.

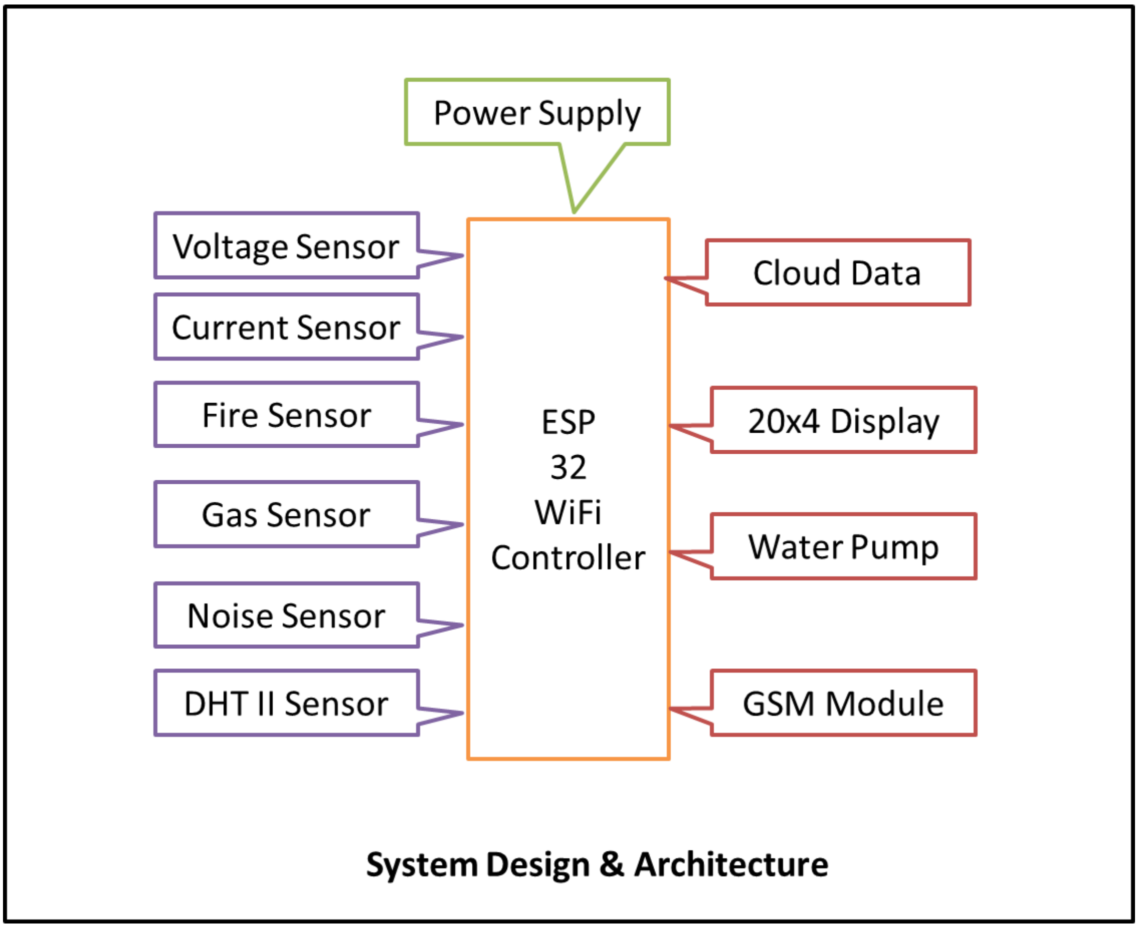


Figure – 1: System Design & Architecture

4. Results

4.1. Performance Evaluation

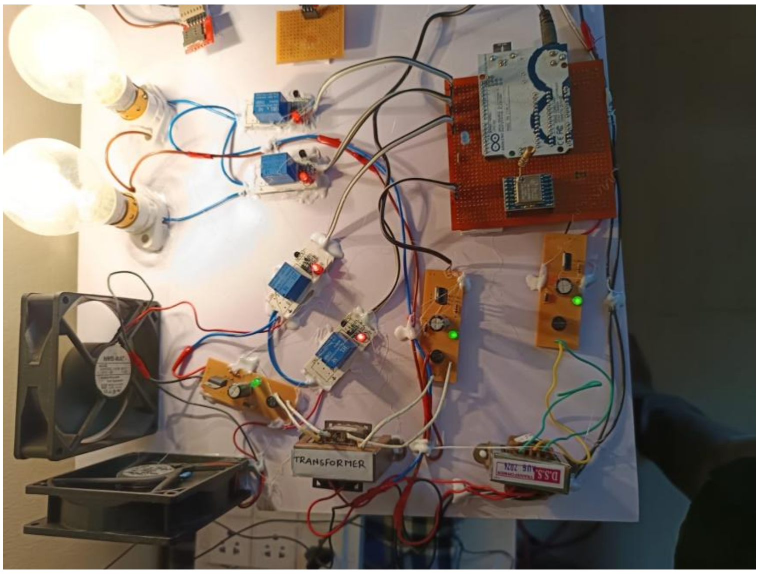
The system's performance was evaluated based on several metrics: **data accuracy**,**communication range**, **power consumption**, and **user interface**.

- **Data Accuracy**:
  - Temperature: ±0.5°C (DHT22).
  - Humidity: ±2% RH (DHT22).
  - Pressure: ±0.12 hPa (BMP280).
  - Vibration: ±0.05g (ADXL345).
- **Communication Range**:
  - The system achieved a range of **10-15 km** in open spaces and **3-5 km** in industrial settings with obstacles.

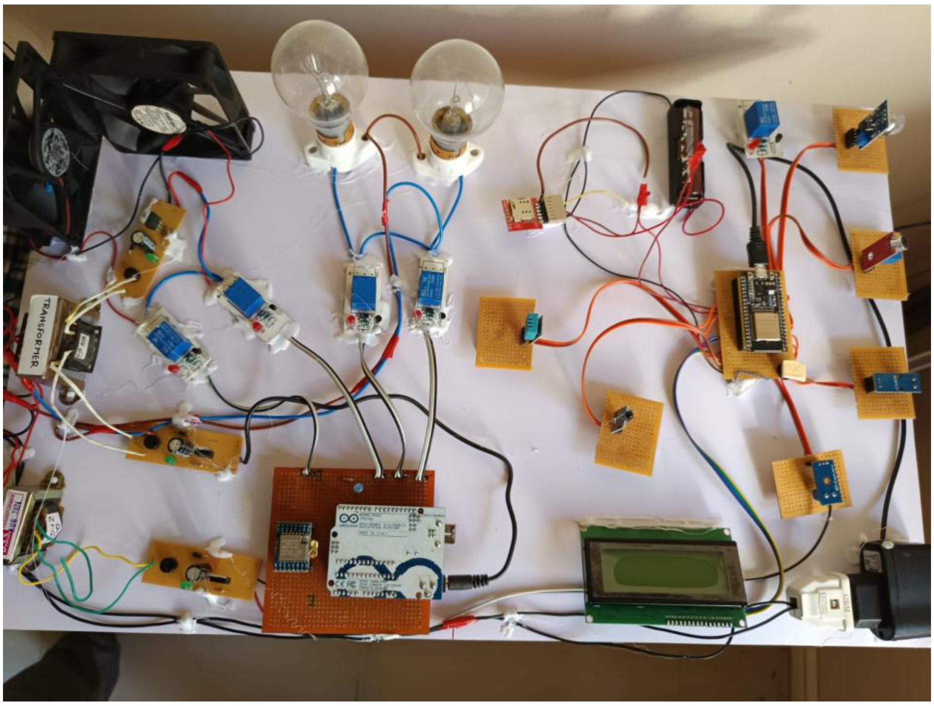
- **Power Consumption**:
  - The LoRa module consumed **50-60 mA** during transmission and less than **1 mA** in sleep mode, ensuring extended battery life of **6-12 months** on a **5V Li-ion battery**.
- **Cloud Integration**:
  - The system's integration with cloud platforms like **ThingSpeak** allowed for fast data storage and visualization. Users could easily monitor data in real-time and access historical trends via dynamic dashboards.

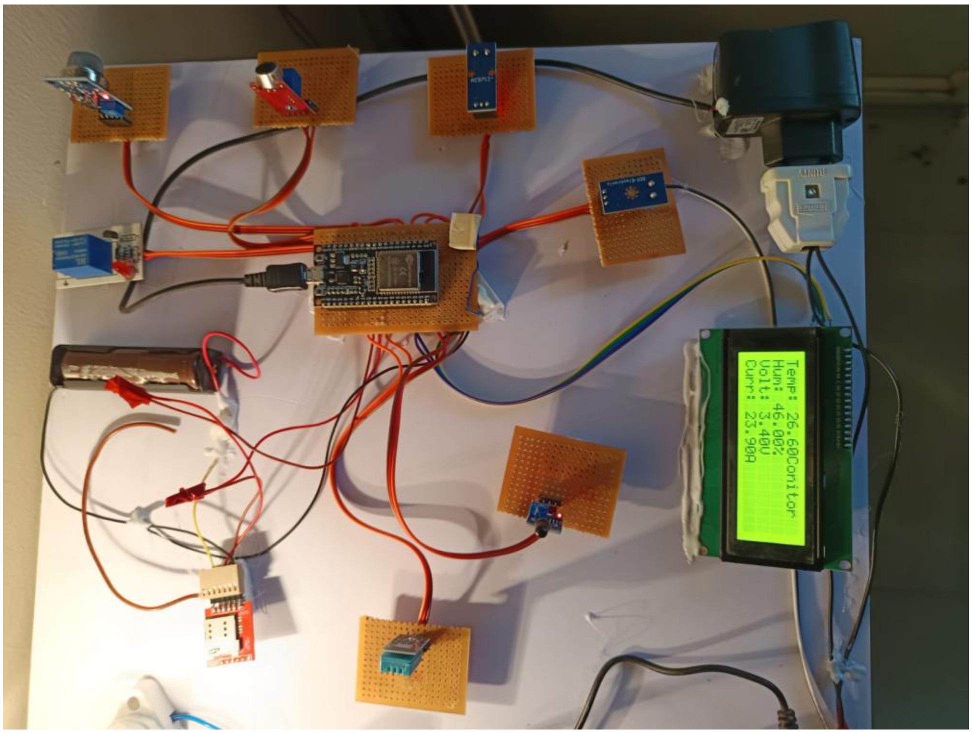
4.2. System Reliability and User Interface

The system demonstrated excellent data transmission reliability (99%) under normal conditions. Minimal delays were observed, and the system was highly rated for its **user-friendly interface** on both **web and mobile platforms**.



International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 02 | Feb - 2025 SJIF Rating: 8.448 ISSN: 2582-3930





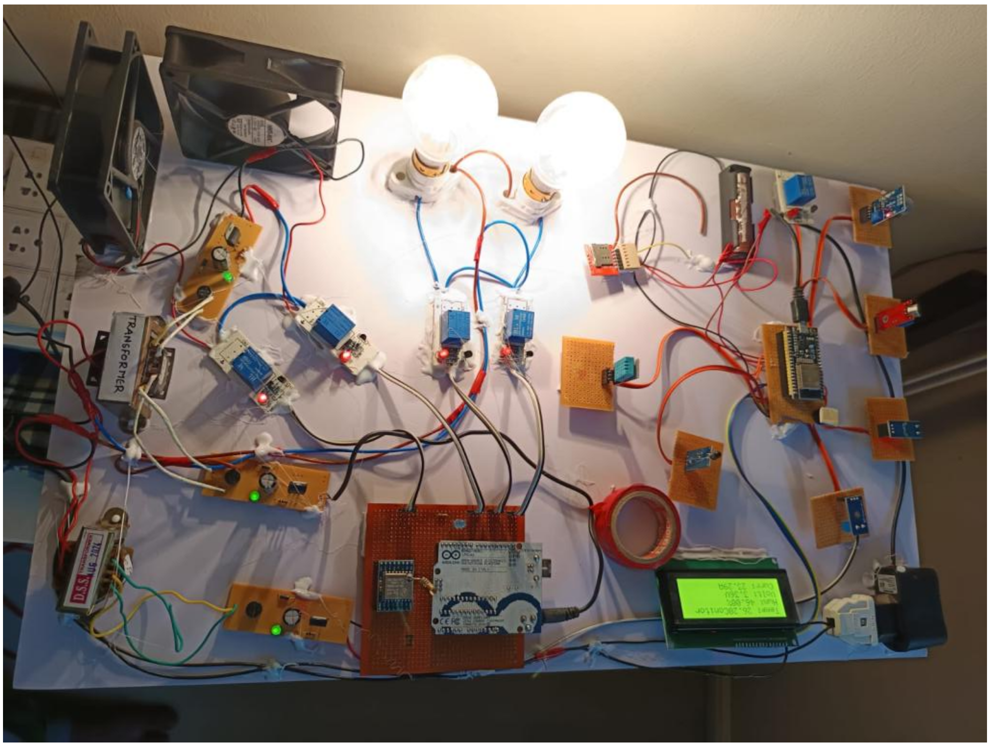
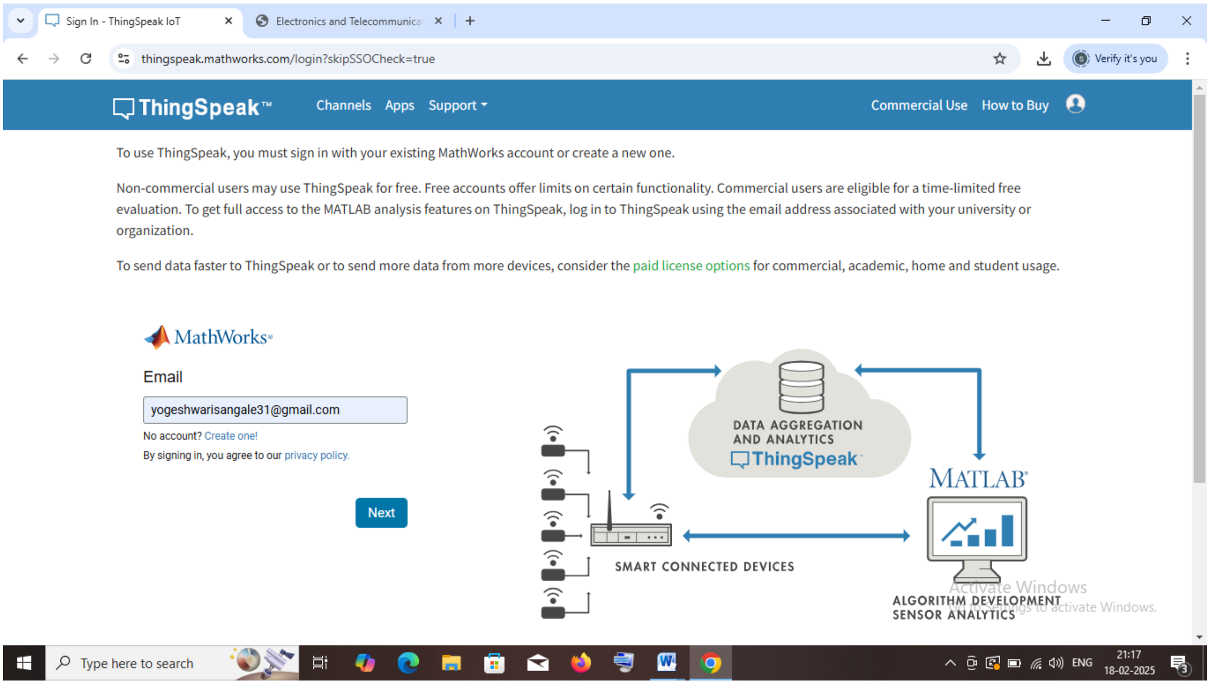
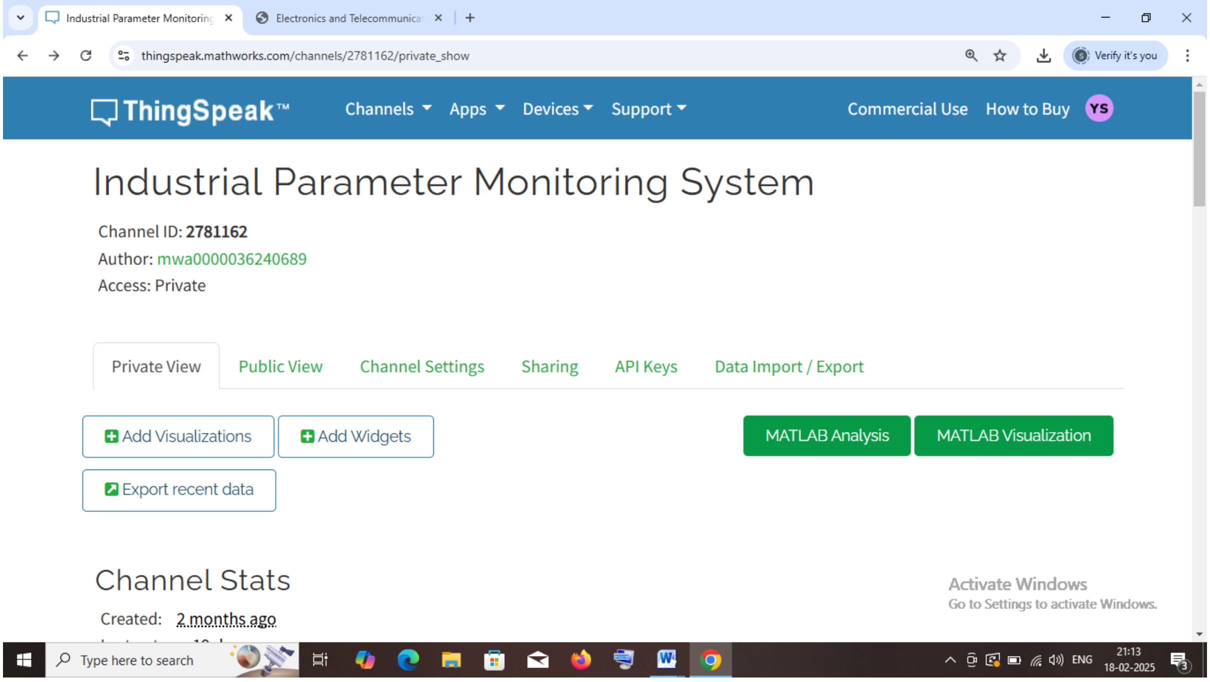


Figure -2 : System Installation & Commissioning

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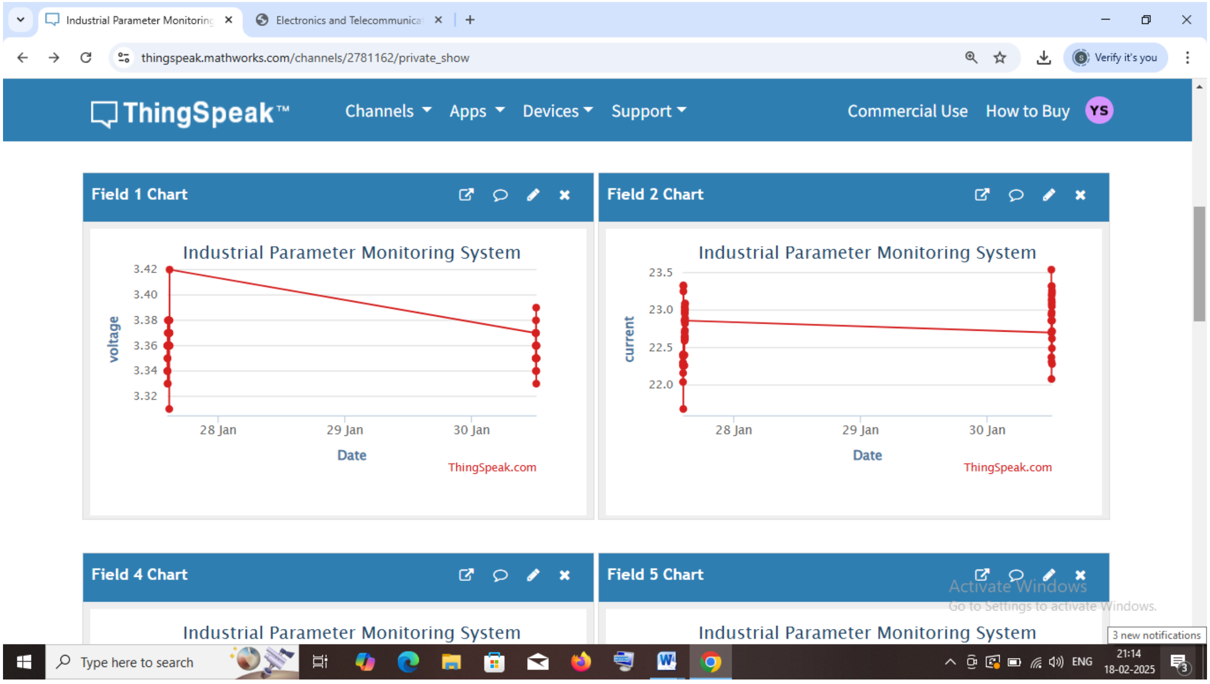
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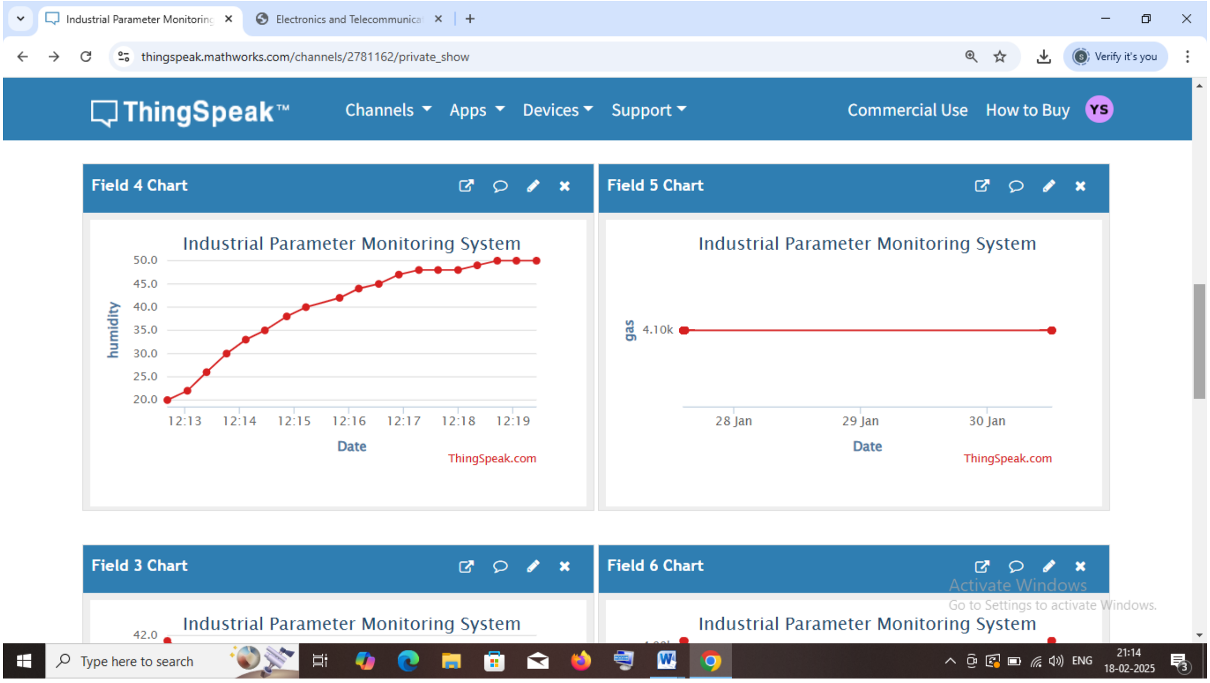
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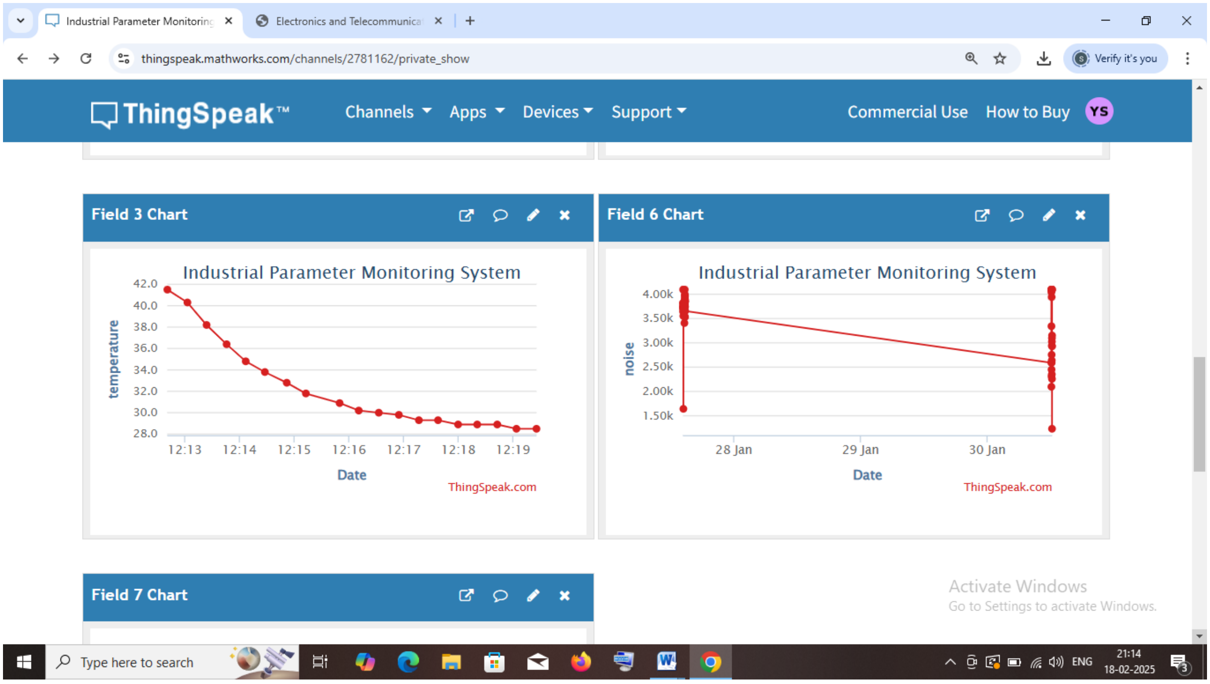
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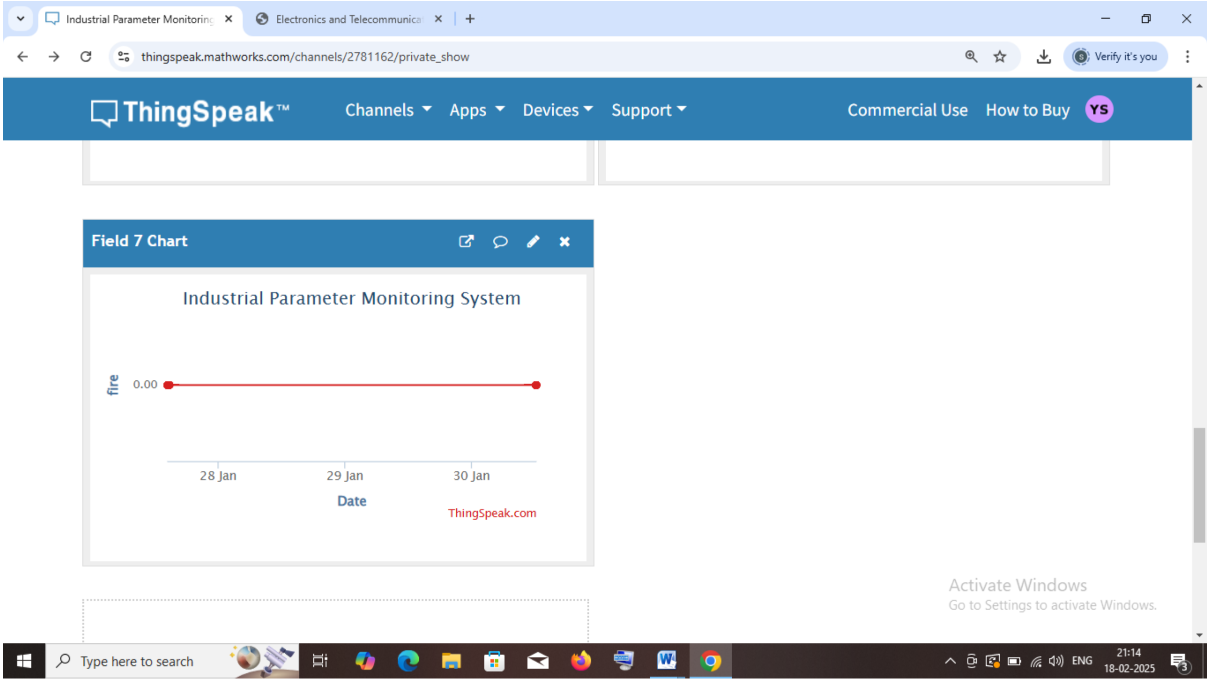

Figure -3: System Result

5. Discussion

5.1. System Advantages

- **Cost-Effectiveness**: The use of **LoRa** technology and **open-source cloud platforms** kept costs low.
- **Scalability**: The system can easily be expanded by adding additional sensors, making it adaptable to industrial environments of various sizes.
- **Real-Time Monitoring**: The real-time alert system ensures that operators can take timely action to prevent machinery failure or hazardous conditions.
- **Low Power Consumption**: The system is ideal for remote, off-grid environments due to its efficient power design.

5.2. Limitations

- **Signal Interference**: Interference from other wireless devices or physical obstructions occasionally reduced the effective communication range.
- **Sensor Accuracy**: Minor deviations were observed, particularly in environments with fluctuating temperatures or air circulation.
- **Network Congestion**: In dense environments with multiple LoRaWAN devices, network congestion may affect transmission rates.

5.3. Mitigation Strategies

- Careful placement of LoRa gateways.
- Calibration and shielding of sensors in extreme environments.
- Optimizing network settings for efficient data transmission.

6. Conclusion

The **LoRa-based IoT industrial parameter monitoring system** has proven to be an effective and cost-efficient solution for industrial environments. The system demonstrated reliable data transmission, low power consumption, and successful cloud integration for real-time monitoring and alerting. While there were minor challenges with interference and sensor accuracy, the overall performance was promising. Future work includes the integration of **machine learning** for predictive maintenance, **solar power integration** for extended battery life, and expanding the system's **communication protocols** for faster data transfer and response times.

7. Future Work

Several improvements can be made to enhance the system's functionality:

- **Machine Learning Integration** for predictive maintenance, improving equipment reliability.
- **Energy Harvesting Solutions** (e.g., solar power) to extend battery life in remote environments.
- **Hybrid Communication Model** using LoRa for long-range and Wi-Fi/5G for high-speed data transfer.
- **Advanced Data Analytics** tools and **edge computing** to reduce latency and improve real-time decision-making.
- **Wider Applications** such as gas detection, energy consumption monitoring, and more comprehensive machine health monitoring.

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