IOT Based Monitoring of Industrial Parameters and Controlling Using Lora Module

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Abstract - The increasing demand for real-time supervision and intelligent control in industrial environments necessitates robust, low-cost, and long-range communication architectures capable of operating reliably under harsh conditions. This paper presents the design and implementation of an Internet of Things (IoT)-based industrial monitoring and control system that integrates multi-parameter sensing with LoRa-enabled long-distance actuation. The proposed system monitors critical industrial parameters including voltage, current, gas concentration, ambient noise level, temperature, humidity, and flame detection using an ESP32 microcontroller as the primary processing and communication unit. Sensor data are acquired through appropriate signal conditioning circuits and continuously processed for anomaly detection and threshold-based alerts.

The ESP32-based monitoring node provides real-time visualization of measured parameters on a local LCD display and transmits data to a cloud-based IoT platform for remote supervision and data logging. A GSM module is incorporated to ensure redundant communication capability, enabling SMS-based alerts during network failures or abnormal operating conditions. This multi-layer communication approach enhances system reliability and ensures uninterrupted monitoring in industrial scenarios where connectivity may be inconsistent.

Key Words: Industry, Parameters, IOT, GSM, Voltage, Monitoring

1. INTRODUCTION

The rapid evolution of the Industrial Internet of Things (IIoT) has fundamentally transformed the way industrial processes are monitored, controlled, and optimized. Modern industries increasingly demand intelligent, scalable, and energy-efficient monitoring systems capable of acquiring real-time operational data, detecting anomalies, and enabling remote supervisory control. Conventional wired monitoring architectures, while reliable, are often expensive to deploy, difficult to scale, and impractical in geographically dispersed or hazardous industrial environments. As a result, low-power wireless communication technologies combined with embedded systems have emerged as a cost-effective and flexible alternative for industrial parameter surveillance and control.

Industrial environments typically involve multiple critical parameters that directly influence operational safety, productivity, and equipment longevity. Parameters such as voltage and current determine electrical system stability and load performance, while temperature and humidity affect machinery efficiency and material integrity. Gas concentration and flame detection are essential for early identification of hazardous conditions such as leakage or fire outbreaks. Noise level monitoring contributes to occupational safety compliance and preventive maintenance by identifying abnormal mechanical behavior. Continuous real-time monitoring of these parameters is therefore indispensable for ensuring operational reliability, minimizing downtime, and enhancing workplace safety.

In this context, the proposed system presents an IoT-based industrial monitoring and control framework integrating ESP32, LoRa communication modules, GSM technology, and Arduino Nano controllers. The system architecture is divided into two coordinated subsystems: (i) an industrial parameter monitoring unit and (ii) a long-range wireless control unit.

The monitoring subsystem employs an ESP32 microcontroller as the central processing and communication unit. Multiple sensors are interfaced with the ESP32 to measure voltage, current, gas concentration, ambient noise level, temperature, humidity, and flame presence. The ESP32 provides high computational capability, integrated Wi-Fi connectivity, and low power consumption, making it suitable for IIoT applications. Sensor data are processed locally and displayed in real time on an LCD module for on-site supervision. Simultaneously, the collected data are transmitted to an IoT cloud platform for remote monitoring, analysis, and data logging. The integration of a GSM module further enhances system reliability by enabling SMS-based alerts and notifications during abnormal conditions such as gas leakage, fire detection, overvoltage, or overcurrent events. This dual communication mechanism ensures redundancy and continuous availability of critical information.

Overall, the proposed IoT and LoRa-enabled system demonstrates a practical and economical approach for comprehensive industrial parameter monitoring and remote load control. By integrating sensor networks, cloud-based IoT platforms, GSM alerts, and long-range wireless communication, the system contributes to the advancement of intelligent industrial automation aligned with Industry 4.0 objectives.

2. RELATED WORK

The rapid evolution of Industrial Internet of Things (IIoT) technologies has significantly enhanced real-time monitoring and control of industrial parameters. Several researchers have explored wireless sensor networks (WSNs), cloud-integrated IoT systems, and long-range communication technologies for industrial automation and safety applications.

2.1 IoT-Based Industrial Monitoring Systems

Industrial monitoring systems leveraging IoT architectures have gained considerable attention due to their ability to enable remote supervision, predictive maintenance, and data-driven decision-making. Gubbi et al. (2013), published by Elsevier, provided one of the earliest comprehensive surveys on IoT architectures, highlighting sensing, communication, and cloud integration layers that form the backbone of modern industrial monitoring systems [1].

Similarly, Atzori et al. (2010), in their work published by Elsevier, analyzed IoT enabling technologies and emphasized the role of wireless communication protocols in industrial applications [2]. Their study laid the groundwork for integrating embedded controllers such as Arduino and ESP-based systems in industrial environments.

Xu et al. (2014), published by IEEE, introduced the concept of Industrial IoT (IIoT), emphasizing real-time parameter monitoring and automated control in industrial systems [3]. Their work established the importance of reliable communication and scalable architectures in industrial environments.

2.2 ESP32-Based Monitoring Systems

The ESP32 microcontroller has emerged as a powerful solution for IoT-based embedded monitoring due to its integrated Wi-Fi and Bluetooth capabilities. Research conducted by Al-Fuqaha et al. (2015), published by IEEE Communications Surveys & Tutorials, discussed IoT platforms that integrate low-power microcontrollers with cloud services for smart industrial applications [4].

Several studies have implemented ESP32 for environmental monitoring systems. For instance, Verma and Sood (2018), published by Springer, developed a cloud-based monitoring system using embedded controllers for temperature and humidity monitoring in industrial settings [5]. Their system demonstrated improved real-time accessibility and data logging.

Furthermore, industrial safety monitoring systems incorporating gas, flame, and temperature sensors were discussed by Saini et al. (2019), published in IEEE Xplore, where microcontroller-based systems were employed for hazardous gas detection and early fire alerts [6].

2.3 LoRa-Based Long-Range Industrial Communication

Long Range (LoRa) communication has become a preferred solution for low-power, long-distance industrial data transmission. LoRa technology, developed by Semtech Corporation, enables communication over several kilometers while maintaining low energy consumption.

Centenaro et al. (2016), in a study published by IEEE Communications Magazine, evaluated LoRaWAN performance and demonstrated its suitability for industrial monitoring due to its long-range capability and low power characteristics [7].

Adelantado et al. (2017), published by IEEE Access, analyzed the scalability and reliability of LoRaWAN networks, highlighting their potential for large-scale industrial deployments [8].

Petäjäjärvi et al. (2015), presented at the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), conducted empirical studies on LoRa coverage and confirmed its effectiveness in industrial environments with extended communication range [9].

These studies validate the use of LoRa modules as transmitter–receiver pairs for reliable industrial parameter monitoring and remote relay control applications.

2.4 GSM-Based Industrial Alert Systems

GSM modules have been extensively used for remote alert systems in industrial safety monitoring. Zhao and Ge (2013), published by IEEE, discussed machine-to-machine (M2M) communication using GSM networks for industrial supervision [10].

Additionally, embedded GSM-based alert mechanisms for fire and gas detection systems were examined by Kumar and Rajasekaran (2016), published by IEEE, demonstrating improved emergency responsiveness in industrial facilities [11].

2.5 Relay-Based Load Control Systems

Remote control of industrial loads using relay modules has been widely investigated. Arduino Nano-based relay control systems are frequently implemented due to their simplicity and cost-effectiveness. Shaikh et al. (2018), published by Elsevier Procedia Computer Science, developed a wireless relay-based automation system for industrial loads using microcontrollers [12].

Similarly, Mahmood et al. (2020), published by Springer, demonstrated a LoRa-based relay switching mechanism for remote load management in smart grid applications [13]. Their architecture closely resembles transmitter–receiver LoRa configurations for industrial load control.

2.6 Integrated Monitoring and Control Architectures

Integrated systems combining IoT monitoring, GSM alerts, and LoRa-based remote control are relatively recent developments. Mekki et al. (2019), published by IEEE Access, provided a survey on LPWAN technologies, including LoRa, for industrial IoT applications [14]. Their findings support the hybrid communication approach adopted in the proposed system.

While previous studies have addressed either IoT-based monitoring or LoRa-based control independently, limited work has focused on combining:

- ESP32-based multi-parameter industrial sensing (voltage, current, gas, noise, temperature, humidity, flame),
- Real-time IoT cloud monitoring with LCD display,
- GSM-based alert notification,
- LoRa transmitter–receiver modules for remote four-relay load control using Arduino Nano.

3. PROPOSED SYSTEM

1. System Overview

The proposed system presents a hybrid IoT and LoRa-enabled industrial monitoring and control architecture designed for real-time supervision of critical industrial parameters and remote load actuation. The system integrates an ESP32-based sensing and IoT gateway unit for environmental and electrical parameter acquisition, combined with a LoRa-based long-range communication subsystem for distributed load control using Arduino Nano microcontrollers.

The architecture is divided into two primary subsystems:

1. **Monitoring and IoT Gateway Unit (ESP32-Based)**

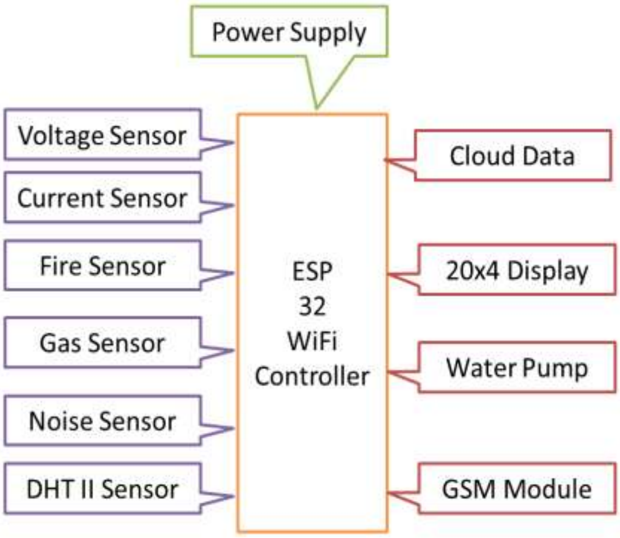

Fig.1-: System Design & Architecture

The industrial parameter monitoring system, which uses voltage, current, fire, gas, noise, and temperature sensors, is depicted in Figure 1. Additionally, an LCD display and an IoT cloud platform display all of the data obtained from the attached sensors.

2. LoRa-Based Remote Control Unit (Arduino Nano Transmitter–Receiver Pair)

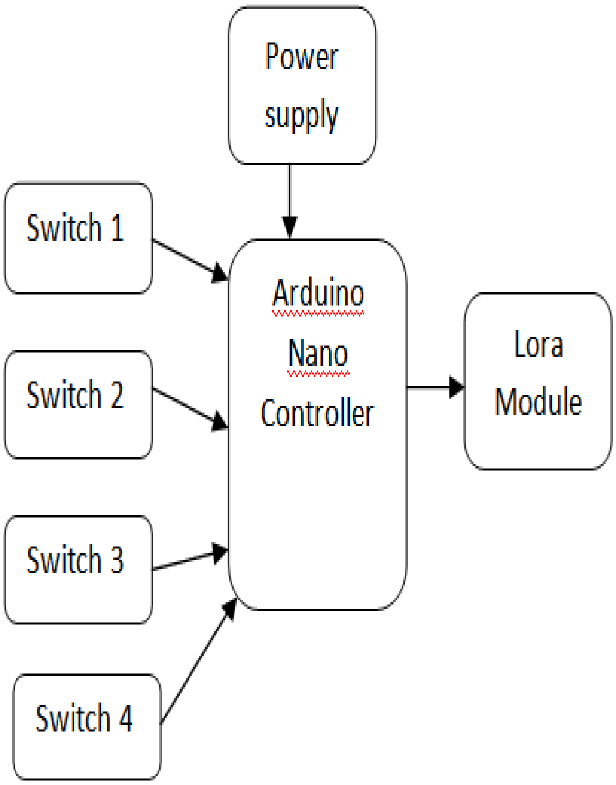

Fig 2: Transmitter Block Diagram

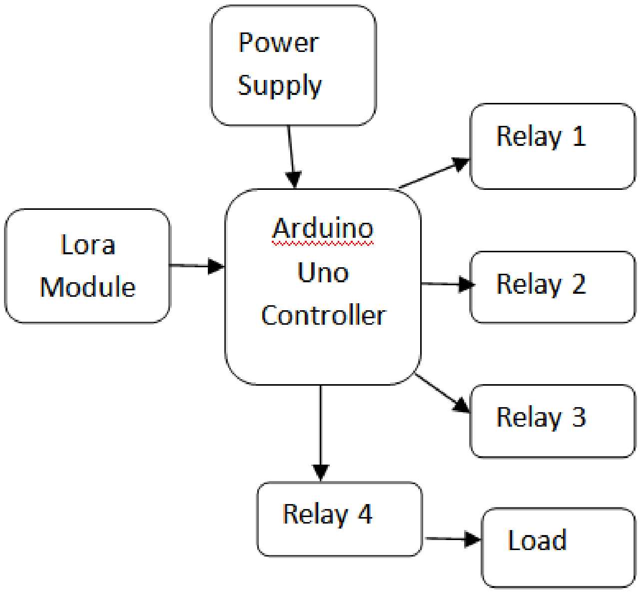

Fig 3: Receiver Block Diagram

The planned project's transmitter and reception system is depicted in the block diagrams above. Wherein the load connected across the controller is controlled by the Lora module. Long-distance sensor data transmission is made possible by the LoRa network, which also offers cloud-based tools for data visualization (like Grafana and Power BI) and push notifications, email, and SMS alerts.

4. RESULT AND DISCUSSION

4.1 System Integration and Functional Validation

The proposed IoT-based industrial monitoring and control system was successfully designed, implemented, and experimentally validated in a laboratory-scale industrial test environment. The system consists of two major subsystems:

1. **Monitoring Unit** – Built around an ESP32 microcontroller interfaced with voltage, current, gas, noise, temperature–humidity, and flame sensors. The measured parameters are displayed locally on an LCD and transmitted to a cloud platform via Wi-Fi. A GSM module provides SMS-based alerts during abnormal operating conditions.

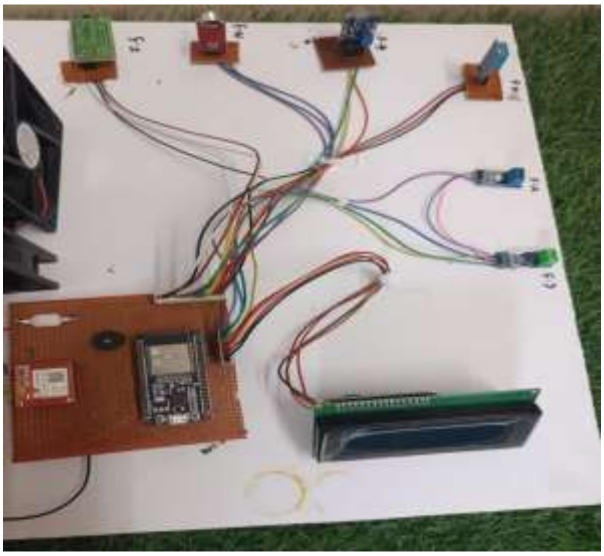

Fig.-5: Monitoring System of The Proposed System

2. **Control Unit** – Implemented using Arduino Nano boards integrated with LoRa transmitter and receiver modules. The receiver unit controls four relays connected to industrial loads.

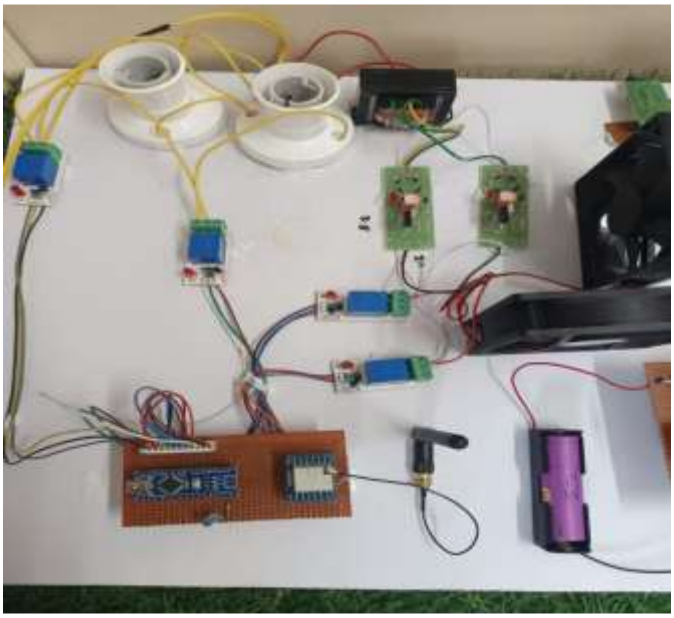

Fig.-5: Receiver System of The Proposed System

Based on real-time sensor data, the LoRa-based Industrial Automation system with NodeMCU, MQ135 sensor, DHT11 sensor, and relay offers economical and effective load control. The system provides accurate and quick data on temperature, humidity, and air pollution and modifies loads appropriately.

Fig.-5: Transmitter System of The Proposed System

Automation increases resource utilization, lowers manual labor, and boosts energy efficiency. The system is appropriate for household and industrial automation applications because of its LoRa wireless communication technology, which guarantees secure and dependable data transfer across extended distances. The system offers an affordable solution for real-time load control because to its inexpensive sensors and wireless communication technology.

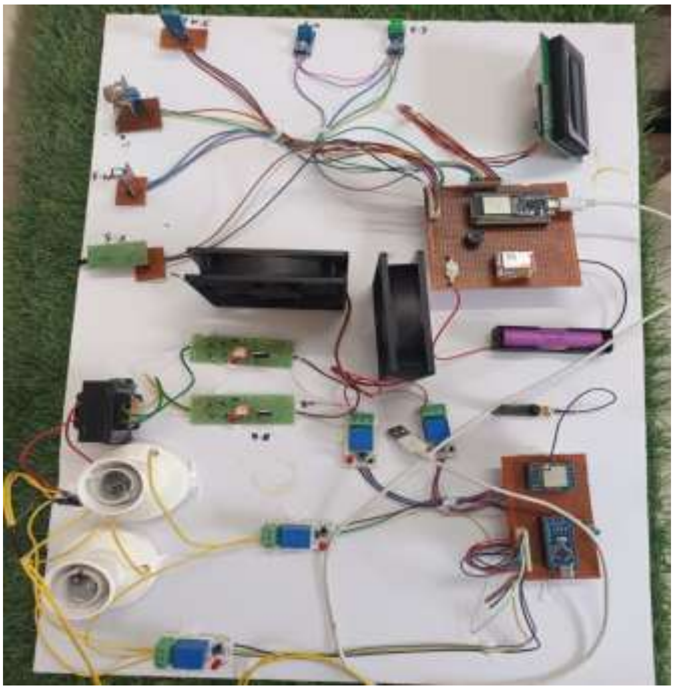

Fig.-5: Hardware of The Proposed System

A LoRa-based industrial automation system comprising NodeMCU, MQ135 sensor, DHT11 sensor, and relay for load management was successfully built and tested. In an industrial setting, the system keeps an eye on temperature, humidity, and gas concentration while regulating the load based on sensor data.

Fig.-6: Results of The Proposed System

The system was tested under various situations, with the following results:

Fig.-7: Results of Voltage & Current

Fig.-8: Results of Temperature & Humidity

Fig.-9: Results of Gas & Flame

Fig.-10: Results of Noise

Sensor readings: Continuous monitoring was made possible by the accurate and reliable data provided by the temperature, humidity, and gas concentration sensors. Load control: The relay's load was managed using sensor readings. For example, the load was turned off when the gas concentration above the same level, but the fan was turned on when the temperature exceeded a safe threshold.
Sensor data was successfully transmitted to other nodes and gateways across great distances thanks to LoRa communication between nodes.

The technology was designed to use as little power as possible and to maximize battery life. Regular recharges are not necessary because the system can operate on battery power for long periods of time. A secure industrial setting was guaranteed by the system's load management.

5. CONCLUSIONS

This paper presented the design and implementation of an IoT-based industrial monitoring and control system integrating ESP32, LoRa communication modules, GSM connectivity, and Arduino Nano-based relay control architecture. The proposed system was developed to continuously monitor critical industrial parameters—voltage, current, gas concentration, noise level, temperature, humidity, and flame detection—while enabling reliable long-distance load control through LoRa-based wireless communication. In conclusion, the proposed IoT and LoRa-based industrial monitoring and control system provides an efficient, reliable, and scalable solution for real-time industrial parameter supervision and remote load management. The system successfully demonstrates how low-power long-range communication combined with IoT technologies can significantly enhance industrial automation, operational safety, and decision-making efficiency in smart industry environments.

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