

Review on Design and Development of An Iot-Based Industrial Monitoring and Control System Using Lora Module

Dipali D. Mote¹, Dr.Syed Sumera Ali², Akshay T. Jadhav³, Dr.D.L. Bhuyar⁴, Dr.G.B. Dongre⁵

¹*M. tech Student at Department. of Electronics and Communication (Advance Communication Technology), CSMSS Chh.Shahu College of Engineering Kanchanwadi, Chh. Sambhajinagar*

²*Associate Professor and Head, Department. of Electronics and Communication (Advance Communication Technology), CSMSS Chh.Shahu College of Engineering Kanchanwadi, Chh. Sambhajinagar*

³*Assistant Professor, Department. of Electronics and Communication (Advance Communication Technology), CSMSS Chh.Shahu College of Engineering Kanchanwadi, Chh. Sambhajinagar*

⁴*Professor and Head, Department. of Electronics and Communication (Advance Communication Technology), CSMSS Chh.Shahu College of Engineering Kanchanwadi, Chh. Sambhajinagar*

⁵*Principal of CSMSS Chh.Shahu College of Engineering Kanchanwadi, Chh. Sambhajinagar*

Abstract—The rapid development of Industry 4.0 has increased the demand for intelligent systems capable of continuously monitoring industrial processes and remotely controlling electrical and mechanical equipment. Conventional industrial monitoring systems frequently depend on wired communication, centralized supervisory systems, or short-range wireless technologies, which can increase installation complexity and limit flexibility when monitoring equipment is distributed across large industrial facilities. This paper presents a review and proposed design of an Internet of Things (IoT)-based industrial monitoring and control system using Long Range (LoRa) wireless communication. The proposed architecture integrates an ESP32 Wi-Fi-enabled microcontroller with multiple industrial sensors to acquire real-time parameters such as temperature, humidity, gas concentration, vibration, voltage, current, flame/fire condition, and other machine-related parameters. A local display provides immediate information to operators, while Wi-Fi connectivity enables transmission of sensor data to an IoT platform for remote monitoring and data visualization. A GSM-based notification mechanism can additionally transmit text messages when abnormal conditions are detected. For long-distance industrial communication, LoRa transmitter and receiver modules are incorporated between the sensing/control section and the remote load-control section. Relays are used to

switch industrial loads according to predefined threshold conditions or commands received through the LoRa communication link. The literature indicates that LoRa/LoRaWAN provides an attractive combination of long communication range, low power consumption, low infrastructure cost, and suitability for distributed IoT sensing, although latency, packet collisions, interference, duty-cycle limitations, and industrial obstructions must be considered. The proposed architecture combines local sensing, IoT connectivity, GSM notification, and LoRa-based remote control in a single platform, providing a practical foundation for industrial condition monitoring, alarm generation, and remote load management.

Index Terms—Industrial Internet of Things, IIoT, ESP32, LoRa, LoRaWAN, Industrial Monitoring, Remote Control, Wireless Sensor Network, GSM, IoT, Industry 4.0, Industrial Automation.

I. INTRODUCTION

The Industrial Internet of Things (IIoT) is an important component of Industry 4.0 because it connects industrial machines, sensors, controllers, communication networks, and cloud-based applications to support continuous monitoring and

intelligent decision-making. IIoT can improve production efficiency, equipment availability, safety, maintenance planning, and operational visibility by connecting physical industrial assets with digital information systems [1]. However, industrial environments present specific challenges that are not normally encountered in residential IoT applications. Machines may be distributed over large areas, metallic structures can attenuate radio signals, electromagnetic interference can affect wireless communication, and many monitoring points may not have convenient wired network connections. Reliability, real-time operation, interoperability, cybersecurity, and energy efficiency are therefore important considerations in industrial IoT system design [1], [2].

Industrial monitoring generally involves the measurement of electrical, mechanical, thermal, environmental, and safety-related parameters. Temperature sensors can be used to identify overheating, humidity sensors can monitor environmental conditions, current and voltage sensors can determine electrical loading, vibration sensors can indicate abnormal machine operation, and gas or flame sensors can provide early warning of hazardous conditions. A modern industrial monitoring platform should combine these measurements and provide information both locally and remotely.

Wireless communication provides an attractive alternative to extensive industrial cabling. Technologies such as Wi-Fi, ZigBee, WirelessHART, cellular IoT, NB-IoT, and LoRa/LoRaWAN have been investigated for industrial applications. Short-range technologies may provide high data rates but can require several access points in large facilities. Cellular systems provide wide-area coverage but can introduce subscription costs and infrastructure dependencies. LPWAN technologies, including LoRaWAN, were developed specifically for applications requiring long-distance communication, low data rates, and low energy consumption [3]–[5].

LoRa is particularly attractive for industrial sensor applications because its chirp spread spectrum-based physical layer provides long-range communication and high receiver sensitivity. LoRaWAN builds a network architecture and communication protocol around the LoRa physical layer. Research has

demonstrated the applicability of LoRaWAN to industrial monitoring, additive manufacturing, energy systems, smart campuses, and other distributed sensing applications [6]–[10].

The proposed work focuses on an ESP32-based industrial monitoring and control platform in which several industrial sensors are connected to a local controller. The ESP32 performs sensor acquisition, local processing, display management, IoT communication, and alarm handling. A LoRa transmitter sends selected monitoring/control information over a long-distance wireless link to a remote LoRa receiver. The receiver interfaces with relay drivers to operate industrial loads. A GSM module provides an additional communication path for emergency text-message notifications.

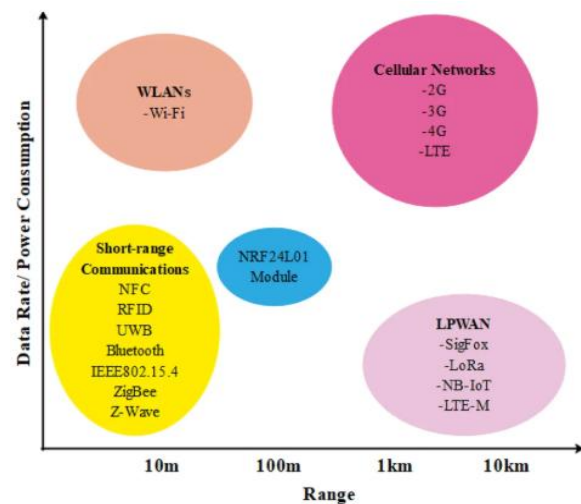


Fig.-1: Comparison of Different Communication Technologies for Communication Range and Data Transfer Rate

The major objective is therefore to develop an integrated architecture that combines multi-parameter sensing + ESP32 + local display + IoT monitoring + GSM notification + LoRa-based remote load control.

II. LITERATURE REVIEW

2.1 Industrial IoT Monitoring

Sisinni et al. [1] examined the evolution of Industrial IoT and identified energy efficiency, real-time performance, interoperability, coexistence, security, and privacy as important challenges. Their work demonstrates that IIoT is not simply the connection of sensors to the Internet; it requires appropriate

communication and computing architectures capable of operating reliably in industrial environments.

Raposo et al. [2] investigated industrial IoT monitoring technologies and proposed an architecture based on wireless sensor networking. Their study emphasized the importance of dependable communication and industrial communication standards. The research also discusses technologies such as ZigBee, WirelessHART, ISA100.11a, and WIA-PA, demonstrating that industrial monitoring requires communication mechanisms adapted to industrial conditions rather than simply adopting consumer wireless technologies.

Hercog et al. [3] studied the design and implementation of ESP32-based IoT devices. Their work demonstrates the suitability of the ESP32 platform for IoT development because it combines microcontroller functionality with wireless connectivity in a relatively inexpensive embedded platform. This supports the use of ESP32 as the sensing and edge-processing controller in the proposed industrial monitoring architecture.

Recent industrial IoT research also shows a trend toward combining edge controllers, sensors, local processing, MQTT/cloud communication, and real-time dashboards. Such architectures reduce dependence on traditional centralized monitoring and allow sensor information to be processed close to the physical system [3], [4].

2.2 LoRa and LPWAN Technologies

Centenaro et al. [4] discussed the emergence of LPWAN technologies as an alternative to short-range mesh networks and conventional cellular communication for IoT applications. Their study identified long communication range, low power requirements, and suitable network architecture as major advantages of LPWAN technologies.

Augustin et al. [5] provided a detailed study of LoRa technology, examining its long-range and low-power characteristics for IoT applications. Their research established the technological basis for using LoRa in applications where large communication coverage and low data throughput are more important than high-speed communication.

Adelantado et al. [6] examined the limits of LoRaWAN and highlighted important restrictions associated with network capacity, duty-cycle constraints, data rate, and scalability. Their work is

important for industrial applications because long range alone does not guarantee deterministic communication performance.

Raza et al. [7] presented a broad overview of LPWAN technologies and discussed their design objectives, standardization, coverage, energy consumption, and application limitations. The study concluded that LPWAN technologies are appropriate for applications requiring low data rates and long communication ranges.

Ertürk et al. [8] reviewed LoRaWAN architecture, protocols, technologies, security, and open research challenges. Their work emphasizes that LoRaWAN provides low-power long-range communication but still requires careful consideration of network architecture, security, and reliability.

Mekki et al. [9] compared LoRa, Sigfox, and NB-IoT for large-scale IoT deployments. The authors reported that LoRa and Sigfox have advantages related to battery lifetime, capacity, and cost, whereas NB-IoT can provide benefits in latency and quality of service. This comparison demonstrates why LoRa can be particularly useful for distributed monitoring systems where low data volume and long range are more important than high bandwidth.

2.3 LoRa Performance and Industrial Applications

Petäjärvi et al. [10] investigated LoRa coverage and channel attenuation and demonstrated the importance of propagation conditions when determining practical communication range. Industrial buildings can create multipath propagation, shadowing, and attenuation, making experimental site evaluation necessary.

Farooq and Pesch [11] studied LoRa communication settings for different IoT use cases. Their analysis showed that spreading factor, bandwidth, coding rate, and transmission parameters affect communication range, packet delivery, and energy consumption. Therefore, LoRa configuration should be selected according to the application rather than using a fixed configuration for every deployment.

Sørensen et al. [12] developed analytical models for LoRaWAN latency, collision probability, and throughput. Their work demonstrated that channel selection and traffic load can significantly influence quality of service. These findings are particularly important when many industrial nodes transmit simultaneously.

Blenn and Kuipers [13] evaluated LoRaWAN using measurements from an operational network and investigated packet behavior, signal quality, spatial characteristics, and packet loss. Their work demonstrates the value of practical measurements in addition to theoretical calculations when evaluating LoRaWAN performance.

Penkov et al. [14] developed an online monitoring system using LoRaWAN and demonstrated its application to industrial monitoring and control. The system used LoRaWAN communication and a visualization environment to observe industrial information, supporting the feasibility of LoRaWAN for digital-industry applications.

Sisinni et al. [15] proposed a LoRaWAN range extender for industrial IoT. Their research addressed the problem of limited coverage in dense industrial environments containing obstacles. The proposed approach demonstrates that additional wireless infrastructure can be introduced where direct end-device-to-gateway communication is inadequate.

2.4 Energy Efficiency in Industrial LoRa Networks

Sherazi et al. [16] investigated energy-efficient LoRaWAN operation in Industry 4.0 environments. Their study considered battery lifetime, sensing intervals, replacement costs, and energy harvesting. The authors emphasized that industrial monitoring requires a balance between frequent sensing and the energy consumption associated with wireless transmission.

Sherazi et al. [17] further studied energy harvesting in LoRaWAN-based Industry 4.0 systems. Their analysis showed that energy harvesting can reduce the dependence on battery replacement while supporting longer-term industrial monitoring.

Zorbas et al. [18] proposed TS-LoRa, a time-slotted approach intended to improve LoRaWAN scalability and reliability in industrial environments. Experimental evaluation with multiple nodes demonstrated the potential for improved packet delivery and lower energy consumption compared with conventional confirmable LoRaWAN operation. These studies indicate that the communication strategy should be considered together with sensing frequency and industrial requirements. For the proposed system, routine measurements can be transmitted periodically, while abnormal events can trigger immediate priority messages.

2.5 LoRaWAN for Industrial Measurement and Monitoring

Dos Santos Filho et al. [19] evaluated LoRaWAN for telemetry and alarm messages in industrial applications. Their work is directly relevant to the proposed system because industrial monitoring normally includes both periodic measurements and event-driven alarms.

Fedullo et al. [20] developed a LoRaWAN-based IoT measurement system for additive manufacturing. Their work demonstrates how low-power long-range wireless sensing can be integrated with manufacturing processes and measurement systems.

Aarif et al. [21] evaluated LoRa communication under harsh industrial conditions. Their results emphasize that industrial noise, interference, fading, and physical obstructions can reduce LoRa performance. Consequently, antenna positioning, spreading factor selection, transmission power, and gateway placement should be considered during implementation.

Pasetti et al. [22] investigated LoRaWAN for monitoring and controlling distributed energy resources. The study illustrates that LoRaWAN can support both monitoring and control functions, which is relevant to the proposed use of a LoRa transmitter-receiver pair for remote load switching.

2.6 IoT, Cloud Monitoring, MQTT and Remote Control

Modern industrial IoT systems commonly separate sensing, communication, processing, and visualization layers. MQTT is frequently used for lightweight machine-to-machine communication, while HTTP/REST interfaces are also commonly employed for cloud data transmission. Research on IoT energy-management systems has demonstrated the usefulness of MQTT for monitoring and control applications [23].

Kurdi and Thayanathan [23] discussed a multi-tier MQTT architecture for industrial IoT and highlighted the importance of edge/fog processing for reducing communication overhead and improving security.

Recent IoT-SCADA research has also demonstrated architectures based on ESP32 controllers, sensor acquisition, MQTT, cloud dashboards, and relay-based load control. Such systems show that low-cost embedded controllers can perform both monitoring and supervisory control functions [24].

Security is increasingly important as industrial sensors become connected to networks. Recent surveys have identified authentication, encryption, access control, key management, and protection against attacks as important requirements for LPWAN-based IoT systems [25].

The literature demonstrates that LoRa is well suited to distributed, low-data-rate industrial monitoring, while ESP32 provides a practical embedded platform for sensor processing and Wi-Fi-based IoT connectivity. However, many existing implementations focus on monitoring, communication performance, or a specific application. A combined architecture incorporating multiple industrial sensors, local display, ESP32 IoT connectivity, GSM emergency notification, LoRa-based long-range control, and relay-actuated loads provides a useful practical direction.

2.7. Research Gap

Based on the reviewed literature, the following research gaps are identified:

1. RSSI is investigated in some LoRa communication studies, but it is not always continuously correlated with industrial sensing and control performance.
2. SNR is frequently used for link-quality analysis, but its relationship with actual monitoring reliability can be insufficiently demonstrated in practical systems.
3. Packet success/reception has been studied, but not always together with the complete industrial monitoring-control workflow.
4. Many systems concentrate on successful data reception rather than end-to-end delay relevant to control actions.
5. Some studies analyze LoRa radio energy or battery life, but complete node-level consumption may not be reported.
6. Reported LoRa range is strongly dependent on the test environment and propagation conditions.
7. Industrial machinery, metallic structures and electromagnetic interference can affect LoRa performance, but practical evaluations vary considerably by environment.
8. Several studies focus primarily on wireless sensing or network performance rather than a combined monitoring and control architecture.

Therefore, the principal research gap is the lack of a unified, experimentally validated LoRa-based industrial monitoring and control framework that simultaneously evaluates communication quality, reliability, latency, energy consumption and coverage under practical industrial conditions. Existing research provides valuable investigations of individual parameters such as RSSI, SNR, packet success, latency or energy efficiency, but there remains a need to integrate these metrics into a single practical system and establish their relationship with industrial monitoring and control performance. Recent work in industrial LoRa networks has increasingly evaluated combinations of PDR, RSSI, SNR, latency and energy consumption, demonstrating the relevance of multi-parameter evaluation; however, the results remain specific to particular hardware, protocols and deployment environments.

III. PROPOSED SYSTEM

3.1 Overall Architecture

The proposed system is divided into five major layers:

1. Sensing layer
2. Processing layer
3. Local display and alarm layer
4. Communication layer
5. Actuation/control layer

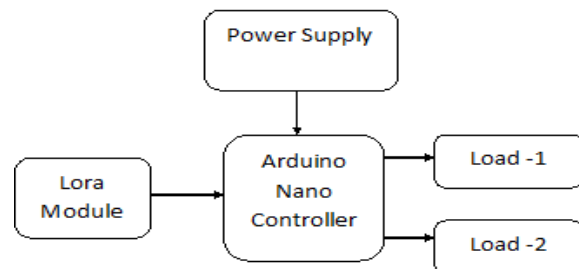


Fig.-2: Transmitter Block Diagram

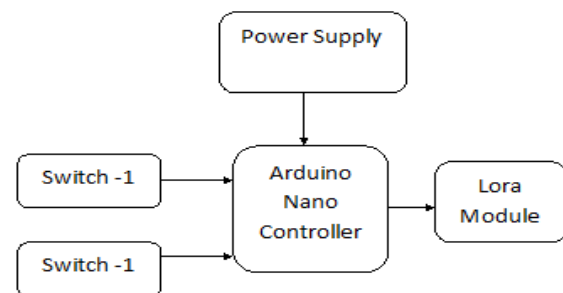


Fig.-3: Receiver Block Diagram

3.2 Hardware Design

3.2.1 ESP32 Controller

The ESP32 is used as the main processing unit. It receives signals from multiple sensors, processes measurements, displays values, connects to the IoT platform using Wi-Fi, communicates with the GSM module, and interfaces with the LoRa transmitter.

The ESP32 is suitable because it combines a microcontroller with Wi-Fi and Bluetooth connectivity and provides multiple digital, analog, UART, SPI, and I2C interfaces [3].

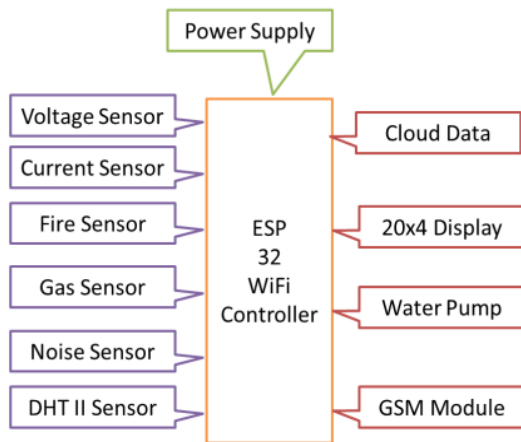


Fig.-4: System Design & Architecture

3.2.2 Industrial Sensors

The exact sensor selection can be modified according to the target industry. For an M.Tech implementation, industrial-grade sensors with appropriate isolation and signal conditioning should be preferred over hobby modules when measurements are connected to actual industrial equipment.

3.3. Iot Monitoring System

The ESP32 connects to a Wi-Fi network and transmits sensor information to an IoT platform.

Possible platforms include:

- ThingSpeak
- Blynk IoT
- MQTT broker
- Firebase
- Node-RED
- Custom web server

The cloud dashboard can display real-time and historical measurements. It can also provide threshold alarms and remote-control commands.

3.4. Gsm Text Message Alert

A GSM module can provide a second notification channel.

The GSM module can be connected to the ESP32 through a UART interface.

INDUSTRIAL ALERT

Temperature = 86.5 °C

Current = 12.8 A

Vibration = HIGH

Machine = M-01

Warning: Abnormal condition detected.

Another example:

INDUSTRIAL CONTROL ALERT

Load-2 switched OFF

Reason: Over-temperature

Temperature: 91.2 °C

The GSM function is particularly useful when the operator does not have continuous access to the IoT dashboard.

3.5. Lora Transmitter And Receiver

The proposed system uses two LoRa modules.

For a simple prototype, modules such as SX1276/SX1278-based LoRa transceivers can be used. For a formal LoRaWAN deployment, the architecture would instead include LoRaWAN end devices, gateway, network server, and application server.

It is important to distinguish between LoRa and LoRaWAN. LoRa is the radio/physical-layer technology, while LoRaWAN is a higher-level network protocol and architecture. The proposed hardware prototype can use direct LoRa transmitter-to-receiver communication without requiring a complete LoRaWAN infrastructure.

3.6. Expected System Operation

The proposed system is designed to operate as follows:

1. Sensors continuously measure industrial parameters.
2. ESP32 receives and processes the measurements.
3. Filtered values are displayed on the 20×4 LCD.
4. The ESP32 checks each parameter against predefined thresholds.
5. Normal measurements are periodically uploaded to the IoT platform.

6. Abnormal measurements generate an event.
7. The event is sent to the IoT platform.
8. GSM sends a text message to the authorized user.
9. A control command can be transmitted through LoRa.
10. The remote LoRa receiver activates/deactivates the corresponding relay.
11. The load status can be returned to the monitoring unit.
12. The operator can observe the complete system through the local display and IoT dashboard.

3.7. Advantages Of The Proposed System

The proposed architecture provides several advantages:

3.7.1 Long-Range Communication

LoRa can provide communication over significantly larger distances than conventional local wireless technologies under appropriate conditions.

3.7.2 Low Power Operation

LoRa is suitable for low-data-rate sensing nodes where battery life is important.

3.7.3 Multi-Parameter Monitoring

Multiple sensors can be connected to a single ESP32 controller.

3.7.4 Real-Time Local Monitoring

The LCD allows operators to observe measurements without requiring Internet access.

3.7.5 Cloud-Based Monitoring

IoT connectivity provides remote access to real-time and historical data.

3.7.6 GSM Backup Notification

SMS notification provides an additional alert path.

3.7.7 Remote Load Control

The LoRa receiver can operate remote relays and loads.

3.7.8 Expandability

Additional sensor nodes and LoRa receivers can be added depending on the network architecture.

IV. CONCLUSIONS

This paper reviewed the development of IoT-enabled industrial monitoring systems and the applicability of LoRa technology to distributed industrial sensing and control. The literature indicates that Industrial IoT requires reliable sensing, communication, processing, control, security, and data visualization rather than

isolated sensor monitoring. LoRa and LoRaWAN are attractive for industrial applications because they provide long-range communication with relatively low power requirements and comparatively simple infrastructure, although communication capacity, latency, interference, duty-cycle restrictions, and industrial propagation conditions must be considered. A combined architecture based on ESP32, multiple industrial sensors, local 20×4 LCD monitoring, Wi-Fi-based IoT communication, GSM text-message notification, and LoRa-based remote load control was proposed. The architecture separates high-level IoT monitoring from long-range local industrial communication and allows the same sensor information to be used for both monitoring and control. The proposed system can monitor parameters such as temperature, humidity, gas concentration, vibration, voltage, current, flame condition, pressure, and other industrial variables. When an abnormal condition is detected, the system can display the event locally, update the IoT platform, send an SMS notification, and transmit a control command through LoRa to a remote relay unit.

The reviewed research supports the suitability of LoRa for low-data-rate industrial monitoring, while ESP32 provides an economical and flexible embedded platform for sensor acquisition and IoT connectivity. Future research should concentrate on experimental evaluation of packet delivery ratio, received signal strength, communication range, latency, energy consumption, sensor accuracy, alarm response time, and relay-control reliability. Integration of machine learning, edge computing, LoRaWAN, energy harvesting, and enhanced cybersecurity can further improve the proposed system and make it suitable for larger Industry 4.0 deployments.

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