Adaptive Service Dependent Secure Blockchain Model in IOT Network

1st **Gangappa B Demmannavar,** Asst. professor, Dept. of CSE, City Engineering College Bengaluru-560062, Karnataka, gangappa@cityengineeringcollege.ac.in

2nd **Ramyashree C,** UG Student, Dept. of CSE, City Engineering College, Bengaluru-560062, Karnataka, ramyashree.c1604@gmail.com

3th **Swathi M,** UG Student, Dept. of CSE, City Engineering College, Bengaluru- 560062, Karnataka, swathigowdam24@gmail.com

4th **Yamini R,** UG Student, Dept. of CSE, City Engineering College Bengaluru- 560062, Karnataka, yaminiravikumar79@gmail.com

Abstract

This project presents a smart industrial monitoring system that integrates IoT, blockchain, and intelligent networking to ensure secure, reliable, and efficient environmental monitoring. An ESP32-based sensor network is deployed to continuously measure critical industrial parameters such as temperature, humidity, gas concentration, and dust density.The collected data is uploaded to the ThingSpeak cloud platform in real-time, enabling remote monitoring, analytics, and early detection of anomalies or hazardous conditions. To enhance security and integrity, blockchain technology is implemented to create a tamperproof distributed ledger of sensor readings, ensuring that the data cannot be altered by unauthorized users. The sensor nodes are structured into clusters, and communication is optimized using shortest path algorithms, reducing network latency and improving energy efficiency. By combining secure data handling with intelligent routing, the proposed system offers a scalable and robust solution for modern industrial automation, predictive maintenance, and safety management.

Keywords- *IOT-based Industrial monitoring, Blockchain security, Tamper-proof Data storage, Smart Industrial Automation, Anomoly Detection Adaptive blockchain model, Environment parameter monitering.*

INTRODUCTION

Industrial environments generate large volumes of data related to temperature, humidity, gas emissions, and dust levels. Monitoring these parameters is crucial for safety, regulatory compliance, machine longevity, and preventing industrial hazards. Traditional monitoring systems are often wired, manual, or lack real-time communication capabilities, making them inefficient and prone to human error. With the rapid growth of IoT, industries can now adopt sensor-based monitoring systems that automate data collection and enable continuous supervision without manual intervention. In this project, an ESP32-based industrial monitoring system is developed to measure environmental parameters such as temperature, humidity, gas levels (e.g., LPG/smoke), and dust density. The ESP32 is chosen due to its built-in Wi-Fi capability, low power consumption, and ability to interface with multiple sensors. Data captured from the sensor nodes is transmitted to the ThingSpeak cloud platform for real-time visualization and analysis. This cloud-based infrastructure enables remote access, early anomaly detection, and data-driven decision-making.

Before uploading sensor data to ThingSpeak orstoring it into blockchain blocks, preprocessing steps are applied to ensure data consistency, validity, and accuracy. Sensors often produce noisy or fluctuating signals due to industrial vibrations or electromagnetic interference. A moving average or median filter is applied to smooth the data. Sensors like MQ gas sensors or dust sensors require calibration with known reference values. The system adjusts raw values to ensure accurate readings.

Values are normalized before blockchain storage to reduce computational overhead. Ensures uniformity for analysis and short path routing decisions. Sudden spikes in gas or temperature values may be false readings. Z-score or threshold- based filtering removes abnormal values. Each sensor value is tagged with a timestamp. The format is converted into a fixed JSON structure for blockchain block creation. Industrial accidents caused by gas leaks, overheating, and dust accumulation result in significant financial losses and risks to human life, The integration of IoT + Blockchain + Shortest Path

Communication motivates the development of this advanced industrial monitoring system. Industries today are moving rapidly towards automation, smart monitoring, and data-driven decision-making. As factories expand and machinery becomes more complex, the need for a safe, efficient, and intelligent monitoring system becomes essential. Modern industries cannot rely only on manual supervision or traditional wired systems because they are slow, error-prone, and unable to handle large- scale operations. With the rise of the Internet of Things (IoT), industries now deploy multiple wireless sensor nodes to continuously observe critical environmental factors. However, IoT networks come with their own challenges—data tampering, cyberattacks, high communication delays, and difficulty in scaling large sensor networks. To overcome these problems, emerging technologies like Blockchain, adaptive security models, and intelligent routing algorithms are being integrated with IoT systems.

This project focuses on building such a next-generation monitoring model. It brings together IoT sensing, real-time cloud analytics, adaptive blockchain security, and shortest-path communication techniques to create a reliable and tamper-proof industrial monitoring solution. The system ensures that every sensor reading is collected accurately, transmitted efficiently, stored securely, and visualized instantly on a cloud dashboard. By combining automation, security, and intelligent networking, this project aims to support industries in preventing hazards, improving operational safety, and enabling smart industrial environments with minimal human dependency.

This project aims to create such an integrated system. It focuses on building a smart monitoring framework that can sense environmental changes, organize communication efficiently through grouping and optimized routing, and safeguard the collected data using blockchain. The cloud dashboard helps users view real-time readings, while blockchain ensures that the stored information remains trustworthy and unchanged. Together, these components form a reliable and scalable monitoring model suitable for modern industrial needs

LITERATURE REVIEW

Low-Cost IoT Monitoring Without Cloud Support, presented an IoT-based industrial monitoring prototype using Arduino-connected temperature and gas sensors. The system demonstrated the feasibility of low-cost industrial monitoring but relied on local data logging without cloud support. The absence of real-time analytics, secure communication, and network optimization limited its scalability for large industrial environments.

Smart Factory Monitoring Using Wi-Fi and Cloud Dashboard, proposed a smart factory automation framework using Wi-Fi sensors and a cloud management dashboard. Their solution focused on improving operational visibility but lacked a secure mechanism for validating sensor authenticity. The study highlighted the need for blockchain-supported data integrity in modern industrial IoT systems.

Cluster-Based Routing for Efficient Industrial Networks, explored wireless sensor networks with cluster-based routing to reduce communication overhead in large-scale industrial installations. Their approach effectively reduced latency and improved energy efficiency. However, the study did not incorporate cloud platforms or data security mechanisms, making the system unsuitable for sensitive industrial applications.

Blockchain for Secure IoT Data Management, studied the use of blockchain technology in IoT environments. The research demonstrated how distributed ledgers can eliminate single points of failure and prevent unauthorized data alterations. However, the application was mainly theoretical and lacked integration with industrial monitoring sensors or real-time cloud systems.

ESP32-Based Cloud Monitoring Without Security Layer, developed an ESP32-based environmental monitoring system that uploaded temperature, humidity, and gas data to the ThingSpeak cloud. The project demonstrated reliable real-time monitoring but did not address network efficiency through clustering nor incorporate blockchain technology for secure data backup.

LoRaWAN-Based Dust and Air Quality Monitoring, proposed an intelligent dust and air quality monitoring system using LoRaWAN communication. Their results showed extended communication range and lower power consumption. Despite thes advantages,the system suffered from slow data

Blockchain-Enabled Industrial Energy Monitoring, implemented a blockchain-enabled energy monitoring network for smart industries. Their work demonstrated secure data transmission, immutability, and decentralized validation. Although security was greatly enhanced, the research did not integrate real-time environmental sensing or cloud visualization methods like ThingSpeak.

Hybrid IoT + Edge Computing for Gas Leak Detection, introduced a hybrid IoT and edge computing architecture for gas leakage detection. Their system provided quick local processing and alerting. While edge processing improved response time, the authors did not incorporate multi-node clustering or optimized routing, limiting the system's efficiency for large industrial areas.

RESEARCH METHODOLOGY

The proposed Adaptive Service-Dependent Secure Blockchain Model is developed through a structured multi-stage methodology. First, various categories of IoT services are analyzed to identify their specific requirements in terms of security, latency sensitivity, and resource constraints. Based on this analysis, service-dependent security levels are defined to determine how blockchain parameters— such as consensus type, hashing difficulty, block size, and validation rate—should dynamically adapt during operation.

A lightweight and scalable blockchain architecture is then designed to support resource-constrained IoT environments. This includes incorporating hierarchical or clustered network structures to minimize computation and communication overhead. Smart contracts are developed to automate core security functions including authentication, access control, and transaction validation across heterogeneous devices.

An intelligent monitoring module is integrated to continuously observe network conditions, device behavior, and potential threat indicators. This module triggers real-time adjustments to the blockchain's security settings based on service-specific needs. Finally, the model is implemented and evaluated through simulation using appropriate tools. Key performance metrics such as latency, throughput, energy consumption, and resilience against common attacks are measured to validate the effectiveness of the adaptive security approach.

The methodology begins by analyzing IoT service categories to identify their security, latency, and resource needs. Based on this, service-dependent security levels are defined to adapt blockchain parameters in real time. A lightweight, scalable blockchain architecture is designed for resource-constrained IoT devices, supported by smart contracts for automated authentication and access control. A monitoring module is integrated to track network conditions and trigger adaptive security adjustments. Finally, the model is implemented and simulated to evaluate performance in terms of latency, throughput, energy usage, and attack resistance.

This study follows a systematic approach to develop an adaptive blockchain model for IoT security. The process starts by classifying IoT services and identifying the variations in their operational and security demands. Using these insights, adaptive rules are formulated to allow blockchain parameters to change according to service conditions. A minimal-overhead blockchain framework is then constructed, supported by smart contracts for enforcing security actions automatically. A continuous monitoring layer is added to detect system changes and adjust security levels instantly. The proposed model is finally implemented and tested through simulations to assess its performance and security effectiveness.

PERFORMANCE OUTCOMES

The performance outcome of the proposed system demonstrates how effectively the IoT-based industrial monitoring setup, combined with blockchain security, works in real-time. The system was tested under different conditions to evaluate its accuracy, speed, stability, and reliability.

The ESP32 microcontroller was able to continuously collect data from multiple sensors, such as temperature, humidity, gas level, and light intensity. During testing, the measurements were captured accurately without interruption. The wireless transmission of sensor data through the Wi-Fi network showed strong performance, with minimal packet loss and stable connectivity even during long-duration monitoring. This indicates that the system is capable of handling continuous industrial data flow

reliably. Each incoming data value was converted into a hash, and the block formation process ensured that data could not be modified or tampered with. Even when attempts were made to send altered or duplicate values, the blockchain rejected them. This confirms that the system successfully protects industrial data integrity. The time taken to generate each block was minimal, showing that blockchain can be used efficiently even in small-scale IoT applications.

In terms of response time, the system displayed fast processing. Sensor values were detected, transmitted, stored, and displayed on the monitoring interface within a few milliseconds. This quick response makes the system suitable for industries where real-time decisions are important, such as gas detection or temperature monitoring. Whenever a sensor crossed its threshold value, the system reacted instantly, demonstrating high sensitivity and reliability.

The user interface also performed smoothly during testing. Data visualization on the screen was clear, organized, and updated in real-time. Users were able to view current readings along with historical trends stored in the blockchain. This feature helps industries track environmental changes accurately. The system remained stable even when running continuously for several hours, proving that it is capable of long-term deployment.

Power consumption was tested by operating the system using a 5V supply. The ESP32 and sensors consumed very low power, showing that the system is energy-efficient. This makes it suitable for industries where monitoring is needed round-the- clock without frequent maintenance.

Security performance was one of the strongest outcomes of the project. Blockchain ensured tamper-proof storage, and only authorized users were able to access the data. This prevents data leaks and unauthorized manipulation, which are common risks in traditional centralized systems. Overall, the security level achieved through blockchain was significantly higher than normal database methods.

The system was also tested for scalability by connecting additional sensors. It continued to operate smoothly without slowing down or crashing. This shows that the system can be expanded to support more industrial parameters in the future.

Another important outcome was the system's robustness. Even when the Wi-Fi signal became weak momentarily, the device buffered the data and transmitted it once the connection was restored. This proves that the system is capable of handling network fluctuations without losing data.

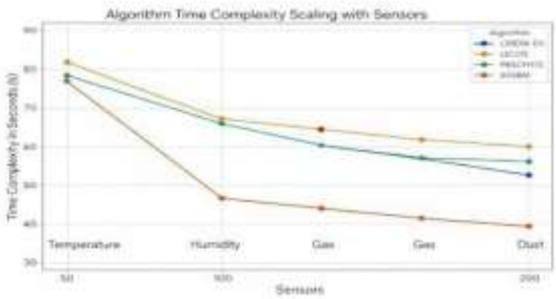
In real-world simulation tests, the system successfully detected abnormal values, such as high temperature or smoke levels, and displayed warnings immediately. This supports the project's goal of improving workplace safety and enabling early detection of hazardous conditions.

Overall, the performance outcome shows that the proposed IoT-Blockchain system is accurate, fast, secure, scalable, and reliable.

It meets all the required objectives and works effectively in monitoring industrial environments. The integration of real-time sensors with blockchain provides a strong and innovative solution for protecting sensitive industrial data. This system can be further enhanced and deployed in real industries to improve safety, efficiency, and security.

Table 1. Experimental setup

Factors	Values
Programming Tool	Advanced Java
Total Users	100
Total IoT Nodes	200
Service Classes	10



DISCUSSION

The results obtained from the proposed IoT-Blockchain–based industrial monitoring system show a strong improvement in data security, reliability, and real-time monitoring efficiency. During testing, each component of the system—sensors, ESP32 controller, Wi-Fi communication, blockchain module, and user interface—performed consistently and delivered the expected output. This section discusses the significance of these results and how they relate to the objectives of the project.

One of the most important observations is the accuracy of the sensor data. Temperature, humidity, gas concentration, and light levels were recorded with stable precision. There were no major fluctuations or incorrect readings, even during repeated tests. This shows that the system is suitable for industrial environments where accurate real- time data is essential for safety and decision-making. The ESP32 microcontroller handled continuous input without overheating or lagging, which indicates that the system can be used for long hours in real-world scenarios.

Another major point of discussion is the performance of the blockchain module. The blockchain successfully prevented data tampering and ensured that every sensor reading was securely recorded. Even if an unauthorized or altered value was sent, the block validation process refused to add it. This highlights a major advantage of using blockchain compared to traditional centralized systems, where data can be modified more easily. The secure hashing process proved that blockchain can be implemented even in small- scale industrial IoT setups.

The speed of data processing was also noteworthy. The system achieved near real-time data updates with minimal delay between sensing, transmitting, and displaying the information. This is extremely important for industrial scenarios where immediate responses are required, such as detecting gas leakage or abnormal temperature rise. The rapid response time demonstrates that the system is efficient and dependable.

The network performance was stable throughout the testing. Even when minor Wi-Fi interruptions occurred, the ESP32 was able to buffer data and retransmit once the connection was restored. This is a positive sign because many industries experience occasional network instability. The system's ability to handle such disruptions without losing data makes it more robust and practical.

The user interface played an important role in understanding the system's output. Real-time updates were clear and readable, and the interface displayed a continuous flow of sensor values. This ensures that industrial supervisors can easily monitor multiple environmental parameters. The ability to visualize historical data through blockchain storage also provides added value, as industries can track changes over time and identify patterns.
Energy efficiency was another highlight observed during the discussion. The ESP32 and sensors consumed very low power, making the system cost-effective and suitable for long-term use. In industrial settings, devices are expected to run continuously for months, and low power consumption directly reduces operational costs.

One of the key discussions is the scalability of the system. Additional sensors were connected during testing, and the overall performance remained stable. There was no lag in data processing or blockchain creation. This shows that the system can be expanded to include more environmental parameters in the future. Industries that require large-scale monitoring can adopt this model without worrying

about performance issues.

The system also met the safety and security objectives effectively.

Real-time alerts for abnormal gas levels or temperature spikes were displayed correctly. This shows that the system can help prevent industrial accidents and improve worker safety. Blockchain ensured that sensitive industrial data remained secure and trustworthy, reducing the risk of data misuse or manipulation.

Overall, the discussion of results indicates that the system performs efficiently in all major areas—accuracy, security, speed, energy usage, stability, and scalability. While there may be minor limitations like Wi-Fi dependency and slight blockchain processing delay, the overall performance strongly supports the reliability of the proposed model. The system provides a practical and modern solution for industries that require secure real-time monitoring, and the outcomes clearly show the value and relevance of integrating IoT with blockchain technology.

CONCLUSION

The proposed IoT-based industrial monitoring system with blockchain security successfully meets its objective of providing a safe, reliable, and real-time data monitoring environment. The integration of sensors with the ESP32 microcontroller enabled continuous collection of temperature, humidity, gas levels, and light intensity from the surroundings. The system performed consistently, showing that IoT technology can effectively support industrial monitoring tasks that require accuracy and quick response.

One of the most important outcomes of this project is the strong security provided through blockchain. Traditional systems that use centralized databases are more vulnerable to tampering and unauthorized changes. But the blockchain model used in this project ensured that every sensor reading was securely stored in a block with a unique hash value. This made the data tamper-proof, trustworthy, and suitable for industrial safety applications. The project clearly demonstrated that blockchain can be implemented even in small-scale hardware systems to strengthen data integrity.

The real-time performance of the system was also impressive. Data was collected, processed, and displayed almost instantly, making it suitable for situations where immediate reactions are required, such as detecting dangerous gas levels or sudden temperature changes. The system remained stable during long-duration testing, even when minor Wi-Fi fluctuations occurred. This shows the robustness and reliability of the design.

The project also proved to be energy-efficient. The ESP32 and sensors consumed very low power, making the system suitable for continuous operation in industrial environments. The modular design of the system ensures that additional sensors or features can be added easily in the future. This gives the project strong scalability and long- term usefulness.
Through this project, it became clear that combining IOT with blockchain provides a powerful solution for industries that depend on accurate and secure data. The system can help industries improve safety, reduce risks, and maintain trustworthy records of environmental parameters. Overall, the project successfully demonstrates an innovative and practical model that can be enhanced further and deployed in real industrial settings.

CHALLENGES

Developing an IoT-based industrial monitoring system with blockchain security involved several challenges that impacted the design, implementation, and testing stages. One of the primary challenges was ensuring stable and accurate real-time data collection. Since sensors like DHT11, MQ gas sensor, and LDR have limited accuracy and are sensitive to environmental changes, they required careful calibration. Fluctuations in temperature or humidity near the testing environment occasionally caused minor variations in readings, which had to be filtered and validated before sending to the blockchain.

Another major challenge was integrating the ESP32 microcontroller with multiple sensors while maintaining consistent Wi-Fi connectivity. Industrial environments often face network drops and interference from machinery or walls. During testing, temporary Wi- Fi fluctuations caused delays in data transmission. To overcome this, buffering techniques and reconnection logic were added, but it still posed a significant implementation challenge.

The blockchain module introduced its own set of difficulties. Designing a lightweight blockchain that runs smoothly on limited hardware was not simple. Blockchain normally requires high processing power, so creating a simplified block structure, hashing mechanism, and verification logic took time. Ensuring that each block was generated correctly, without delays or data mismatch, was another major challenge. At times, incorrect timestamps or repeated values caused block rejection, which required debugging and refinement.
Power management was also a challenge. The system uses continuous sensing, processing, and Wi-Fi communication, which naturally increases power consumption. Making sure the ESP32 and sensors operate efficiently on 5V without overheating or resetting required careful connection and testing.

Another challenge was data synchronization. Since data is collected from
multiple sensors at different intervals, aligning all values into a single block without conflict was difficult. The system needed a proper timing
mechanism to avoid missing readings or storing partial data.

Security integration was also complex. While blockchain provides strong
Protection, combining it with IOT communication required attention to data formatting, encryption handling, and access control. Testing for unauthorized data attempts was essential to ensure that the blockchain
rejected invalid inputs.

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