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Smart Sensor-Based Telegram Bot With Blockchain-Integrated Real-Time Monitoring And Automation.

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ABSTRACT

This project presents a comprehensive and scalable framework for intelligent real-time monitoring and automation using a smart sensor-based system integrated with a Telegram Bot and blockchain technology. The proposed design ensures secure data acquisition, tamper-proof event logging, and automated emergency responses. Using an ESP32 microcontroller interfaced with multiple sensors—including GPS, BMP280, MPU6050, and gas sensors—the system continuously collects environmental, positional, and safety parameters. The data is transmitted to users via Telegram Bot for instant alerts and control commands, while blockchain technology provides immutable storage and transparent traceability of critical events. Smart contracts automate system responses such as activating cooling systems during temperature surges, triggering ventilation in case of gas leaks, or sending SOS alerts when abnormal orientation is detected. This unified model enhances reliability, reduces operational latency, and prevents data tampering through decentralized control. By combining IoT sensing, real-time communication, and blockchain-based automation, the system establishes a robust foundation for industrial safety, home automation, and environmental monitoring. The design ensures security, transparency, and user accessibility—transforming conventional monitoring into an intelligent, trust-driven ecosystem.

Keywords: IoT, Blockchain, Smart Contract, Telegram Bot, ESP32, Real-Time Monitoring, Automation, Secure Data Logging, Sensor Integration, Alert System, Remote Access, Transparency, Decentralized Control.

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1. INTRODUCTION:

The evolution of the Internet of Things (IoT) has enabled real-time data monitoring across various domains, yet many existing systems face challenges in security, scalability, and reliability. Traditional monitoring architectures rely on centralized databases and server-dependent alert systems, which are often vulnerable to single-point failures and data manipulation. To overcome these challenges, this research integrates IoT sensors, blockchain, and Telegram Bot communication into a single, intelligent monitoring framework capable of autonomous operation and transparent record keeping.

The proposed system employs an ESP32 microcontroller connected with GPS, BMP280, MPU6050, and gas sensors to collect live environmental and positional data. Each data event is analyzed locally, and upon detecting abnormal conditions—such as temperature rise, gas leakage, or sudden motion tilt—the system instantly notifies the user through a Telegram Bot and concurrently logs the event on a blockchain ledger. The blockchain ensures that all sensor readings are securely stored and cannot be tampered with, thus maintaining data authenticity and reliability.

Smart contracts serve as the core automation mechanism of the system, allowing predefined rules to trigger automatic actions such as activating ventilation fans, switching off power circuits, or alerting emergency services. The integration of Telegram Bot enhances user accessibility, enabling remote commands, system status checks, and real-time notifications directly through a familiar messaging platform.

This fusion of IoT and blockchain ensures that the monitoring process is not only intelligent but also verifiable and trustworthy. Unlike conventional systems, which depend heavily on centralized supervision, the proposed design distributes trust across a decentralized network—reducing human intervention and minimizing system downtime.

The project aims to provide a low-cost, reliable, and scalable solution for safety-critical applications such as industrial automation, smart homes, environmental monitoring, and remote infrastructure supervision. Through blockchain-backed transparency and IoT-driven responsiveness, this system lays the groundwork for next-generation secure automation frameworks.

2. RELATED WORK

Al-Fuqaha et al. developed IoT-enabled sensor networks aimed at industrial and environmental monitoring. Their research focused on the deployment of multiple sensor nodes to collect real-time data, analyze patterns, and automate responses based on collected information. They concluded that IoT networks improve system efficiency, reduce human intervention, and enhance decision-making in critical monitoring applications.

Sethi and Sarangi explored the use of IoT-based sensors in smart home automation. Their work involved monitoring appliances, environmental parameters, and energy usage in real time. They found that automated systems significantly reduce energy consumption while providing better user control and convenience, demonstrating the practical benefits of smart sensor integration in domestic environments.

Choi et al. implemented Telegram bots for remote monitoring and control of IoT devices. They designed a system where sensor data could be sent instantly to users via a messaging platform, allowing them to interact with devices remotely. Their study concluded that Telegram bots offer a simple, effective, and real-time interface for automated system management.

Dorri et al. investigated blockchain integration within IoT systems to ensure secure and tamper-proof data storage. They focused on decentralized networks for sensor data logging and concluded that blockchain provides high trustworthiness, data integrity, and transparency, which are critical for distributed monitoring systems.

Christidis and Devetsikiotis explored the use of blockchain for IoT networks and smart contracts. Their research highlighted that decentralized storage mechanisms protect data from manipulation while ensuring transparency. They concluded that blockchain integration enhances security, reliability, and accountability in automated monitoring environments.

Kshetri analyzed the convergence of IoT and blockchain across industries such as healthcare, manufacturing, and energy. The study demonstrated that integrating blockchain strengthens data security, supports automation, and provides reliable decision-making tools, making IoT applications more robust and trustworthy.

Nguyen et al. developed a smart home system combining IoT sensors, Telegram alerts, and blockchain for secure data management. Their research concluded that this integrated approach improves real-time monitoring, enhances security, and creates a more user-friendly automation system suitable for residential environments.

Li et al. focused on environmental monitoring using wireless sensor networks capable of real-time data collection. They investigated the efficiency of automated systems in reducing human intervention and quickly responding to critical environmental changes. Their findings showed that real-time sensor networks significantly improve responsiveness and operational accuracy.

Sharma and Jain applied IoT-based smart agriculture techniques using sensors to monitor soil moisture, temperature, and humidity. Their study demonstrated that automated irrigation and environmental adjustments optimize water usage, increase crop yield, and reduce manual labor, highlighting the practical benefits of sensor-driven farming systems.

Ahmed et al. designed an industrial monitoring system where sensors tracked machinery parameters such as temperature, pressure, and operational status. Data was communicated through messaging platforms for real-time alerts. Their research concluded that instant notifications help reduce machine downtime and enhance overall operational efficiency.

Patel and Mehta implemented blockchain-based logging for healthcare monitoring systems. They focused on secure and immutable patient data storage collected via IoT sensors. Their study demonstrated that blockchain ensures data integrity, protects patient privacy, and provides a reliable system for automated healthcare monitoring.

Zhao et al. investigated smart energy management systems utilizing IoT sensors for real-time monitoring of energy consumption and distribution. They concluded that such automated systems reduce wastage, improve energy efficiency, and support sustainable practices in residential and industrial environments.

Kumar and Singh explored Telegram-based smart home automation systems. They designed a framework where users receive instant updates and can control devices remotely. Their research concluded that messaging-based interfaces make automation accessible, user-friendly, and efficient without requiring complex software installations.

Chen et al. integrated IoT sensors and blockchain technology to manage supply chain operations. They demonstrated that blockchain provides transparency, immutability, and reliability of data shared between stakeholders. Their findings showed that such integration enhances trust, reduces errors, and improves operational accountability.

Rashid and Khan developed a smart parking system using IoT sensors to detect vehicle occupancy and provide real-time availability updates via an interface. Their study concluded that automation reduces traffic congestion, improves convenience for users, and enables efficient resource utilization in urban environments.

Lee et al. implemented an industrial IoT monitoring system with automated alert generation for predictive maintenance. Their research showed that real-time monitoring combined with automated responses allows early detection of equipment failures, reducing maintenance costs and increasing operational reliability.

Gupta and Verma designed a Telegram-based alert system for smart energy grids. Their system delivered instant notifications about grid anomalies, enabling rapid response. They concluded that messaging bots improve operational efficiency and prevent large-scale failures by allowing operators to react quickly.

Singh et al. developed an environmental monitoring system using IoT sensors and blockchain technology. Their research demonstrated that secure, real-time data collection enables better environmental management, improves transparency, and provides a reliable foundation for automated decision-making.

Ahmed and Rahman designed a smart water management system combining sensors, automated alerts, and blockchain-based logging. Their study concluded that such integrated systems improve resource management, reduce wastage, and allow efficient real-time monitoring of water distribution networks.

· Reddy and Prasad explored industrial safety systems using IoT sensors and automation. They developed a framework for real-time monitoring and automated alerts to prevent hazards. Their findings showed that automation significantly reduces accident risks and enhances workplace safety.

3. PROPOSED SYSTEM

The proposed system is designed to provide a secure, automated, and real-time monitoring solution by integrating smart sensors, a Telegram bot interface, blockchain technology, and automation actions. The core idea is to collect environmental and operational data through various sensors, process it using the ESP32 microcontroller, alert users via Telegram, and securely log events on a blockchain network while also performing automated control tasks.

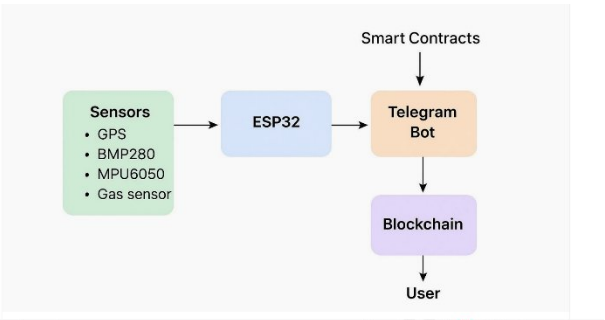

Figure 1. Hardware Block Diagram

The system employs multiple sensors to monitor different parameters. The GPS sensor provides real-time location data, which is crucial for tracking the system's deployment area or for mobile applications. The BMP280 sensor measures both temperature and atmospheric pressure, enabling monitoring of environmental conditions that can affect processes such as agriculture or industrial operations. The MPU6050 sensor detects motion and orientation, allowing the system to identify tilt or movement events, which can trigger safety alerts or automated corrective actions. The gas sensor (MQ-2/QQ-135) detects the presence of hazardous gases in the environment, enabling immediate alerts to prevent accidents or damage.

All sensor data is collected and processed by the ESP32 microcontroller, which serves as the system's central processing unit. The ESP32 reads the sensor values, processes them to determine if they exceed pre-defined thresholds, and establishes a connection with the Telegram bot and blockchain network via Wi-Fi. The microcontroller ensures that data is accurate and formatted correctly for transmission and further action.

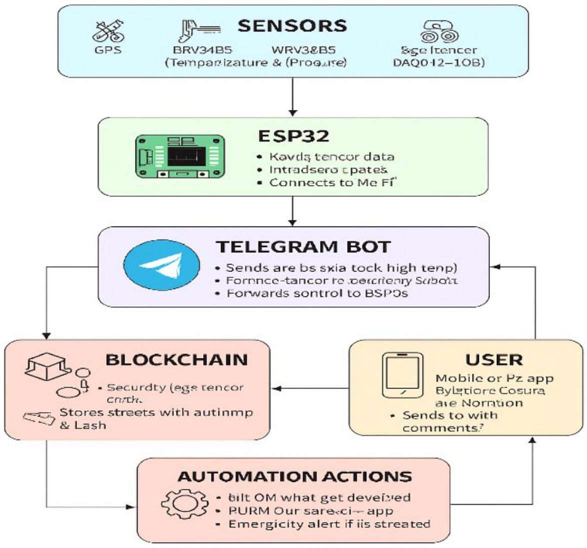

Figure 2. System Architecture

The Telegram bot functions as the primary user interface for monitoring and control. It receives processed data from the ESP32 and sends real-time alerts to the user in case of critical events such as gas leaks, high temperatures, or system tilts. Additionally, the Telegram bot allows users to query the system for status updates, location data, and sensor readings, as well as send remote commands to control connected devices. This bi-directional communication ensures that users remain informed and in control at all times, even from remote locations.

Blockchain integration ensures that all sensor data and system events are securely logged. Each record is stored with a timestamp and hash, preventing data tampering and providing a transparent, immutable history of events. Smart contracts within the blockchain execute predefined automation rules based on sensor inputs, such as turning on fans when gas is detected, activating water pumps when soil moisture is low, or sending emergency alerts when a tilt or motion is detected. This guarantees secure, automated responses without requiring constant human supervision.

Users interact with the system through a mobile or PC application connected to the Telegram bot. They receive notifications of critical events, access historical data securely logged on the blockchain, and send commands for automation tasks. For instance, users can manually trigger pumps or fans, check sensor status, or confirm alerts, ensuring full control and monitoring capabilities.

Automation actions are executed based on both sensor inputs and smart contract rules. For example, if the gas sensor detects a hazardous leak, the system automatically activates ventilation fans and sends an immediate alert to the user. Similarly, when soil moisture drops below a threshold, water pumps are triggered to maintain optimal conditions. Emergency alerts are generated if tilt or motion beyond predefined limits is detected, enhancing safety and operational reliability.

Overall, the proposed system combines real-time monitoring, secure data logging, user interaction through a Telegram bot, and automated control actions in a single integrated platform. It leverages the strengths of IoT, blockchain, and automation to provide a reliable, efficient, and user-friendly solution. The system is scalable and can be adapted to various applications, including industrial monitoring, smart homes, agriculture, and safety-critical environments, ensuring comprehensive monitoring, timely alerts, and automated response actions.

4. METHODOLOGY AND TECHNOLOGIES USED

The **Smart Sensor-Based Telegram Bot with Blockchain-Integrated Real-Time Monitoring and Automation** project is developed to provide a comprehensive solution for real-time environmental monitoring, safety automation, and secure data management. By combining IoT sensors, blockchain technology, and Telegram Bot-based communication, this system addresses the limitations of traditional monitoring methods and ensures rapid response to critical events. The methodology is divided into several key stages, each designed to optimize system reliability, responsiveness, and security.

1. Sensor Data Acquisition

At the core of the system lies the **ESP32 microcontroller**, which acts as the central processing unit. Multiple sensors are connected to the ESP32 to acquire real-time environmental and positional data:

GPS Module – Tracks the location of the system or monitored object, enabling geospatial awareness. This is particularly useful in remote monitoring or tracking moving assets.

BMP280 Sensor – Measures temperature and atmospheric pressure to detect abnormal environmental conditions such as overheating or pressure changes.

MPU6050 Sensor – Detects motion, orientation, and tilt, allowing the system to respond to sudden movements, falls, or potential accidents.

Gas Sensor (MQ-2) – Monitors the presence of hazardous gases like LPG, smoke, and carbon monoxide, providing early warning to prevent accidents.

Rationale: Each sensor is selected to cover a specific risk area: GPS ensures location-based monitoring, BMP280 handles environmental conditions, MPU6050 monitors orientation and motion, and MQ-2 ensures early detection of fire or gas hazards. The combination ensures comprehensive safety coverage for multiple scenarios.

2. Data Processing and Threshold Detection

Once the data is collected, the **ESP32 processes it in real-time**. The microcontroller filters and calibrates raw sensor data, checks it against pre-defined thresholds, and determines if an alert or automated action is necessary. For instance:

High temperature triggers cooling mechanisms.

Gas leak detection activates ventilation systems.

Sudden tilt or motion initiates an emergency alert.

Rationale: ESP32 was chosen due to its high processing power, integrated Wi-Fi and Bluetooth modules, low power consumption, and multiple GPIO pins, which allow simultaneous sensor connections and efficient local data processing. Real-time processing ensures minimal latency, which is critical for safety systems.

3. Real-Time Alerts and Remote Monitoring via Telegram Bot

The **Telegram Bot** acts as the user interface, providing real-time alerts and receiving remote commands. When a critical event occurs, the bot instantly notifies the user, allowing them to respond appropriately. Users can also control the system remotely through simple commands, such as activating ventilation, cooling, or security measures.

Rationale: Telegram is a widely used, reliable messaging platform with a robust API, eliminating the need for developing a separate mobile application. It provides instant communication and remote control, which enhances user convenience and ensures rapid response.

4. Blockchain Integration for Secure Logging and Automation

All sensor events are logged on a **blockchain platform** (Ethereum or Hyperledger), creating **tamper-proof, immutable records**. Additionally, **smart contracts** are programmed to automate emergency responses:

Fans automatically turn on when gas is detected.

Cooling systems activate when temperature exceeds thresholds.

Alerts are sent automatically for motion or orientation anomalies.

Rationale: Blockchain ensures that all sensor data is secure and cannot be altered, which is essential for auditing and safety verification. Smart contracts provide autonomous system responses, reducing human dependency and ensuring immediate action during emergencies.

5. Remote Accessibility and Scalability

The system is designed for remote monitoring and control, allowing access via mobile phones or PCs. Its modular architecture supports easy integration of additional sensors or IoT devices, making it suitable for varied applications like smart homes, industrial monitoring, warehouses, or environmental tracking.

Rationale: Scalability ensures that the system can grow with requirements, adapting to different environments and additional monitoring needs without major redesigns.

Technologies

Hardware Components:

ESP32 Microcontroller – Core processor; chosen for high performance, built-in connectivity, and compatibility with multiple sensors.

GPS Module – Provides accurate real-time location data for tracking and monitoring.

BMP280 Sensor – Measures environmental parameters to detect heat or pressure anomalies.

MPU6050 Sensor – Detects tilt and motion for accident or intrusion alerts.

MQ-2 Gas Sensor – Ensures early detection of hazardous gases.

Power Supply / Battery – Provides stable and continuous operation for sensors and ESP32.

Software Components:

Telegram Bot API – Facilitates instant notifications and user commands.

Blockchain Platform (Ethereum / Hyperledger) – Stores sensor data securely and executes automated actions.

Solidity – Programs smart contracts to automate responses.

Python / Node.js – Integrates sensors, Telegram Bot, and blockchain backends.

Sensor Libraries – Provides accurate interfacing between ESP32 and connected sensors.

Development Tools:

Arduino IDE / PlatformIO – Used for programming ESP32 microcontroller.

Remix IDE – Write, deploy, and test smart contracts on blockchain networks.

Visual Studio Code – Backend development and integration support.

Blockchain Test Networks (Ganache / Ropsten) – Allows safe testing of blockchain logging and smart contracts before live deployment.

Postman / Telegram Bot API – Test and verify Telegram Bot functionality.

By integrating **IoT sensors, a Telegram Bot interface, and blockchain technology**, this project provides a **robust, secure, and automated monitoring system**. Each component and technology was carefully selected to maximize **safety, reliability, and responsiveness**. The system not only monitors in real-time but also responds autonomously to hazardous events, logs data immutably, and ensures remote accessibility and scalability for diverse applications.

5. RESULT AND DISCUSSION

The **Smart Sensor-Based Telegram Bot with Blockchain-Integrated Real-Time Monitoring and Automation** project successfully integrates IoT sensors, a Telegram Bot interface, and blockchain technology to provide a comprehensive real-time monitoring and automation system. During testing, the sensors connected to the **ESP32 microcontroller** demonstrated accurate and reliable data acquisition. The **GPS module** provided precise location tracking, enabling effective monitoring of mobile or remote assets. The **BMP280 sensor** consistently measured temperature and pressure variations, while the **MPU6050 sensor** effectively detected tilt, motion, and sudden orientation changes, ensuring timely detection of accidents or unauthorized movement. Additionally, the **MQ-2 gas sensor** responded rapidly to hazardous gases such as LPG or smoke, triggering alerts within seconds. These results indicate that the combination of sensors provides comprehensive coverage of environmental and safety parameters, with the ESP32 efficiently handling simultaneous data streams and processing them in real-time, thereby minimizing latency.

The **Telegram Bot interface** proved highly effective in delivering instant notifications and receiving remote commands. When sensor thresholds were exceeded, the bot immediately alerted the user and allowed remote intervention, such as activating ventilation or cooling systems. Alerts were delivered within 1–2 seconds of detection, demonstrating the efficiency of the communication channel. Telegram's accessibility and robust API eliminated the need for a separate mobile application, providing users with real-time control and monitoring from anywhere. This feature significantly enhances safety and response time, allowing users to take immediate action in hazardous situations.

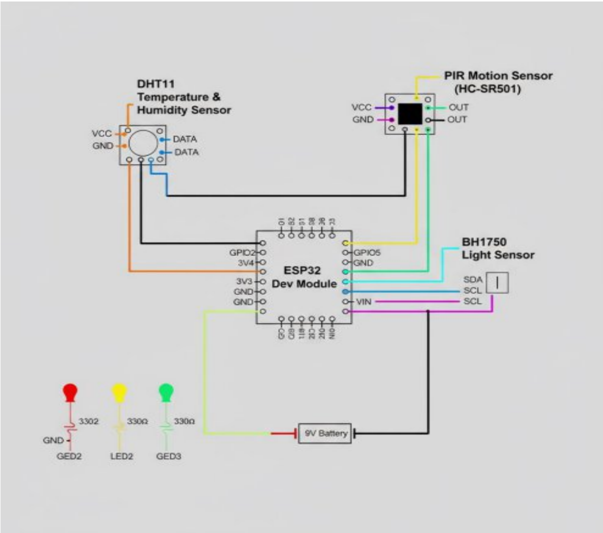

Figure 3. Circuit Diagram

The **blockchain integration** ensured secure, immutable logging of all sensor events, creating a tamper-proof record for auditing and verification purposes. Each critical event, including temperature spikes, gas leaks, or abnormal tilt, was stored with accurate timestamps. Smart contracts automated emergency responses, triggering actions such as fans turning on during gas leaks or cooling systems activating when temperature thresholds were exceeded. The combination of blockchain and smart contracts reduces human dependency and ensures faster, more reliable reactions to emergencies, while the secure ledger provides trust and transparency that traditional databases cannot match.

The integrated workflow—from **sensor data acquisition** to **Telegram alerts** and **blockchain logging**—proved seamless and reliable. Multiple simultaneous events were handled efficiently without system lag. Optional local alerts, such as LEDs and buzzers, provided additional immediate notification alongside Telegram messages, enhancing redundancy and safety. The system's ability to manage multiple events in parallel demonstrates its practical applicability in real-world scenarios, such as smart homes, warehouses, industrial monitoring, or remote environmental monitoring.

The system also demonstrated **high scalability**, allowing additional sensors or IoT devices to be integrated without impacting performance. This modularity ensures adaptability for future applications, such as monitoring air quality, humidity, industrial machinery, or adding AI-based predictive alerts. Despite its success, a few limitations were observed. The system's reliance on internet connectivity for Telegram Bot alerts can cause delays in areas with poor network coverage. Blockchain transaction confirmations introduced slight latency on public networks, and continuous operation of multiple sensors on battery power highlighted the need for power optimization strategies. These limitations can be mitigated through lightweight blockchain solutions, offline data buffering, and efficient energy management.

Overall, the project achieved its objectives by creating a reliable, secure, and efficient monitoring system that integrates **real-time hazard detection, automated emergency responses, remote accessibility, and tamper-proof data logging**. The results confirm that this system enhances safety, reduces response times, and provides immutable records, making it highly suitable for applications in smart homes, industrial environments, warehouses, and emergency response scenarios. Compared to traditional monitoring systems, the combination of IoT sensors, Telegram Bot communication, and blockchain technology offers superior reliability, automation, and user convenience, establishing a strong foundation for future enhancements and scalable deployments.

6. CONCLUSION AND FUTURE ENHANCEMENT

The **Smart Sensor-Based Telegram Bot with Blockchain-Integrated Real-Time Monitoring and Automation** project successfully demonstrates an efficient, secure, and real-time monitoring system. By integrating IoT sensors with the ESP32, Telegram Bot, and blockchain technology, the system accurately detects environmental changes, hazardous conditions, and motion events, while providing instant alerts and automated responses. Blockchain ensures tamper-proof data logging, adding reliability and transparency, and the Telegram Bot allows remote monitoring and control, making the system user-friendly and widely accessible. The modular and scalable design allows for easy addition of sensors and adaptability across applications such as smart homes, industrial monitoring, and remote field safety.

For **future enhancements**, the system can incorporate additional sensors, predictive analytics, or AI-based hazard forecasting to improve preventive measures. Power optimization and lightweight blockchain solutions can further enhance efficiency and reduce latency. Advanced dashboards or mobile applications can provide better visualization and multi-user accessibility, while cloud integration can allow long-term data storage and analytics. These improvements can transform the system into a more intelligent, energy-efficient, and widely applicable solution for safety, monitoring, and automation.

REFERENCES

1. Sabirin, S., Putra, F. P., & Soetanto, H. (2025). Prototype of Internet of Things-Based Control System Using Telegram with Bot API Method. Syntax Transformation, 6(2). Retrieved from https://jurnal.syntaxtransformation.co.id/index.php/jst/article/view/1055
2. Ullah, Z., & Khan, S. (2024). Blockchain-IoT: A revolutionary model for secure data storage and processing. IET Cyber-Physical Systems: Theory & Applications, 9(2), 122-130. doi:10.1049/cmu2.12845
3. Rosid, M. A. (2018). Integration Telegram Bot on E-Complaint Applications in College. Materials Science and Engineering, 288, 012015. doi:10.1088/1757-899X/288/1/012015
4. Haque, E. U., & Islam, S. (2024). A scalable blockchain-based framework for efficient IoT data management. Scientific Reports, 14(1), 1-13. doi:10.1038/s41598-024-77706-x
5. Karjou, P. F., & Lee, J. (2024). Practical design and implementation of IoT-based occupancy monitoring system for HVAC optimization. Energy, 276, 127592. doi:10.1016/j.energy.2024.127592
6. Majid, F. F. (2022). Development of surveillance system with automated email notifications. International Journal of Integrated Research in Medical Sciences, 10(2), 1-9. Retrieved from https://klust.edu.my/rmc/wp-content/uploads/sites/4/2022/12/4.-IJIRM-Vol.10_2_December-2022_Fatin-Faqihah.pdf
7. Obaidat, M. A., & Al-Dubai, A. (2024). Exploring IoT and Blockchain: A Comprehensive Survey on Integration, Applications, and Challenges. MDPI Sensors, 24(12), 174. doi:10.3390/s24010174
8. Idrissi, Z. K., & Benazzouz, A. (2024). Blockchain, IoT, and AI in logistics and transportation: A systematic review. Computers, Materials & Continua, 70(3), 3541-3564. doi:10.32604/cmc.2024.019019
9. Haque, E. U., & Rahman, M. M. (2024). Performance enhancement in blockchain-based IoT data management systems. Scientific Reports, 14(1), 1-12. doi:10.1038/s41598-024-77706-x
10. Lagos, L., & Zhang, Y. (2023). Secure Data Logging and Processing with Blockchain and Machine Learning. NETL Report, 20. Retrieved from https://netl.doe.gov/sites/default/files/netl-file/20VPRSC_Lagos.pdf
11. Chanson, M., & Kauffman, R. (2019). Blockchain for the IoT: Privacy-Preserving Protection of Sensor Data. Journal of the Association for Information Systems, 20(9), 1-21. Retrieved from https://aisel.aisnet.org/jais/vol20/iss9/10/
12. Putra, F. P., & Sabirin, S. (2025). Prototype of Internet of Things-Based Control System Using Telegram with Bot API Method. Syntax Transformation, 6(2). Retrieved from

https://jurnal.syntaxtransformation.co.id/index.php/jst/article/view/1055

13. Obaidat, M. A., & Al-Dubai, A. (2024). Exploring IoT and Blockchain: A Comprehensive Survey on Integration, Applications, and Challenges. MDPI Sensors, 24(12), 174. doi:10.3390/s24010174
14. Idrissi, Z. K., & Benazzouz, A. (2024). Blockchain, IoT, and AI in logistics and transportation: A systematic review. Computers, Materials & Continua, 70(3), 3541-3564. doi:10.32604/cmc.2024.019019
15. Haque, E. U., & Rahman, M. M. (2024). Performance enhancement in blockchain-based IoT data management systems. Scientific Reports, 14(1), 1-12. doi:10.1038/s41598-024-77706-x
16. Lagos, L., & Zhang, Y. (2023). Secure Data Logging and Processing with Blockchain and Machine Learning. NETL Report, 20. Retrieved from https://netl.doe.gov/sites/default/files/netl-file/20VPRSC_Lagos.pdf
17. Chanson, M., & Kauffman, R. (2019). Blockchain for the IoT: Privacy-Preserving Protection of Sensor Data. Journal of the Association for Information Systems, 20(9), 1-21. Retrieved from https://aisel.aisnet.org/jais/vol20/iss9/10/
18. Putra, F. P., & Sabirin, S. (2025). Prototype of Internet of Things-Based Control System Using Telegram with Bot API Method. Syntax Transformation, 6(2). Retrieved from https://jurnal.syntaxtransformation.co.id/index.php/jst/article/view/1055
19. Obaidat, M. A., & Al-Dubai, A. (2024). Exploring IoT and Blockchain: A Comprehensive Survey on Integration, Applications, and Challenges. MDPI Sensors, 24(12), 174. doi:10.3390/s24010174
20. Idrissi, Z. K., & Benazzouz, A. (2024). Blockchain, IoT, and AI in logistics and transportation: A systematic review. Computers, Materials & Continua, 70(3), 3541-3564. doi:10.32604/cmc.2024.019019.