Journal of Engineering for THERMAL ENERGY AND POWER

ISSN: 1001-2060
Vol. 23 No. 1, 2020

BLOCKCHAIN-ENABLED SECURE COMMUNICATION IN INDUSTRIAL IOT

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Received: 05/01/2020
Revised: 19/02/2020
Accepted: 22/03/2020

DOI:
10.12060/jet-ep-v23.i1-1

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Abstract

Industrial Internet of Things (IIoT) systems are transforming manufacturing, energy, and infrastructure sectors by integrating sensing, automation, and data analytics. However, the increasing connectivity and scale of IIoT devices amplify security concerns—especially for secure communication, authentication, and data integrity. Blockchain technology has emerged as a promising solution by providing decentralized trust, tamper-proof data storage, and secure communication mechanisms. This paper explores blockchain-enabled secure communication in IIoT environments, analyzes current architectural approaches, proposes a secure framework leveraging private blockchain and smart contracts, and evaluates the outcomes in terms of data integrity, latency, and resilience. The findings demonstrate that blockchain integration enhances security without compromising performance, paving the way for resilient industrial networks.

Keyword: Industrial IoT, blockchain, secure communication, decentralization, smart contracts, data integrity

1. INTRODUCTION

Industrial IoT (IIoT) systems consist of interconnected sensors, actuators, and control devices that facilitate automation and real-time monitoring in industrial environments. While these systems improve operational efficiency, they also expose critical assets to advanced cybersecurity threats due to distributed network topology and limited built-in security of IoT devices. Traditional centralized security models are often insufficient, as they create single points of failure and lack transparency. Blockchain, with its decentralized and immutable ledger, offers a mechanism to secure communication across IIoT nodes by ensuring data integrity, authentication, and traceability. Such features are critical in industrial scenarios where unauthorized access, data tampering, or service disruption can result in severe physical and financial consequences.

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2. LITERATURE REVIEW

2.1 IIoT Security Challenges

IIoT devices often suffer from resource constraints, heterogeneous protocols, and lack of unified security standards, which make them vulnerable to attacks such as man-in-the-middle (MITM), replay attacks, and unauthorized access. These challenges necessitate robust communication security models tailored to decentralized environments.

2.2 Blockchain for Secure Communication

Blockchain provides decentralized trust and cryptographic integrity through distributed ledgers and consensus mechanisms. It can authenticate devices, record immutable transactions, and manage secure communication channels across IIoT networks. Prior work has shown that blockchain can improve data integrity and access control in IoT infrastructures.

2.3 Application of Blockchain in IIoT

Recent research presents blockchain-based architectures tailored for IIoT, emphasizing enhanced security, lightweight consensus, and scalability. Examples include private blockchain systems regulating sensor and actuator data access, and smart contract-enabled platforms for secure machine-to-machine communication.

2.4 Secure Communication Frameworks

Several frameworks have been proposed combining blockchain with cryptographic methods, such as proof of authentication and smart contract enforcement mechanisms, to secure communication, preserve integrity, and facilitate distributed trust across IIoT nodes.

3. METHODOLOGY

3.1 Objective

The primary objective is to design and evaluate a blockchain-enabled secure communication framework for IIoT systems that:

- Ensures tamper-proof data exchange among devices
- Provides authentication and trust without centralized authority
- Maintains acceptable communication latency and energy efficiency

3.2 System Architecture

The proposed architecture consists of:

- **IIoT Devices:** Sensor and actuator nodes generating data
- **Private Blockchain Network:** Governs transactions and stores hashed records
- **Smart Contracts:** Encode communication policies and access control
- **Consensus Mechanism:** Proof of Authority (PoA) optimized for resource-constrained devices

Data transmissions are wrapped into blockchain transactions where device credentials and message hashes are recorded on the ledger for auditability.

3.3 Security Processes

1. **Device Authentication:** Nodes register with blockchain using cryptographic signatures
2. **Message Transmission:** Sensor data is signed and hashed
3. **Verification:** Each transaction broadcast is verified by peer validators
4. **Smart Contract Enforcement:** Access policies are automatically enforced

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4. PROCESS

4.1 Data Flow

Data from sensors are encrypted and broadcast to a consortium blockchain network. Validators confirm message integrity using smart contract logic. Once consensus is reached, the transaction is added to the ledger and logged for future verification.

4.2 Smart Contract Execution

Smart contracts govern security policies such as access rights and enforce communication rules. For example, only authenticated devices with valid digital certificates can broadcast sensor updates.

4.3 Consensus and Verification

Proof of Authority (PoA) consensus helps minimize computational overhead while maintaining a secure approval mechanism that scales well for private IIoT networks.

5. RESULTS

5.1 Security Outcomes

- **Data Integrity:** Tamper-proof record of messages prevents unauthorized alteration
- **Authentication:** Only registered devices could communicate successfully
- **Traceability:** Every transaction is logged on the blockchain for audit trails

5.2 Performance Evaluation

Comparative analysis showed:

- **Latency:** Slightly higher than centralized methods but within acceptable limits
- **Throughput:** Compatible with large IIoT deployments due to lightweight consensus

5.3 Resilience

The decentralized nature of the blockchain network eliminated single points of failure, increasing fault tolerance of communication channels.

6. CONCLUSION

Blockchain technology significantly enhances the security of communication in Industrial IoT environments by enabling decentralized authentication, tamper-proof message records, and trustless interactions among devices. The proposed framework demonstrates that blockchain can be integrated with existing IIoT infrastructures without prohibitive performance costs. Future research should explore hybrid consensus models and standardization efforts for broader industrial applicability.

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