Decentralized Blockchain-Based Access Control and Database Management for IoT Security

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Abstract

This paper explores blockchain technology's role in bolstering access control security within IoT devices and systems. It demonstrates the security benefits of applying blockchain in IoT systems for access control, comparing it with the current approach. The potential advantages and challenges of using blockchain for access control and database management in IoT networks and devices are thoroughly reviewed. Additionally, we employ a secure database management system to store and manage access control policies. This ensures the integrity and confidentiality of IoT data, emphasizing a robust foundation for safeguarding sensitive information within IoT environments.

1. Introduction

The Internet of Things (IoT) expansion has created a network containing many interconnected devices and systems. IoT devices collect sensitive data and manage critical systems. The increasing number of interconnected devices has made the security of the IoT network a significant concern. Weaknesses in security protocols can make IoT devices more vulnerable to cyberattacks. Over the past few years, blockchain technology has been used to reduce risks and security breaches of IoT systems. Blockchain technology takes a decentralized approach to provide security and transparency to control access. The security required for IoT networks and devices can be enhanced by blockchain technology, providing a solution that does not rely on a central authority and contains mechanisms that maintain security, help in setting access control policies, and provide an accurate and clear track of all access attempts.

This paper is organized as follows: Section II provides related work, which focuses specifically on blockchain technology for IoT security. Section III presents the proposed blockchain-based decentralized access control solution for IoT security using a motivating example to show its effectiveness. Section IV presents a threat model showing the information that affects the Blockchain and IoT network. Section V discusses the research hypothesis and empirical evidence supporting the hypothesis of enhancing the security of IoT systems using blockchain-based access control. Moreover, Section VI synthesizes the research findings, encapsulating key insights, and outlines avenues for future exploration and development in the realm of blockchain and IoT security. Finally, Section VII summarizes the research with its findings and suggests future work in the blockchain and IoT security field.

2. Related Research

In recent years, several research papers have explored integrating blockchain technology into access control mechanisms for enhancing the Internet of Things (IoT) security. This section reviews these research papers, discussing their findings and contributions while highlighting how our approach builds upon and addresses certain limitations identified in the existing literature.

Zaidi and his colleagues proposed an attribute-based access control system for IoT using blockchain and smart contracts [1]. Their work leveraged blockchain technology to establish a secure and efficient access control mechanism to store access control policies. However, the research did not comprehensively address the scalability issues associated with blockchain technology.

In contrast to Zaidi et al.'s approach, our method addresses the scalability problem by combining blockchain-based access control mechanisms with database management. This innovative combination not only ensures secure access control but also offers a solution to scalability, thereby contributing to the reliability of IoT systems.

Li and his team presented a blockchain-based system to preserve privacy while rewarding private data sharing in IoT [2]. Their work focused on data privacy, particularly in the context of private data sharing within IoT networks. However, it did not emphasize access control.

In contrast to Li et al.'s method, our approach prioritizes data privacy in IoT systems by implementing a private blockchain and integrating it with a robust database management system. This, in turn, addresses privacy concerns while simultaneously providing a robust access control mechanism.

Yu and his collaborators proposed a system that enables attribute revocation for fine-grained access control in blockchain-IoT systems [3]. Their research

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aimed to enhance access control through attribute-based mechanisms, but it did not sufficiently address the issue of data privacy.

In contrast, our approach takes a holistic approach to IoT security. By combining blockchain-based access control with database management, we ensure fine-grained access control and address data privacy concerns using private blockchain and database management. This integrated system guarantees that only authorized users can access data, enhancing the security and privacy of IoT networks.

Charles et al. [4] discussed that when using blockchain technology in healthcare, health transactions, and data will be secure, which can lead to the development of new solutions in healthcare.

Our approach distinguishes itself from previous research by offering a comprehensive and secure access control mechanism that overcomes traditional access control limitations and scalability issues. By addressing privacy concerns and providing robust access control, our method contributes to developing more secure, reliable, and transparent IoT networks and systems.

3. Motivating Example

The increasing number of interconnected devices across the Internet has increased security risks. These devices became vulnerable to various types of attacks and security breaches. However, traditional security solutions are no longer sufficient for security and protection. Therefore, various mechanisms are being developed, including blockchain-based access control mechanisms and database management. Using the blockchain mechanism for access control and database management enhances the security of IoT systems and data and provides a decentralized solution characterized by accuracy, transparency, and reliability.

Healthcare is an example of the effectiveness of a blockchain-based access control mechanism and database management system. The authors in [4] have argued that blockchain technology provides a secure and transparent environment for securing and managing patient data and policies to control access and data sharing. This research has obtained funding to create and develop a platform that manages healthcare data based on blockchain technology.

4. Threat Model

Accessing sensitive data and systems is one objective of the IoT attack. Therefore, it is necessary to understand and identify devices in the IoT network and understand how communication between devices occurs and how information is transmitted and stored.

When the IoT network is understood, the assets that need to be protected can be identified. This includes sensitive data, devices, applications, and communication channels for data transmission. Identifying these assets will help develop access control policies that ensure that only authorized users and devices have access, protecting the IoT system and network.

Access control is an essential component of IoT security. Implementing robust access control strategies and developing access control policies are effective when studying anticipating attackers and possible types of attacks on the system, as well as an assessment of the likelihood of an attack. This study includes identifying security threats and vulnerabilities in the network, so access control strategies, and policies will be developed specifically for each of the threats and vulnerabilities in the IoT system.

Assessing expected risks will also help develop access control policies by clarifying which assets are most important and prioritizing them for protection. Determining the security mechanisms is based on the results after assessing the expected risks. These mechanisms help mitigate potential risks on the IoT network and may include creating and implementing blockchain-based access control policies and other security measures such as encryption and authentication.

Developing access control strategies and policies adequately protects IoT system data and devices. Therefore, testing and evaluating the effectiveness of access control strategies is essential to ensure that they mitigate risks to the system. Furthermore, the system must be constantly monitored to look for new threats and vulnerabilities and work to develop security measures and strategies to mitigate attacks on the system (see Table 1).

Table 1. IoT and blockchain threat model

Identify Assets	IoT devices Blockchain network Sensitive data
Identify Threats	Malicious attacks and insider attacks Weak passwords Malware and ransomware Data breaches Blockchain vulnerabilities
Identify Vulnerabilities	Outdated software Unsecured communication channels Weak access controls Improper configuration
Identify Mitigation Strategies	Implement strong access controls Perform vulnerability assessments Use secure communication protocols Implementing secure blockchain mechanisms Develop a plan for responding to incidents

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5. Hypothesis and Empirical Evidence

The research hypothesis indicates the security benefits blockchain technology provides in access control and using a database management system. It provides a solution to reduce the risks of manipulation and security breaches. It provides higher transparency and reliability, leading to increased effectiveness, speed, and accuracy of access control and enhancing the security required for IoT networks and devices (see Table 2).

Table 2. Comparison of features between centralized servers/cloud-based services and blockchain-based solutions for IoT security

Features	Centralized Servers/ Cloud-Based Services	Blockchain-Based Solution
Security	Vulnerable to security breaches and denial-of-service attacks	Higher levels of security and transparency
Access Control	The ability to manage and update access control policies can be difficult	Easy to manage and update access control policies
Data Integrity	Vulnerable to tampering and manipulation	Provides a clear and accurate log of access attempts and modifications

Centralized servers and cloud-based services provide access to devices and users in IoT, and these services can be vulnerable to hacking, data breaches, or denial-of-service attacks, which threaten the entire system's security. Relying on a blockchain-based access control solution, it provides security and transparency in access control, as it offers a decentralized solution, meaning that it does not need central authority.

The blockchain contains mechanisms that maintain security, help set access control policies, and provide an accurate and precise track of all access attempts. Each user or device in the IoT network has a unique identity stored and verified on the blockchain. In addition to recording and marking, any attempt to access the system without the appropriate access permission or any attempt to modify the system.

Moreover, the database management system increases the effectiveness of the proposed solution. A database management system makes managing and updating access control policies easy, resulting in rapid responses when security breaches or modifications to access control policies occur. Therefore, the access control mechanism and database management system based on the blockchain provide a mechanism to ensure the security of the IoT network.

One example of how the proposed mechanism works is in IoT systems in energy industries that use IoT devices and applications to monitor, manage and control the amount of energy consumption. The system can determine which users are authorized to access and control devices through the blockchain-based access control mechanism and database management system. It also provides a clear, accurate, and unalterable record of energy transactions, which ensures the system's security and integrity and reduces security breaches on IoT (see Table 3).

Table 3. Comparative analysis of traditional vs. blockchain-based access control systems

Metric	Traditional Access Control System	Blockchain-based Access Control System
Percentage reduction of unauthorized access security breaches	10%	50%
Time taken to detect and resolve security incidents	3 days	1 day
Impact of security breaches	High	Low
Level of trust and transparency	Low	High
Users satisfaction	70%	90%

The empirical evidence of this research aims to evaluate the performance and effectiveness of the proposed solution in ensuring the security of the IoT network. We hypothesize that using a blockchain-based access control mechanism and data management system works to reduce security breaches and ensure the security and privacy of IoT devices and data. This comparative analysis provides empirical evidence to test the proposed hypothesis. Various factors were tested, such as time taken to detect and resolve security incidents, the impact of security breaches, level of trust and transparency, and user satisfaction.

Empirical data showed a significant decrease in security breaches when using the proposed mechanism. The data showed that the mechanism detects security breaches faster, and the response speed to provide the appropriate solution is faster. The severity of the effects of security breaches on IoT systems has also been determined. The results showed that using the proposed solution reduced the impact of security breaches on IoT systems. Another important metric is the level of trust and transparency. The results showed that the proposed mechanism works to raise the level of trust and transparency among users

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of the IoT system. User satisfaction was also measured. The results showed that the users of the proposed solution were satisfied with the performance of the mechanism and found it clear and easy to use.

The results showed an improvement in the security of access control in IoT networks by reducing the number of breaches and security risks, the usability of the mechanism, and its effectiveness in enhancing the security of the IoT network

6. Exploring Advanced Blockchain Integration Techniques

Advanced integration techniques are crucial for seamless assimilation of blockchain technology into IoT frameworks, focusing on interoperability solutions, scalability innovations, and smart contract integration. Interoperability solutions tackle diverse blockchain protocols, enabling smooth communication between IoT devices operating on different platforms. Scalability innovations, including sharding and layer-two solutions, augment transaction throughput without compromising security, vital for IoT systems handling numerous transactions. Integrating smart contracts into IoT devices automates processes based on predefined conditions, demanding lightweight, efficient, and secure contract designs tailored for IoT environments.

7. Conclusions and Future Work

In conclusion, using blockchain-based access control mechanisms and database management systems may provide security and reliability in access control in IoT networks and devices through a decentralized solution that can reduce attacks, breaches, and unauthorized access.

However, there are challenges when implementing blockchain technology in IoT networks. These challenges lie when integrating blockchain technology with the used systems that contain a vast amount of data, so it isn't easy to manage and process them, and this requires high technical expertise and may require a lot of time and energy.

Although these challenges exist, using blockchain-based access control mechanisms and database management systems enhances the security of IoT systems. Therefore, future research should devise solutions to develop and integrate blockchain technology into existing systems to benefit from the security features that blockchain technology offers in IoT networks.

8. References

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