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A PROXY RE-ENCRYPTION APPROACH TO SECURE DATA SHARING IN THE INTERNET OF THINGS BASED ON BLOCK CHAIN

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ABSTRACT

The evolution of the Internet of Things has seen data sharing as one of its most useful applications in cloud computing. As eye-catching as this technology has been, data security remains one of the obstacles it faces since the wrongful use of data leads to several damages. In this article, we propose a proxy re-encryption approach to secure data sharing in cloud environments. Data owners can outsource their encrypted data to the cloud using identity-based encryption, while proxy re-encryption construction will grant legitimate users access to the data. With the Internet of Things devices being resource-constrained, an edge device acts as a proxy server to handle intensive computations. Also, we make use of the features of information-centric networking to deliver cached content in the proxy effectively, thus improving the quality of service and making good use of the network bandwidth. Further, our system model is based on blockchain, a disruptive technology that enables decentralization in data sharing. It mitigates the bottlenecks in centralized systems and achieves fine-grained access control to data. The security analysis and evaluation of our scheme show the promise of our approach in ensuring data confidentiality, integrity, and security.

I.INTRODUCTION

The rapid expansion of the Internet of Things (IoT) has significantly transformed the way devices interact and communicate in both personal and industrial environments. From smart homes to healthcare applications and industrial automation, IoT enables real-time data collection and analysis, contributing to more efficient decision-making processes. However, as IoT systems proliferate, the security and privacy of shared data have become critical concerns. With vast amounts of sensitive data being exchanged between devices, ensuring the confidentiality, integrity, and accessibility of this information is essential to prevent potential breaches and unauthorized access.

One promising approach to secure data sharing in IoT ecosystems is Proxy Re-Encryption (PRE), a cryptographic technique that allows a proxy to transform ciphertexts from one key to another without revealing the underlying plaintext. This ensures that the data remains confidential even when being transferred or accessed by multiple parties, thus enabling secure data sharing between IoT devices, users, or services. However, challenges remain in efficiently managing and securing data shared between a growing number of IoT devices, as well as maintaining trust and accountability in the system.

In recent years, blockchain technology has emerged as a powerful tool for enhancing security and trust in distributed systems.

Blockchain provides a decentralized, immutable ledger that ensures transparency, accountability, and traceability of data transactions. By integrating blockchain with proxy re-encryption techniques, we can enhance the security, privacy, and scalability of data sharing in IoT networks. Blockchain can be leveraged to manage encryption keys, authenticate users, and log access permissions, while proxy re-encryption can facilitate the secure transfer of data between authorized parties, ensuring that only the intended recipients can decrypt the information.

This project explores a novel Proxy Re-Encryption approach for secure data sharing in IoT environments, integrating it with blockchain technology. The proposed solution aims to address the challenges of data privacy, access control, and key management in IoT networks, enabling secure and efficient communication between devices. By combining the strengths of both blockchain and proxy re-encryption, the project aims to provide a scalable, trustworthy, and secure framework for sharing sensitive data in IoT-based applications. Through the use of blockchain's decentralized ledger and the flexibility of proxy re-encryption, this approach offers a robust solution for ensuring that data is only accessible by authorized parties while maintaining its confidentiality and integrity across the IoT ecosystem.

II.LITERATURE REVIEW

The integration of Proxy Re-Encryption (PRE) and Blockchain technology for secure data sharing in the Internet of Things (IoT) has gained considerable attention in recent research due to the increasing need for privacy, security, and efficiency in the rapidly expanding IoT landscape. This literature review explores existing works related to IoT security, Proxy Re-Encryption, Blockchain technology, and their applications in data sharing, focusing on the challenges, advancements, and proposed solutions in these areas.

1. Security Challenges in IoT Systems

The Internet of Things involves numerous interconnected devices that generate and share sensitive data, including personal, medical, and financial information. The decentralized nature of IoT systems, where devices communicate with minimal human intervention, makes them vulnerable to various attacks such as data breaches, man-in-the-middle attacks, eavesdropping, and unauthorized access (Zhou et al., 2016). Traditional security mechanisms such as public-key infrastructure (PKI) and symmetric encryption struggle to address the unique security challenges of IoT, including scalability, key management, and the resource constraints of IoT devices. Thus, securing data transfer and ensuring privacy and confidentiality are primary concerns in IoT research (Raza et al., 2017).

2. Proxy Re-Encryption for IoT

Proxy Re-Encryption (PRE) has been identified as an effective cryptographic technique for securing data in distributed environments, such as IoT systems. PRE allows a third-party proxy to re-encrypt ciphertext from one user's public key to another user's public key without revealing the underlying plaintext. This enables secure data sharing between different entities while maintaining confidentiality, as the proxy does not have access to the decrypted data

(Yu et al., 2014). For example, in healthcare IoT systems, PRE can enable secure sharing of patient records between different healthcare providers without disclosing sensitive information to unauthorized parties. Several studies have explored the use of PRE in IoT environments for ensuring confidentiality and efficient access control (Wang et al., 2016). The advantage of PRE lies in its ability to support secure and seamless data sharing without requiring the re-encryption of the entire dataset, making it scalable and lightweight for resource-constrained IoT devices.

Despite its potential, the challenge remains in key management, scalability, and flexibility. IoT devices are often heterogeneous and vary in terms of processing power and storage capabilities. As such, developing lightweight, computationally efficient PRE schemes that can be integrated into IoT systems is a focus of ongoing research (Zhang et al., 2018).

3. Blockchain in IoT Security

Blockchain technology, originally designed for cryptocurrencies, has emerged as a robust solution to many security challenges in IoT systems due to its decentralized and immutable nature. Blockchain ensures that all data transactions are transparently recorded in a ledger that is resistant to tampering, ensuring integrity and traceability (Zheng et al., 2018). Several studies have proposed the use of blockchain to handle authentication, access control, and auditing in IoT systems. For instance, Zheng et al. (2017) introduced a blockchain-based solution to provide secure device authentication and data integrity in IoT environments. Moreover, blockchain's ability to manage encryption keys and facilitate trustless interactions makes it particularly suitable for IoT applications where multiple entities (devices, users, services) need to securely interact with one another without a central authority.

One of the challenges of using blockchain in IoT is its scalability and latency issues due to the computational requirements of consensus algorithms. However, recent advancements in blockchain technologies, including the development of permissioned blockchains and lightweight consensus mechanisms, have shown promising results in addressing these scalability concerns for IoT systems (Dinh et al., 2017). Additionally, blockchain has been combined with other cryptographic techniques, such as PRE, to enhance its capabilities in providing secure data sharing and key management.

4. Integrating Proxy Re-Encryption and Blockchain

The combination of Proxy Re-Encryption and blockchain has been increasingly explored as a potential solution to secure data sharing in IoT. In this hybrid model, blockchain is used to maintain a distributed ledger for managing cryptographic keys, access permissions, and auditing while PRE ensures that data can be securely re-encrypted and shared across multiple parties without compromising confidentiality (Ruj et al., 2017). For instance, blockchain can be used to store the public keys of IoT devices, ensuring a decentralized key management approach that avoids the need for a central authority.

Recent research by Chen et al. (2020) has demonstrated how the integration of smart contracts in a blockchain system can automate the process of data sharing and

access control, using PRE to ensure that sensitive data is only accessible to authorized parties. In this scenario, when a new user needs access to encrypted data, the proxy re-encryption mechanism will enable the data to be re-encrypted from the original user's key to the new user's key, without exposing the plaintext. Blockchain ensures that all interactions are transparent and auditable, improving the trustworthiness of the system.

III.METHODOLOGY

A) System Architecture

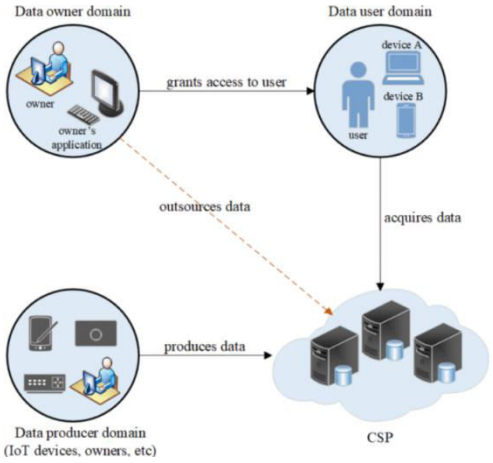

Fig1.System Architecture

In such a system, data producers are entities that generate the data, but their role does not necessarily imply ownership. They can contribute to data protection by encrypting the data and outsourcing its storage to Cloud Service Providers (CSPs). However, the distinction between data producers and data owners is important, as ownership is typically tied to the control of the data. The data owners are responsible for the management and access rights of the data. These owners generate a random number that is used to encrypt the data before uploading it to the cloud for sharing with authorized users. The access rights are then defined and enforced by the owner. While data producers can also be data owners, there is the possibility that separate entities might be responsible for generating the data. It is assumed that data owners communicate with other entities, such as users or systems, through an agent or server running on a trusted computer, ensuring secure interaction.

The data user domain includes both legitimate individuals and devices that are authorized to access the data shared by the owners or producers. These users retrieve the encrypted data stored by the CSP, which acts as a semi-trusted intermediary. The CSP provides storage services but does not have access to the plaintext of the data, ensuring that the confidentiality of the data is maintained. The data is accessed through secure communication channels, preventing unauthorized access.

It is critical that all sensitive data is encrypted before being uploaded to the cloud, with decryption restricted only to legitimate users. Despite the semi-trusted nature of the CSP, there may be incentives for the provider to attempt accessing the data. Data sharing scenarios arise when, for example, user2 wants to access data previously shared between data owner and user1. To optimize the quality of service and bandwidth usage, it becomes essential to allow the cached data in edge nodes to be shared directly with user2 based on its identity or credentials. This approach eliminates the need for retrieving and encrypting the data from the cloud again, reducing overhead and enhancing network performance.

B. System Model

Our system model, as shown in Fig. 2, introduces a blockchain-based Proxy Re-Encryption (PRE) approach to secure data sharing. In this enhanced model, two additional components—edge devices and the blockchain—are integrated into the traditional data-sharing framework, as depicted in Fig. 1. The edge devices act as proxy nodes, providing re-encryption services to authorized users. These devices are strategically placed at the edge of the network to offer high availability and performance, ensuring efficient data access and reduced latency for users. When data is cached at the edge, these devices receive the re-encryption key from the data owner, fetch the ciphertext from the Cloud Service Provider (CSP), and re-encrypt it for the specific data user's identity. This process ensures that the data is only accessible by the intended recipients. The edge devices are assumed to be honest-but-curious entities, meaning they follow the protocol but may attempt to infer or access sensitive information beyond their authorized scope. This model leverages the blockchain to ensure the integrity of the re-encryption process and track access to the shared data in a decentralized, secure manner.

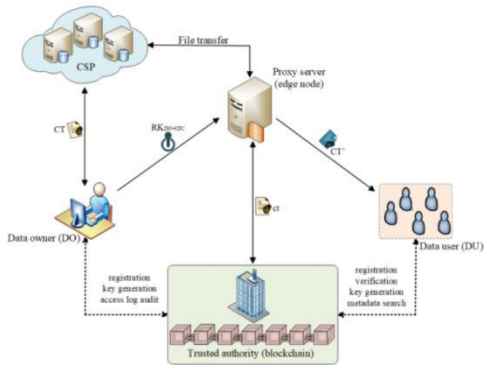

Fig2

The blockchain acts as the trusted authority (TA), initiating system parameters and providing secret keys linked to user identities, ensuring authenticity, transparency, and verifiability in data sharing. This enhances data security and privacy, enabling data owners to effectively manage their data. The blockchain registers and issues membership keys to both data owners and users. Upon a data access request, the owner generates a re-encryption key using the user's identity and sends it to the proxy server. Access rights and policies are also sent to the blockchain, where the user is verified before access is granted.

The Setup algorithm is executed by the TA to generate system parameters and a master key, while the KeyGen algorithm creates user keys. The data owner encrypts the data using the Encrypt algorithm, creating ciphertext that is outsourced to the CSP, and metadata is stored on the blockchain.

In our model, data caching improves content delivery, enhances availability, and mitigates packet losses. It supports both content and functionality caching (re-encryption). Additionally, the ICN multipoint delivery system optimizes bandwidth and storage, reducing bandwidth usage as the number of users grows, by avoiding unicasting.

C) System Workflow

Data storage and retrieval in the system follows these steps: The data hash is calculated using the SHA-256 algorithm to ensure data integrity. The data owner generates a random number for encryption, and the resulting ciphertext is uploaded to the CSP. Metadata is created to support

search functionality, and the data owner signs the hash with their private key.

The data owner generates a re-encryption key based on the user's identity and provides it to the proxy server. The user is added to an access list sent to the proxy, which verifies the owner's signature for authenticity. The proxy then retrieves a URL for the ciphertext, assigns an ID (dID), signs it, and stores it in the proxy server's cache. Metadata, access policies, signatures, hash, and dID are uploaded to the blockchain.

When a user requests data access, they query the blockchain's metadata. The authenticity is verified by checking the signatures of both the data owner and the proxy server. After successful authentication, the signed data is sent to the proxy for the actual data. The proxy fetches the ciphertext from the CSP, re-encrypts it, and sends it to the user, who can then decrypt it with their private key. The blockchain verifies the user's signature, validates the timestamp, and logs the request for auditing purposes.

IV.CONCLUSION

The proposed proxy re-encryption approach for secure data sharing in the Internet of Things (IoT) based on blockchain offers a robust and efficient solution for managing access control and privacy. By combining the decentralization and immutability of blockchain with proxy re-encryption, the system ensures secure and verifiable data sharing across different stakeholders in the IoT ecosystem. The use of blockchain as the trusted authority (TA) enhances the authenticity and transparency of data access, while the proxy re-encryption mechanism enables efficient data sharing without compromising security.

This system addresses key challenges in IoT data sharing, such as data confidentiality, access control, and scalability. The use of edge devices for re-encryption and caching ensures high availability and performance, while also optimizing bandwidth usage. By leveraging blockchain, the system guarantees data integrity, accountability, and non-repudiation, providing a reliable platform for secure IoT data sharing.

In future work, this approach can be extended to support more advanced access control policies, improve re-encryption efficiency, and explore additional use cases beyond IoT, such as in healthcare and finance sectors.

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