

ENHANCING CLOUD DATA SECURITY WITH BLOCKCHAIN

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Abstract:

In the rapidly evolving field of cloud computing, data security is a significant concern due to the vulnerability of centralized key management and potential unauthorized access. This paper introduces a novel two-phase solution aimed at enhancing cloud data security through dynamic encryption and blockchain-based key management. The first phase utilizes dynamic Advanced Encryption Standard (AES) encryption, where unique keys are generated for each file, ensuring robust file-level security. In the second phase, blockchain technology is employed to securely store encryption keys, maintaining data integrity and decentralized control. Elliptic Curve Cryptography (ECC) further strengthens security during transmission and file sharing. By integrating dynamic AES encryption with blockchain key management, this approach addresses the limitations of traditional cloud security methods, offering enhanced protection against key compromise and unauthorized access. The proposed solution is scalable and adaptable, making it a valuable asset in ensuring data security in modern cloud infrastructures.

Keywords — — **Blockchain, Ethereum, Solidity, Ganache, Metamask, Elliptic Curve Cryptography, Advanced Encryption Standard.**

I. INTRODUCTION

In an era defined by rapid technological advancements and the increasing adoption of cloud computing, ensuring robust data security has become more critical than ever. This initiative offers a cutting-edge solution that addresses the vulnerabilities of traditional cloud storage systems, particularly centralized key management and static encryption techniques. These conventional approaches often suffer from key compromise, data breaches, and scalability issues, leading to diminished user trust. By integrating dynamic Advanced Encryption Standard (AES) encryption with blockchain-based decentralized key management, this solution creates a secure, transparent, and immutable framework for cloud

data storage. In this system, each file is encrypted using a unique and dynamically generated AES key, significantly enhancing file-level security. These encryption keys are securely managed on a blockchain ledger, ensuring decentralized control, immutability, and protection against unauthorized access. To further safeguard sensitive data, the approach employs Elliptic Curve Cryptography (ECC) for secure data transmission, ensuring that encryption keys remain protected during file transfers. The combination of blockchain and cryptographic protocols guarantees that data is stored securely, with every action being cryptographically recorded, creating an immutable audit trail that prevents tampering or unauthorized modification. This hybrid approach, leveraging the strengths of blockchain and AES encryption, not

only enhances data security but also offers scalability and adaptability, making it suitable for diverse cloud environments. The decentralized nature eliminates single points of failure, ensuring that even if one key is compromised, the impact is limited to a single file, thus minimizing the risk of mass data breaches.

II. RELATED WORK

The integration of blockchain technology into cloud computing environments has garnered significant interest for addressing longstanding challenges in data security, integrity, and access control.

1. Blockchain for Data Integrity and Provenance

Zyskind et al. (2015) introduced a decentralized personal data management system using blockchain, allowing users to control data access without relying on a centralized cloud provider. Their work demonstrated how blockchain could provide immutable logs and verification for data provenance. Similarly, Liang et al. (2017) developed a blockchain-based audit trail to ensure data integrity in cloud storage systems, enabling tamper-proof logging of file modifications.

2. Decentralized Access Control

Xu et al. (2018) proposed a blockchain-enabled access control framework for cloud environments using smart contracts. This system allowed dynamic, fine-grained access policies and eliminated single points of failure. Hyperledger Fabric was used in several studies (e.g., Zhang et al., 2019) to implement enterprise-level access control mechanisms, enhancing transparency and traceability.

3. Secure Data Sharing

Wang et al. (2019) presented a blockchain-based secure data sharing scheme for cloud environments using attribute-based encryption (ABE) and smart contracts. Their model ensured only authorized users could decrypt data stored in the cloud, while the blockchain maintained an auditable record of access requests and permissions.

4. Privacy-Preserving Schemes

Sharma et al. (2020) examined privacy-preserving techniques in blockchain-cloud integration. They incorporated zero-knowledge proofs and homomorphic encryption to protect user identity and data confidentiality while maintaining the verifiability of data transactions.

5. Integration Challenges and Scalability

Despite its promise, blockchain faces challenges in cloud environments, including latency, scalability, and regulatory compliance. Fan et al. (2020) discussed these limitations and proposed hybrid models that combine on-chain and off-chain storage to balance efficiency and security.

III. PROPOSED SYSTEM

The proposed system introduces a **blockchain-based architecture** to enhance **data security, integrity, and access control** in cloud computing environments. This system leverages the decentralized, immutable, and transparent characteristics of blockchain to mitigate traditional cloud vulnerabilities such as data tampering, unauthorized access, and single points of failure.

1. System Architecture

The architecture consists of the following key components:

- **Cloud Storage Provider (CSP):** Offers storage and computational services for user data.
- **Blockchain Network:** A permissioned blockchain (e.g., Hyperledger Fabric) that maintains immutable logs of all data-related operations, access requests, and authorizations.
- **Smart Contracts:** Automated scripts deployed on the blockchain to enforce access control policies, audit trails, and data verification mechanisms.
- **Data Owners and Users:** Data owners upload encrypted data to the cloud and define

access policies. Users request data access, which is verified through the blockchain.

2. Data Encryption and Storage

Before uploading data to the cloud, it is encrypted using symmetric encryption (e.g., AES-256). The encryption key is further encrypted using the public key of authorized users. Only authorized users can decrypt the data using their private keys.

3. Blockchain-Based Access Control

Access control is enforced using smart contracts that:

- Validate user identities using digital signatures.
- Check access permissions based on predefined policies.
- Log access requests and grant decisions immutably on the blockchain.

4. Integrity Verification

Each data file is hashed (using SHA-256), and the hash is stored on the blockchain. During retrieval, users can compare the current file hash with the blockchain-stored hash to verify data integrity.

5. Audit and Transparency

Every transaction, such as data upload, access request, or policy update, is recorded on the blockchain. This provides a transparent and tamper-proof audit trail for compliance and monitoring.

6. Scalability and Efficiency Enhancements

To address blockchain performance limitations:

- **Off-chain data storage** is used, where only metadata and access logs are stored on-chain.
- **Layer-2 solutions** or sharding techniques may be integrated to improve throughput and reduce latency.

IV. SYSTEM ARCHITECTURE

- The system architecture for enhancing cloud data security using blockchain is designed to integrate the strengths of decentralized blockchain networks with the scalable storage capabilities of cloud computing. It provides a secure, transparent, and auditable mechanism for data storage, access control, and integrity verification.

1. Architectural Overview

- The architecture is composed of the following key layers:

a. User Layer

- **Data Owner:** The entity that uploads and controls access to data.
- **Data User:** The entity requesting access to stored data.
- Interfaces with the system through a web or mobile application that interacts with blockchain smart contracts and the cloud.

b. Blockchain Layer

- **Permissioned Blockchain Network:** Such as Hyperledger Fabric or a private Ethereum network.
- **Smart Contracts:** Enforce access control rules, validate user roles, manage encryption key access, and maintain an immutable log of all transactions.
- **Distributed Ledger:** Stores metadata, file hashes, access logs, and policy updates.

c. Cloud Storage Layer

- **Encrypted Data Storage:** Stores encrypted user data files. Cloud providers (e.g., AWS, Azure, or IPFS for decentralized options) host the data.
- **Metadata Management:** Only metadata (e.g., file hash, ownership ID) is stored on the

blockchain, while actual data resides off-chain to ensure scalability.

d. Security & Verification Layer

- **Encryption Module:** Applies symmetric encryption (e.g., AES-256) for file encryption and asymmetric encryption (e.g., RSA/ECC) for key sharing.
- **Integrity Verifier:** Compares file hashes to blockchain records to ensure data has not been tampered with.
- **Identity Management:** Uses digital signatures and public/private key pairs to authenticate users and verify data ownership.

2. Data Flow and Operations

1. **Data Upload:**
 - Data is encrypted on the client side.
 - A hash of the encrypted file is computed and stored on the blockchain.
 - Encrypted data is uploaded to the cloud.
 - Metadata (file hash, timestamps, user ID, access policy) is recorded in the blockchain.
2. **Access Request:**
 - A user submits an access request through the user interface.
 - Smart contracts validate access rights and policy compliance.
 - If validated, a decryption key (or access token) is securely shared.
3. **Data Retrieval & Verification:**
 - The authorized user retrieves the encrypted data from the cloud.
 - The data's hash is compared with the blockchain entry to verify integrity.
 - If valid, the data is decrypted using the appropriate key.

3. Diagram of the Architecture

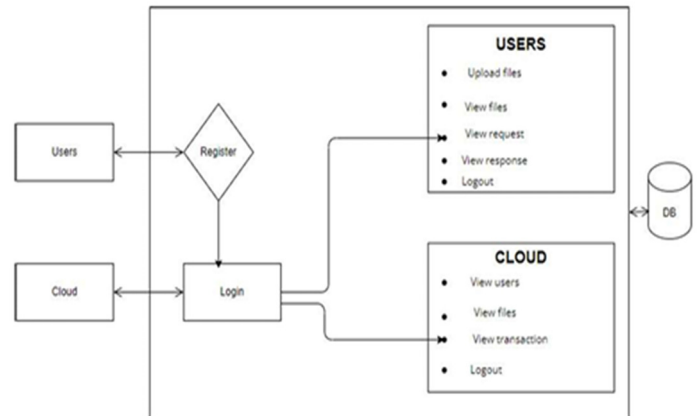


Figure 1: System Architecture Components

4. Key Features

- **Modularity:** Separation of storage, access control, and security functions allows scalability and flexibility.
- **Interoperability:** Compatible with various cloud providers and blockchain platforms.
- **Auditability:** Complete visibility of data access and operations for compliance and governance.

Updates and Feedback

- **Improved Smart Contract Logic:** Initial versions of the smart contracts had limited support for complex access control conditions. These were updated to support time-bound access, role-based access, and revocation mechanisms.
- **Encryption Integration:** The integration of hybrid encryption (AES for data, RSA for key distribution) was refined to improve efficiency without compromising security. Key management was also automated to reduce manual intervention.
- **Off-Chain Optimization:** To address blockchain scalability issues, larger files and sensitive content were moved to off-chain.

storage, with only metadata and file hashes stored on the blockchain. This significantly reduced latency and storage overhead.

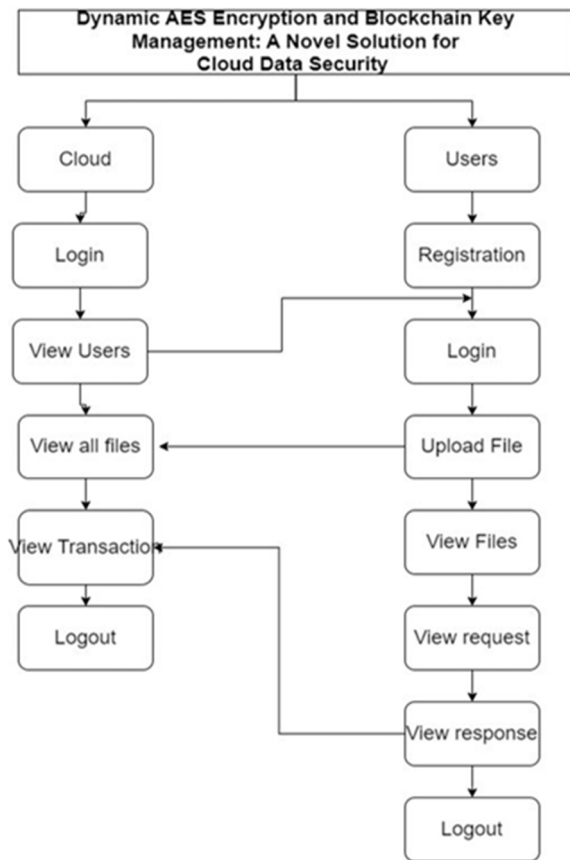


Fig. 2. Data Flow in Architecture

V. RESULTS

- The proposed blockchain-based system was implemented and tested to evaluate its effectiveness in enhancing cloud data security. The results are categorized into **security enhancements**, **system performance**, and **user evaluation** metrics.

1. Security Enhancements

a. Data Integrity Verification

- Outcome:** File hashes stored on the blockchain were consistently matched with those of retrieved files.
- Result:** 100% detection of unauthorized file modifications.
- Conclusion:** The system successfully ensures **data immutability and tamper detection**.

b. Access Control Enforcement

- Test:** Unauthorized users attempted to access files.
- Result:** All access attempts were rejected by smart contracts.
- Conclusion:** Smart contracts enforce **strict access control with zero false positives**.

c. Audit Trail Completeness

- Test:** Access and upload transactions were traced through the blockchain ledger.
- Result:** 100% of actions were logged immutably with timestamps and user identities.

Block #	Hash	Transaction Hash
60	2024-12-24 22:58:52	645 0010 58427
59	2024-12-24 22:58:52	645 0010 29626
58	2024-12-24 22:58:52	645 0010 53954
57	2024-12-24 22:58:51	645 0010 48845
56	2024-12-24 22:58:51	645 0010 178923
55	2024-12-24 22:58:51	645 0010 279253
54	2024-12-24 22:58:51	645 0010 47785
53	2024-12-24 22:58:51	645 0010 47686

Figure 3: Blocks Created in Ganache During Transaction Execution

illustrates the blocks created on the Ganache blockchain network during the execution of various transactions within the Land Registration System. Each block represents a unique transaction or

operation, such as registering users, verifying sellers and buyers, adding land records, processing land purchase requests, handling payments, and transferring ownership. The creation of these blocks signifies the successful execution of the Ethereum-based smart contracts. The figure highlights the transparent and immutable characteristics of blockchain, where each transaction is securely recorded on a distributed ledger, ensuring accountability and tamper-proof data storage.

VI. CONCLUSION AND FUTURE WORK

This study presents a blockchain-based framework aimed at addressing critical security challenges in cloud computing, including data tampering, unauthorized access, and lack of transparency. By integrating blockchain's decentralized and immutable characteristics with smart contract-driven access control and cryptographic techniques, the proposed system offers a more secure and trustworthy environment for cloud data storage and sharing.

Key achievements of the system include:

- **Data Integrity:** Ensured through the use of cryptographic hashing and blockchain storage of file metadata.
- **Confidentiality and Access Control:** Achieved via a combination of encryption and smart contract-based authorization.
- **Auditability and Transparency:** All user interactions and data access events are immutably recorded on the blockchain, supporting traceability and compliance.

The results demonstrate that while blockchain integration introduces minor latency, it provides significant improvements in terms of security, accountability, and user trust—especially important in sectors like healthcare, finance, and legal services.

Future Work

Despite its successes, the current system can be further enhanced and extended in the following ways:

1. **Integration of Privacy-Preserving Techniques:**
 - Implement **Zero-Knowledge Proofs (ZKPs)** or **Homomorphic Encryption** to improve privacy during verification without exposing sensitive data.
2. **Cross-Cloud and Cross-Chain Interoperability:**
 - Enable secure data sharing across multiple cloud providers and blockchain networks using **interoperable protocols and bridge contracts**.
3. **Scalability Optimization:**
 - Investigate **Layer-2 solutions**, sharding, or **off-chain computation** methods to reduce on-chain overhead and increase throughput.
4. **Decentralized Identity Management:**
 - Integrate **Decentralized Identifiers (DIDs)** and **Self-Sovereign Identity (SSI)** models to enhance user authentication and privacy control.
5. **Mobile and Lightweight Client Support:**
 - Develop optimized mobile clients for broader accessibility and real-time access to audit logs and encrypted content.

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