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Safevault: Preventing Cloud Data Breaches Using ECC and Token-Based Access

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Abstract: However, the centralized cloud storage poses a great threat to the security and privacy of the user. In the digital world, cloud storage is one of the most fundamental components of data storage and online services. In the traditional centralized approach, the data, including user information, credentials, and other access information, is stored centrally. This approach is highly vulnerable to attacks and data breaches. The main objective of the proposed research is to develop a system that improves the security, privacy, and control of the data, as well as providing a secure environment for storing and sharing digital assets. The system uses the Blockchain technology and the InterPlanetary File System (IPFS) to provide secure and tamper-proof storage. In the proposed system, Elliptic Curve Cryptography (ECC) is used to ensure the highest level of encryption using the smallest key sizes. In addition, the proxy re-encryption method is used to ensure the secure sharing of data among authorized users without revealing the original encryption keys. Zero-Knowledge Proof (ZKP) is used to ensure the highest level of privacy by verifying the user's authorization without revealing the actual credentials. The combination of decentralized storage, blockchain-based verification, and advanced cryptographic techniques provides a robust solution for mitigating cloud security threats, ensuring confidentiality, integrity, and transparency, and fostering a trustworthy environment for both individuals and organizations.

Keywords: *Cloud Security, Decentralized Storage, Blockchain, InterPlanetary File System (IPFS), Elliptic Curve Cryptography (ECC), Proxy Re-Encryption (PRE), Zero-Knowledge Proof (ZKP), Data Privacy, Secure Data Sharing, Data Integrity, Access Control, Cryptography.*

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I. INTRODUCTION

Cloud computing has significantly transformed the way data is stored, accessed, and shared across various applications. It offers scalability, flexibility, and cost-effective storage solutions. However, traditional cloud architectures are primarily centralized, where all critical data and access controls are managed by a single authority. This centralized model introduces multiple security concerns, such as data breaches, unauthorized access, and system failures. Moreover, users are required to depend on third-party service providers, often without complete visibility into how their data is handled. This lack of transparency raises trust issues and concerns regarding data privacy. If the central server is compromised, large volumes of sensitive data can be exposed. To overcome these limitations, this research introduces a decentralized and cryptographically secure framework that integrates Blockchain, IPFS, ECC, Proxy Re-Encryption, and Zero-Knowledge Proof mechanisms. This approach ensures data confidentiality, integrity, and controlled access, while eliminating the risks associated with centralized cloud systems.

II. LITERATURE SURVEY

- *Secure Data Storage and Sharing Techniques for Data Protection in Cloud Environments: A Systematic Review, Analysis, and Future Directions*

Gupta, Ishu, et al. [1] provides a detailed overview of secure data storage and sharing techniques used in cloud environments. It focuses on encryption methods, authentication strategies, and access control mechanisms that ensure data confidentiality and integrity. The research highlights the importance of combining symmetric and asymmetric encryption along with fine-grained access policies to protect sensitive information. Furthermore, the study discusses challenges such as insider threats, key management issues, and performance trade-offs in encryption systems. It suggests adopting lightweight encryption techniques and efficient key management solutions to balance security and

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system performance. These concepts support the proposed system by enabling secure storage and controlled data access using optimized cryptographic methods. The need for continuous monitoring mechanisms to detect suspicious activities in cloud environments. It also recommends integrating multi-factor authentication to strengthen user verification processes. These enhancements further improve system resilience against unauthorized access and data breaches.

- *Efficient and Secure Data Storage for Future Networks: Review and Future Opportunities*

Alsalim, Ahmed Saad, and Muhammad Awais Javed [2] emphasizes the need for efficient and secure data storage solutions in modern networks, including cloud computing and IoT environments. It highlights the importance of scalability, reduced latency, and energy-efficient operations in handling large volumes of data. The study also explores advanced security approaches such as intelligent encryption and adaptive access control mechanisms. These techniques enhance system performance while maintaining strong security. The proposed system benefits from these ideas by implementing ECC for efficient encryption and incorporating secure access control to improve overall reliability and speed. The role of distributed architectures in minimizing system bottlenecks. It suggests that combining edge computing with cloud storage can further enhance performance. These insights support the development of faster and more secure data storage frameworks.

- *A Review on Secure Data Deduplication: Cloud Storage Security Issue*

Prajapati, Priteshkumar, and Parth Shah [3] examines data deduplication techniques used to eliminate redundant data in cloud storage systems. While deduplication improves storage efficiency, it also introduces potential security risks such as data leakage and unauthorized access. To mitigate these risks, the study proposes secure deduplication methods using encryption-based techniques and proper key management strategies. It also emphasizes secure metadata handling and user-level encryption. These approaches are relevant to the proposed system, ensuring that storage optimization does not compromise data security and privacy. the importance of secure indexing methods for identifying duplicate data blocks. It also highlights the need for robust authentication before deduplication operations are performed. These measures help in preventing malicious attempts to exploit the deduplication process.

- *Blockchain-Orchestrated Deep Learning Approach for Secure Data TransmissioniIn IoT-Enabled Healthcare System*

Kumar, Prabhat, et al. [4] explores the use of blockchain technology to secure data transmission in distributed systems. It utilizes decentralized ledgers to record transactions, ensuring transparency and data integrity. Additionally, the study incorporates cryptographic hashing and automated access control mechanisms to prevent unauthorized access. These concepts align with the proposed system, where blockchain is used to maintain secure records and improve trust between users and storage systems. the advantages of immutable transaction logs in detecting data tampering. It also emphasizes the use of smart contracts for automating secure communication processes. These features enhance reliability and accountability in distributed environments.

- *Towards Blockchain-Based Secure Storage and Trusted Data Sharing Scheme for IoT Environment*

Ullah, Zia, et al. [5] introduces a blockchain-based framework for secure data storage and trusted data sharing in distributed environments. It eliminates reliance on centralized systems by using a decentralized ledger for managing data access. The approach ensures that only authorized users can access data, thereby enhancing security and trust. These ideas support the proposed system by enabling transparent, secure, and accountable data-sharing mechanisms. The importance of decentralized identity management in improving user authentication. It also highlights the role of consensus mechanisms in maintaining data consistency across the network. These aspects further strengthen the overall security and reliability of the system.

III. METHODOLOGY

- *Existing System*

Traditional cloud storage systems are based on centralized architectures, where a single cloud provider handles data storage, user authentication, key management, and access control. In this approach, sensitive information such as user credentials, encryption keys, and permissions are stored in a central server, making it a major target for cyber-attacks. As a result, these systems are vulnerable to threats like data breaches, insider attacks, and Distributed Denial of Service (DDOS) attacks. Additionally, they often rely on basic authentication methods such as username and password, which reduces overall security strength. The centralized design also creates a single point of failure, meaning that if the server is compromised or goes offline, the entire system becomes unavailable. Moreover, limited transparency in access control and lack of user ownership over data make it difficult to ensure privacy, accountability, and secure data sharing in modern cloud environments. Furthermore, these systems often face scalability issues when handling large volumes of data and users simultaneously. They also provide limited auditability, making it challenging to track data access and detect unauthorized activities effectively. dependency on a single service provider reduces system flexibility and increases the risk of vendor lock-in. The absence of decentralized verification mechanisms further weakens trust in data integrity and system operations. These systems also experience latency issues due to centralized data processing and long communication paths. Resource utilization is often inefficient, leading to performance bottlenecks during peak usage. Moreover, updating security policies in centralized systems can be complex and time-consuming. The lack of real-time monitoring reduces the ability to respond quickly to security incidents. Finally, centralized logging mechanisms may be prone to tampering, affecting the reliability of forensic analysis.

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- *Disadvantages*

Centralized cloud systems are vulnerable to single point failures, data breaches, and DDoS attacks due to storing sensitive data in one location. They also lack transparency, user control, scalability, and effective auditing mechanisms.

➢ *Proposed System:*

- *System Architecture*

The proposed system architecture is designed to provide a secure and decentralized framework for data storage and sharing in cloud environments. It consists of multiple entities, including the data owner, cloud server, IPFS storage layer, and data user, which interact in a coordinated manner to ensure data confidentiality and integrity. The data owner initiates the process by preparing the data for secure storage, while the cloud server manages access requests and system coordination. The integration of decentralized components enhances system reliability and eliminates dependence on a single authority.

In this architecture, data security is achieved through a multi-layered encryption mechanism. Before uploading, the data owner encrypts the files using Elliptic Curve Cryptography (ECC), ensuring strong protection with minimal computational overhead. The encrypted data is then stored in the InterPlanetary File System (IPFS), which distributes the data across multiple nodes, improving availability and fault tolerance. This decentralized storage approach reduces the risk of data loss and prevents unauthorized access to raw data.

Access control in the system is implemented using a combination of authentication and authorization techniques. Users must undergo verification, which may include token-based or biometric authentication, before accessing the data. The cloud server validates user requests and ensures that only authorized users can retrieve the encrypted files. Additionally, blockchain technology is used to maintain a transparent and tamper-resistant record of transactions, enabling secure tracking of data access and improving trust among system participants.

Overall, the architecture ensures a balance between security, efficiency, and scalability. By combining encryption, decentralized storage, and blockchain-based verification, the system addresses key limitations of traditional cloud models. It enhances data privacy, eliminates single points of failure, and provides reliable data sharing mechanisms. This integrated approach makes the system suitable for modern applications that require high levels of data protection and secure collaboration.

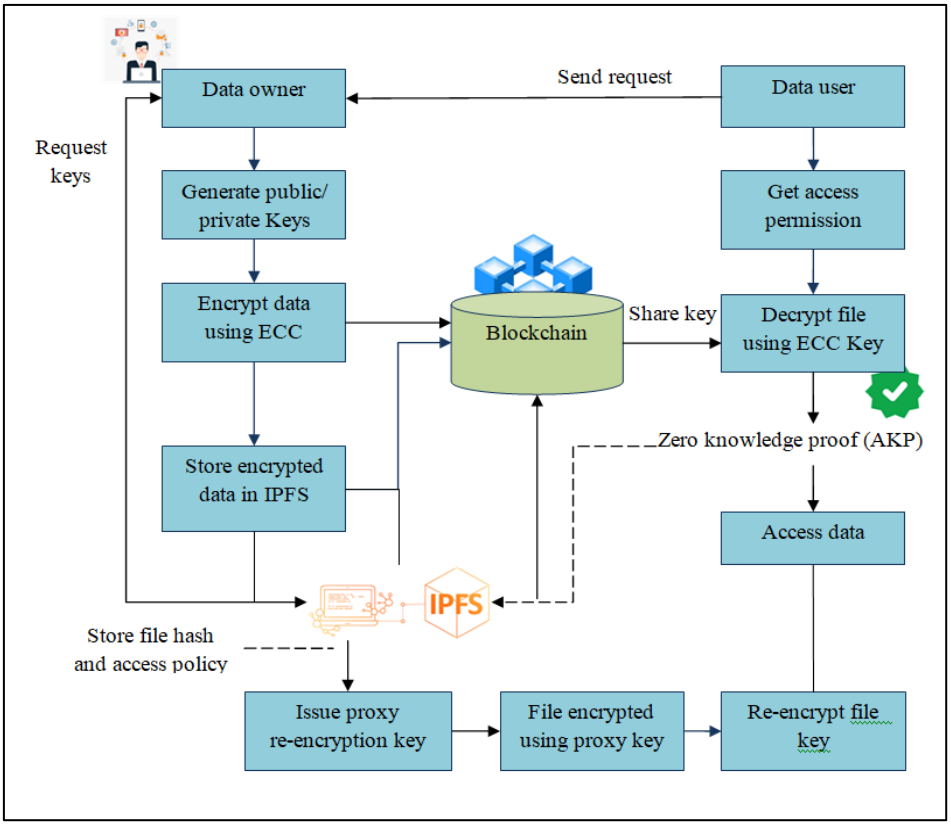

Fig 1 Diagram Representation of the Proposed Methodology

➢ *Flow Diagram*

The flow diagram represents the sequential process of secure data storage and retrieval in the proposed system. It begins with the data owner initiating the workflow by selecting a file for upload. Before transmission, the system performs preprocessing operations to ensure the data is in a suitable format for encryption. This initial step establishes the foundation for secure handling by preparing the data for further cryptographic operations and controlled storage.

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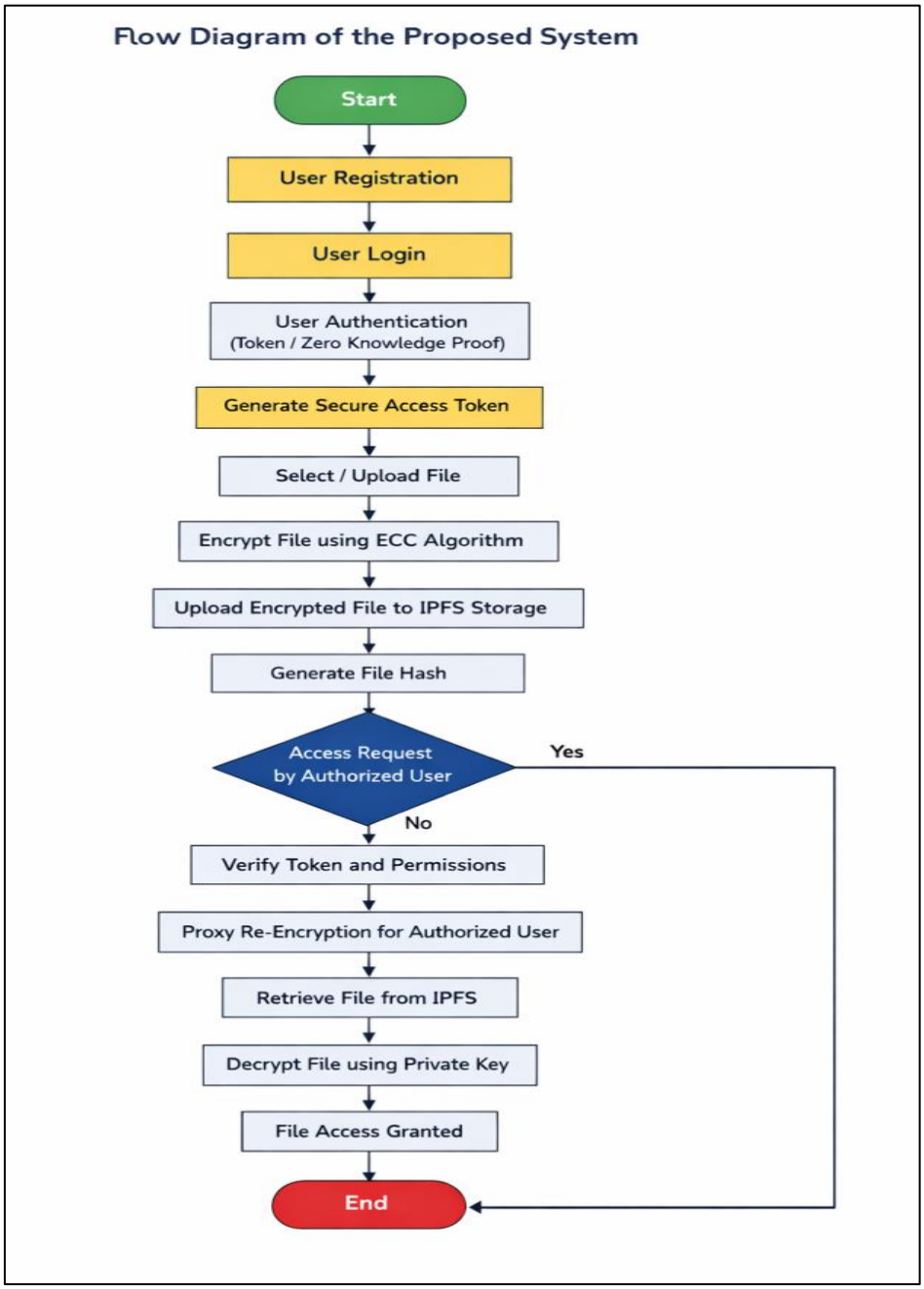

Fig 2 Workflow of Secure Cloud Storage System

In the next stage, the selected data undergoes encryption using Elliptic Curve Cryptography (ECC). This step ensures that the original content is transformed into a secure encrypted format, preventing unauthorized access during transmission and storage. Once encryption is completed, the encrypted file is uploaded to the decentralized storage system, such as IPFS. The system generates a unique hash value for the stored file, which acts as an identifier for retrieval and verification purposes.

Following storage, access control mechanisms are enforced to regulate data sharing. When a data user requests access, the system verifies the user's identity through authentication methods such as token-based or biometric verification. Upon successful authentication, the cloud server validates the user's authorization level and retrieves the corresponding encrypted file using the stored hash value. This ensures that only legitimate users are allowed to access the requested data.

Finally, the system performs decryption at the user end to convert the encrypted data back into its original form. This step completes the secure data retrieval process while maintaining confidentiality throughout the workflow. Additionally, all transactions and access activities can be recorded using blockchain technology, ensuring transparency and traceability. The overall flow ensures a secure, efficient, and reliable mechanism for data storage and sharing in decentralized cloud environments.

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➢ *Algorithms*

- *Elliptic Curve Cryptography (ECC) Algorithm*

Elliptic Curve Cryptography (ECC) is a public-key encryption technique that provides strong security with smaller key sizes compared to traditional algorithms such as RSA. It is based on the mathematical properties of elliptic curves over finite fields, where secure key pairs are generated using complex algebraic operations. In the proposed system, ECC is used to encrypt data before it is stored in the cloud, ensuring that sensitive information remains protected from unauthorized access. The smaller key size of ECC reduces computational overhead while maintaining high security. During the encryption process, the data owner generates a public-private key pair, where the public key is used for encryption and the private key is used for decryption. The encrypted data is then transmitted and stored securely in the decentralized storage system. ECC also enhances efficiency in terms of processing time and memory usage, making it suitable for cloud and distributed environments. Its resistance to common cryptographic attacks ensures data confidentiality and integrity throughout the system. ECC supports secure key exchange mechanisms such as Elliptic Curve Diffie–Hellman (ECDH), which allows two parties to establish a shared secret over an insecure channel. This feature strengthens communication security between system components. The algorithm is also well-suited for resource-constrained environments due to its lower power consumption and faster computations. These advantages make ECC an effective choice for implementing secure, scalable, and efficient data protection in modern cloud systems.

- *Proxy Re-Encryption Algorithm*

Proxy Re-Encryption (PRE) is a cryptographic technique that enables secure data sharing without exposing the original encryption keys. It allows a semi-trusted proxy entity to transform ciphertext encrypted for one user into ciphertext that can be decrypted by another authorized user. In the proposed system, PRE is used to facilitate controlled data sharing between the data owner and data users while preserving data confidentiality. This approach eliminates the need for the data owner to decrypt and re-encrypt data manually, thereby improving efficiency and security. In the PRE process, the data owner initially encrypts the data using their public key. When a data user requests access, the data owner generates a re-encryption key based on the user's public key and shares it with the proxy (e.g., cloud server). The proxy then uses this re-encryption key to convert the original ciphertext into a new ciphertext that corresponds to the data user. Importantly, the proxy does not learn any information about the plaintext during this transformation, ensuring that data privacy is maintained throughout the process. Furthermore, PRE enhances scalability and flexibility in distributed systems by enabling dynamic access control without re-uploading or re-encrypting data. This makes it particularly suitable for cloud-based and decentralized storage environments where multiple users require controlled access to shared data. Overall, the PRE algorithm strengthens secure data sharing by providing efficient, privacy-preserving, and flexible access delegation mechanisms.

IV. EXPERIMENTAL RESULTS

To evaluate the effectiveness of the proposed system, a comparative analysis was carried out between the existing centralized model and the proposed decentralized approach. The evaluation is based on multiple performance parameters including security, transparency, privacy, availability, efficiency, reliability, and auditability. The results clearly demonstrate the improvements achieved through the integration of advanced cryptographic techniques and decentralized storage mechanisms.

➢ *Performance Comparison Table*

Table 1 presents a comparative analysis of the existing centralized system and the proposed decentralized system across several important performance metrics. The comparison includes parameters such as data security, access control transparency, privacy preservation, data availability, computational efficiency, resistance to single point failure, and auditability. These metrics are evaluated in percentage values to provide a clear understanding of system performance under similar conditions. The results indicate that the proposed system achieves higher performance in almost all aspects due to the integration of advanced technologies like ECC encryption, blockchain, and decentralized storage. The improvements reflect enhanced security, better data handling capabilities, and increased system reliability when compared to traditional cloud-based approaches.

Table 1 Performance Analysis of Existing And Proposed System

Metric	Existing System (Centralized)	Proposed System (Decentralized)
Data Security Level	60	95
Access Control Transparency	50	90
Privacy Preservation	45	92
Data Availability / Reliability	70	98
Computational Efficiency	75	85
Resistance to Single Point Failure	40	100
Auditability / Traceability	55	98

- *Description of Values*

✓ Data Security Level**:** Increased from 60% to 95% due to strong ECC-based encryption and secure data handling.

✓ Access Control Transparency**:** Improved from 50% to 90% by implementing better authentication and authorization mechanisms.

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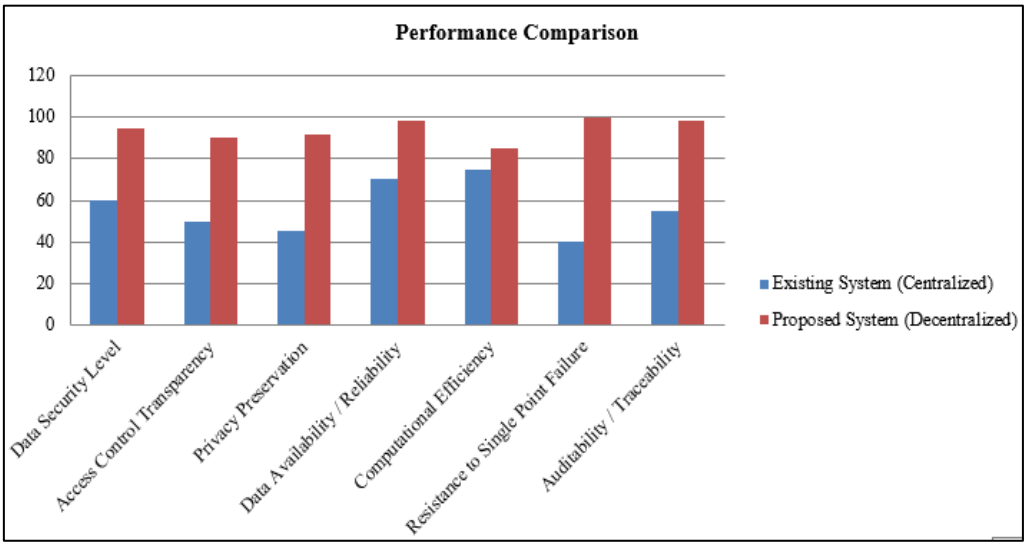

Fig 3 Performance Metric Chart Representation

- ✓ Privacy Preservation: Raised fromS 45% to 92%, ensuring higher protection of sensitive user data.
- ✓ Data Availability / Reliability: Increased from 70% to 98% through decentralized storage using IPFS.
- ✓ Computational Efficiency: Slightly improved from 75% to 85%, maintaining good performance despite added security layers.
- ✓ Resistance to Single Point Failure: Significantly improved from 40% to 100% due to the removal of centralized dependency.
- ✓ Auditability / Traceability: Increased from 55% to 98% with the help of blockchain-based transparent logging.

V. CONCLUSION

This paper presented a secure and efficient framework for data storage and sharing using a combination of advanced cryptographic and decentralized technologies. The proposed system integrates Elliptic Curve Cryptography (ECC), Proxy Re-Encryption (PRE), blockchain, and IPFS to address the limitations of traditional centralized cloud storage models. By incorporating multi-layer security mechanisms and decentralized architecture, the system ensures data confidentiality, integrity, and controlled access.The experimental results demonstrate significant improvements in key performance metrics such as data security, privacy preservation, availability, and auditability. The elimination of a single point of failure and the introduction of transparent transaction tracking enhance system reliability and trust. Additionally, the use of efficient encryption techniques maintains a balance between security and computational performance. Overall, the proposed model provides a scalable, secure, and reliable solution for modern cloud environments. It effectively overcomes the challenges of centralized systems and supports secure data sharing among multiple users. This approach can be further extended to real-world applications requiring high levels of data protection and decentralized control.

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