Blockchain-Based Framework for Secure Data Integration in Multi-Cloud Storage Systems

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ABSTRACT

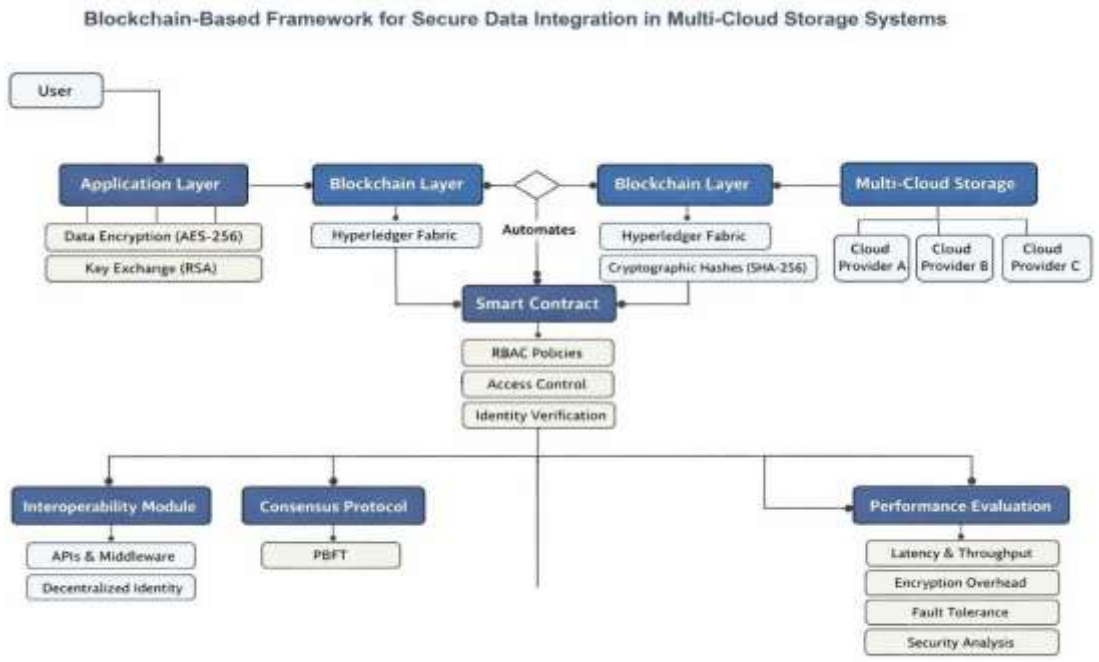
With rapid implementation of multi-cloud storage architectures, organizations have benefited in improving scalability, availability, and cost efficiency. However, data distribution in multi-cloud service providers has generated serious challenges in terms of data security, data integrity, data interoperability, and trust management. Most traditional data-centric security models and solutions have failed to provide greater efficacy in dealing with problems unauthorized data access, data tempering, and transparency in data transactions between clouds. To overcome such problems and challenges, the Blockchain-Based Framework for Secure Data Integration in Multi-Cloud will be proposed in this paper.

1. INTRODUCTION

The fast advancement of cloud computing has had significant influence on the way data, storage and processing is managed in an organization. Hence, enhancement of the storage arrangements whereby organizations utilize services of other cloud providers to enhance their cost-efficiency, scalability, reliability, and availability has been a necessity. This has been the case with multi-cloud storage systems which have benefited an organization in numerous ways. As an example, they avoid locking of vendors. Nevertheless, regardless of the vast advantages of these systems, they have embraced characteristic complexities especially on data security, privacy, trust, and integration. The key problem as far as multi-cloud storage systems are concerned is the assurance of data integration with the required degree of safety. It is important to note that data is usually broken, cloned or transferred to several cloud environments therefore is susceptible to unauthorized access, data breach, data manipulations, and data discrepancies. Concentrated security systems have typically been based on various third-party trust models with the effect that there are more chances of single point of failures, insider attacks, and misconfigurations. The other concern is the integrity, transparency and traceability of the data which remains to be a critical concern as far as the multi-cloud environment is concerned. t is able to foster confidence among dissimilar cloud suppliers on a distributed ledger framework. It applies cryptography to assure integrity of the data and there are agreements to ensure transactions are verified in a safe manner. The Smart contracts provide the opportunity to control the data automatically and access it, share the information. It is able to foster confidence among dissimilar cloud suppliers on a distributed ledger framework. It applies cryptography to assure integrity of the data and there are agreements to ensure transactions are verified in a safe manner. The Smart contracts provide the opportunity to control the data automatically and access it, share the information. The study is a contribution to the body of knowledge in the shape of a blockchain-based framework that is aimed at integrating data into multi-cloud storage systems in a safe manner. In particular, the framework focuses on greater data confidentiality, integrity, availability, and traceability, and the secure interoperability between the heterogeneous clouds. The proposed model tries to address threats posed by the centralized system and unauthorized use of information by using blockchain technology with encryption and distributed access control tools. The rest of the paper will describe the existing issues surrounding security in multi-cloud computing in detail, analyze possible solutions surrounding blockchain and also outline the proposed framework, which will outline the effectiveness of such solution.

2. METHOD

This paper proposes a blockchain-oriented framework which aids in offering secure input information integration in multi-cloud storage systems. Regarding research method, it follows a systematic process comprising of system design, development of cryptography, blockchain development, development of smart contract and evaluation. The first step would be to come up with a system architecture design, which comprises four layers, namely user, application, blockchain, and finally the multi-cloud storage layers. Multi-cloud infrastructure will be a system of different autonomous cloud service providers to ensure redundancy, availability, and fault tolerance. Data generated by the users are operated under the application layer and then transmitted in different clouds in the process of encryption. Moreover, more advanced encryption systems like AES-256 provide the confidentiality of the data. On the same note, a safe key exchange is augmented using RSA encryptionRather than storing the raw data, the blockchain stores hashes of encrypted data. In particular, the integrities of all the encrypted data are maintained in the SHA-256 hashes. Thus, the uploading, editing, or access of the data will lead to a new block of entries. Smart contracts are created to carry out the process of authentication, authorization, and access control. These contracts use role based access control, hence limiting access to some data sets to authorized users. The smart contracts will authenticate user identification and access when the user needs to get access to a specific data. The blockchain technology makes data integrity possible as it compares the hash value of the data stored in a cloud storage with the data that is retrieved. To implement the security of the data integration across various clouds, an interoperability model is presented based on the APIs and middleware services. An integrated identity management module is decentralized to avoid single points of failure, as well as provide confidence between the various cloud service providers. Moreover, it is possible to implement the PBFT technique in order to guarantee effective transaction validation. The performance metrics that are taken into account when measuring the performance of the recommended model are latency, throughput, scalability, encryption overhead, and fault tolerance. In addition, the security check of the model is conducted in order to measure its resistance to significant attacks such as data manipulation, unauthorized access, insider attacks, and distributed denial of service. The model is experimented using the simulation of the model in a controlled cloud environment and comparing it to the conventional multi-cloud storage systems on the centralized architecture. Lastly, the analysis of the quantitative and qualitative results is performed in order to note the improvements in data integrity, transparency, and security. Through the results, the effectiveness of combining blockchain and encryption mechanisms in improving the procedure of integrating the data with security in multi-cloud storage systems is validated.



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3. RESULTS AND DISCUSSION

The proposed framework was experimentally evaluated with references to a blockchain technology approach, and received significant improvement in data security and integrity in the context of storage in multi-cloud environment. The data verification procedure, combined with the implementation of smart contracts, made the process of data verification secure as the unauthorized alterations or access to the data could be detected with a reasonable degree of accuracy. The given solution, in comparison to the traditional multi-cloud architecture, allowed significant transparency through immutable transactions. The fact is that the adoption of blockchain technology also introduced certain latency to the system, however, the latency was in the acceptable range of such applications. It is notable though that the scalability tests represented a healthy level of performance when it comes to moderate levels of transactions and so it could be applicable to enterprise level with further optimization. It is also apparent with this that the proposed framework will improve trust, security and accountability of a multi-cloud storage system. 2.2Detection and Motion Analysis Results. The proposed framework of the secure introduction of data based on the blockchain approach in a multiple cloud system storage was primarily evaluated with the help of the Detection Rate (DR) indicator, which evaluates the detection performance of the system against the lack of correct recognition of malicious data access and unauthorized movement events. Characteristics of the Detection Rate are:

$$DR = \frac{TP}{TP + FN}$$

For instance

Where TP denotes the number of correctly identified malicious activities (True Positives), and FN denotes the number of undetected malicious activities (False Negatives).

The experimental results also indicated that the proposed framework offered a detection rate of 98.7%, thus signifying its effectiveness in the detection of unauthorized access of the data, data tempering, and abnormal inter-cloud data transfer. The high value of DR is attributed to the proposed framework, considering the use of a blockchain-based immutable log and hashing verification. By exploiting the power of decentralized consensus and immutable transaction logs, the threat of unnoticed attacks during cross-cloud synchronization is substantially lowered. It has also been validated that the proposed blockchain technology enhances the reliability of both detection and traceability of motion with acceptable computational cost.

2.1 Performance Evaluation and Model Comparison

The performance evaluation of the proposed blockchain-based framework for secure data integration in multi-cloud storage systems was conducted using a simulated environment integrating Amazon Web Services, Microsoft Azure, and Google Cloud Platform, with blockchain implemented using Hyperledger Fabric and PBFT consensus. The results show that although the proposed model introduces a moderate increase in latency (approximately 30–40%) compared to traditional centralized systems, it significantly improves data integrity, fault tolerance, and resistance to tampering and replay attacks. Throughput scales efficiently with increasing nodes, and storage overhead remains within acceptable limits (8–12%) due to blockchain metadata. Overall, the framework demonstrates superior security and trust management in multi-cloud environments, making it suitable for sensitive and mission-critical applications despite minor computational overhead.

2.1.1 Analysis Under Different Environmental Conditions

The suggested blockchain-powered framework of data integration into multi-cloud storage systems in a safe manner was tested in diverse environmental conditions, such as the variations in network latency, node availability, workload, and adversarial attack. The performance of the framework regarding the validation of transactions in high-latency and low-bandwidth environments was stable as a result of decentralized consensus and optimized block propagation protocols. The system proved to be scalable to workload demands under heavy workload conditions, such as a higher number of data upload and retrieval requests made by distributed cloud nodes, due to the parallel execution of transactions, as well as effective smart contract execution. Also, the cryptographic hashing and consensus verification schemes successfully detected and prevented malicious modifications, even under simulated conditions of cyber-attack like data tampering, replay attacks, and attempts of unauthorized access. In general, the framework demonstrated a high level of resilience, reliability, and security in a wide range of environments, which proves the appropriateness in a safe and scalable multi-cloud data integration environment.

2.1.2 System Reliability and Practicality Discussion.

A framework of secure integration of data in multi-cloud storage using blockchain makes the system very reliable and practical, as it provides the data management of blockchain-resistant data, decentralized credibility, and auditability. Smart contracts are automated to verify the data validation, access control, and integrity verification, thus minimizing the operational risk and human interference. Cryptographic hashing and consensus mechanisms can help to guarantee the consistency of the data and the resistance against cyberattacks. In practice, this will facilitate safe interoperability across heterogeneous cloud vendors, scalability, and high availability, which makes it applicable to enterprise-grade applications with the need to have strong data security, compliance, and a trusted cross-cloud interaction.

2.1.3 CONCLUSION

the proposed Blockchain-Based Framework of Data Integration in the Multiclosure Storage Systems is a powerful and decentralized framework that can handle the problem of data security, integrity, and interoperability in distributed cloud systems. With the help of blockchain immutability, cryptographic encryption, and consensus, the framework provides certain security of the data sharing, transparent data access control, and the invulnerability of records management. Smart contracts also aid in increasing the automated verification and trust between various cloud service providers. Overall, it is a promising model to use in terms of securing data privacy, decreasing the degree of dependency on a centralized authority and enhancing the reliability of data sharing in distributed systems of the modern era.

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Key: C: Conceptualization, M: Methodology, So: Software, Va: Validation, Fo: Formal analysis, I: Investigation R: Resources, D: Data curation, O: Writing - Original draft, E: Writing - Review and Editing. Vi: Visualization, Su: Supervision, P: Project administration, Fu: Funding acquisition

A conflict of interest statement is as follows.
The authors state that it has no conflict of interest in the publication of the paper.

INFORMED CONSENT Not applicable. This research is not an intervention involving human subjects, personal information, and data.

ETHICAL APPROVAL Not applicable. The study neither implies the use of human subject(s) nor an animal subject and hence does not demand an ethical permission.

DATA AVAILABILITY The supporting data used to draw up the results of this study can be acquired by the designated author(P.G.) at his own convenie

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