Journal of Theoretical and Computationsl Advances in Scientific Research (JTCASR)
An International Open Access, Peer-Reviewed, Refereed Journal

Hybrid Blockchain and Big Data Framework for Privacy-Preserving Medical Data Sharing

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Abstract. In the healthcare sector, the need for privacy-preserving and secure data sharing is paramount, especially as the volume of medical data continues to grow due to advancements in big data and digital health technologies. To address these challenges, a hybrid blockchain and big data framework offers a promising solution for secure medical data sharing. Blockchain technology provides a decentralized and immutable ledger that ensures the security, transparency, and privacy of medical data. However, traditional blockchain systems face scalability and efficiency issues when handling large-scale datasets, such as electronic health records (EHRs), medical imaging data, and real-time health monitoring data. By integrating big data technologies into the blockchain infrastructure, the hybrid framework can leverage the strengths of both systems to enable efficient and privacy-preserving medical data sharing. This paper proposes a hybrid framework that combines the immutability and security of blockchain with the scalability and processing power of big data analytics. Through the use of smart contracts, healthcare institutions can securely share medical data while maintaining compliance with regulations like HIPAA and GDPR. The framework also incorporates privacy-preserving mechanisms such as zero-knowledge proofs (ZKP) and differential privacy to protect patient data during data sharing. This paper provides a detailed analysis of current challenges in medical data sharing and presents a novel hybrid blockchain and big data solution that enhances the security, privacy, and scalability of healthcare systems.

Keywords. Hybrid Blockchain, Big Data, Privacy-Preserving Medical Data Sharing, Smart Contracts, Electronic Health Records (EHR), Zero-Knowledge Proofs, Differential Privacy, Healthcare Data Security, Decentralized Systems, GDPR Compliance.

1. INTRODUCTION

The rapid digital transformation of healthcare has led to an unprecedented increase in the volume of medical data generated by patients, healthcare providers, and medical devices. The digitization of electronic health records (EHRs), medical imaging, and real-time health monitoring devices has opened up new opportunities for data-driven healthcare, personalized medicine, and predictive diagnostics. However, the sheer volume of healthcare data, coupled with its sensitive nature, presents significant challenges in terms of privacy, security, and data sharing.

Healthcare organizations are increasingly required to share medical data for research, diagnostics, and collaboration. However, ensuring the privacy and security of patient data during these exchanges is a major concern, especially with the stringent requirements of data privacy regulations such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States and the General Data Protection Regulation (GDPR) in Europe. Traditional centralized data storage systems are vulnerable to data breaches, unauthorized access, and cyberattacks, which can compromise patient privacy and lead to legal and financial repercussions.

Blockchain technology has emerged as a potential solution for addressing these privacy and security challenges. Blockchain's decentralized and immutable architecture ensures that medical data is securely stored and shared across multiple entities, providing transparency and traceability while reducing the risk of data

breaches. However, blockchain's limitations in handling large datasets and high throughput, particularly in healthcare settings, have raised concerns about its scalability and efficiency.

To address these challenges, this paper proposes a hybrid blockchain and big data framework for privacy-preserving medical data sharing. By integrating big data technologies with blockchain, the framework can effectively manage the storage, processing, and sharing of large-scale medical datasets. Smart contracts enable automated data sharing agreements, while privacy-preserving techniques such as zero-knowledge proofs (ZKP) and differential privacy ensure that patient data remains secure and private during data exchanges. This framework offers a novel solution for enhancing the security, privacy, and scalability of healthcare data sharing while complying with data privacy regulations.

2. LITERATURE SURVEY

The application of blockchain technology in healthcare has been widely explored due to its potential to improve data security, privacy, and traceability. Blockchain's decentralized nature allows healthcare providers, patients, and researchers to share data without relying on a centralized authority, thus reducing the risk of data breaches and ensuring data integrity. In their study, Azaria et al. (2016) introduced MedRec, a blockchain-based system for managing electronic health records (EHRs). MedRec demonstrated how blockchain could provide a secure and transparent infrastructure for EHR sharing while allowing patients to retain control over their data. However, the study also highlighted scalability concerns, as blockchain networks can become slow and inefficient when dealing with large datasets.

Xia et al. (2017) proposed a blockchain-based privacy-preserving healthcare system that leveraged smart contracts to facilitate secure data sharing between healthcare providers. Their study showed that smart contracts could automate the process of granting and revoking access to medical data, reducing the administrative burden on healthcare organizations. However, the study noted that blockchain alone could not efficiently handle the storage and processing of large medical datasets, such as medical images and real-time monitoring data.

The advent of big data technologies has revolutionized the way healthcare organizations store, process, and analyze large datasets. Wang et al. (2018) demonstrated the potential of big data analytics to improve healthcare outcomes by enabling real-time monitoring, predictive analytics, and personalized treatment plans. Big data technologies, such as Apache Hadoop and Apache Spark, have the ability to process massive amounts of data in parallel, making them ideal for handling large-scale healthcare datasets. However, big data systems are typically centralized, which raises concerns about data privacy and security.

To address these challenges, researchers have explored the integration of blockchain with big data technologies. Zhang et al. (2020) proposed a hybrid blockchain-big data architecture for managing healthcare data. The hybrid approach leveraged blockchain for secure data sharing while using big data technologies to handle the processing and storage of large datasets. The study demonstrated the feasibility of combining these two technologies but did not address specific privacy-preserving techniques that could enhance patient data protection.

This paper builds on the existing literature by proposing a hybrid blockchain and big data framework that incorporates privacy-preserving mechanisms such as zero-knowledge proofs (ZKP) and differential privacy. These techniques ensure that patient data remains confidential during data sharing and analysis, while the integration of blockchain and big data enhances the system's scalability and efficiency.

3. PROPOSED METHODOLGY

The proposed Hybrid Blockchain and Big Data Framework is designed to enable secure and privacy-preserving medical data sharing while addressing the scalability challenges of blockchain in handling large datasets. The system integrates blockchain technology with big data analytics and incorporates privacy-preserving techniques such as zero-knowledge proofs (ZKP) and differential privacy.

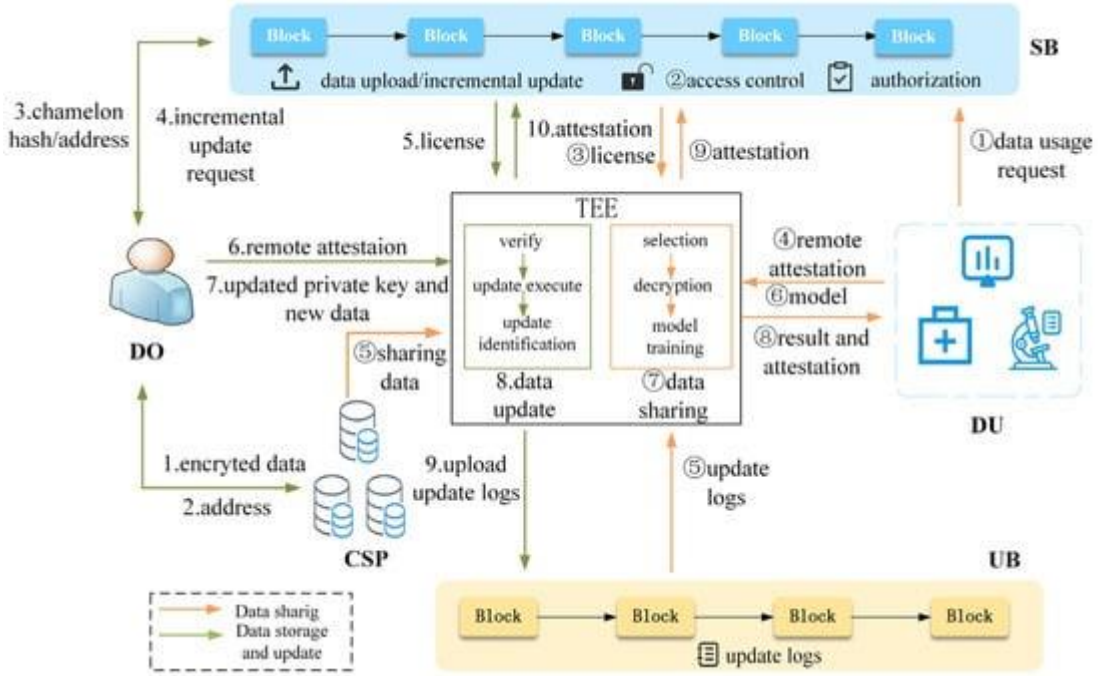

FIGURE 1. *A Blockchain-Based Privacy-Preserving Healthcare Data Sharing Scheme*

Blockchain Layer for Data Security and Sharing

The blockchain layer serves as the foundation for securing medical data and enabling decentralized data sharing between healthcare providers, patients, and researchers. Medical data is hashed and stored on the blockchain, ensuring data integrity and immutability. Smart contracts are used to automate data-sharing agreements and enforce access control policies. Each healthcare provider, patient, or researcher has access to the blockchain, allowing them to share data securely and transparently.

Big Data Layer for Scalable Data Processing

The big data layer handles the storage and processing of large medical datasets, such as EHRs, medical imaging, and real-time health monitoring data. The system utilizes big data technologies such as Apache Hadoop and Apache Spark to process and analyze these large datasets in parallel. This layer ensures that the system can handle high-throughput data processing while maintaining efficiency and scalability.

Privacy-Preserving Mechanisms

To ensure patient privacy during data sharing, the system incorporates zero-knowledge proofs (ZKP) and differential privacy. ZKP allows one party to prove to another party that they possess certain data without revealing the actual data. This ensures that medical data can be verified without exposing sensitive information. Differential privacy is used to add noise to datasets before sharing them with researchers, ensuring that individual patient data cannot be re-identified.

Smart Contracts for Data Access Control

Smart contracts are deployed on the blockchain to automate the process of granting and revoking access to medical data. These contracts define the terms and conditions under which data can be accessed, ensuring compliance with privacy regulations such as HIPAA and GDPR. The use of smart contracts reduces administrative overhead and ensures that only authorized parties can access the data.

4. CONCLUSION

The proposed Hybrid Blockchain and Big Data Framework offers a secure, scalable, and privacy-preserving solution for medical data sharing in healthcare. By integrating the immutability and security of blockchain with the processing power of big data technologies, the framework addresses the challenges of handling large medical datasets while ensuring compliance with data privacy regulations. The use of privacy-preserving techniques such as zero-knowledge proofs (ZKP) and differential privacy enhances patient data protection during data exchanges, allowing healthcare organizations to securely collaborate and share medical information. This hybrid framework not only improves data security and privacy but also enables real-time data analysis, which can enhance healthcare outcomes and drive advancements in medical research. Future work should focus on optimizing the system for real-time health monitoring and exploring additional privacy-enhancing technologies.

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