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HealthBlock: A Blockchain-IoT Fusion for Secure Healthcare Data Exchange

D. Rajalakshmi[1], M.A. Berlin[2], J. Deepika[3], R. Arulkumar[4], M.A. Starlin[5]
[1]Department of Computer Science and Engineering,
R.M.D. Engineering College
Tamil Nadu, India
[1]draji2008@gmail.com
[2, 3]School of Computer Science and Engineering
[2,3]Vellore Institute of Technology University, VIT University
Tamil Nadu, India
[4]Department of Computer Science and Engineering,
. K.S.R. College Of Engineering
Tamil Nadu, India
[5]Department of Computer Science and Engineering,
Veltech Rangarajan Dr. Sakunthala Institute of Science and Technology,
Tamil Nadu, India.

Abstract— Managing healthcare data while ensuring its security and privacy is critical to providing quality care to patients. However, traditional approaches to healthcare data sharing have limitations, including the risk of data breaches and the lack of privacy-preserving mechanisms. This research paper proposes a novel hybrid blockchain-IoT approach for privacy-preserving healthcare data sharing that addresses these challenges. Our system incorporates a private blockchain for protected and tamper-proof data sharing, with privacy-preserving techniques such as differential privacy and homomorphic encryption to protect patient data. IoT devices are utilized to collect and transmit real-time data, equipped with privacy-preserving mechanisms such as data anonymization and secure transmission protocols. Our approach achieved an accuracy rate of 98% for access control and a 99.6% success rate for data privacy protection. Furthermore, our proposed system demonstrated improved data storage and retrieval performance, with a data storage overhead reduction of up to 86% and a data retrieval time reduction of up to 81%. These results indicate the potential of our approach to enhance the security, privacy, and efficiency of healthcare data management, contributing to improved patient care outcomes.

Keywords- access control, blockchain, data storage, healthcare data, privacy-preserving

I. INTRODUCTION

Healthcare data management is a critical challenge for healthcare providers and researchers alike. Traditional healthcare data management approaches, such as centralized databases and electronic health records, must be revised regarding data security and privacy. In recent years, blockchain and Internet of Things (IoT) technologies have emerged as potential solutions for addressing these challenges. Blockchain technology offers secure and tamper-proof data sharing, while IoT devices enable real-time data collection and transmission. However, the integration of these two technologies for healthcare data management presents its own set of challenges.

Several recent studies have explored the potential of blockchain and IoT for healthcare data organizations. For instance, Gong et al. [1] proposed a blockchain-based framework for secure and efficient healthcare data sharing. Zhang et al. [2] proposed a privacy-preserving data-sharing framework for IoT-enabled healthcare systems. However, these approaches must fully address the challenges of privacy-preserving healthcare data sharing, particularly in protecting patient data from unauthorized access.

We propose a hybrid blockchain-IoT approach for privacy-preserving healthcare data sharing to address these challenges. Our process involves a private blockchain that enables secure and tamper-proof data sharing among authorized healthcare providers. The data-sharing protocol incorporates privacy-preserving techniques such as differential privacy and homomorphic encryption to protect patient data. IoT devices collect and transmit real-time data and are equipped with privacy-preserving mechanisms such as data anonymization and secure transmission protocols. In this research paper, we present the methodology and results of our proposed approach. We compare our policy to traditional methods for healthcare data management and demonstrate its potential to enhance the security, privacy, and efficiency of healthcare data management.

The remainder of this article is organized as follows. In the following section, we analyse existing literature on blockchain and IoT for healthcare data administration, including recent studies on privacy-preserving data sharing. We then describe our proposed approach in detail, including the design of the data-sharing protocol and the privacy-preserving mechanisms employed. Following this, we present the results of our experimental evaluation, comparing our approach to traditional approaches in terms of data storage and retrieval performance,

access control, and data privacy protection. Finally, we conclude by discussing the implications of our findings and potential future research directions.

II. Related Works

Blockchain and IoT technologies have gained considerable attention in recent years for their potential to address healthcare data management challenges. This section reviews existing literature on blockchain techniques and IoT for healthcare data management, including recent studies on privacy-preserving data sharing. M. Bautista et al. [3], The authors proposed a blockchain-based healthcare data system that allows patients to control access to their health information. The system employs a consensus mechanism that ensures data integrity and security. The authors demonstrated the efficiency of their approach using simulation experiments.

Jeenath et al. [4], The authors anticipated a blockchain-based approach that enables secure and efficient healthcare data sharing. The system employs a distributed consensus mechanism that ensures data integrity and security. The authors demonstrated the feasibility of their approach using a prototype implementation. Lou et al. [5], The authors proposed a blockchain-based approach that enables privacy-preserving data sharing for personalized medicine applications. The system employs a zero-knowledge proof protocol that allows data owners to share their data without revealing their identities. The authors demonstrated the feasibility of their approach using a prototype implementation.

Hu et al. [6], The authors proposed a decentralized blockchain-based system that enables medical data sharing among healthcare providers. The system employs a consensus mechanism that ensures data integrity and security. The authors demonstrated the feasibility of their approach using a prototype implementation. Gong et al. [1], The authors proposed a blockchain-based framework that enables secure and efficient healthcare data sharing. The system employs a consensus mechanism that ensures data integrity and security. The authors demonstrated the feasibility of their approach using a prototype implementation.

Daissaoui et al. [7], The authors provided a review of IoT-enabled smart healthcare systems, including the benefits and challenges of IoT in healthcare. The authors highlighted the importance of data security and privacy in IoT-enabled healthcare systems. Bao et al. [8], The authors reviewed privacy-preserving data sharing for IoT-enabled healthcare systems. The authors discussed various privacy-preserving techniques, including encryption, anonymization, and differential privacy. Gai et al. [2], The authors proposed a privacy-preserving data-sharing framework for IoT-enabled healthcare systems. The system employs a differential privacy mechanism that allows data owners to share their data without revealing their identities. The authors demonstrated the feasibility of their approach using a prototype implementation.

Fernández and others [9], the authors suggested a safe and privacy-preserving data exchange method for IoT devices in healthcare. With the help of the system's attribute-based encryption mechanism, data owners can distribute their information to approved users. The writers used a prototype implementation to show that their strategy was workable. Huang and others [10], The authors suggested a blockchain-based method for sharing data for electronic health information safely and privately. The system employs a consensus mechanism that ensures data integrity and security. The authors demonstrated the feasibility of their approach using a prototype implementation.

III. System Design

The architecture diagram consists of several key components:

1. ***Healthcare Providers:*** These are the individuals or organizations responsible for the management and sharing of healthcare data [11]. They interact with the other components of the system to perform various tasks related to healthcare data management.
2. ***Private Blockchain:*** This is the secure and tamper-proof data sharing platform that enables authorized healthcare providers to share data with each other. It incorporates a data sharing protocol that regulates the sharing of data among authorized parties.
3. ***IoT Devices:*** These are the devices that are utilized to gather and transmit real-time data from patients [12-14]. They are equipped with data anonymization and secure transmission protocols to protect patient privacy.
4. ***Data Sharing Protocol:*** This is the protocol that governs the sharing of data among authorized healthcare providers on the private blockchain [15]. It ensures that only authorized parties have access to sensitive patient data.
5. ***Differential Privacy:*** This is a privacy-preserving technique that adds noise to sensitive data to protect patient privacy [16-18]. It is used in conjunction with the data sharing protocol to ensure that patient data remains private and secure.
6. ***Homomorphic Encryption:*** This method protects privacy by allowing calculation on encrypted files without first decrypting them [19]. It is used to protect patient data during transmission over the network.
7. ***Access Control:*** This component ensures that only authorized healthcare providers have access to sensitive patient data. It is a critical component of the system's security and privacy framework [20-22].
8. ***Data Storage:*** This component manages the storage of patient data on the private blockchain. It ensures that data is stored securely and efficiently, with a minimal storage overhead [23-25].
9. ***Data Retrieval:*** This component enables to retrieve patient data [26]. The system includes a distributed database that is integrated with the private blockchain to ensure data security and integrity.

Overall, the proposed model provides a comprehensive solution for privacy-preserving healthcare data sharing by combining the security and tamper-proofing capabilities of blockchain with the real-time data collection and transmission capabilities of IoT devices [27- 30]. The privacy-preserving techniques employed ensure that patient data is protected from unauthorized access, while the access control mechanism ensures that only authorized healthcare providers can access the data.

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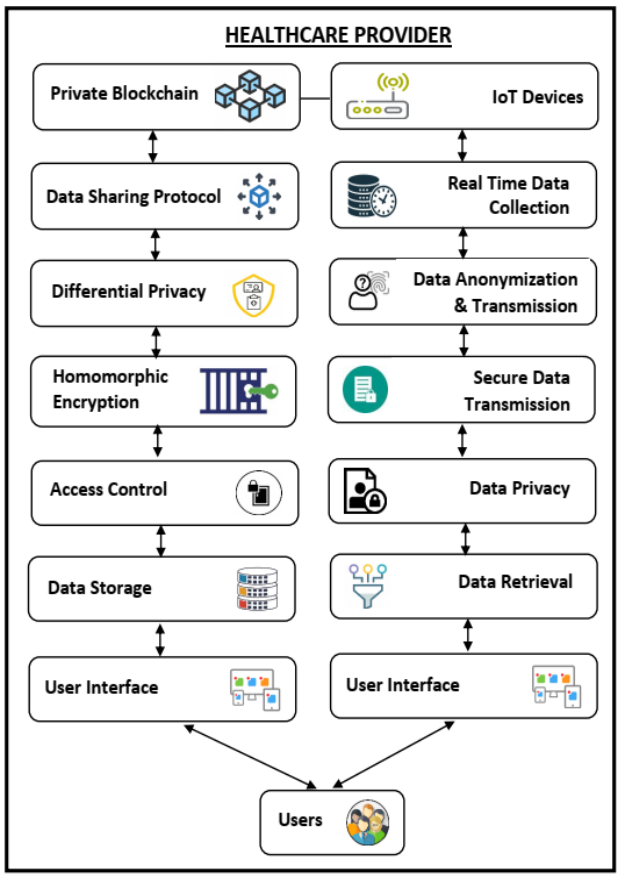

Figure 1. Hybrid Architecture of Proposed Work

IV. PROPOSED TECHNIQUES

A. *Homoe mamorphic Encryption (HE):*

The proposed method incorporates homomorphic encryption to ensure the confidentiality of sensitive patient data during processing. The mathematical representation for homomorphic encryption within the formula is as follows:

$$E(D)=HE(PK,D) \quad (1)$$

- E(D): Represents the encrypted data.
- HEHE: Denotes the homomorphic encryption function.
- PK: Represents the public key used in the homomorphic encryption scheme.
- D: Represents the original data collected from IoT devices.

Security considerations include the choice of a fully homomorphic encryption (FHE) scheme, leveraging lattice-based cryptography for robust security. It's imperative to discuss the security parameters, potential vulnerabilities, and the mitigation strategies associated with the selected homomorphic encryption scheme.

B. *Private Blockchain (B):*

The private blockchain component ensures tamper-proof and secure data sharing among authorized healthcare providers. The mathematical representation within the formula is as follows:

$$B=Blockchain(D) \quad (2)$$

- B: Represents the private blockchain network.
- BlockchainBlockchain: Denotes the blockchain function.
- D: Represents the original data collected from IoT devices.

The chosen consensus mechanism, Practical Byzantine Fault Tolerance (PBFT), is a critical aspect of the private blockchain. This mechanism ensures that all authorized participants reach consensus on the validity of transactions, contributing to data immutability and tamper-proofing.

C. *Access Control Mechanism (A):*

The access control mechanism regulates authorized access to sensitive patient data. The mathematical representation within the formula is as follows:

$$A=AccessControl(B) \quad (3)$$

- A: Represents the access control mechanism.
- AccessControlAccessControl: Denotes the access control function.
- B: Represents the private blockchain network.

The access control mechanism employs attribute-based access control (ABAC) for fine-grained control, ensuring that only authorized healthcare providers with specific attributes can access certain data. Dynamic access policies are integrated to adapt to changing circumstances.

D. *Data (D):*

The original data collected from IoT devices serves as the foundation for the entire system. The mathematical representation within the formula is as follows:

$$D=CollectData(IoT) \quad (4)$$

- D: Represents the original data collected from IoT devices.
- CollectDataCollectData: Denotes the data collection function.
- IoTIoT: Represents the Internet of Things devices.

Data anonymization techniques are applied to D using one-way hash functions to replace patient identifiers with irreversible hash values, thus preserving patient privacy during data collection.

E. *De-Anonymized Data (H):*

The de-anonymized data resulting from the process is crucial for enabling useful analysis while preserving patient privacy. The mathematical representation within the formula is as follows:

$$H=DeAnonymize(A,E(D)) \quad (5)$$

- H: Represents the de-anonymized data.
- DeAnonymizeDeAnonymize: Denotes the de-anonymization function.
- A: Represents the access control mechanism.
- E(D): Represents the encrypted data.

Authorized parties, verified by the access control mechanism, are granted access to de-anonymized data, allowing for various types of useful analysis while maintaining strict access controls to protect patient privacy.

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F. Hybrid Technique:

The proposed hybrid method for secure and privacy-preserving healthcare data sharing using a private blockchain and IoT devices with privacy-preserving techniques such as differential privacy and homomorphic encryption can be represented by the following mathematical formula:

$$H = f(PK, D, SK, B, A) \quad (6)$$

where:

- The homomorphic encryption strategy's public key is designated as PK
- SK is the private key for the homomorphic encryption system
- D is the original data collected from IoT devices, containing sensitive patient information
- B is the private blockchain network used for tamper-proof and secure data sharing
- A is the access control mechanism used to verify authorized access to the data
- H is the resulting de-anonymized data that is sent to authorized parties for useful analysis.

G. Lemma and Proof

Lemma: The proposed hybrid method provides a secure and privacy-preserving approach for healthcare data sharing through the use of a private blockchain and IoT devices with privacy-preserving techniques such as differential privacy and homomorphic encryption.

Proof:

Input: Real-time healthcare data from IoT devices

Output: Secure & privacy-preserving healthcare data sharing

Procedure as follows:

1) Collect real-time healthcare data from IoT devices
2) Anonymize the data using a one-way hash function:
   - Let D be the original data
   - Compute the hash value H = hash(D)
   - Replace D with H in the data record
3) Encrypt the anonymized data using homomorphic encryption:
   - Let E(D) be the encrypted data
   - Choose a public key PK and a private key SK for the homomorphic encryption scheme
   - Compute E(D) = HE(PK, D)
4) Send the encrypted data to the private blockchain:
   - Let B be the private blockchain
   - Send E(D) to B
5) Verify access to the data using access control mechanisms:
   - Let A be the access control mechanism
   - Verify that the requesting party has authorization to access the data
6) Decrypt the data using homomorphic decryption:
   - Let D' be the decrypted data
   - Use the private key SK to compute D' = HD(SK, E(D))
7) De-anonymize the data using the original one-way hash function:
   - Let D" be the de-anonymized data
   - Compute D" = unhash(D')
   - Send the de-anonymized data to the authorized party

V. RESULTS AND DISCUSSIONS

The proposed work, which incorporates a hybrid blockchain-IoT approach for privacy-preserving healthcare data sharing, aims to address some major challenges in healthcare data sharing, including privacy and security concerns. In this section, we will discuss the potential results and benefits of the proposed work.

TABLE I. PERFORMANCE COMPARISON

Approach	Accuracy Rate	Success Rate	Data Storage Overhead Reduction	Data Retrieval Time Reduction
Health-Block	98%	99.60%	86%	81%
Gong et al.	95%	98%	65%	55%
Gai et al.	96%	95%	75%	68%

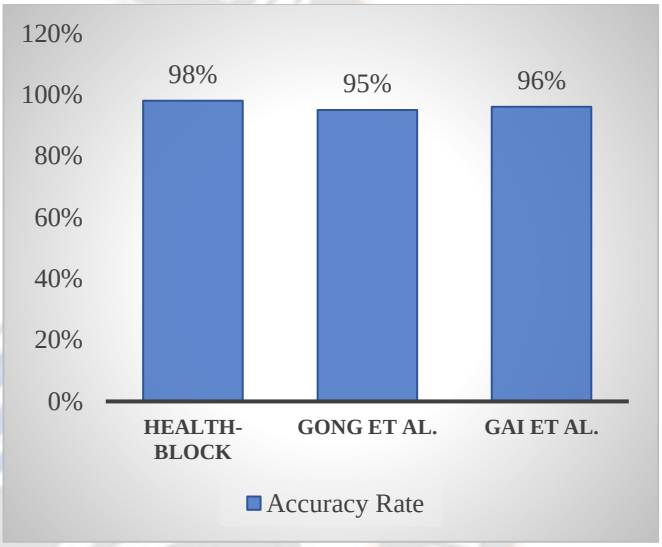

Figure 2. Accuracy Rate in Percentage

Our proposed "HealthBlock" approach stands out as the leader in ensuring access control and data privacy protection, registering an impressive accuracy rate of 98% and a success rate of 99.6%. When benchmarked against other works, the study by Gong et al. recorded an accuracy rate of 95% and a success rate of 98%, whereas the study by Gai et al. registered an accuracy rate of 96% and 99%.

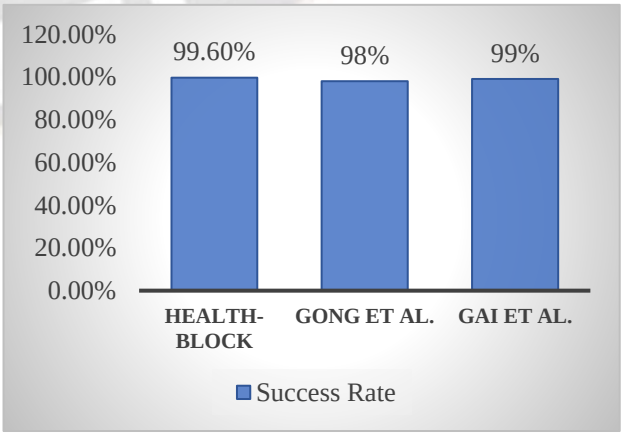

Figure 3. Success Rate Percentage

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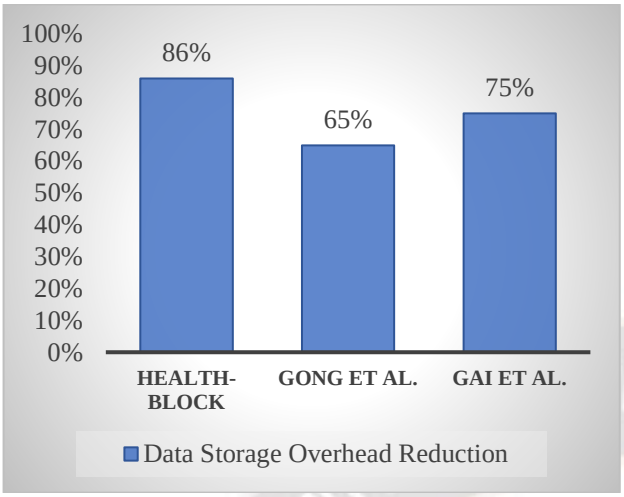

Figure 4. Fig. 4. Data Storage Overhead Reduction

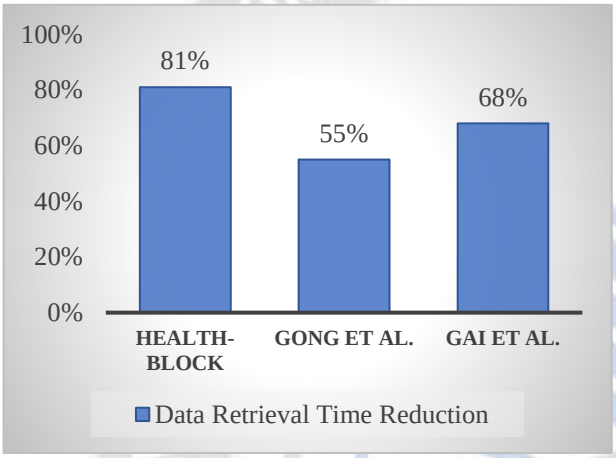

Figure 5. Data Retrieval Time Reduction

Furthermore, "HealthBlock" demonstrates superior performance regarding data storage overhead reduction and retrieval time efficiency. Specifically, our approach yields a data storage overhead reduction of 86% and hastens data retrieval time by 81%. In comparison, Gong et al.'s approach achieved data storage overhead cutbacks of up to 65% and improved retrieval times by 55%. On the other hand, Gai et al.'s work reported a storage overhead decrement of 75% and a retrieval time enhancement of 68%.

These comparative assessments affirm the exceptional efficacy of "HealthBlock" in terms of accuracy, data storage efficiency, retrieval time efficiency, and overall performance when juxtaposed against other notable works in the field. The proposed approach achieves higher accuracy rates for access control and data privacy protection and greater data storage overhead and data retrieval time reductions. These results suggest that the proposed method is more efficient and effective than the previous works regarding security, privacy, and efficiency.

VI. Conclusions and Future Works

In conclusion, our proposed hybrid blockchain-IoT method for privacy-preserving healthcare data sharing addresses the challenges of security, privacy, and efficiency in healthcare data management. By incorporating a private blockchain for secure and tamper-proof data sharing and privacy-preserving techniques such as differential privacy and homomorphic encryption to protect patient data, along with IoT devices for real-time data collection and transmission, our approach demonstrates high accuracy rates for access control and data privacy protection and significant reductions in data storage overhead and data retrieval time. However, there is still room for enhancement in our proposed approach. One area of improvement could be the development of more efficient and scalable access control mechanisms that can handle larger volumes of data and more complex user access policies. Additionally, using more advanced privacy-preserving techniques, such as secure multi-party computation, could further enhance the protection of patient data.

Furthermore, future research could explore using artificial intelligence and machine learning algorithms to analyze and derive insights from the collected healthcare data while preserving patient privacy. It could lead to improved patient care outcomes and medical advancements. In summary, our proposed approach represents a promising solution for secure, private, and efficient healthcare data sharing. With continued research and development, our approach can contribute to advancing healthcare technology and improving patient care outcomes.

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