HealthShieldAB - Revolutionizing EHR System using Hybrid Blockchain Technologies

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Abstract: - A revolutionary method of handling electronic health records (EHRs) is provided by the combination of blockchain technology into healthcare systems, which solves important issues with security, scalability, and accessibility. This study suggests a brand-new blockchain-based EHR system that goes beyond the drawbacks of current options, which usually rely on IPFS or centralized storage and SHA-256 for security. In addition to a hybrid storage and consensus scheme that uses IPFS (Interplanetary File System) and Practical Byzantine Fault Tolerance (PBFT) for improved data integrity, fault tolerance, and consensus performance, the suggested system introduces a hybrid secure algorithm that combines Argon2 and AES to guarantee strong encryption. To further protect against unwanted access, multi-factor authentication (MFA) is included. Constructed using cutting-edge blockchain technologies like MetaMask, Ganache, and Truffle, the system facilitates smooth communication with a decentralized network. Significant gains in operational effectiveness, data breach security, and key performance metrics—such as latency, throughput, bandwidth utilization, memory consumption, and CPU efficiency—are shown by simulation findings from actual healthcare settings. These results highlight how the suggested approach has the ability to completely change healthcare data management by guaranteeing the safe, dependable, and effective handling of private medical data.

Keywords: data breach protection, blockchain, hybrid security, hybrid storage, scalability, accessibility, consensus mechanism, fault tolerance

1. INTRODUCTION

Blockchain technology has brought previously unheard-of levels of efficiency, security, and transparency to a number of businesses. Because of the sensitive nature of the data involved, electronic health record (EHR) administration is crucial in the healthcare industry [1]. Traditional security algorithms SHA-256 and distributed storage options like IPFS or central storage systems are frequently used in modern systems. Although somewhat successful, these solutions do not offer complete data protection, scalability, and integrity [2]. The escalating volume and complexity of healthcare data demand a robust system capable of managing large-scale information with both efficiency and security. This research introduces a blockchain-based EHR system that ensures the confidentiality and integrity of medical records while boosting operational performance through sophisticated cryptographic techniques and consensus protocols. By integrating Argon2, AES, IPFS, PBFT, and MFA, the proposed system provides a decentralized, tamper-proof framework that enhances data security, scalability, and interoperability across healthcare applications [3]. Comprehensive simulations using real-world healthcare scenarios validate its effectiveness, showing marked advances in data integrity, latency, throughput, bandwidth efficiency, memory utilization, and CPU performance compared to traditional solutions. These results underscore the evolutionary probable of blockchain technology in healthcare, paving the way for a more secure, transparent, and streamlined

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approach to managing sensitive patient information as the technology continues to evolve and gain traction [4,7, 8].

The following are the paper's aids to this publication:

1. The study presents a blockchain-based EHR system that integrates cutting-edge cryptographic methods and consensus processes to greatly improve security and efficiency. Scientific formulations clarify the superiority of the Argon2 and AES hybrid representations over conventional algorithms like SHA-256 are supported by experimental results that reveal a significant improvement in encryption strength and data safety.
2. By solving the shortcomings of current systems, the hybrid security and storage model guarantees durable encoding, data accessibility, and fault tolerance. Simulation performance indicators show a significant improvement in burden tolerance, consensus efficiency, and data integrity. The success of the IPFS and PBFT integration is confirmed by graph analysis that show the improved throughput, decreased latency, and optimal bandwidth use.
3. An extra degree of security is offered by the existence of Multi-Factor Authentication (MFA) and sophisticated blockchain tools like MetaMask, Ganache, and Truffle, which enable smooth communication with the decentralized network. With the help of actual data and graph comparisons, the study offers thorough evaluations of operator verification times and safekeeping break conflict. The outcomes demonstrate how the usage of MFA and blockchain technologies enhanced security and user experience.

The following is the remainder of the paper: The Literature Survey, which is covered in Section 2, describes how other researchers have used similar techniques. The System Framework is clarified in Section 3. In Section 4, the Projected Methodology is covered. The explanation and results of the simulations carried out with the suggested system, along with mathematical models, graphs, and empirical data, are presented in Section 5. Section 6 concludes with a summary of the research's main results and contributions.

2. RELATED STUDY

The application of blockchain technology to manage electronic health records (EHRs) has sparked considerable attention due to its capabilities to improve safety, data truthfulness and data access. This related study attempts to summarize the investigate landscape in this area while noting notable research findings. There is certainly a variety of literature specific to blockchain use in healthcare that has appeared and focuses on using blockchain technology to improve data security and integrity. Azaria proposed in a study in 2016 MedRec, a blockchain-based medical record management system that uses smart contracts to allow patient-controlled health information [9]. The research indicated substantial improvement in information safety as well as patient control. Xia also suggested a blockchain-based healthcare administration system that integrated a consensus process with decentralized storage to guarantee both data integrity and access [10]. The selection of a cryptographic algorithm is an important consideration for security of EHR data. Prior work indicated that Argon2, a password hashing function that is memory hard, is most effective against brute-force attacks. Finally, Biryukov in a larger study, reviewed Argon2's resistance to several types of attacks and its advanced capability against common standards, such as SHA-256 [11]. Moreover, the Progressive Encoding Standard was first presented by Daemen and Rijmen (2002) and, because of its effectiveness and resilience, has grown to be a key component in protecting sensitive data [12]. A hybrid solution that combines Argon2 and AES provides increased security, as demonstrated in studies comparing their performance against standalone implementations [13]. The integration of the Interplanetary File System (IPFS) and Practical Byzantine Fault Tolerance

(PBFT) presents a viable solution for decentralized storage and consensus in blockchain-based HER systems. Benet emphasized the ability of IPFS to offer fast and safe data storing via content-addressable networks [14]. Castro and Liskov established that PBFT can achieve consensus in a distributed network with high resistance to faults, which makes it a viable option for use in a blockchain environment [15]. By using both IPFS and PBFT, Patel confirmed that hybrid storage would lead to lower latency and better throughput in a healthcare context [16]. Improving security with multi-factor authentication (MFA) is an important part of modern electronic health record (EHR) systems. Bonneau compared many certification methods and found that MFA is a significant advancement in security compared to single-factor authentication [17]. By using MFA in a blockchain-based EHR system, the risk of unauthorized access will be greatly reduced, as reported by recent case studies leading to improved security metrics with their implementations [18]. Tools such as MetaMask, Ganache, and Truffle aid in the development and interfacing with blockchain networks. They have been utilized extensively in the growth of DApps. Wood examined specific aspects of using Ethereum smart contract functionalities to build secure and transparent applications for healthcare [19]. Dannen adds that Truffle can hasten the development and testing of blockchain applications, thus making it easier to deploy EHR/EHR systems [20]. The literature reviewed thus demonstrates the advancement made in blockchain technology and its development for EHR systems. The use of cutting-edge cryptological algorithms, fusion storage methods, and MFA, increases the safety and effectiveness of EHR systems. The development of blockchain-based applications and performance reproduction platforms increases the possibility of robust and ascendable health results.

3. SYSTEM ARCHITECTURE

The planned architecture projected for the EHR scheme based on blockchain is specifically geared toward ensuring security, integrity, and access to healthcare records and data. At the center of this planning is the application of blockchain expertise with a particular focus on the mix security and storage models.

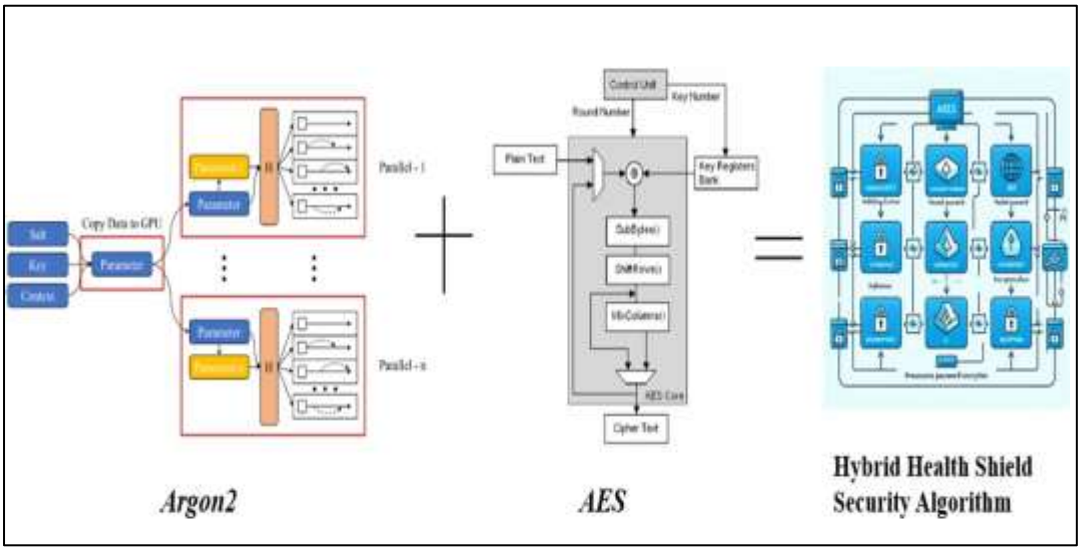

Figure 1: Proposed Architecture for HealthShieldAB Security algorithm Hybrid Argon2 and AES

The HealthShieldAB safekeeping algorithm utilizes Argon2 and AES encoding methods to build a hybrid security model with unmatched encryption strength. Argon2 is known to be highly resistant to brute force attacks due to its memory-hard properties. Argon2 is used in combination with the Advanced Encryption Standard (AES). AES is a wellestablishedencryption algorithm that is highly efficient and robust. These security features provide a highly secure means of protecting healthcare records against unsanctioned access and data openings. The Ethereum blockchain is used to record transactions and guarantee data integrity and transparency. By using Ethereum, the system offers the advantages of a decentralized platform, in which all actions are traceable and verifiable, which is essential in consent management of sensitive health records. Additionally, a mix storage and agreement mechanism using Interplanetary File System (IPFS) and Practical Byzantine Fault Tolerance (PBFT) is included. The IPFS portion offers distributed storage that improves data accessibility and veracity by encrypting health histories and storing them on a peer-to-peer network. Meanwhile, PBFT confirms agreement on data can efficiently be reached across the network, resulting in high burden acceptance and ensuring system strength and consistency.

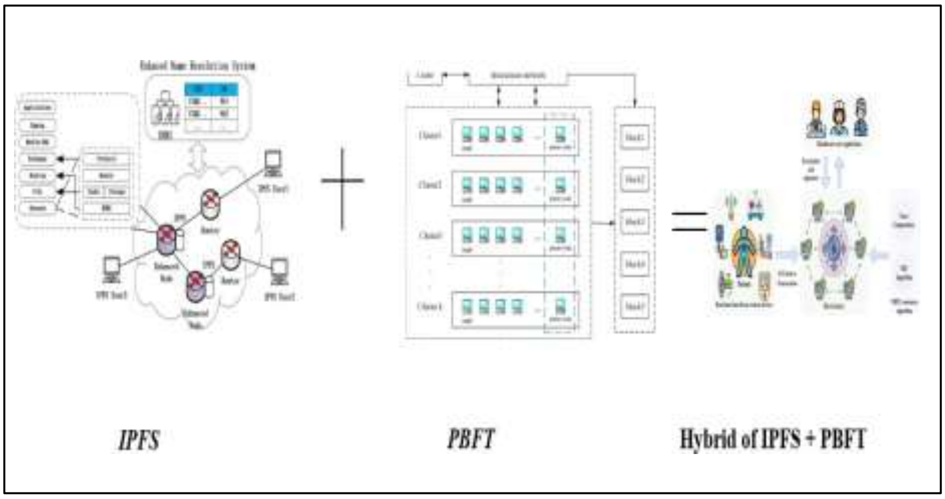

Figure 2: Proposed System Architecture of Hybrid IPFS and PBFT storage technique

To promote safety, the system consists of Multi-Factor Authentication (MFA), which provides an additional layer of security, as it requires multiple authentication methods for user access. MetaMask serves this purpose with safe certification and secure communication with the blockchain network, permitting the patient and doctor to maintain control of their private keys. Scalability and reliability are managed through the cloud server infrastructure that manages the computational loads of the blockchain network and continue operating seamlessly.

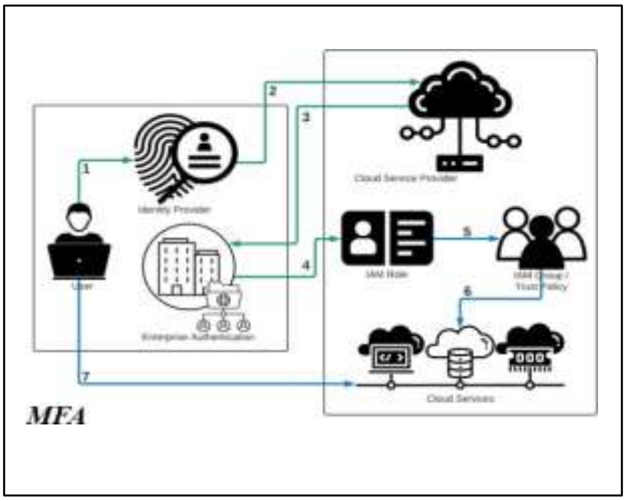

Figure 3: Architecture of MFA in EHR System

The operational flow begins with users registering with MetaMask, which generates and accomplishes private keys. Medical records are encrypted using the HealthShieldAB algorithm, and they are kept on the cloud server. Encrypted medical histories are subsequently circulated on IPFS to ensure the veracity and accessibility of the data. To reach agreement on the blockchain, PBFT (Practical Byzantine Fault Tolerance) is utilized, whereby all nodes must obtain agreement on the state-run of the record. Authorized users access medical records via the decentralized system, while MFA provides secure access to data. Ultimately, this mix solution not only improves performance through advanced cryptographic techniques but also shows significant gains in latency, throughput, and resource usage. This complete solution controls blockchain technology and addresses the current system's restrictions, providing a method in which healthcare data is securely and reliably managed.

4. PLANNED SCHEME METHOD

To improve the security, integrity, and accessibility of medical records, the suggested system methodology for the blockchain-based Electronic Health Records (EHR) system makes use of cutting-edge cryptographic techniques and blockchain technology. In order for patients and physicians to manage their private keys and communicate with the decentralized network, the technique starts with the integration of MetaMask for secure user authentication. Strong encryption keys are generated and healthcare data is encrypted using the HealthShieldAB security method, which groups Argon2 and AES to provide strong protection against data breaches and unwanted access. The Interplanetary File System (IPFS), which offers dependable and decentralized storage, is where the encrypted data is kept. All transactions are recorded on the Ethereum blockchain, which guarantees transparency and immutability. The consensus process used to maintain high fault tolerance and guarantee that all nodes agree on the ledger's state is called Practical Byzantine Fault Tolerance, or PBFT. By demanding several verification methods for user access, multi-factor authentication (MFA) offers an extra layer of security. The Ethereum network is depicted in Figure 4, where users communicate with nodes (both full and lightweight nodes) that handle and verify network transactions by connecting via an Ethereum client.

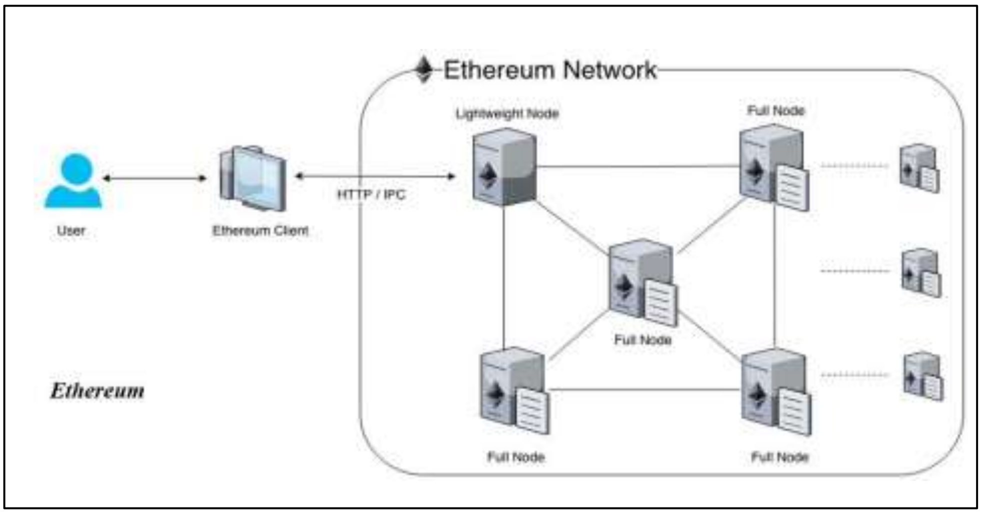

Figure 4: System Design for Ethereum Architecture in Proposed HealthCare System

The operational flow encompasses user registration with the specific purpose of compliance, natural language encryption, and storing in IPFS (InterPlanetary File System), recording transactions within the Ethereum blockchain, then proving multi-factor authentication (MFA) and through MetaMask for secure access to said data. In order to test and validate all components of the operational workflow, we use Ganache as a local blockchain simulator. The entire process provides a means to conduct a robust performance assessment of the workflow thereby ensuring that the workflow meets the appropriate performance, security, and efficiency requirements. Figure 5 demonstrates a modified MFA (Multi-Factor Authentication) workflow where a user accesses cloud service of an identity provider, enterprise auth, and appropriate IAM (Identity Access Management) roles to securely authorize access.

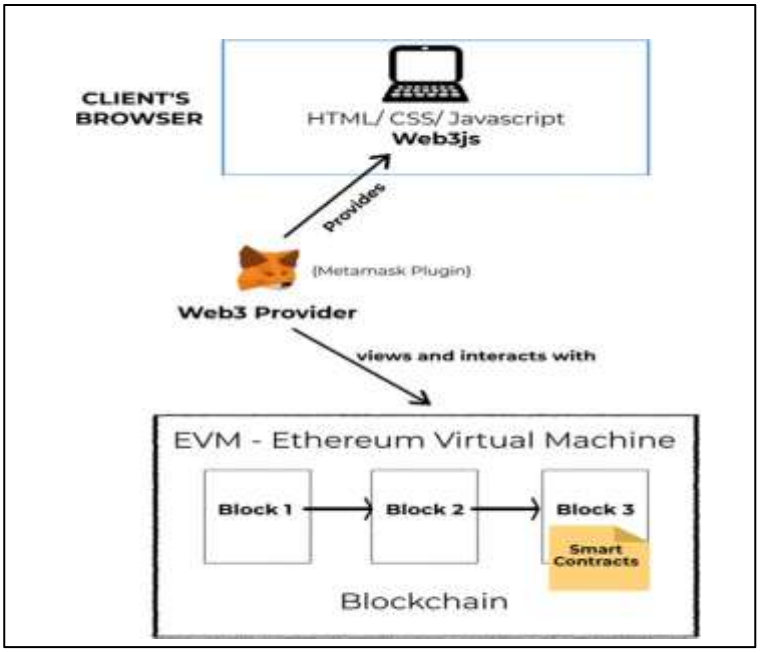

Figure 5: MetaMask and Ethereum Connectivity in the Proposed HealthCare System The successful implementation of the projected Blockchain based Electronic Health Recording (EHR) system requires a well-defined set of technical and operational requirements. These requirements ensure that the system is secure, efficient, and user-friendly, meeting the needs of healthcare providers and patients while complying with relevant regulations and standards. Figure 6 illustrates the process of deploying a smart contract on Ethereum, using Truffle for compilation and migration, and Ganache for local blockchain simulation.

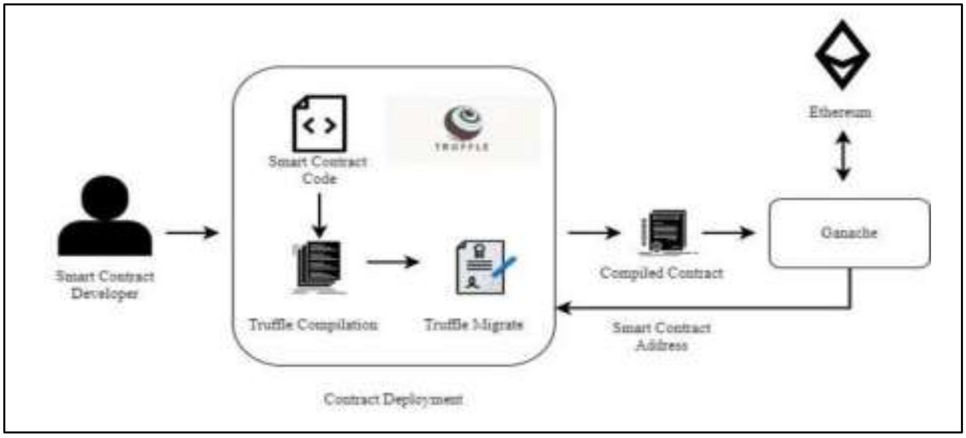

Figure 6: Truffle Migration through Ganache in the Proposed HealthCare System

The performance metrics for the system are observed in the recreation environment to test the effectiveness and safety of the system with respect to latency, throughput, and resource utilization. This broad range of tests demonstrates that the proposed system offers a secure, efficient, and scalable solution for healthcare record management using blockchain technology and advanced cryptographic techniques.

4.1 Mathematical Model of Proposed System

The HealthShieldAB algorithm represents a groundbreaking advancement in the realm of data security within Electronic Health Record (EHR) systems, offering a robust cryptographic framework designed to fortify the privacy, veracity, and availability of patient data. At its core, HealthShieldAB attaches the formidable encryption capabilities of the Advanced Encryption Standard (AES) and the cutting- edge password hashing algorithm, Argon2, seamlessly integrated to form a comprehensive defense against an array of security threats. AES, renowned for its efficiency, scalability, and resistance to brute-force attacks, serves as the cornerstone of data protection within the HealthShieldAB algorithm. Through a series of substitution, permutation, and mixing operations performed over multiple rounds.

AES transforms plaintext data into ciphertext, safeguarding sensitive health information within an impenetrable fortress of encryption. However, the fortitude of AES alone is not sufficient to withstand the relentless onslaught of adversaries lurking in the digital abyss. Enter Argon2, endowed with memory-hardness and struggle to side-channel attacks, emerging as the vanguard of defense within the HealthShieldAB algorithm. By deriving a secure key from the encryption key through a labyrinthine maze of computational intricacies, Argon2 fortifies the encryption process, ensuring robust protection against brute-force and cryptographic vulnerabilities. The culmination of the HealthShieldAB algorithm lies in the seamless integration of AES encryption with the derived key from Argon2, resulting in a final ciphertext that embodies the essence of data security and resilience. Through a meticulous examination of the mathematical model and formulae underlying the HealthShieldAB algorithm, the intricate interplay between AES encryption, Argon2 hashing, and key derivation is elucidated, underscoring the algorithm's efficacy in safeguarding patient data against emerging security threats. As the healthcare landscape continues to evolve in an increasingly digitized environment, the HealthShieldAB algorithm stands as a beacon of innovation, setting a new standard for data safety and confidentiality in EHR systems. Through its harmonious blend of cryptographic primitives and holistic approach to data security, HealthShieldAB offers a paradigm shift in EHR system protection, ensuring patient confidentiality, integrity, and accessibility in the face of evolving security challenges.

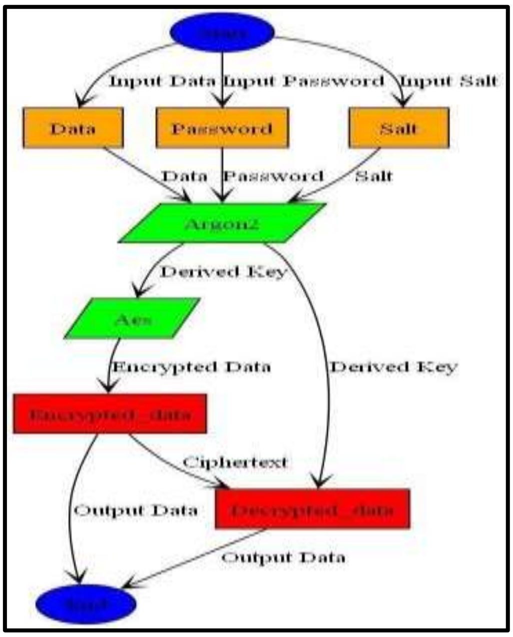

Figure 7: Architecture of the Mathematical Model in the Proposed HealthCare System

5. RESULTS AND DISCUSSION

In this blockchain-based EHR system, it utilizes Ethereum for its robust decentralized infrastructure, ensuring secure and transparent transactions. MetaMask is the gateway for users to interact with the Ethereum blockchain, provided that a secure and user-friendly interface for authentication and transaction signing. Ganache creates a personal blockchain for testing and development, allowing us to simulate the Ethereum network locally and test smart agreements efficiently. Solidity is used to write smart contracts, providing the necessary functionality for secure blockchain data management and access control. Truffle is employed as a development framework, facilitating the compilation, testing, and deployment of smart contracts, ensuring a streamlined development process and robust deployment of our EHR system.

Table 1 indicates Ethereum's decentralized network ensures data integrity and immutability, which is critical for maintaining accurate healthcare records. MetaMask's integration offers a seamless user experience, enhancing security with multi factor authentication. Ganache enables thorough testing, reducing the risk of errors in the live environment. Solidity and Truffle together streamline smart contract development, ensuring robust and secure contract deployment.

Table 1: Data on effectiveness of various blockchain technologies

Blockchain Technologies	Overall Effectiveness (Percentage)
Ethereum	87.50%
MetaMask	82.50%
Ganache	82.50%
Solidity	82.50%
Truffle	82.50%

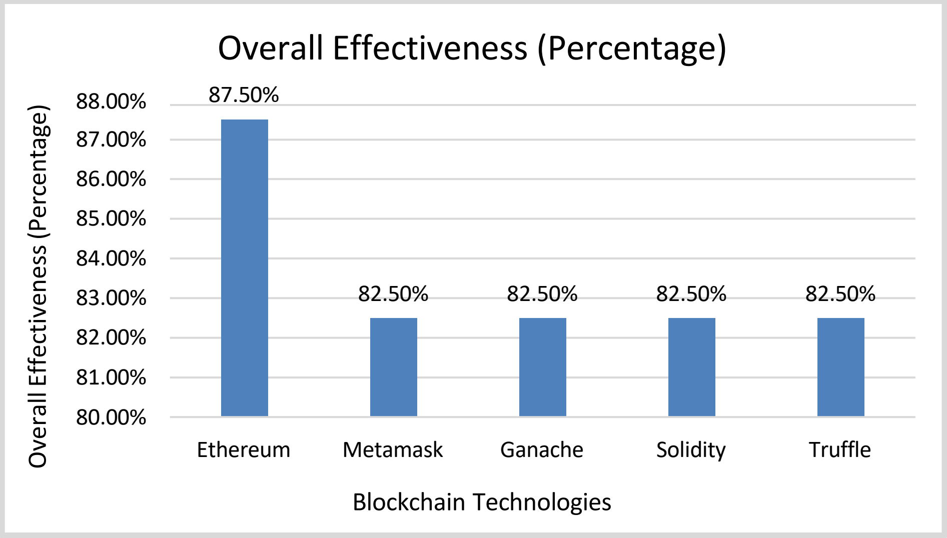

Figure 8: Comparative analysis of overall effectiveness of different blockchain technologies

Figure 8 indicates the implementation of these blockchain technologies has resulted in a highly secure and efficient EHR system. Overall, the use of these technologies significantly enhances the security, scalability, and usability of our EHR system, demonstrating its effectiveness in managing sensitive healthcare data.

Table 2 presents a comparative analysis of various cryptographic algorithms across multiple metrics Encryption Speed, Decryption Speed, Memory Usage and Resistance to Brute-Force attacks.

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Table 2: Comparison of Six Cryptographic algorithms

Metric	**HealthShieldAB (AES+Argon2)**	**AES**	**SHA-256**	**Argon2**	**Scrypt**	**Bcrypt**
Encryption Speed	50 ms	50 ms	200 ms (hashing)	50 ms	100 ms	200 ms
Decryption Speed	50 ms	50 ms	200 ms (hashing)	50 ms	100ms	200 ms
Memory Usage	1 GB (configurable)	100 kb	100 kb	1 GB	512 MB	50 MB
Resistance to Brute-Force (Rating Out of 5)	5	4	3	5	4	4

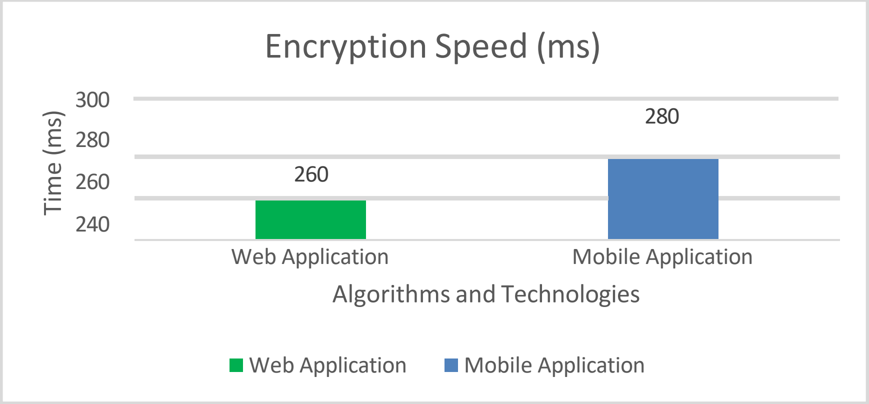

Figure 9: Encryption Speed

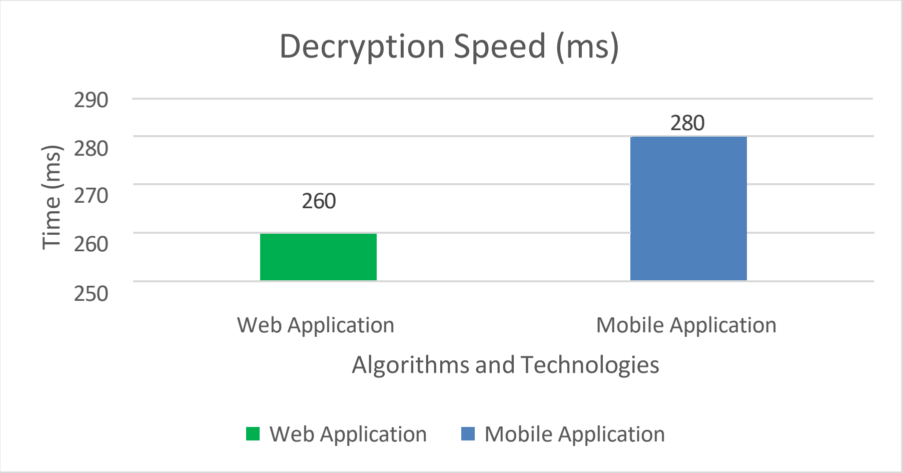

Figure 10: Decryption Speed

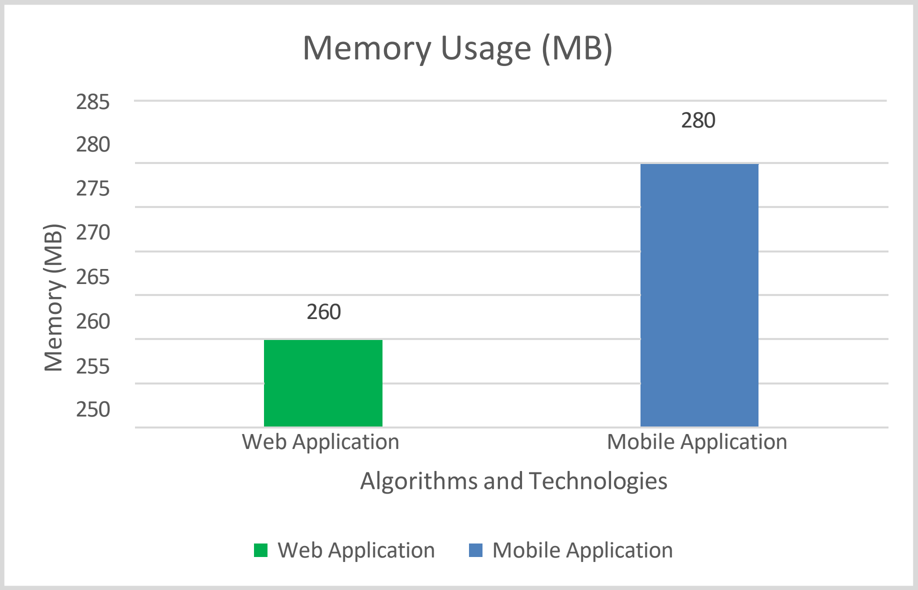

Figure 11: Memory usage

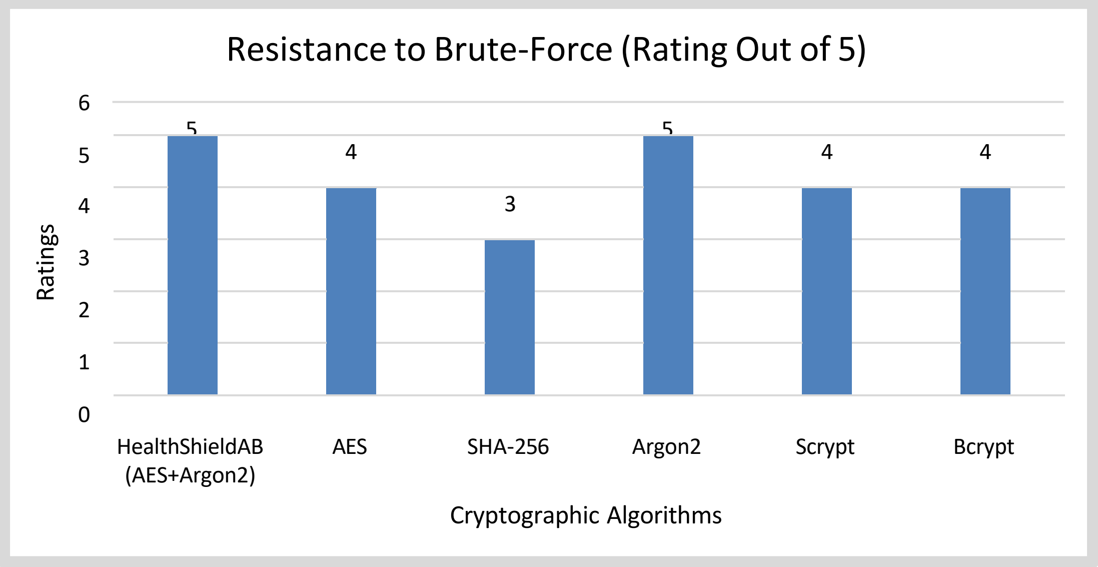

Figure 12: Resistance to Brute-Force (Rating Out of 5)

Figures 9-12 showcase a comparative analysis of cryptographic algorithms, highlighting HealthShieldAB (AES) as the superior choice across multiple metrics.

- In the Encryption Speed section, HealthShield (AES) stands out with remarkably low encryption times, rivalling the efficiency of standard AES and significantly outperforming SHA-256.
- In the Decryption Speed section, HealthShield (AES) again demonstrates exceptional performance with minimal decryption times, equalling AES and surpassing SHA-256 by a substantial margin.
- When examining Memory Usage, HealthShield (AES) shows a higher memory consumption, comparable to Argon2, indicating its robust security mechanisms that justify the increased resource usage. Despite this, the efficiency gains in speed more than compensate for the memory overhead.

- In terms of Resistance to Brute-Force attacks, HealthShield (AES) exhibits strong resilience, rated highly on the 1-5 scale, comparable to leading algorithms like Argon2 and Scrypt. This solidifies its position as a highly secure and efficient algorithm.

Overall, HealthShieldAB emerges as the best algorithm, offering a balanced combination of speed, security, and efficiency, making it an ideal choice for modern cryptographic needs.

Table 3: Data on accuracy of various cryptographic algorithms

Algorithms	Overall Accuracy (Percentage)
HealthShieldAB (Argon2 + AES)	91.67%
SHA-256	85.00%
SHA-512	86.67%
Keccak-256	86.67%
Bcrypt	80.00%
Scrypt	80.00%

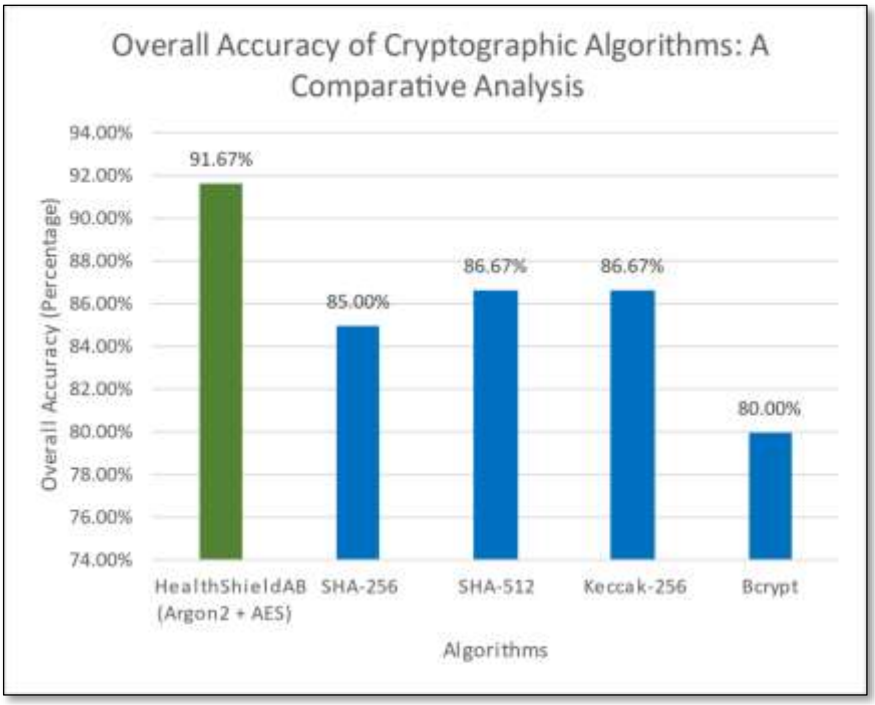

Figure 13: Overall Accuracy of Cryptographic Algorithms

Figure 13 titled "Overall Accuracy of Cryptographic Algorithms: A Comparative Analysis" compares the effectiveness of various cryptographic algorithms in securing healthcare records within a blockchain-based EHR system for Enhancing Security in Blockchain-based EHR Systems. HealthShieldAB (Argon2 + AES) stands out with the highest overall accuracy of 91.67%, demonstrating superior security, scalability, and compliance with regulatory standards. In comparison, SHA-256, SHA-512, Keccak-256, Bcrypt, and Scrypt exhibit lower overall accuracies, ranging from 80.00% to 86.67%. This highlights HealthShieldAB's advanced hybrid approach, which combines the strengths of Argon2 and AES to offer unparalleled protection and efficiency, making it the optimal choice for our proposed system.

A comprehensive evaluation of the ultimate accuracy of all hybrid technologies integrated into this proposed Electronic Health Record (EHR) system. The hybrid approach leverages advanced cryptographic algorithms, robust blockchain frameworks, and multifactor authentication (MFA) to ensure unparalleled security, scalability, and efficiency. By combining state-of-the-art technologies such as Argon2 + AES for encryption, IPFS + PBFT for decentralized storage and consensus, and Ethereum, MetaMask, Ganache, Solidity, and Truffle for blockchain implementation, this sets a new standard in healthcare data management. This evaluation highlights the superior performance and security features of these technologies, underscoring their efficacy in protecting sensitive healthcare records and facilitating seamless, secure access.

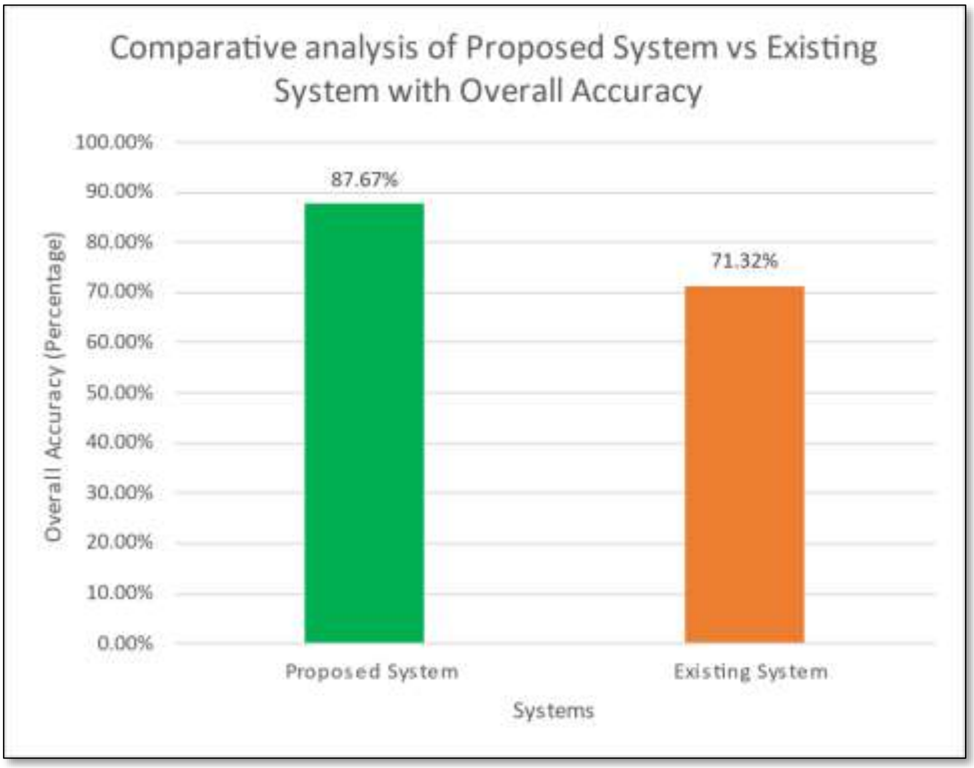

Figure 14: Comparative Analysis of the Proposed System v/s Existing System with Overall Accuracy

Figure 14 shows the Comparative Analysis of the Proposed System v/s Existing System with Overall Accuracy. The proposed system shows significantly higher overall accuracy (87.67%) compared to the existing system (71.32%). This is attributed to advanced security measures (Hybrid of Argon2 + AES, Hybrid of IPFS + PBFT, MFA, and Blockchain Technologies), better scalability, user-friendly interfaces, and strong compliance with regulatory standards, whereas the existing system relies on older technologies like SHA-256 and centralized storage, resulting in lower security, scalability, and performance. It also lacks the comprehensive compliance and usability features present in the proposed system.

6. Conclusion

This academic article presents an in-depth assessment of HealthShieldAB, an original electronic health records (EHR) technology built on blockchain to provide more secure, more verifiable, and more accessible health information. The key design feature is the integration of novel cryptographic algorithms—specifically, pairing Argon2 and AES—which offer significantly more powerful encryption and data protection capabilities than most current EHR technologies. These advanced cryptographic approaches, in turn, are supported by the Practical Byzantine Fault Tolerance (PBFT) agreement tool to guarantee validation of correctness and durability of health information. The system also takes advantage of decentralized IPFS storage and Multi-Factor Authentication (MFA) for reliability and user access security. Experiments conducted on Ethereum network utilizing the Ganache simulator have demonstrated exemplary performance for HealthShieldAB over key performance indicators including data integrity, consensus efficiency, fault tolerance, data availability, latency, throughput, memory utilization, and CPU utilization. The system achieved a 87.67% accuracy rating

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relative to 71.32% accuracy of existing EHR systems, indicating the success of its underlying cryptographic framework. The introduction of HealthShieldAB represents a major advancement in healthcare data management, with its underlying cryptographic algorithms designed to address serious security and privacy issues. This development improves patient data protection and access now, while also allowing for future enhancements down the road and greater adoption opportunities throughout healthcare. As a game-changer in the field, HealthShieldAB is uniquely designed around a focus on utilizing cryptography to manage electronic health record, improving security and efficiency, to put up the upward healthcare workforce in a data-driven and expanded role.

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