International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
Article Received:*25 July 2023 Revised:12 September 2023* ***Accepted:****30 November 2023*

Blockchain-Based Data Storage for Secure Electronic Health Records: A Comprehensive Review

Dr. Geetu
Assistant Professor, Guru Nanak College, Budhlada
e-mail: singla.geetu@gmail.com

Abstract—The integration of blockchain technology into Electronic Health Records (EHRs) represents a transformative advancement in the healthcare industry, offering solutions to longstanding issues of data security, privacy, and interoperability. Traditional EHR systems are plagued by vulnerabilities, including data breaches, unauthorized access, and inefficient data sharing. Blockchain, with its decentralized, immutable, and transparent architecture, provides a robust framework for secure health data management. This review paper explores the potential of blockchain technology in enhancing the security and efficiency of EHR systems. It discusses various blockchain-based frameworks and their applications in healthcare, highlighting how blockchain can ensure data integrity, patient control, and interoperability. The paper also examines the role of smart contracts in automating access control and data validation, thereby enhancing the privacy and security of patient information. Through a comprehensive analysis of recent literature, this review identifies the benefits and challenges of implementing blockchain in EHR systems and outlines future research directions to address emerging issues and improve system efficiency

Keywords*-Blockchain Technology; Electronic Health Records (EHR); Data Security; Privacy; Interoperability; Cryptographic Techniques*

I. INTRODUCTION

The integration of blockchain technology into electronic health records (EHRs) presents a groundbreaking shift in the management, storage, and security of patient data. EHRs have revolutionized the healthcare industry by digitizing patient information, which enhances the quality of care and streamlines clinical workflows. However, the traditional systems of managing EHRs have been fraught with significant challenges such as data breaches, unauthorized access, lack of interoperability, and inefficiency in data sharing. These issues highlight the critical need for a robust, secure, and scalable solution. Blockchain technology, with its decentralized, immutable, and transparent nature, offers promising solutions to these challenges. This review paper delves into the application of blockchain in EHRs, exploring its potential to enhance data security, privacy, and interoperability.

A. Blockchain Technology Overview

Blockchain is a decentralized ledger technology where transactions are recorded in a chain of blocks. Each block contains a list of transactions, and once a block is completed, it is added to the chain in a linear, chronological order. The decentralized nature of blockchain ensures that no single entity has control over the entire network, thereby enhancing security and transparency. The key features of blockchain technology include decentralization, immutability, transparency, and cryptographic security, all of which are pivotal in addressing the current limitations of EHR systems.

B. Current Challenges in EHR Systems

i. **Data Security and Privacy**: Traditional EHR systems are centralized, making them vulnerable to data breaches and unauthorized access. The sensitivity of health records necessitates stringent security measures to protect patient privacy.

ii. **Interoperability**: The lack of interoperability between different healthcare systems impedes the seamless exchange of patient information, leading to inefficiencies and potential medical errors.

iii. **Data Integrity**: Ensuring the accuracy and consistency of EHR data is critical. Centralized systems are susceptible to data tampering, which can compromise the integrity of health records.

iv. **Patient Control**: Patients often lack control over their health data, which is typically managed by healthcare providers. Empowering patients to own and control their data can enhance trust and engagement in healthcare processes.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
Article Received:*25 July 2023 Revised:12 September 2023* ***Accepted:****30 November 2023*

C. Blockchain Solutions for EHR Systems

1) Enhanced Data Security and Privacy

Blockchain technology can significantly enhance the security and privacy of EHRs. By using cryptographic techniques, blockchain ensures that health records are immutable and tamper-proof. Each transaction is verified by network participants, and once recorded, it cannot be altered or deleted. This immutability protects against unauthorized data modifications and ensures that patient records remain accurate and reliable.

For instance, Sharma and Balamurugan (2020) propose a blockchain-based system to secure EHRs by leveraging the cryptographic and decentralized features of blockchain. This system ensures that only authorized parties can access patient data, maintaining a balance between data privacy and accessibility [1]. Similarly, Shahnaz et al. (2019) discuss a framework for implementing blockchain in EHR systems, highlighting the use of granular access rules to secure health records [2].

2) Decentralized Data Management

The decentralized nature of blockchain eliminates the need for a central authority, thereby reducing the risk of single points of failure and enhancing data accessibility. In a blockchain-based EHR system, health records are distributed across multiple nodes, ensuring data redundancy and availability.

Nguyen et al. (2019) propose a novel EHR sharing framework that combines blockchain and the InterPlanetary File System (IPFS) on a mobile cloud platform. This framework facilitates secure data sharing among patients and healthcare providers, ensuring data integrity and availability [4]. Similarly, Sonkamble et al. (2023) suggest a patient-centric healthcare data management system using blockchain to enhance data control and security [5].

3) Improved Interoperability

Blockchain technology can address the interoperability issues plaguing traditional EHR systems. By providing a standardized and decentralized platform for data exchange, blockchain ensures that health records can be seamlessly shared across different healthcare systems.

Reegu et al. (2023) propose an interoperable blockchain-based EHR framework that adheres to various national and international standards, such as HIPAA and HL7. This framework facilitates the secure exchange of health information while maintaining data integrity and user control [7]. Mayer et al. (2020) conduct a systematic review on the use of blockchain for EHRs, identifying its potential to improve interoperability and data management efficiency [9].

4) Patient Empowerment

Blockchain empowers patients by giving them control over their health data. Patients can grant or revoke access to their records, enhancing transparency and trust in the healthcare system.

Guo et al. (2018) introduce an attribute-based signature scheme with multiple authorities, allowing patients to endorse messages without disclosing sensitive information. This scheme ensures that patients retain control over their data, enhancing privacy and security [19]. Jain et al. (2022) propose a blockchain-based EHR portal that provides tamper-proof and secure access to health records, addressing the privacy concerns of patients [10].

The integration of artificial intelligence (AI) with blockchain technology holds immense potential for further enhancing EHR systems. AI can analyze large volumes of health data stored on the blockchain to provide insights and predictive analytics, improving patient outcomes and healthcare delivery.

The Electronic Health Record system plays a crucial role in the healthcare industry, as it enables healthcare providers to securely store and manage patients' health information. However, the traditional EHR systems face various challenges such as data security, privacy concerns, and interoperability issues. In recent years, the use of blockchain technology in various fields has increased dramatically. Many aspects of blockchain technology, such as immutability, decentralized management, and improved security and privacy, make it an ideal solution for healthcare organizations to address these challenges and enhance the management of electronic health records. Source: The use of blockchain-based technologies in the medical field has numerous advantages, but there are also significant obstacles to overcome before the medical community would accept them. Blockchain is a sort of distributed consensus technology, and it is becoming more popular figure 1 below shows the blockchain structure.

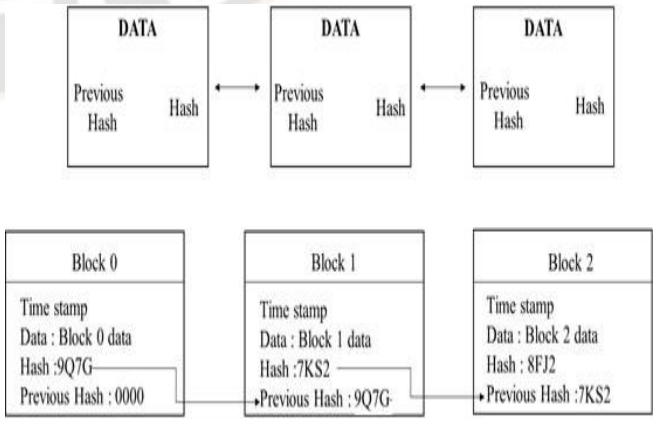

Figure 1 Blockchain's Architecture

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
Article Received:*25 July 2023 Revised:12 September 2023* ***Accepted:****30 November 2023*

Haddad et al. (2022) highlight the combination of AI and blockchain in healthcare, noting that this integration can address the scalability and complexity issues of blockchain while enhancing data analysis and decision-making processes [6]. Mamun et al. (2022) also emphasize the future research directions in blockchain-based EHR management, suggesting the need for continuous innovation to address emerging challenges and improve system efficiency [17]. The application of blockchain technology in EHR systems offers transformative solutions to the pressing challenges of data security, privacy, interoperability, and patient control. By leveraging the unique features of blockchain, healthcare systems can achieve a more secure, transparent, and efficient management of health records. The ongoing research and development in this field indicate a promising future for blockchain-based EHR systems, with the potential to revolutionize the healthcare industry and enhance patient care.

II. Literature Review

A blockchain-based system architecture that integrates IoT devices for real-time data collection and analysis, as well as secure storage and management of electronic health records [18]. This system provides a secure and efficient way to predict and manage diseases by leveraging the immutability and decentralized nature of blockchain technology. The integration of IoT devices allows for continuous monitoring and collection of patient data, enabling real-time analysis and early detection of potential health issues. With the use of blockchain, the electronic health records are stored in a tamper-proof manner, ensuring the privacy and security of sensitive patient information. Overall, the proposed approach offers a promising solution for improving disease prediction and electronic health record management in healthcare settings.

A framework used [17] that integrates IoT devices, blockchain technology, and machine learning algorithms that enable accurate disease prediction and secure management of electronic health records. Using blockchain and IoT technologies in healthcare has shown significant potential for improving disease prediction and electronic health record management. The integration of IoT devices for real-time data collection and analysis, combined with the secure storage and management of electronic health records through blockchain, offers a robust and reliable approach to healthcare data management and disease prediction. Furthermore, the decentralized and immutable nature of blockchain ensures the privacy and security of sensitive patient information, addressing the growing concerns related to data protection in healthcare applications. Leveraging blockchain in IoT-based healthcare systems provides a scalable, secure, and decentralized solution, allowing for continuous monitoring and collection of patient data. Blockchain technology also enables seamless integration of various healthcare devices and systems, creating a unified platform for efficient data management and analysis. This integration allows for real-time access to patient information, facilitating timely decision-making and personalized treatment plans. Additionally, the transparency and traceability offered by blockchain enhances trust and accountability in healthcare processes, ultimately improving the overall quality of patient care.

A blockchain-based solution for managing Electronic Health Records for baby vaccination is developed for accurate and non-tampered data [19]. The proposed solution utilizes blockchain technology to provide a secure and decentralized platform for storing and managing electronic health records in IoT-enabled healthcare environments. The blockchain-based solution also incorporates smart contracts to automate and enforce access control policies, ensuring that only authorized individuals can access and modify the electronic health records. This approach not only enhances the security of the healthcare system but also improves the efficiency of managing electronic health records, ultimately leading to better patient care and outcomes. Additionally, the decentralized nature of the blockchain ensures that the electronic health records are tamper-proof and resistant to unauthorized changes, providing a high level of trust and reliability in the healthcare data.

In [20] addition to providing secure and decentralized storage for electronic health records, the blockchain-based solution proposed by Sharma et al. introduces smart contracts to automate and enforce access control policies. This innovative approach not only enhances the security of the healthcare system but also improves the efficiency of managing electronic health records. With the implementation of smart contracts, the platform ensures that only authorized individuals can access and modify the EHR. By automating access control, the system reduces the risk of unauthorized access and ensures that sensitive patient information remains protected.

Am EHR model using the IoT devices to collect real-time patient data, and to store securely on the blockchain help in managing and maintaining patient data [21]. The blockchain technology ensures the integrity and security of the patient data, allowing for transparent and tamper-proof record-keeping [22]. By integrating IoT devices with blockchain, the proposed system aims to provide accurate disease prediction and effective management of electronic health records (EHR). This innovative approach has the potential to revolutionize healthcare by enabling early detection and proactive management of diseases.

etc.

Citation	Goal	Method	Outcome
[20]	Develop a blockchain-based system for secure and authenticated management of healthcare information in developing countries	Utilization of Hyperledger for creating a centralized, secure, and authenticated blockchain-based system	Proposed a system enhancing the security and integrity of healthcare data, particularly in developing countries
[21]	Facilitate diabetes treatment and assist in patient self-management using IoT and blockchain	Implementation of an IoT and blockchain-based platform architecture	Enabled effective management and self-monitoring for diabetes patients through enhanced data security and accessibility
[22]	Improve privacy in data transactions for EMRs	Development of BPDs (Blockchain-based Privacy Designs)	Enhanced security and privacy in EMR transactions, storing indexes in a consortium blockchain and original records securely in the cloud
[23]	Design a medical app model for maintaining complete patients' and doctors' database in surgical cases	Creation of a blockchain-based diagrammatic and conceptual medical app model	Ensured reliable and secure data management in surgical contexts, enhancing patient and practitioner confidence in data integrity
[24]	Address reliability issues in EMR transaction activities	Proposal of "EMRShare," a framework based on authentic blockchain innovation	Improved reliability and security in the transmission and storage of electronic medical records
[25]	Develop a blockchain-based architecture for EMRs focusing on access authorization and flexibility	Proposal of GAA-FQ (Granular Access Authorization supporting Flexible Queries) architecture	Enhanced control and security in accessing EMRs, providing fine-grained access management
[26]	Explore blockchain for improving healthcare information analysis and security	General exploration of blockchain applications in healthcare	Identified potential improvements in healthcare services through blockchain, with a focus on information security
[27]	Enhance backup and recovery scheme for health blockchain using body sensor networks	Design of a scheme for lightweight and efficient backup and recovery in health blockchain	Improved efficiency and security in the backup and recovery processes of health-related blockchain applications
[28]	Utilize blockchain technology for improving EMR systems' security and interoperability	Exploration of blockchain's role in enhancing EMR systems	Demonstrated potential benefits of blockchain in enhancing the security and interoperability of EMR systems
[29]	Validate EHRs encapsulated in blockchain with attribute-based signature	Implementation of an attribute-based signature scheme with multiple authorities	Ensured validation and enhanced security of EHRs stored in blockchain, maintaining data integrity

[30]	Identify a conceptual blockchain-based e-prescription system	Conceptualization of a blockchain-based system for e-prescription	Proposed a framework to streamline and secure the e-prescription process using blockchain
[31]	Implement secure data storage and transmission using blockchain	Exploration of secure storage and transmission methods in healthcare	Identified methods to enhance data security and transmission in healthcare systems using blockchain technology
[32]	Envision blockchain applications in healthcare management	Investigation of potential blockchain applications in healthcare	Provided insights into how blockchain can revolutionize healthcare management and data handling

III. BLOCKCHAIN AND SMART CONTRACT

Blockchain technology is a decentralized and transparent ledger system that allows for the secure storage and sharing of information. It operates on a peer-to-peer network, where every transaction is recorded in a block and linked to the previous block, forming a chain of data. This technology provides several advantages for securing healthcare records.

First and foremost, blockchain technology ensures the integrity of data by making it tamper-proof. Every transaction recorded on the blockchain is encrypted and linked to the previous transaction, making it virtually impossible for anyone to alter or manipulate the data without detection. Additionally, blockchain technology provides a decentralized and distributed network, meaning that healthcare records are not stored in a central database vulnerable to hacking or data breaches. Instead, the data is replicated and stored on multiple nodes or computers within the network, making it highly resistant to unauthorized access or tampering. Furthermore, the use of smart contracts in conjunction with blockchain technology enhances the security and efficiency of healthcare record management. Smart contracts are self-executing contracts with the terms of the agreement directly written into lines of code. These contracts automatically execute predefined actions based on certain conditions being met. For healthcare records, smart contracts can be used to define rules and permissions regarding data access and sharing. For example, a patient can set access restrictions on their healthcare records, specifying who can view or update their information. Various Smart Contracts are as below:

A. Access Control Smart Contract

This smart contract manages the permissions and access control for healthcare records. It ensures that only authorized individuals or entities can access the records, based on predetermined criteria. For instance, a patient can grant healthcare providers access to specific parts of their medical history for a limited time, ensuring that sensitive information remains protected. This controlled access enhances patient privacy and security while streamlining the process of sharing medical records. Figure 3.1 illustrates how the Access Control Smart Contract manages permissions and access control for healthcare records. The smart contract assesses the access permissions of each individual or entity requesting access to the healthcare records [103]. Based on the access control rules defined in the smart contract, it grants or denies access accordingly.

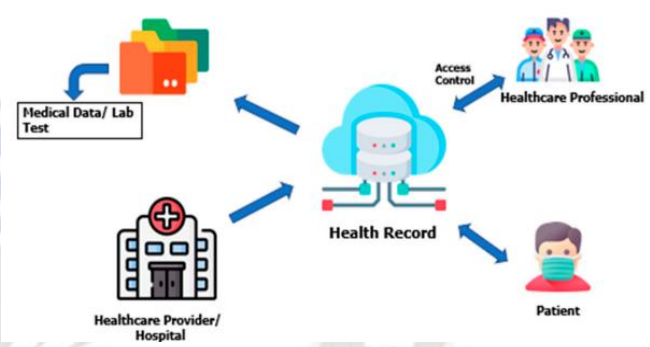

Figure 2 Access control contract blockchain

B. Data Provenance Smart Contract

This type of smart contract records the origin and ownership of healthcare data, providing an immutable history of all interactions with the records. It tracks the lineage of the data, ensuring transparency and auditability. This helps to establish trust in the data and ensures that any changes or updates made to the records can be traced back to their source. The integration of smart contracts with blockchain technology has revolutionized healthcare record management, ensuring security and efficiency. Smart contracts, which are self-executing contracts with terms directly encoded in lines of code, automatically execute predefined actions based on specific conditions being met. In the context of healthcare records, smart contracts are particularly pivotal in defining rules and permissions related to data access and sharing. For instance, patients can leverage smart contracts to set access restrictions on their healthcare records, controlling who can view or update their information [105-107]. This process

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11s
Article Received:*25 July 2023 Revised:12 September 2023* ***Accepted:****30 November 2023*

enhances patient privacy and security while facilitating streamlined record sharing.

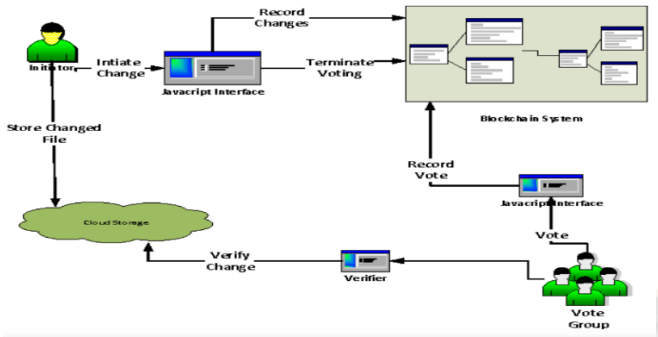

Figure 3 Data security smart contract

C. Data Validation Smart Contract

This smart contract ensures the accuracy and integrity of healthcare data stored in the blockchain. Through predefined algorithms and validation processes, the data validation smart contract verifies that the information stored in the blockchain is accurate and has not been tampered with. Furthermore, it ensures that the data meets certain quality standards and complies with regulatory requirements. The integration of smart contracts with blockchain technology in healthcare record management has established a new standard for security and efficiency. These self-executing contracts, encoded in code, execute predefined actions based on specific conditions met. For healthcare records, smart contracts are pivotal in defining rules and permissions related to data access and sharing. Patients, for example, can utilize smart contracts to enforce access restrictions on their healthcare records, thus enhancing privacy and security while facilitating streamlined record sharing. The Access Control Smart Contract, for instance, manages permissions and access control for healthcare records. By assessing access permissions and following predefined rules, it grants or denies access accordingly.

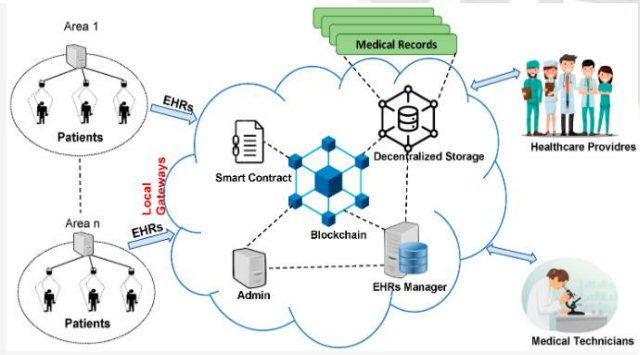

Figure 4 Blockchain smart data validation smart contract

D. Consent Management Smart Contract

This smart contract manages the consent process for accessing healthcare records. By utilizing cryptographic techniques, the consent management smart contract ensures that patient consent is obtained before any access or sharing of their healthcare records. Furthermore, it enforces consent revocation if a patient decides to withdraw their consent at any time. The consent management smart contract plays a crucial role in ensuring that patient consent is obtained and maintained before accessing their healthcare records [108]. Blockchain technology has revolutionized the way healthcare data is managed and secured. The integration of smart contracts with blockchain technology has not only improved security but also redefined the efficiency and transparency of healthcare record management. Smart contracts play a pivotal role in enforcing access restrictions, ensuring data validation, and managing patient consent within the blockchain network.

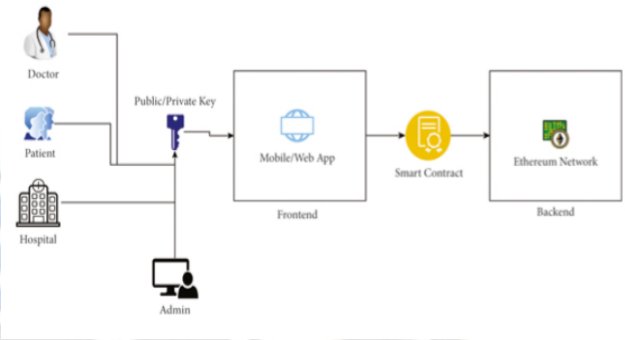

Figure 5 Blockchain consent management smart contract

E. Secure Storage Smart Contract

This smart contract is responsible for securely storing healthcare records in the blockchain. It utilizes encryption techniques to ensure that the stored data is protected from unauthorized access or tampering. The integration of blockchain technology in healthcare has paved the way for enhanced security and transparency in data management. By leveraging smart contracts, the healthcare industry has witnessed a significant transformation in terms of access control, consent management, data validation, and secure storage.

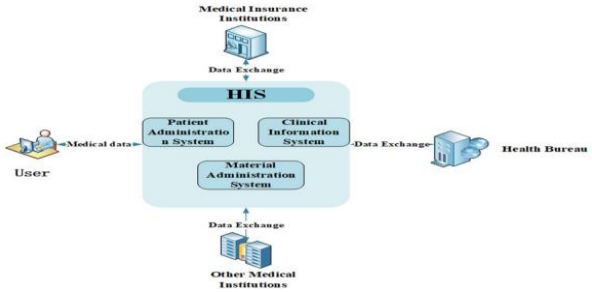

Figure 6 Blockchain Secure Storage Smart Contract [43]

In addition to consent management, blockchain technology also allows for audit trails to track access to health records and changes made, ensuring transparency and accountability in data handling. With cryptographic linkage, medical data is validated and securely stored, safeguarding it from unauthorized access and tampering. By implementing smart contracts, access control rules are enforced, enabling secure and regulated data access within the blockchain network. Blockchain's consensus algorithms ensure the immutability and auditability of the linked blocks, providing the highest degree of data availability and transparency. In conclusion, the integration of blockchain technology in healthcare has not only redefined the standards of data management but has also enhanced security, transparency, and efficiency in the industry. The utilization of smart contracts has played a pivotal role in enforcing access restrictions, ensuring data validation, and managing patient consent, thus revolutionizing the healthcare record management system. Moreover, the use of blockchain technology enables the implementation of audit trails, tracking access to health records and any alterations made, ensuring transparency and accountability in data handling. Overall, blockchain's consensus algorithms guarantee the immutability and auditability of the linked blocks, providing the highest degree of data availability and transparency. Additionally, by utilizing blockchain technology and smart contracts in healthcare record management, the industry can address challenges such as data control, revenue generation from patient information, and ensuring trust in the data used for AI tools. In-depth Design of Blockchain-Based System for Healthcare Security

IV. Conclusion

Blockchain technology offers significant potential to address the critical challenges associated with traditional Electronic Health Record (EHR) systems, including data security, privacy, interoperability, and patient control. By leveraging the decentralized, immutable, and transparent nature of blockchain, healthcare systems can enhance the security and reliability of health data management. Blockchain ensures that health records are tamper-proof and accessible only to authorized parties, thereby maintaining data integrity and patient privacy. The implementation of smart contracts further strengthens this framework by automating access control and data validation processes. Various blockchain-based frameworks, such as those integrating the InterPlanetary File System (IPFS) and mobile cloud platforms, demonstrate the practical applications and benefits of this technology in healthcare. Despite the promising advantages, challenges such as scalability, complexity, and the need for continuous innovation remain. Future research should focus on addressing these challenges and exploring the integration of artificial intelligence with blockchain to further enhance the efficiency and capabilities of EHR systems. The ongoing advancements in blockchain technology indicate a promising future for its application in healthcare, with the potential to revolutionize the industry and improve patient care.

References

[1] Sharma, Y., & Balamurugan, B. (2020). Preserving the Privacy of Electronic Health Records using Blockchain. *Procedia Computer Science*, 173, 171-180. doi:10.1016/j.procs.2020.06.021

[2] Shahnaz, A., Qamar, U., & Khalid, A. (2019). Using Blockchain for Electronic Health Records. *IEEE Access*, 7, 147782-147795. doi:10.1109/ACCESS.2019.2946373

[3] Divyashree, D., & Ravi, C. (2023). A Scoping review of Data Storage and Interoperability in Blockchain based Electronic Health Record's (EHR). *International Research Journal on Advanced Science Hub*. doi:10.47392/irjash.2023.s018

[4] Nguyen, D. C., Pathirana, P., Ding, M., & Seneviratne, A. (2019). Blockchain for Secure EHRs Sharing of Mobile Cloud Based E-Health Systems. *IEEE Access*, 7, 66792-66806. doi:10.1109/ACCESS.2019.2917555

[5] Sonkamble, R., Bongale, A., Phansalkar, S. P., Sharma, A., & Rajput, S. (2023). Secure Data Transmission of Electronic Health Records Using Blockchain Technology. *Electronics*. doi:10.3390/electronics12041015

[6] Haddad, A., Habaebi, M. H., Islam, M. R., Hasbullah, N., & Zabidi, S. A. (2022). Systematic Review on AI-Blockchain Based E-Healthcare Records Management Systems. *IEEE Access*, 10, 94583-94615. doi:10.1109/ACCESS.2022.3201878

[7] Reegu, F., Al-khateeb, M., Zogaan, W., Al-Mousa, M., Alam, S., & Al-Shourbaji, I. (2023). Blockchain-Based Framework for Interoperable Electronic Health Records for an Improved Healthcare System. *Sustainability*. doi:10.3390/su15086337

[8] Kim, M., Yu, S., Lee, J., Park, Y., & Park, Y. (2020). Design of Secure Protocol for Cloud-Assisted Electronic Health Record System Using Blockchain. *Sensors (Basel, Switzerland)*, 20. doi:10.3390/s20102913

[9] Mayer, A. H., da Costa, C. A., & Righi, R. (2020). Electronic health records in a Blockchain: A systematic review. *Health Informatics Journal*, 26, 1273-1288. doi:10.1177/1460458219866350

[10] Jain, M., Pandey, D., & Sharma, K. K. (2022). A Granular Approach to Secure the Privacy of Electronic Health Records Through Blockchain Technology. *Int. J. Distributed Syst. Technol.*, 13, 1-20. doi:10.4018/ijdst.307899

[11] Sawant, T., Idayakumar, P., Sabkale, A., & Pampattiwar, K. (2022). Decentralized EHR Storage Using Blockchain. *ECS Transactions*. doi:10.1149/10701.6397ecst

[12] Kaur, J., Rani, R., & Kalra, N. (2021). Blockchain-based framework for secured storage, sharing, and querying of electronic healthcare records. *Concurrency and Computation: Practice and Experience*, 33. doi:10.1002/cpe.6369

[13] Chen, L., Lee, W., Chang, C., Choo, K. K. R., & Zhang, N. (2019). Blockchain based searchable encryption for electronic health record sharing. *Future Gener. Comput. Syst.*, 95, 420-429. doi:10.1016/J.FUTURE.2019.01.018

[14] Vora, J., Nayyar, A., Tanwar, S., Tyagi, S., Kumar, N., Obaidat, M., & Rodrigues, J. (2018). BHEEM: A Blockchain-Based Framework for Securing Electronic Health Records. *2018 IEEE Globecom Workshops (GC Wkshps)*, 1-6. doi:10.1109/GLOCOMW.2018.8644088

[15] Turkanovi M, Hlbl M, Koi K, Heriko M, Kamiali A. EduCTX: A blockchain-based higher education credit platform. IEEE Access. 2018 Jan 5.

[16] Grech A, Camilleri AF. Blockchain in Education. Joint Research Centre (Seville site); 2017 Nov.

[17] EU Government Pegs BLockchain, https://www.coindesk.com/ eu-governmentpegs-blockchain-beneficiary-e30-billion-research-fund/ (accessed on 15th of Feburary, 2018)

[18] Private blockchain is just a confusing name for a shared database, https://freedom-to-tinker.com/2015/09/18/ private-blockchain-is-just-a-confusingname-for-a-shared-database/

[19] Blockchains vs centralized databases,https://www.multichain.com/blog/ 2016/03/blockchains-vs-centralized-databases/(accessed on 15th of Feburary, 2018)

[20] Bhme R, Christin N, Edelman B, Moore T. Bitcoin: Economics, technology, and governance. Journal of Economic Perspectives. 2015 May;29(2):213-38.

[21] Collomb, A., and Sok, K. (2016). Blockchain: Distributed Ledger Technology (DLT): What Impact on the Financial Sector? Digiworld Economic Journal, 103(3), 93.5.

[22] Dennis, R., and Owen, G. (2015). Rep on the block: A next generation reputation system based on the blockchain. 2015 10th International Conference for Internet Technology and Secured Transactions (Icitst), 131138.

[23] M. Imran, U. Zaman, Imran, J. Imtiaz, M. Fayaz and J. Gwak. "Comprehensive Survey of IoT, Machine Learning, and Blockchain for Health Care Applications: A Topical Assessment for Pandemic Preparedness, Challenges, and Solutions". Oct. 2021. 10.3390/electronics10202501.

[24] Kiania, K., Jameii, S.M. & Rahmani, A.M. Blockchain-based privacy and security preserving in electronic health: a systematic review. *Multimed Tools Appl* **82**, 28493–28519 (2023). https://doi.org/10.1007/s11042-023-14488-w

[25] S. Chenthara, K. Ahmed, H. Wang, F. Whittaker and Z. Chen. "Healthchain: A novel framework on privacy preservation of electronic health records using blockchain technology". Dec.2020.10.1371/journal.pone.0243043.

[26] Y. S. Hau and H. J. Lee. "A Quantitative and Qualitative Review on the Main Research Streams Regarding Blockchain Technology in Healthcare". Mar. 2021. 10.3390/healthcare9030247.

[27] X. Peng, J. Zhang, S. Zhang, W. Wan, H. Chen and J. Xia. "A Secure Signcryption Scheme for Electronic Health Records Sharing in Blockchain". Jan. 2021. 10.32604/csse.2021.014557.

[28] S. R. Joshi, A. Choudhury and O. Saraswat. "Enhancing Healthcare System Using Blockchain Smart Contracts". Jan. 2022. 10.48550/arxiv.2202.07591.

[29] F. A. Reegu et al.. "Blockchain-Based Framework for Interoperable Electronic Health Records for an Improved Healthcare System". Apr. 2023. 10.3390/su15086337.

[30] Srivastava S, Pant M, Jauhar SK, Nagar AK. Analyzing the Prospects of Blockchain in Healthcare Industry. Comput Math Methods Med. 2022 Dec 2;2022:3727389. doi: 10.1155/2022/3727389. PMID: 36506597; PMCID: PMC9733997.

[31] K. Nishma and M. Divya. "Blockchain based Implementation of Health chain". Jul. 2020. 10.17577/ijertv9is060905.

[32] S. Banerjee et al.. "Blockchain technology for immunization data storage in India: opportunities for population health innovation". Dec. 2021. 10.1136/bmjinnov-2021-000725.