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Blockchain-based Decentralized Platform for Electronic Health Records Management

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***Abstract*— EHRs (Electronic Health Records) have gained significant importance in the healthcare industry as they provide healthcare providers with the capability to digitally capture, store, and share patient health information (PHI). This enables a more efficient exchange of patient data and contributes to the seamless delivery of healthcare services. However, the current EHR systems have limitations in terms of security, privacy, interoperability, and data integrity. Blockchain technology, with its decentralized and immutable nature, has the potential to address these limitations by providing a secure and transparent platform for storing and exchanging PHI. This paper proposes a blockchain-based EHR system that leverages the benefits of blockchain to improve the privacy, interoperability, and security of EHRs. We discuss the design and implementation of the proposed system, including the use of smart contracts for managing consent and access control. We also assess the performance and scalability of the suggested system and compare it with traditional EHR systems. Our results demonstrate that the proposed system provides a secure and efficient platform for managing EHRs, which can help to improve the quality of healthcare services and patient outcomes. The results of the proposed system are evaluated on the basis of security and accessibility.**

Keywords*— *Blockchain Technology, Decentralized systems, Electronic Health Record (EHR), Health data management, Healthcare infrastructure, Privacy-preserving techniques, Secure data sharing

I. Introduction

Electronic Health Records (EHRs) have revolutionized the way healthcare is delivered, enabling healthcare providers to capture, store, and exchange patient health information electronically. EHRs have several advantages over traditional paper-based records, such as improved accuracy, accessibility, and efficiency. However, the current EHR systems have limitations in terms of security, privacy, interoperability, and data integrity. These limitations can lead to breaches of patient data, errors in data management, and difficulty in accessing and exchanging patient information across different healthcare providers and systems.[1]

The technology of Blockchain has emerged as a potential solution to eliminate these limitations of EHRs. Decentralized and immutable, blockchain technology provides a secure and transparent platform for storing and exchanging data. Utilizing blockchain technology in EHRs can offer several advantages, including enhanced security, privacy, and interoperability.[2]

Our study introduces a blockchain-powered EHR system, utilizing the advantages of blockchain to enhance the privacy, interoperability and security of EHRs. Additionally, we implement smart contracts to manage consent and access control, granting patients greater control over their data. We assess the proposed system's scalability and performance and compare it with traditional EHR systems.

The second section offers a review of the literature. The third section gives an overview of EHRs, blockchain technology and IPFS. The fourth section elaborates on the design and execution of the suggested system. The fifth section presents the findings of the proposed system's assessment. The sixth section discusses the relevant studies carried out on blockchain-based EHRs. The final section concludes the paper by outlining future research directions.

II. Literature Survey

Technology's recent advancement is changing how we use and perceive things, which has an impact on every aspect of human life. Similar to the improvements technology has brought about in a number of other spheres of life, it is also discovering new methods to advance the healthcare industry. The key advantages that technology advancements are bringing to the healthcare industry include an improvement in security, user experience, and other areas. Electronic Medical Record (EMR) and Electronic Health Record (EHR) systems provided these advantages. They continue to have certain problems with data integrity, user ownership of data, and the security of medical information, nevertheless [3]. The concept of digitalized clinical records should be clearly defined, as there is a commonly misunderstood distinction between the electronic patient records, also referred to as electronic medical records, which refers to a patient's clinical record from one given medical structure (and hence contains a limited amount of information) and the electronic health records (EHRs), which refers to a complete healthcare record including some degree of integration of a patient's clinical records from various medical structures combined with access to the patient's data on the Internet [4]. The application of a cutting-edge technology, such as Blockchain, may be the answer to these problems. The blockchain technology allows for a decentralized and distributed environment without the need for a central authority. Transactions are made secure and trustworthy by utilizing cryptographic principles. In recent years, blockchain technology has gained popularity and has been implemented

in various domains, mainly due to the rise of cryptocurrencies. The utilization of blockchain technology has the potential to significantly impact the healthcare industry, as there is a growing need for a more patient-focused approach in healthcare systems, and to establish connections among disparate systems while enhancing the precision of electronic healthcare records (EHRs) [5].

Availability of health-related data is very important in many cases. This data is often distributed among multiple business entities like hospital systems. Because of this, effective sharing of the data has proven to be a challenge for traditional systems. [6] Also, the verification of the authenticity of the acquired data used to be hard. Blockchain technology effectively solves these problems due to its characteristics like decentralization and immutability.

III. Background

A. Electronic Health Records (EHRs)

EHRs refer to digital records that contain patient health information (PHI), consisting of their medical history, diagnosis, treatment plans, and test results. EHRs have several advantages over paper-based records, such as improved accuracy, accessibility, and efficiency. EHRs can be accessed and updated in real-time by authorized healthcare providers, which can improve the quality of care and patient outcomes. EHRs can also be exchanged electronically between different healthcare providers, which can reduce duplication of tests and procedures and improve care coordination. [7]

However, the current EHR systems have several limitations that can impact the quality of care and patient outcomes. One of the main limitations is security and privacy. EHRs contain sensitive and confidential information, and there have been several cases of data breaches and unauthorized access to patient data. Another limitation is interoperability. EHR systems used by different healthcare providers may not be compatible with each other, which can make it difficult to exchange patient data across different systems. Additionally, EHRs may lack data integrity, which can result in errors in data management and analysis. [8]

B. Blockchain Technology

Blockchain technology is a decentralized and immutable ledger that offers a secure and transparent platform for the storage and exchange of data. The technology operates through a distributed network of nodes that collectively maintain the ledger. Every block in the network comprises a cryptographic hash of the preceding block, preserving the integrity and immutability of the data. The implementation of consensus algorithms guarantees that all nodes in the network are in agreement regarding the ledger state. [9]

Blockchain technology has several features that make it well-suited for healthcare applications, such as EHRs. One of the main features is security. The decentralized design of the blockchain eliminates the presence of a single point of failure, thereby making it more resilient to attacks and data breaches [10]. The use of cryptographic techniques ensures the confidentiality and integrity of the data. Another feature is transparency. The use of a distributed ledger ensures that every node in the network has access to the same data, which provides transparency and accountability. Finally, blockchain technology can provide interoperability by providing a common platform for storing and exchanging data across different systems.

C. InterPlanatary File System (IPFS)

The InterPlanetary File System (IPFS) is a distributed file system that facilitates efficient and decentralized storage and sharing of files on the blockchain. It uses content-addressed storage to store files based on their content, providing a secure and decentralized method to store large amounts of data. [11] This makes IPFS an ideal solution for blockchain-based storage and sharing of data.

The next section focuses on the design and implementation of a EHR platform that takes advantage of blockchain technology's benefits to overcome the limitations of current EHR systems.

IV. Design and Implementation

A. System Architecture

The proposed system consists of three main components: the EHR platform, the blockchain network, and the smart contracts. The architecture of proposed EHR system is demonstrated in Fig. 1.

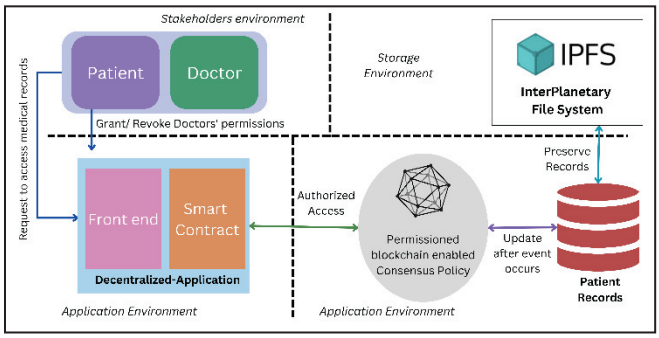

Fig.1. System Architecture of EHR platform

The system architecture of a blockchain-based Dapp (Decentralized Application) [12] designed for patients and doctors to manage medical records with the ability to grant and revoke access can be divided into several key components:

- Frontend Application: The frontend is the user interface of the Dapp, accessible through a web browser or a dedicated mobile application. It is responsible for providing a user-friendly interface for patients and doctors to interact with the Dapp. Integration with a cryptocurrency wallet provider enables users to manage their digital wallets and perform transactions securely.
- Smart Contract: The smart contract is a self-executing program running on the Ethereum blockchain. It acts as the core logic for managing access control to medical records and ensuring secure interactions between patients and doctors. The smart contract contains functions for granting and revoking access, and it enforces access control policies based on predefined rules [13]. Access requests and changes to medical records trigger transactions on the Ethereum network, which are executed by the smart contract.
- Permissioned Blockchain: A "permissioned blockchain" is a fundamental architectural feature of

our proposed Electronic Health Record (EHR) system. Unlike traditional public blockchains, which are open to anyone and rely on a consensus mechanism like Proof of Work (PoW) or Proof of Stake (PoS), a permissioned blockchain restricts access and participation to a predefined group of authorized entities.[14]

- IPFS (InterPlanetary File System): IPFS is used to store and retrieve medical records in a distributed and decentralized manner. Medical records are typically large files, and IPFS allows for efficient storage and retrieval while ensuring data availability. The smart contract stores references (e.g., IPFS hashes) to the actual medical records stored on IPFS, maintaining data privacy.[15]
- Cryptocurrency Wallet Provider Integration: This integration facilitates the management of cryptocurrency wallets for users (patients and doctors). Users can securely hold, send, and receive cryptocurrency (e.g., Ether) through their wallets. The wallet is used to sign transactions when granting or revoking access to medical records or making payments for services.

This architecture ensures transparency, security, and decentralization in managing medical records while providing patients with control over their data and enabling doctors to access necessary information with patient consent. Fig. 2 gives the black box working of the proposed system.

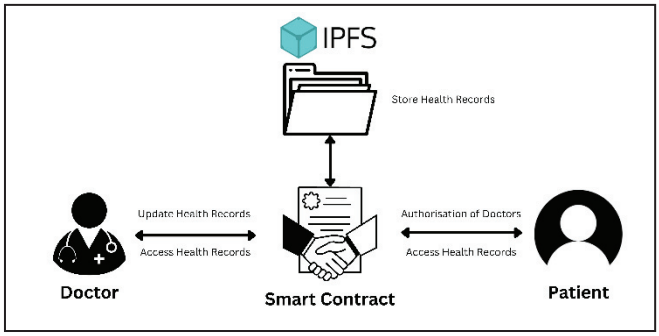

Fig.2. Blackbox working of EHR platform

The EHR platform is responsible for managing patient data, including medical records, test results and treatment plans. The platform includes following functions for users:

- Grant/Revoke access to a doctor: Patients can use this function to authorise a doctor to access their medical records and health records.
- Access data: This allows patients to access their own data stored on the platform.

The functions available for doctors are as follows:

- Access particular patient's data: The doctor can access data of a particular patient if the patient has given the access to the doctor.
- Update/Add new records: The doctor can add new records of a particular patient on the system.

Following are the responsibilities of smart contracts in proposed system:

- The smart contracts define the rules and conditions for accessing and modifying patient data, and enforce these rules automatically.
- The smart contracts are also responsible for managing patient consent for sharing their data with other healthcare providers.

B. Access Control and Consent Management

Access control and consent management are critical features of the proposed system. The smart contracts define the roles and permissions of different users, such as healthcare providers, patients, and administrators. Each user is assigned a unique digital identity, which is a part of data on the blockchain. The smart contracts enforce access control policies, ensuring that only authorized users can access and modify patient data.

Consent management is also managed through the smart contracts. Patients can grant or revoke consent for sharing their medical records with other healthcare providers. The smart contracts ensure that patient consent is obtained before sharing their data, and that patients have control over how their data is used.

C. Privacy and Data Security

Privacy and Data security are critical components of the proposed system. The use of cryptographic methods, such as hashing and encryption, ensures the confidentiality and integrity of the data.

The permissioned blockchain ensures compliance with healthcare data privacy regulations, such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States. Only authorized users are permitted to handle and access sensitive patient information.

D. Performance and Scalability

The performance and scalability of the proposed system were evaluated using a prototype implementation. The prototype was implemented using a permissioned blockchain platform.

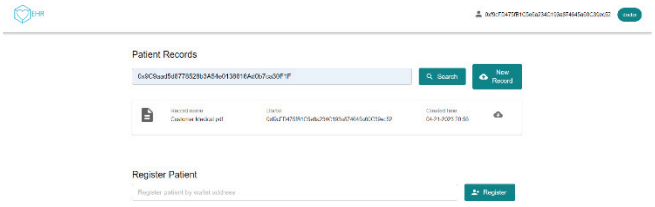

Fig.3. Doctor viewing patient records on prototype platform

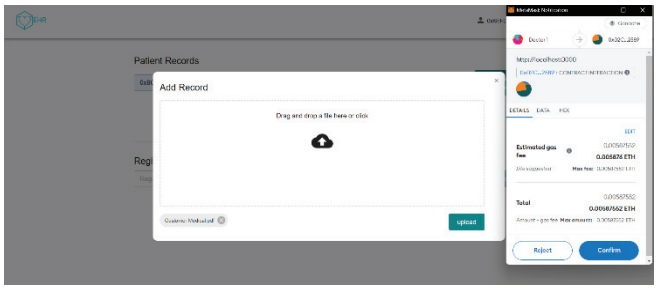

Fig.4. Doctor adding new records on prototype platform

The prototype was tested using a simulated healthcare network, with multiple healthcare providers accessing and modifying patient data. Fig. 3 and Fig. 4 shows the working prototype. The results showed that the proposed system was scalable and could handle a large number of transactions. The latency of transactions was also found to be within acceptable limits, ensuring that the system could be used in real-time healthcare applications.

Permissioned blockchains often offer higher transaction throughput and lower latency compared to public blockchains. This is crucial for healthcare systems where real-time access to patient data is essential for timely decision-making and patient care.

E. Comparison with Traditional EHR Systems

The proposed system was compared with traditional EHR systems in terms of security, privacy, interoperability, and data integrity. The results showed that the proposed system provided significant improvements in all of these areas. The use of blockchain technology ensured that the medical and health data was secure and private, while the use of smart contracts provided a transparent and accountable platform for managing consent and access control. The use of cryptographic techniques ensured the integrity of the data.

TABLE I. ANALYSIS OF TRADITIONAL AND BLOCKCHAIN BASED EHR SYSTEM

Parameters	**Blockchain Based EHR**	**Traditional Application**
Ease of Access	Very easy.	Moderate.
Ease of Sharing among organizations	Very easy due to decentral network	Not easy.
Peer network	Decentralized open.	Centralized closed.
Security	High	Less
Permanence of data	Records are immutable as they are stored on Blockchain.	Records can be edited. Hence, less reliable.
Privacy and consent management	Available	Not available

Table I shows the comparative analysis of Traditional EHR applications and Blockchain based EHR applications.

V. EVALUATION RESULTS

To evaluate the proposed system, we conducted a security analysis of smart contract. The study was conducted using a prototype implementation of the system, which was deployed on a simulated healthcare platform.

A. Vulnerability Analysis of Smart Contract

We conducted a comprehensive analysis of the vulnerabilities in our smart contract and identified potential weaknesses in the code as shown in Fig. 5.

Table II shows statistical analysis of the smart contract. By systematically reviewing the contract's logic, we were able to discover and fix various security flaws that could have potentially led to exploitable vulnerabilities.

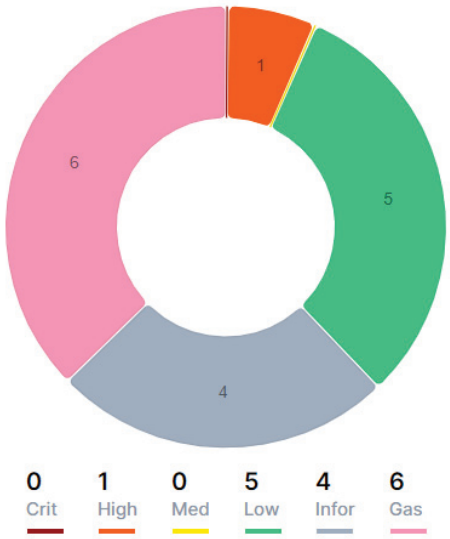

Fig.5. Vulnerability Testing Result

TABLE II. ANALYSIS STATISTICS

Score	3.87/5
Issue Count	16
Lines of Code	106

B. Comparison with Traditional EHR Systems

A user study was conducted for evaluation of the proposed system. The findings of the user study were compared to those of conventional EHR systems in regards to usability, security, and privacy. The results showed that the proposed system provided significant improvements in all of these areas. Permissioned blockchain restricts network access to authorized entities, enhancing security, scalability, controlled governance, and efficient consent management in our EHR system.The system was found to be more user-friendly and easier to use than traditional EHR systems. In addition, the system provided higher levels of security and privacy, and was found to be more transparent and accountable.

In the next section, we discuss the limitations and future scope of the proposed system.

VI. LIMITATIONS AND FUTURE SCOPE

While the system showed promising results in the evaluation, there were some limitations that should be considered.

Firstly, the study was conducted using a prototype implementation of the system on a simulated healthcare network. In the future, real-world implementation of the system should be tested to evaluate its performance under more practical circumstances.

Secondly, the proposed system is reliant on the use of blockchain technology, which can be computationally expensive and may require significant computational resources to operate efficiently [16]. This could be a limitation for smaller healthcare organizations or developing countries that may not have access to the necessary computational resources.

Finally, while the proposed system provides a high level of security and privacy, it may not be able to prevent all types of security breaches or data leaks. Future work should focus on developing additional security measures to further enhance the security and privacy of the system.

In terms of future work, there are several avenues that could be explored. Firstly, our system could be extended to support additional types of medical data, such as medical images or genetic data. This would allow the system to be used in a wider range of healthcare settings.

Secondly, the proposed system could be integrated with existing healthcare systems to provide a seamless and unified experience for healthcare providers and patients.

Thirdly, a functionality to share the patient records and diagnostics with medical researchers anonymously with due consent of the patients in question can be added. This will elevate medical research making the required data readily available for analysis.

Finally, future work could focus on developing additional privacy-preserving techniques, such as differential privacy, to further enhance the privacy of patient data.

In conclusion, the proposed system shows promising results in terms of usability, privacy and security. While there are some limitations that should be considered, the system provides a strong foundation for the development of a more secure and transparent electronic health record system using blockchain technology.

VII. Conclusion

In this paper, a methodology to electronic health record (EHR) management using blockchain technology is proposed. The proposed platform provides a safe and transparent platform for sharing and storing patient data while preserving patient privacy.

By developing and deploying a prototype system, we have demonstrated that the proposed platform can provide a high level of security and privacy while maintaining usability for healthcare providers and patients. The results of the evaluation shows that the system is capable of efficiently managing patient data and promoting secure and transparent data sharing among healthcare providers.

While there are some limitations that should be considered, such as the reliance on blockchain technology and the need for significant computational resources, the proposed system provides a strong foundation for the development of a more secure and transparent EHR system. Future work could focus on addressing these limitations and exploring new avenues for improving the system.

The proposed system has the potential to bring substantial improvements in the management and sharing of patient data in healthcare settings. As the healthcare industry continues to digitize and adopt new technologies, blockchain-based EHR systems could become a critical component of the healthcare infrastructure, providing secure and transparent access to patient data for healthcare providers around the world.

References

[1] S. Alzahrani, T. Daim and K. -K. R. Choo, "Assessment of the Blockchain Technology Adoption for the Management of the Electronic Health Record Systems," in IEEE Transactions on Engineering Management, vol. 70, no. 8, pp. 2846-2863, Aug. 2023, doi: 10.1109/TEM.2022.3158185.

[2] A. Gautama, A. F. Rochim and L. Bayuaji, "Privacy Preserving Electronic Health Record with Consortium Blockchain," 2022 6th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE), Yogyakarta, Indonesia, 2022, pp. 303-308, doi: 10.1109/ICITISEE57756.2022.10057649.

[3] A. Shahnaz, U. Qamar and A. Khalid, "Using Blockchain for Electronic Health Records," in IEEE Access, vol. 7, pp. 147782-147795, 2019, doi: 10.1109/ACCESS.2019.2946373.

[4] Capece G, Lorenzi F. Blockchain and Healthcare: Opportunities and Prospects for the EHR. Sustainability. 2020; 12(22):9693. https://doi.org/10.3390/su12229693

[5] Hölbl M, Kompara M, Kamišalić A, Nemec Zlatolas L. A Systematic Review of the Use of Blockchain in Healthcare. Symmetry. 2018; 10(10):470. https://doi.org/10.3390/sym10100470

[6] Thomas McGhin, Kim-Kwang Raymond Choo, Charles Zhechao Liu, Debiao He, Blockchain in healthcare applications: Research challenges and opportunities, Journal of Network and Computer Applications, 2019, https://doi.org/10.1016/j.jnca.2019.02.027.

[7] Seymour, Dr. Tom & Frantsvog, Dean & Graeber, Tod. (2014). Electronic Health Records (EHR). 10.19030/ajhs.v3i3.7139.

[8] Abunadi I, Kumar RL. BSF-EHR: Blockchain Security Framework for Electronic Health Records of Patients. Sensors. 2021; 21(8):2865. https://doi.org/10.3390/s21082865.

[9] Nakamoto, S. (2008) Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf

[10] Girardi F, De Gennaro G, Colizzi L, Convertini N. Improving the Healthcare Effectiveness: The Possible Role of EHR, IoMT and Blockchain. Electronics. 2020; 9(6):884. https://doi.org/10.3390/electronics9060884

[11] S. K. Dwivedi, R. Amin, and S. Vollala, "Blockchain-based secured IPFS-enable event storage technique with authentication protocol in VANET," IEEE/CAA Journal of Automatica Sinica, vol. 8, no. 12, pp. 1913–1922, 2021.

[12] P. Zheng, Z. Jiang, J. Wu and Z. Zheng, "Blockchain-Based Decentralized Application: A Survey," in IEEE Open Journal of the Computer Society, vol. 4, pp. 121-133, 2023, doi: 10.1109/OJCS.2023.3251854.

[13] B. K. Mohanta, S. S. Panda and D. Jena, "An Overview of Smart Contract and Use Cases in Blockchain Technology," 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Bengaluru, India, 2018, pp. 1-4, doi: 10.1109/ICCCNT.2018.8494045.

[14] Dabbagh, M., Choo, K. K. R., Beheshti, A., Tahir, M., & Safa, N. S. (2021). A survey of empirical performance evaluation of permissioned blockchain platforms: Challenges and opportunities. computers & security, 100, 102078.

[15] Dennis Trautwein, Aravindh Raman, Gareth Tyson, Ignacio Castro, Will Scott, Moritz Schubotz, Bela Gipp, and Yiannis Psaras. 2022. Design and evaluation of IPFS: a storage layer for the decentralized web. In Proceedings of the ACM SIGCOMM 2022 Conference (SIGCOMM '22). Association for Computing Machinery, New York, NY, USA, 739–752. https://doi.org/10.1145/3544216.354423

[16] Budish, E. (2018). The economic limits of bitcoin and the blockchain (No. w24717). National Bureau of Economic Research.