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Ethereum and Smart Contracts based Healthcare Data Management

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Abstract – This paper delivers a comprehensive report on the successful implementation of an Ethereum and Smart Contract based decentralized web application that is a platform for healthcare institutes to maintain their patient medical records. The system allows multiple healthcare institutes to share patient medical data. The immutability of the data is an essential requirement when handling sensitive data like a patient's medical history, hence the incorporation of blockchain technology which is a digital edger that keeps track of transactions or information in a secure and transparent way.

Key Words: Blockchain, Ethereum, Smart Contracts, Healthcare, Security and Privacy.

1. INTRODUCTION

Blockchain technology offers significant benefits for healthcare data management. It enhances data security, ensuring that healthcare information is stored securely and cannot be tampered with. The immutability of blockchain ensures data integrity, providing a reliable source of truth. Blockchain technology is a digital ledger that keeps track of transactions or information in a secure and transparent way. Instead of being stored in a central location, the information is stored in blocks that are linked together in a chain. Each block contains a unique code that connects it to the previous block, forming a chain of blocks. Once information is recorded in a block, it cannot be easily changed or tampered with, ensuring its integrity. The information stored on the blockchain is distributed across many computers, called nodes, making it difficult for anyone to manipulate the data. Whenever a new transaction or piece of information is added to the blockchain, it is verified by the network of nodes to ensure its accuracy.

In Healthcare the self-correcting and transparent nature of Blockchain aids to keep the data in the network consistent. Tampering becomes impossible and accountability is maintained as the address of all the concerned parties are recorded at every step, while maintaining the security of each user's medical records.
Several entities like the patients, doctors, insurance and pharmaceutical companies can participate in this network. This paper describes the project leveraging the Ethereum blockchain for storing a patient's healthcare relevant data.

In the existing systems, healthcare relies on centralized databases and traditional security measures, making it vulnerable to data breaches and unauthorized access. in contrast, blockchain provides a decentralized and immutable ledger, enhancing data security. the use of cryptographic algorithms and consensus mechanisms ensures data is tamper-resistant and transparent, reducing the risk of data breaches. The healthcare industry struggles with interoperability issues in the existing system, as different organizations and systems use incompatible data formats and standards. This hinders seamless data exchange and collaboration. Blockchain, on the other hand, enables a standardized and decentralized infrastructure that promotes interoperability.

Smart contracts and standardized data models facilitate the exchange of data between different stakeholders, allowing for streamlined and efficient data sharing. Data integrity is a challenge in the existing system, as it relies on trust in a single entity or organization. Any data manipulation or errors can be difficult to detect and correct. In contrast, blockchain provides an immutable and transparent record of transactions. Every transaction is recorded in a decentralized manner, making it easier to detect and prevent data manipulation. This enhances data integrity and trust in the system.

Privacy and consent management are often lacking in the existing system. Patient data is scattered across multiple databases, making it challenging to maintain privacy and control over personal information. Blockchain allows for granular privacy controls and patient consent management through smart contracts. Patients have control over their data and can grant or revoke access to specific parties, ensuring privacy and data ownership. Furthermore, blockchain streamlines processes by eliminating intermediaries, reducing administrative overhead, and automating data sharing and transactions. This can potentially lead to cost savings and improved operational efficiency.

2. LITERATURE SURVEY

The paper "MedBlock: Efficient and Secure Medical Data Sharing Via Blockchain" by Kai Fan, Shangyang Wang, Yanhui Ren, Hui Li, Yingtang Yang focuses on EMR and data sharing between various different Healthcare institutes. Traditionally each hospital maintains their own database which has the patient record, consequently a single patient will have

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different record in different hospitals. Furthermore, current EMRs systems lack a standard data management and sharing policy, making it difficult for pharmaceutical scientists to develop precise medicines based on data obtained under different policies. To solve these problems the aforementioned paper proposes a blockchain-based information management system, MedBlock, to handle the patients' information.

In this scheme, the distributed ledger of MedBlock allows the efficient EMRs access and EMRs retrieval. The improved consensus mechanism achieves consensus of EMRs without large energy consumption and network congestion. In addition, MedBlock also exhibits high information security combining the customized access control protocols and symmetric cryptography. MedBlock can play an important role in the sensitive medical information sharing.

As IoT devices and remote patient monitoring systems become more prevalent, concerns regarding the security of data transactions arise. To address these concerns and handle protected health information (PHI) generated by such devices, the authors of the paper "Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring ", Kristen N. Griggs, Olya Ossipova, Christopher P. Kohlios, Alessandro N. Baccarini, Emily A. Howson & Thaier Hayajneh, propose leveraging blockchain-based smart contracts for secure analysis and management of medical sensors.

The proposed system utilizes a private blockchain based on the Ethereum protocol. In this system, the sensors communicate with a smart device that interacts with smart contracts and records all events on the blockchain. By using smart contracts, real-time patient monitoring and medical interventions can be supported. The system is designed to send notifications to patients and medical professionals while ensuring a secure record of the activities' initiators.

In the paper titled "Blockchain technology in healthcare: A systematic review" by Huma Saeed, Hassaan Malik, Umair Bashir, Aiesha Ahmad, Shafia Riaz, Maheen llyas the systematic literature review (SLR) focuses on exploring the potential impact of blockchain technology (BCT) on the healthcare sector. The review analyzed research articles published between January 2016 and August 2021 in reputable venues such as IEEE Xplore, ACM Digital Library, Springs Link, Scopus, Taylor & Francis, ScienceDirect, PsycINFO, Ovid Medline, and MDPI. Out of 1,192 studies identified, 51 articles were selected for the SLR.

The findings indicate that BCT has the potential to bring about a paradigm shift in healthcare by improving the management, distribution, and processing of clinical records and personal medical information. BCT offers benefits such as increased efficiency, technological innovation, access control, data privacy, and security. The review also identifies areas for future research, including data protection, system architecture, and regulatory compliance.

Another paper titled "Application of Blockchain Technology in Healthcare: A Comprehensive Study" by Mohamed Jmaiel, Mounir Mokhtari, Bessam Abdulrazak, Hamdi Aloulou, and Slim Kallel explored the various applications of Blockchain within the Healthcare context. The paper covers applications such as Electronic Medical Records (EMR), Remote Patient Monitoring, Pharmaceutical Supply Chain and Health Insurance Claims. The study conducted also revealed several potential drawbacks and limitations;

First, EMR systems do not address semantic interoperability. Consequently, manual inspection and mapping of predefined ontologies from medical and health data experts are required. Second, clinical malpractice cannot be controlled at this level. Moreover, scalability and interoperability issues represent the main focus of current and future studies in this field. Interoperability challenge reveals the fact of missing standards for developing healthcare applications based on blockchain technology. Thus, the different developed applications may not be able to interoperate. In addition, scalability is a major issue in blockchain-based healthcare systems especially towards the volume of medical data involved. Due to high-volume healthcare data, it is not practicable to store it on-chain i.e., on blockchain, as this may lead to serious performance degradation.

Furthermore, there is a problem of latency caused by the speed of transactions' processing and off-chain data load in a blockchain-based system. Finally, another weakness is related to blockchain immutability and self-execution of code, since smart contracts could become vulnerable to hackers. Just between 2016 and 2018, attacks such as the decentralized autonomous organization (DAO) attack cause a loss of millions of dollars as part of the assets held by the smart contracts.

3. METHODLOGY

This section is about the methodology of the proposed system for healthcare data management. The proposed system has 4 entities –

i. Hospitals/Doctors: Can upload diagnosis, prescriptions and bills for each patient.
ii. Chemists: Can view prescriptions, and upload receipts.
iii. Insurance Companies/Corporates: Can view receipts in order to validate claims.
iv. Patients: Can view their medical records.

A private Ethereum blockchain network is operated with Ganache, MetaMask and Truffle Suite. Smart Contracts are used to execute functions, each trigger of smart contract requires gas (ether) which is deducted from the wallet of the entities involved.

3.1 Designing the DApp (Decentralized Application)

This involves determining the high-level architecture of the DApp, including the user interface, backend components, and smart contracts. Deciding whether the DApp will be a single smart contract or multiple contracts interacting with each other. The implemented system operates using three smart contracts, each smart con

3.2 Choosing the development tools

Selecting the appropriate tools and frameworks to aid development. Popular choices include the Solidity programming language for smart contracts, the Truffle framework for development and testing, and the web3.js library for interacting with Ethereum.

3.3 Smart Contract Development

Writing Solidity code to define the data structures, functions, and logic of the contracts.

3.4 Testing

Creating comprehensive test cases to validate the functionality of the smart contracts. Using tools like Truffle or Ganache for testing in a local development environment, and also running additional tests on public test networks like Rinkeby or Ropsten.

3.5 Frontend development

Developing the user interface (UI) for the DApp. Using web development technologies like HTML, CSS, and JavaScript to create an intuitive and user-friendly interface. Integrating the UI with the Ethereum blockchain using web3.js or other Ethereum libraries

3.6 Deployment

Choosing the appropriate Ethereum network (mainnet, testnet, or private network) for deploying the smart contracts and DApp. Deploying the smart contracts using tools like Truffle or Remix. Managing gas costs and upgrading the contract if necessary.

4. EXPERIMENT AND RESULTS

4.1 Functionality

The core EHR functions were rigorously tested, including the creation, updating, sharing, and accessing of medical records. These tests covered a wide range of data types and formats commonly encountered in healthcare contexts, ensuring the system's adaptability and versatility.

4.2 Security Testing

A thorough examination of the system's security was carried out through penetration testing. This rigorous assessment aimed to uncover vulnerabilities and potential points of exploitation. Rigorous scrutiny was applied to detect any possible data breaches, unauthorized access attempts, or tampering with records.

4.3 Scalability

The system's performance was assessed under varying load conditions, encompassing different user volumes and transaction rates. This testing phase provided valuable insights into response times and throughput, pinpointing potential performance bottlenecks and the system's overall scalability.

4.4 Smart Contract Logic Testing

Thorough scrutiny was directed towards the logic governing the smart contracts, ensuring precise execution of actions based on predefined conditions. Rigorous testing verified the effectiveness of permissions, access controls, and data validation mechanisms.

4.5 Results

- **Reduced Administrative Costs:** Automation through smart contracts can streamline administrative tasks such as claims processing, billing, and insurance verification, leading to reduced costs and more efficient processes.
- **Efficient Insurance Claims:** Insurance companies could directly access patient records through the blockchain, reducing the need for manual information exchange and potentially accelerating the claims approval process.
- **Smart Contracts for Workflow:** Smart contracts could be utilized to automate various aspects of the healthcare workflow. For instance, when a patient visits a doctor, the smart contract could automatically trigger insurance claim processing or notify the hospital about the appointment.
- **Security and Privacy:** Blockchain technology, which Ethereum is built upon, provides a secure and transparent way to store and manage sensitive medical data. Patient records can be securely stored in the blockchain, ensuring privacy and data integrity.
- **Data Accessibility:** Patients can have control over who accesses their medical records. They can provide explicit permissions to doctors, hospitals, and insurance companies to view their records, improving data sharing efficiency and security.
- **Immutable Records:** Once data is recorded on the blockchain, it becomes nearly impossible to alter or delete. This can be advantageous in maintaining accurate and tamper-proof medical records.

5. CONCLUSION

Ethereum smart contract-based Electronic Health Record (EHR) system that involves patients, doctors, hospitals, and insurance companies brings to light a transformative landscape for healthcare data management. By harnessing the power of blockchain technology and smart contracts, this system offers a plethora of benefits while demanding careful attention to challenges. The advantages, such as heightened data security, patient agency over records, streamlined workflows, and enhanced interoperability, paint a promising picture of efficient and patient-centric healthcare operations. Smart contracts automate processes, diminishing administrative burdens and fostering transparency. Moreover, the potential for research insights from aggregated, anonymized data could pave the way for medical advancements. However, the road to realization is accompanied by noteworthy considerations. Regulatory compliance is paramount, as healthcare data demands adherence to stringent laws. Migrating data from legacy systems while addressing scalability limitations necessitates meticulous planning. User-friendly interfaces are vital to encourage system adoption, while rigorous security measures mitigate vulnerabilities. Integration challenges, ethical concerns, and the ongoing maintenance of the system all contribute to the complexity of this endeavour. Success lies in harmonizing technological innovation with the practical intricacies of healthcare, safeguarding patient privacy, data integrity, and quality care. In essence, while the concept of an Ethereum smart contract-based EHR system holds great promise, its effective implementation hinges on a comprehensive strategy that embraces advantages, confronts challenges, and ensures a seamless transition into a new era of healthcare management.

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