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Healthcare Record Management Using Blockchain

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Abstract
Blockchain has been in popular demand for the last decade or so, but it recently gained recognition with the popularity of Bitcoin. It has been extensively used in fields like finance, government, energy, etc. It is the need of the hour that the technology was utilized in other relevant areas as well like healthcare. Making maximum use of blockchain in the healthcare industry is expected to have numerous significant impacts and positive outcomes. The technology is defined as a decentralized and distributed ledger that can be used to record transactions securely across many computers in a peer-to-peer network, without the need for a third party. A block consists essentially of a header and a body. The header of each block contains the hash of the previous block. Among the important features of blockchain is how it is impossible to tamper with and is censorship resistant, giving access to the timestamped transaction while maintaining anonymity at the same time. The method used is literature survey. We perform a study selection process in four steps. After each steps the number of publications is reduced as unwanted publications are omitted using search strings, inclusion and exclusion criteria. We even conducted a study quality assessment which helps us analysis the quality of findings from the final set of selected papers in answering the research questions. We have summarized the findings from the 10 selected papers from the study selection process according to the research questions. The most prominent feature of blockchain technology is the fact that it removes the need for a centralized third party and makes it possible for two parties to carry out transactions without a centralized authority. This paper intends to explore how decentralization makes it easier to maintain transparent and open records for patients to see how, when, and where their information is being used. By employing the programming language Solidity, a smart contract will be created which will be deployed on the Ethereum blockchain. This in turn will further ensure that no recorded data can be deleted. Any data recorded by the doctor in the blockchain can be edited whereas the patients will only have viewing access to the entered medical records. This will not only ensure a high level of security, but also the credibility of the information provided.

Keywords: Blockchain, Healthcare, Smart Contracts, Use Cases, EMRs, Literature Survey

1. INTRODUCTION

In recent years, blockchain technology, popularized by cryptocurrencies like Bitcoin, has gained significant attention across various sectors. However, its potential in healthcare remains largely untapped. Blockchain, a decentralized and immutable ledger system, offers secure transaction recording without intermediaries. Its transparency and privacy features make it relevant for healthcare. This project aims to create a transparent patient record system using Solidity on the Ethereum blockchain. Patients control their data, while doctors record and edit medical records. This initiative enhances data security, privacy, and accessibility, contributing to healthcare's digital transformation.

1.1 Evolution of Blockchain Technology in Healthcare

1. The evolution of blockchain technology has been instrumental in transforming various industries, and its potential impact on healthcare is increasingly being recognized. Blockchain's first generation emerged with the introduction of Bitcoin and its distributed ledger system. Bitcoin showcased the decentralized and transparent nature of blockchain.
2. The second generation of blockchain technology brought significant advancements with the introduction of smart contracts and programmable blockchains. The second-generation advancements that enable the execution of self-executing and predefined contractual agreements.
3. The third generation of blockchain technology focuses on addressing scalability, interoperability, and enterprise adoption challenges. These advancements aim to make blockchain systems more efficient and compatible with existing healthcare infrastructures. The third generation also emphasizes enterprise adoption, encouraging the integration of blockchain solutions into healthcare organizations, promoting transparency, and improved patient outcomes.

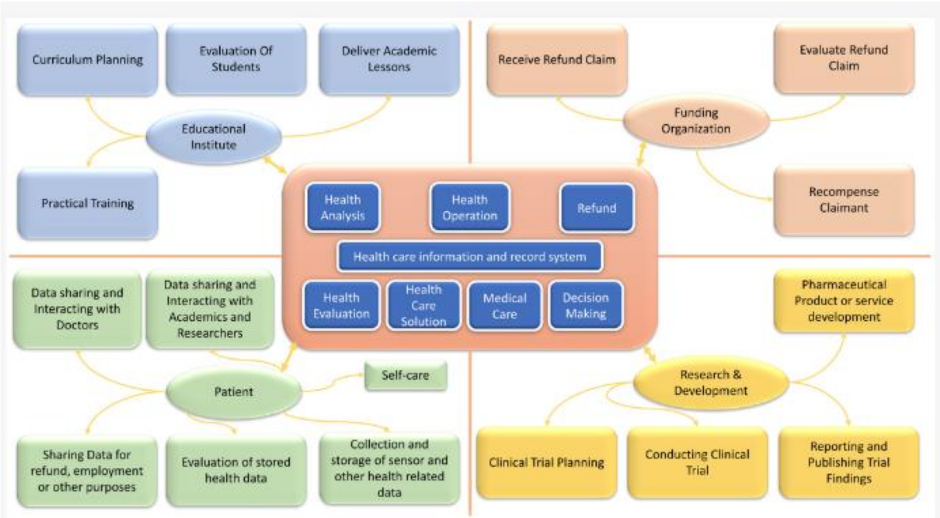

Figure 1: Map of Health Sector

1.2 Categorization of Blockchain Systems in Healthcare

In the abstract, the importance of blockchain technology in healthcare is emphasized, and understanding the categorization of blockchain systems is crucial for its effective implementation. Blockchain systems can be categorized into different types based on their governance models and access control. These categories include public, private, consortium, and hybrid blockchains, each offering unique characteristics and suitability for various healthcare applications.

1. Public Blockchain:

Public blockchains, such as the Bitcoin blockchain, are open and permission less networks where anyone can participate as a node and validate transactions. These blockchains are decentralized, providing a high level of transparency and security. In the context of healthcare, public blockchains can enable secure and tamper-proof medical records, giving patients control and visibility over their data. However, privacy concerns may arise due to the public nature of the blockchain, making it necessary to implement mechanisms to protect sensitive healthcare information.

2. Private Blockchain:

Private blockchains are restricted networks where only authorized participants can join and validate transactions. These blockchains are often utilized within single organizations or consortiums, allowing for efficient collaboration and streamlined processes. In healthcare, private blockchains can be employed within a specific healthcare provider network or a group of collaborating organizations, ensuring data privacy while enabling secure sharing of medical records and improving interoperability.

3. Consortium Blockchain:

Consortium blockchains are a hybrid approach that combines elements of both public and private blockchains. In a consortium blockchain, a predefined group of organizations or entities collectively maintains the network and validates transactions. Consortium blockchains are well-suited for healthcare scenarios involving multiple stakeholders, such as healthcare networks, insurance providers, and research institutions. These blockchains enable shared governance and improved interoperability while maintaining a certain level of control over data access.

4. Hybrid Blockchain:

Hybrid blockchains incorporate a combination of public and private elements, allowing for customization and flexibility based on specific use cases. In a hybrid blockchain, certain transactions or data can be made public, while other sensitive or private information remains restricted. This approach can be beneficial in healthcare, where a balance between transparency and privacy is required. For example, medical research data can be shared transparently, while patient-specific information remains private and accessible only to authorized entities. Understanding the categorization of blockchain systems in healthcare is essential for selecting the most suitable approach for a given application.

Blockchain Type\Properties	Private Blockchain	Consortium Blockchain	Public Blockchain
Efficiency	High	High	Low
Determination of consensus	An organization	Chosen node set	All miners
Constancy	Could be tampered	Could be tampered	Almost impossible
Centralized	Yes	Partial	No
Reading authorization	Public or restricted	Public or restricted	Public
Process of Consensus	Approved	Approved	Permissionless

Table 1: Blockchain types and their properties

1.3 Mechanisms for Consensus

1. Data entries in a blockchain are accepted through distributed ledgers and distributed ledger data entry by a distributed consent protocol. **Table 1** lists the three most widely used consensus protocols.
2. Proof of Work (PoW): PoW is the consensus mechanism behind Bitcoin and many other cryptocurrencies. In this participating miners compete to solve complex mathematical puzzles. The

first miner to solve the puzzle gets the right to add a new block to the blockchain, and this process is known as mining. PoW is renowned for its security but criticized for its energy-intensive nature.
3. Proof of Stake (PoS): In PoS, validators are chosen to create new blocks based on the number of cryptocurrency tokens they hold and are willing to "stake" as collateral. This mechanism is energy-efficient compared to PoW and is used in cryptocurrencies like Ethereum 2.0.
4. Proof of Authority (PoA): PoA relies on a group of approved validators who are considered trustworthy. Transactions are validated by these validators, making it suitable for private or consortium blockchains where participants are known entities.

Possessions	PBFT	PoS	PoW
Management of nodes	Authorized	Accessible	Accessible
Adversarial tolerance	Faulty replicas less than 33.3%	Stake less than 51%	Computation power less than 25%
Expenditure of energy	Poor	Moderate	High
Instance	Hyper ledger Fabric	Peer coin	Bitcoin

Table 2: Comparison of consensus method

2. Related Work

1. In recent times, blockchain technology has emerged as an attractive and versatile solution with a wide range of potential applications in various industries. This includes the healthcare sector, which has garnered significant interest among researchers and innovators. As the unique advantages of blockchain, such as enhanced security, transparency, and decentralized control, become more apparent, the healthcare industry has embarked on a journey to explore how this transformative technology can effectively address its unique challenges, optimize data management processes, and ultimately elevate the quality of patient care.

2. In reference to [3], the authors conducted a systematic literature review focused on the application of blockchain technology within the healthcare domain. This comprehensive analysis delves into the existing body of research concerning blockchain in healthcare. The primary objectives of the paper are to identify potential use cases for this technology and to underscore the associated challenges while also suggesting possible avenues for future research in this domain. The outcomes of this investigation reveal a growing trend in blockchain technology research within the healthcare sector, with predominant applications revolving around data sharing, healthcare record management, and access control. Notably, a substantial portion of the analyzed publications lacks technical details regarding the specific blockchain elements employed. Furthermore, many of these studies do not provide prototype implementations, and even when they do, specific blockchain element details are frequently absent.

3. In a separate study referenced as [4], the authors reached the conclusion that research into blockchain technology is experiencing exponential growth. Furthermore, this research highlights a concurrent

surge in efforts to leverage blockchain technology within the healthcare sector. It is evident that certain domains within the healthcare sector hold the potential for significant transformation through the adoption of blockchain technology.

4. In the study denoted as [5], the authors conducted a systematic mapping study employing a meticulously designed search protocol to identify relevant publications. The research findings indicate that numerous studies have proposed various potential use cases for applying blockchain technology in the healthcare sector. However, they also underscore a notable deficiency in the actual implementation of this technology within the field. Furthermore, the review provides insight into the current state-of-the-art regarding the development of blockchain applications for healthcare, outlining their inherent limitations and suggesting areas for future research. Consequently, there remains a clear imperative for additional research to gain a deeper understanding, characterize, and assess the practical utility of blockchain technology in healthcare.

5. In their study referenced as [6], Conoscenti et al. performed a systematic literature review with a specific focus on the utilization of blockchain technology in the context of the Internet of Things (IoT). Their findings underscored that within blockchain technology, the aspect of anonymity is the most assured. In terms of adaptability and integrity, the authors highlighted that the blockchain's integrity is predominantly reliant on the high complexity of the Proof-of-Work mechanism and the substantial number of honest miners. However, it's worth noting that a challenging Proof-of-Work requirement can also potentially limit its adaptability.

3. Literature Survey

We first define the used methodology for conducting the literature survey for this paper. Systematic literature survey paves a good way for a foundation for all types of research and, if well conducted it has the capacity to engender new ideas and directions for a particular field.

3.1. Search Strategy

A proper structured search for the literature on the topic was conducted using the following academic databases.

1. ACM digital library
2. Scopus
3. IEEE Xplore
4. Google Scholar
5. Springer

Blockchain && Healthcare && Healthcare applications && Medical && Medicine && Electronic Medical Records

3.2. Data extraction & Data Selection

In this stage of the literature survey, the information is extracted from the research papers after the selection process to perform meta-analysis and to answer the research questions. The following data was extracted from the papers

1. Title
2. Author(s)
3. Year of publication
4. Publication type
5. Abstracts
6. Research methods used
7. Findings
8. Conclusion drawn by the author(s)

Inclusion criteria
1. Original publications.
2. Publications specifically about Blockchain and healthcare sector.
3. Publications from the years 2016-2020.

Exclusion criteria
1. Publications not in English.
2. Publications which were not related to the topic.

3.3 Proposed Methodology

Research Work

Using our search protocol, we were able to retrieve a total of 10 papers from the scientific databases. After the screening process, which is based on the titles of the papers, for further screening, duplicates, abstract and introduction of the papers. After reading all the selected papers in full, at the end of the screening process, 4 papers were selected for inclusion in the study. The full list of the selected papers and some of the extracted data items are included in the references [1], [2].

Technical Work
1. Deployment on Ethereum - Creation of Smart Contract and deploy on Ethereum
2. Generation of Health Record - Storing data in the blockchain when entered by Doctor
3. Validation of Data - Using Smart Contracts
4. Designing Frontend - For customer Interaction
5. Testing - Testing of Smart Contract for proper usage

4. Identified Use Cases

Blockchain technology has recently garnered significant attention among researchers due to its versatile applications across various industries. Numerous studies have been undertaken to explore, assess, and implement blockchain technology's potential use cases within the healthcare sector, with the goal of optimizing and enhancing its efficiency. In this subsection of our findings, we aim to delineate the identified use cases within the healthcare industry. We commence by discussing research papers that have outlined these use cases, and subsequently, we delve into papers that have not only identified but also implemented these use cases to develop prototypes, frameworks, and more.

4.1. Electronic Medical Records (EMRs)

1. An Electronic Medical Records (EMRs), as outlined in [7], are digital archives of patients' medical histories, including diagnoses, prognoses, and lab reports. Improving EMRs is vital for enhancing healthcare intelligence. Globally, healthcare systems face data leakage issues, leaving both patients and providers with incomplete records. The incorporation of blockchain technology into EMRs offers a promising solution, ensuring data security and enabling seamless healthcare data interoperability.
2. Data on blockchain is visible to everyone on the network. This can be dealt with by opting for a private blockchain system in place of a public blockchain. In a private blockchain network the participants need permission to join and access the data whereas a public blockchain network is open to everyone who has access to internet such type of network can possess a large number of security concerns regarding privacy.
3. Utilizing a private blockchain network restricts access to a select group. The 'MedRec' [8] prototype demonstrates a proof-of-concept system leveraging blockchain's decentralization for a secure, interoperable Electronic Medical Record (EMR) system. Using Ethereum smart contracts, MedRec empowers patients with comprehensive access to their medical records.
4. MeDShare facilitates secure sharing of medical data and electronic health records among cloud service providers, hospitals, and healthcare research entities. It offers enhanced data provenance, personalized audit control, and minimizes security and privacy risks.

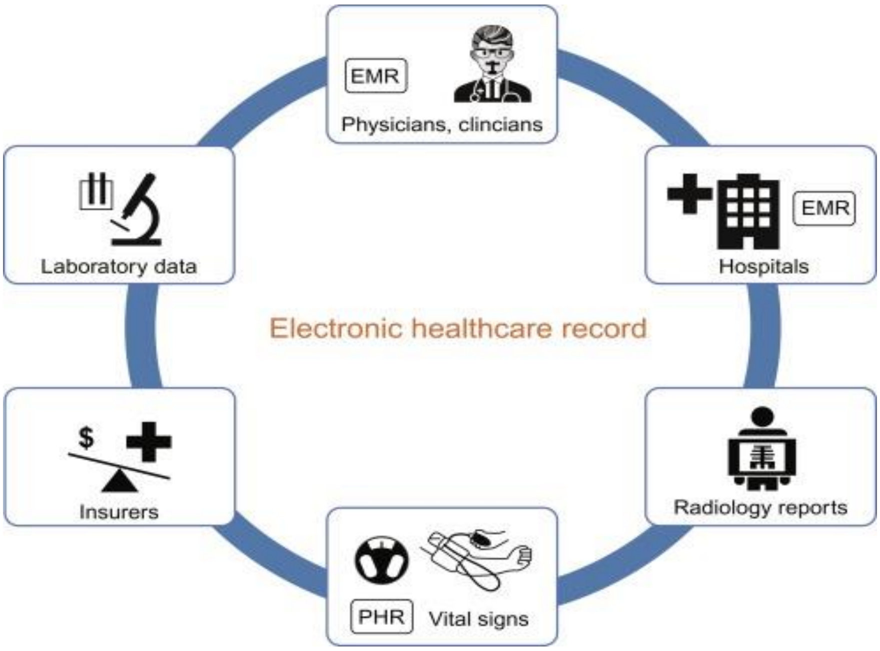

Figure 2: Electronic healthcare records

4.2 Challenges

Even though blockchain based EMR provide security, access control, there are still issues to be addressed. Blockchain was designed to record transaction data which is comparatively small in size. Medical records such as imaging, schedules, and appointments are bigger in size compared to the transactional record. To mitigate this, off site storage can be employed where the data is stored off the chain but the hashes of this (which are relatively small) are stored on the blockchain. However, this again pushes back to the initial problem to trusting an individual entity to hold the actual information.

Identified challenges faced by Blockchain are given below.

4.2.1 Scalability Issue

The scalability problem in blockchain technology pertains to its restricted transaction processing speed within the network. This scalability challenge arises due to the trade-off between available computing power and the volume of medical transactions, potentially constraining healthcare system scalability

4.2.2 Social Acceptance

Blockchain, while promising, is still an emerging technology that requires extensive research before widespread adoption. Its acceptance may be challenging, especially among those unfamiliar with the technology. The medical industry is gradually transitioning to digitization, but full adoption of blockchain technology will require clinical validation. Convincing people to embrace decentralized data sharing is a major challenge as it involves changing established behaviors

4.2.3 Security Concerns

The primary challenge lies in data security and privacy. With blockchain eliminating the need for third-party intermediaries and relying on community verification, there are potential privacy and security risks. Patients may need to authorize representatives to access their medical data in emergencies.

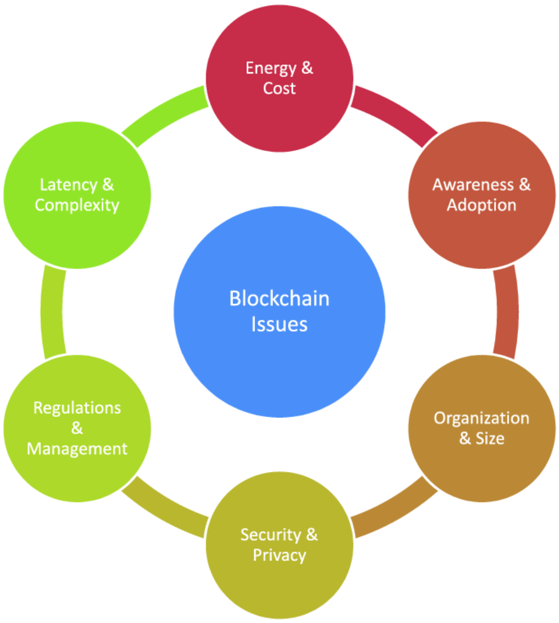

Figure 3: Blockchain issues

5. Results and Discussion

5.1. The smart contract

1. The smart contract defines a `*PatientData*` contract that has three structs: `*Patient*`, `*MedicalRecord*` and `*Doctor*`.
2. The `*Patient*` struct stores the name and age of a patient.
3. The `*MedicalRecord*` struct stores the IPFS hash and the date of a medical record.
4. The `*Doctor*` struct stores the name and the address of a doctor.
5. The contract also has three mappings: `*patients*`, `*records*` and `*authorizedDoctors*`.
6. The `*patients*` mapping maps an address to a `*Patient*` struct. This is used to store the patient information for each address.

7. The `*records*` mapping maps an address to an array of `*MedicalRecord*` structs. This is used to store the medical records for each patient address.
8. The `*authorizedDoctors*` mapping maps an address to another mapping that maps an address to a bool. This is used to store the authorization status of each doctor for each patient address.
9. The contract has five functions: `*addPatient*`, `*authorizeDoctor*`, `*revokeDoctorAuthorization*`, `*addRecord*` and `*getRecords*`.
10. The `*addPatient*` function takes a name and an age as parameters and assigns them to the patient struct for the sender's address. This is used to register a patient on the contract.
11. The `*authorizeDoctor*` function takes a doctor address as a parameter and sets it to true in the authorizedDoctors mapping for the sender's address. This is used to give permission to a doctor to access and modify the patient's records.
12. The `*revokeDoctorAuthorization*` function takes a doctor address as a parameter and sets it to false in the authorizedDoctors mapping for the sender's address. This is used to revoke permission from a doctor to access and modify the patient's records.

1. The `*addRecord*` function takes a patient address and an IPFS hash as parameters and pushes a new medical record struct to the records array for the patient address. This is used to add a new medical record for a patient on the contract. The function requires that the sender is an authorized doctor for the patient address.
2. The `*getRecords*` function takes a patient address as a parameter and returns the records array for that address. This is used to view the medical records for a patient on the contract. The function requires that the sender is either the patient or an authorized doctor for the patient address.

```
// SPDX-License-Identifier: GPL-3.0

pragma solidity ^0.8.9;

contract PatientData{
    struct Patient {
        string name;
        uint age;
        string ailment;
    }

    struct MedicalRecord {
        string IPFS_Hash;
        uint date;
    }

    mapping(address => Patient) public patients;
    mapping(address => MedicalRecord[]) private  records;
    mapping(address => mapping(address => bool)) public
authorizedDoctors;

    function addPatient(string memory _name, uint _age) public {
        patients[msg.sender].name = _name;
        patients[msg.sender].age = _age;
    }

    function authorizeDoctor(address _doctorAddress) public {
        authorizedDoctors[msg.sender][_doctorAddress] = true;
    }

    function revokeDoctorAuthorization(address _doctorAddress) public {
        authorizedDoctors[msg.sender][_doctorAddress] = false;
    }

    function addRecord(address _patientAddress, string memory IPFS_Hash)
public {
        require(authorizedDoctors[_patientAddress][msg.sender], "Only
authorized doctors can add records");
        records[_patientAddress].push(MedicalRecord(IPFS_Hash,
block.timestamp));
    }

    function getRecords(address _patientAddress) public view returns
(MedicalRecord[] memory) {
        require(msg.sender == _patientAddress ||
authorizedDoctors[_patientAddress][msg.sender], "Only patient or
authorized doctors can view records");
        return records[_patientAddress];
    }
}
```

Figure 4: The smart contract code

The "PatientData" smart contract has undergone comprehensive testing, and we are pleased to announce that it has successfully passed all the test cases. Functions such as "addPatient," "authorizeDoctor," "revokeDoctorAuthorization," "addRecord," and "getRecords" have been thoroughly tested and have demonstrated their expected behavior. This successful testing outcome ensures the code's reliability and confirms its ability to securely manage patient data and medical records on the blockchain.

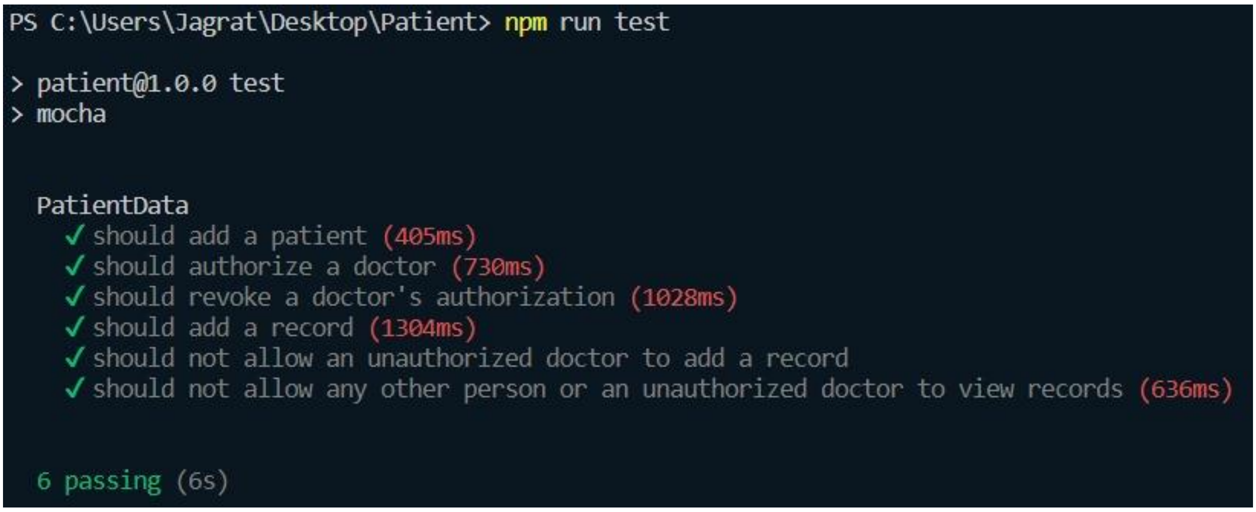

Figure 5: Passed Test Cases

1.2 DocBlock

We have successful deployed a fully functional website for the "PatientData" project. The website, accessible at https://docblock-xi.vercel.app/, provides a user-friendly interface for users to interact with the blockchain-based patient data management system. Through this website, users can conveniently add patients, authorize and revoke doctor access, add medical records, and retrieve patient records securely. It enables seamless access and utilization of the "PatientData" system, ensuring efficient and secure management of medical records.

The home page

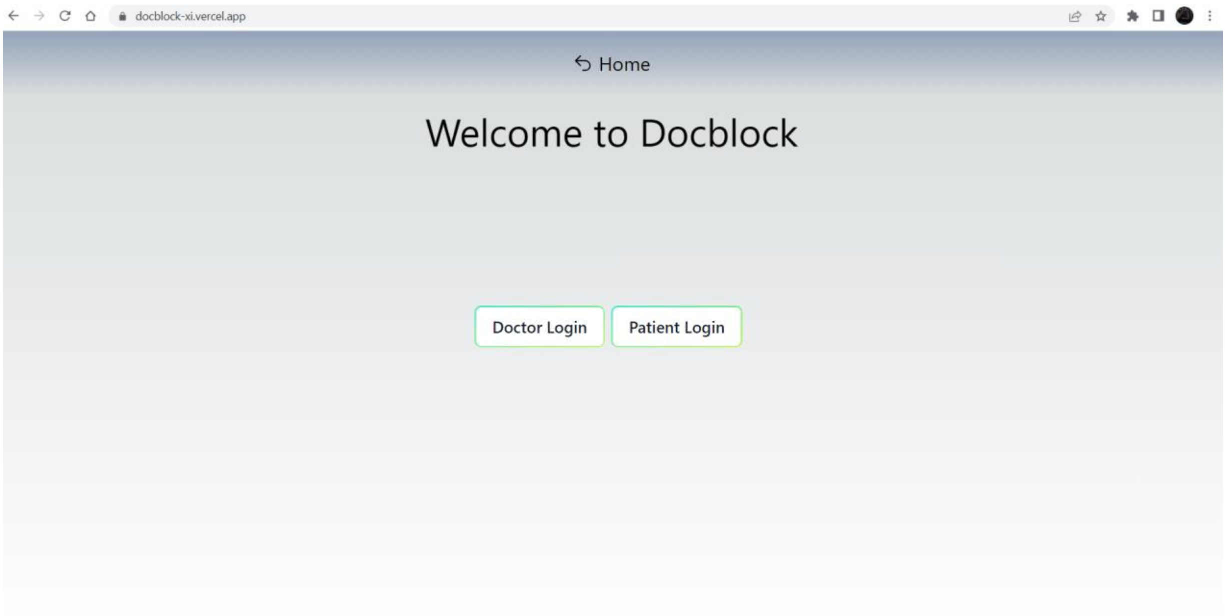

Figure 6: Website home page

- Doctor's login

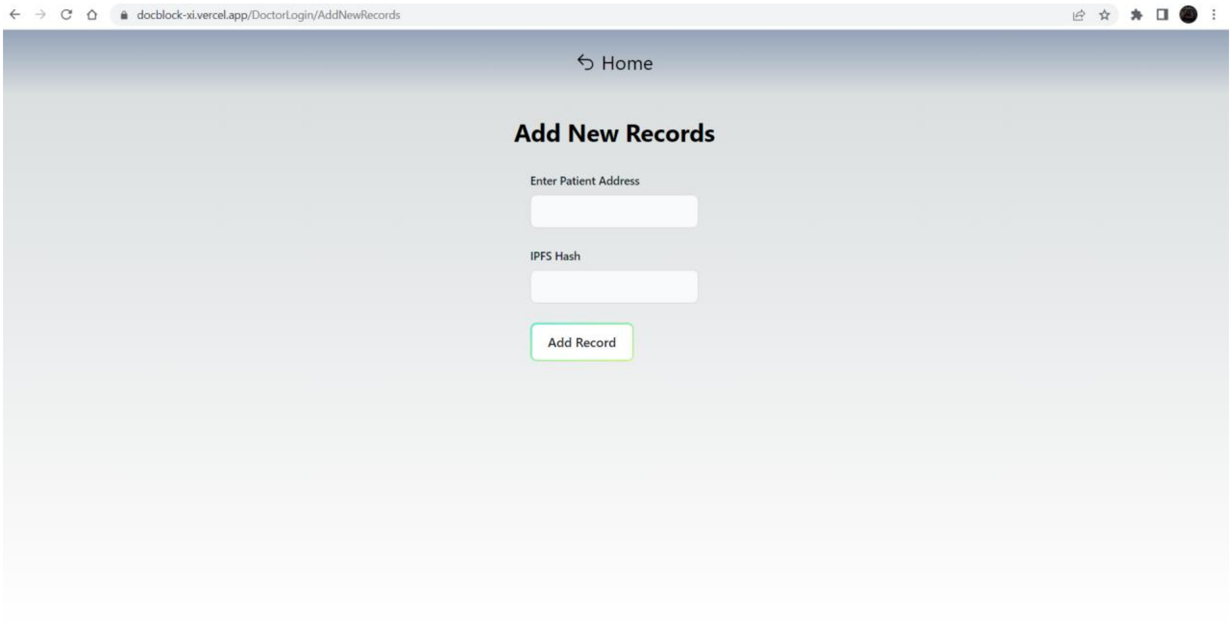

Figure 7: Doctor's login page

Patient's Login

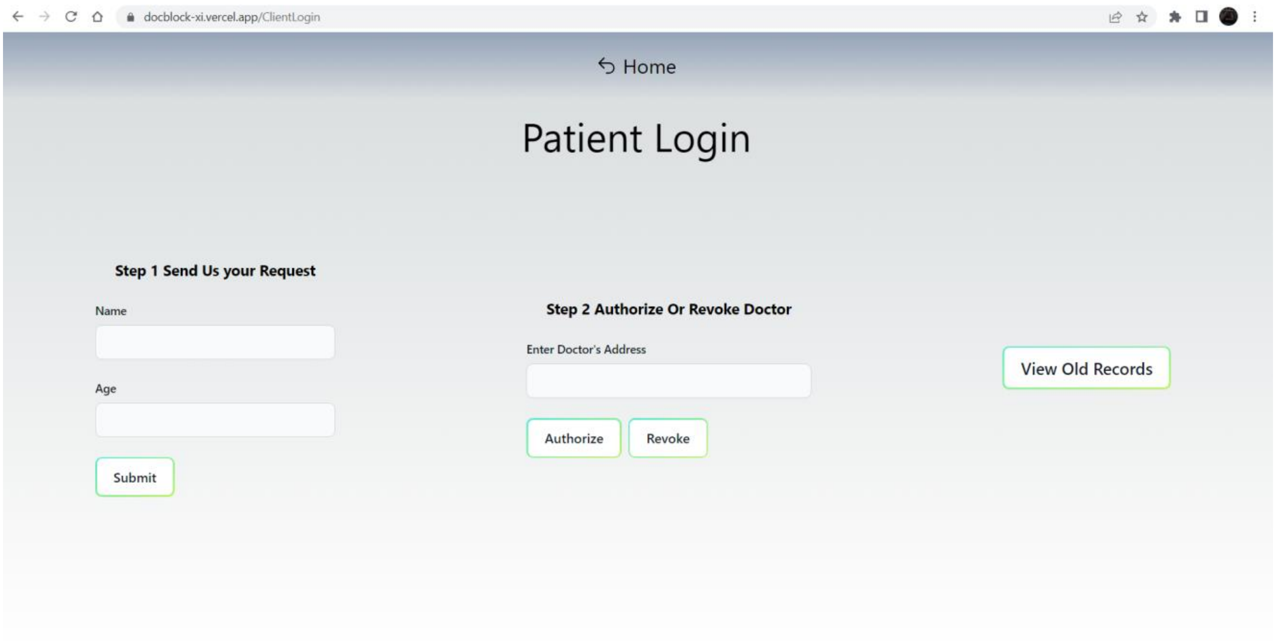

Figure 8: Patient's login page

- View old records

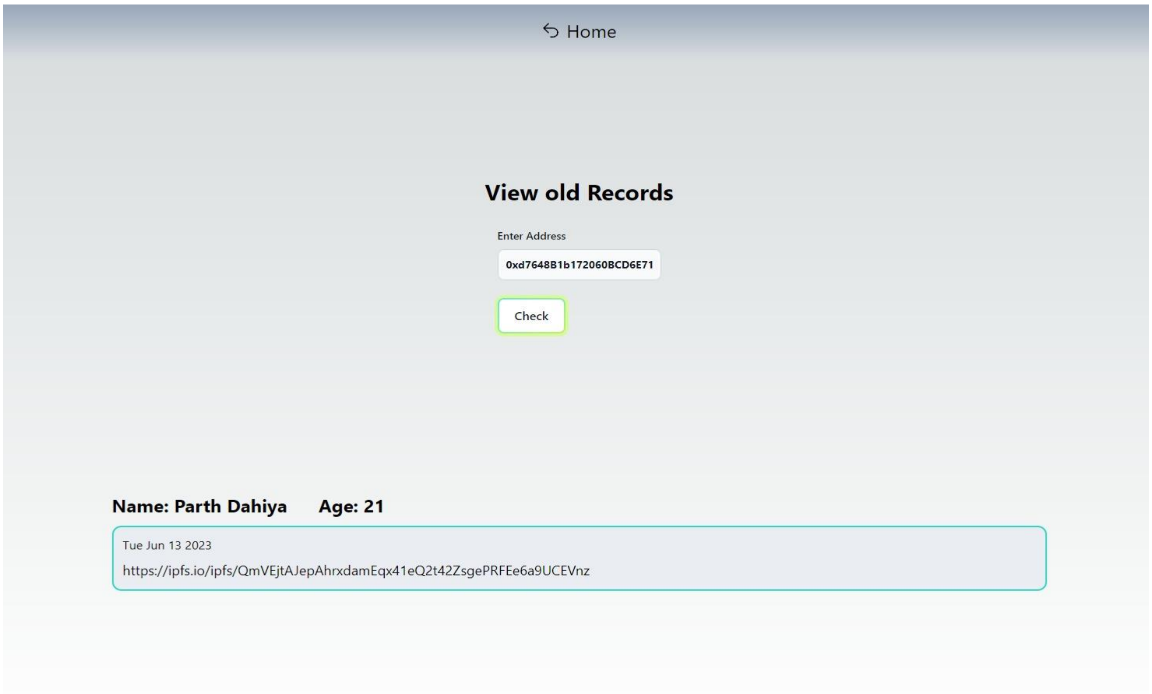

Figure 9: Viewing old records

Conclusion

1. In this report, we conducted a systematic literature survey to explore current trends in blockchain technology within the healthcare sector. We employed a rigorous study selection process, utilizing a search string and inclusion/exclusion criteria. After obtaining relevant papers, we thoroughly reviewed them to address our research questions. The insights from these papers informed the development of a fully functional website using smart contracts.
2. Blockchain is a revolutionary technology which has the potential to disrupt the whole healthcare industry. The features of blockchain like, decentralization, immutability and transparency provide a good platform on which the existing healthcare domain can improve. This provides data security, once any data is registered on the blockchain it cannot be altered or manipulated. As blockchain is decentralized, this entirely removes the need for a third party to verify the transactions on the chain which gives the patient complete authorization over their own medical information which was not accessible with the traditional centralized databases.
3. We have explored few uses of smart contracts, which is a smart programmable lines of code. Smart contracts are self-executing code, which activate upon meeting some predefined set of agreement. Smart contracts can be used in EMRs as a way to restrict access control.
4. As a result of this research we have developed a website **DocBlock**.
5. In this project, a website was created using the Solidity programming language and smart contracts specifically designed for the storage of medical records. The website's primary purpose was to provide a secure and decentralized platform for storing and accessing sensitive medical information.

Through the website, healthcare providers and authorized personnel were able to securely upload and store medical records using the smart contracts. The Solidity language enabled the implementation of strict access controls and encryption mechanisms to safeguard the confidentiality and privacy of the stored records. Patients, on the other hand, had controlled access to their own medical records through the website. They could securely view and manage their health information, granting permissions to healthcare providers as needed.

Overall, the creation of a website utilizing the Solidity language and smart contracts for medical record storage showcased the potential of blockchain technology in revolutionizing healthcare data management. It offered a secure, decentralized, and patient-centric approach to storing and accessing medical records, ensuring data privacy, integrity, and accessibility for all relevant stakeholders.

6. Future Work

As Blockchain technology is relatively new, necessitating extensive research to explore its full potential. In the healthcare domain, many theoretical frameworks exist, but practical implementations are limited. Future work can focus on expanding implementations beyond EMRs in healthcare.

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