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An Innovative Healthcare Records Management System with Ethereum and IPFS

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Abstract:

In an era where data is considered the new currency, secured record management systems are crucial for organizations to operate smoothly and effectively. Pens and papers are becoming obsolete, and modern-day record management systems that utilize basic databases have limited scalability and security vulnerabilities. Even the EHR that utilizes SHA-3 has drawbacks, as it requires custom-made codes and firmware for every device; in the medical sector, where the value of time is immeasurable, and possibilities of deception are higher than before, a transparent and immutable solution is required. The implementation of blockchain in records management solves all these issues single-handedly. Storing records using the Ethereum blockchain involves hashing the record, adding it to a block on the Ethereum blockchain, and then storing the file on the IPFS network using CID, with the IPFS hash being recorded on the blockchain as manifest on the decentralized ledger, which utilizes Smart Contracts for automated execution of predefined rules. This blockchain-based record management, already having Keccak-256 built-in, ensures enhanced data security, network analysis involving studying the structure and behavior of nodes, transaction bottlenecks, data integrity, no data manipulation, improved patient control, and privacy. The project's outcome is to leverage the Ethereum blockchain network to maintain patient healthcare records in a tamper-proof and encrypted format.

Keywords: Innovative Healthcare Records, Management System, Ethereum and IPFS.

Introduction

An Innovative Healthcare Records Management System with Ethereum and IPFS is a cutting-edge platform that combines the decentralized power of blockchain technology with the speed and scalability of IPFS (Inter-Planetary File System) to create a secure and efficient healthcare records management system [6]. This system is designed to address the challenges faced by traditional healthcare record management systems, such as lack of interoperability, security vulnerabilities, and limited accessibility [7]. With the Ethereum blockchain and IPFS, this system aims to provide a secure, transparent, and decentralized solution that can be accessed by authorized parties from anywhere in the world [8-12]. The system allows healthcare providers to securely store and share patient data on the Ethereum blockchain [13]. Ethereum provides a decentralized platform that enables the creation of smart contracts, which can be used to manage the permissions and access rights of different stakeholders involved in the healthcare ecosystem. This helps ensure that only authorized parties have access to sensitive patient data while providing a transparent and auditable record of all transactions [14-19].

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In addition to Ethereum, the system utilizes IPFS to store and distribute healthcare records. IPFS is a distributed file system that enables the creation of a decentralized web where data can be stored and accessed in a peer-to-peer network [20]. With IPFS, healthcare records can be distributed across multiple nodes, ensuring that the data is always available, even if some nodes go offline. This also provides a more resilient and scalable solution for managing healthcare records [21]. Overall, the Innovative Healthcare Records Management System with Ethereum and IPFS has the potential to transform the healthcare industry by providing a secure decentralized, and efficient solution for managing healthcare records [22]. With the use of blockchain and IPFS, the system addresses many of the challenges traditional healthcare record management systems face [23]. It provides a more secure, transparent, and accessible solution for patients, healthcare providers, and other stakeholders [24-27].

A block is a collection of transactions arranged in chronological order. A blockchain comprises a sequence of blocks, with each block including the preceding block's hash, forming a blockchain [28-35]. The initial block in a blockchain is called the genesis block (fig.1).

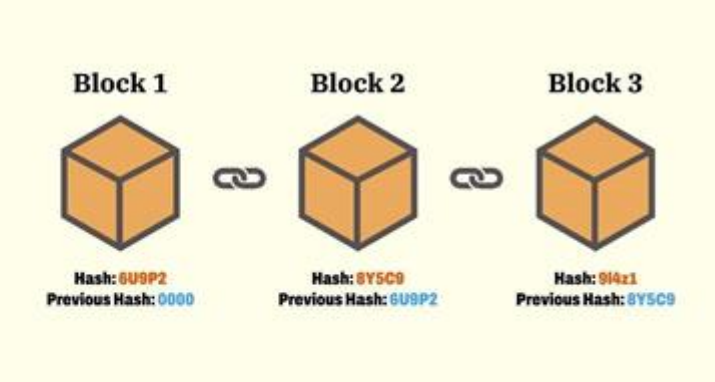

Figure 1: Chaining Between Blocks in A Blockchain [91]

A DAPP is an autonomously operated open-source application not managed by any central authority. Instead, it is decentralized over the web and built on blockchain technologies [36-41]. The data of a DAPP is stored cryptographically in a public and decentralized blockchain to avoid any single point of failure. It uses cryptographic tokens for monetizing the application (fig.2).

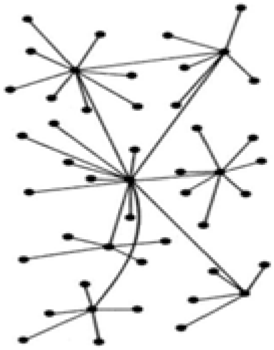

Figure 2: Model of centralized vs. Ethereum app [92]

The objective of An Innovative Healthcare Records Management System with Ethereum and IPFS is to provide a secure, decentralized, and efficient solution for managing healthcare records that addresses the challenges faced by traditional healthcare record management systems [42-47]. The system aims to leverage the power of blockchain technology and IPFS to create a transparent, auditable, and accessible platform for storing and sharing patient data while ensuring data privacy, data integrity, and data security [48-51]. The objective is to improve the interoperability, efficiency, and transparency of healthcare record management while reducing costs and enhancing the quality of patient care. Ultimately, the system aims to transform the healthcare industry by providing a more secure, transparent, and accessible solution for managing healthcare records that can benefit patients, healthcare providers, and other stakeholders [52-57].

Scope of the Project

The project scope for An Innovative Healthcare Records Management System with Ethereum and IPFS includes designing, developing, and implementing a secure and decentralized platform for managing healthcare records [58-63]. The project will involve integrating blockchain technology, specifically the Ethereum blockchain, with the IPFS to create a platform that ensures data privacy, security, and integrity. The project will cover the following key areas.

Architecture design: The system architecture will leverage the benefits of the Ethereum blockchain and IPFS. This will include the creation of smart contracts to manage access permissions, data privacy, and data sharing between stakeholders [64].

Data management: The system will provide a secure and efficient mechanism for storing, accessing, and sharing healthcare records. The data will be stored on IPFS nodes, and access to the data will be managed through the Ethereum smart contracts [65-71].

User interface: The system will have an intuitive and user-friendly interface that allows healthcare providers and patients to access and manage their records easily.

Security: The system will incorporate advanced security features such as encryption, multi-factor authentication, and auditing to ensure data privacy, security, and integrity.

Testing and deployment: The system will be thoroughly tested to ensure its reliability, scalability, and usability. The deployment process will involve integrating the system with the existing healthcare infrastructure.

Project Goals

This project aims to develop a decentralized healthcare record management system that uses blockchain technology and the Inter Planetary File System (IPFS) to create a secure, transparent, and tamper-proof system. By leveraging blockchain technology, the system ensures that patient data is tamper-proof, easily auditable, and transparent to all authorized parties. At the same time, IPFS provides distributed storage to ensure data redundancy and availability. This system will empower patients to securely store and manage their medical records while giving them full control over their data. It will also provide doctors and healthcare providers with a secure platform to access patient records and collaborate on patient care, thereby improving the quality of healthcare services [72-81].

Moreover, the system will be insurance fraud-proof, with all the services the user receives. This project aims to create an accessible healthcare record management system that will benefit all stakeholders, including patients and healthcare providers [82]. This project aims to develop a decentralized healthcare record management system that uses blockchain technology and the Inter Planetary File System (IPFS) to create a secure, transparent, and tamper-proof system [83]. By leveraging blockchain technology, the system ensures that patient data is tamper-proof, easily auditable, and transparent to all authorized parties. At the same time, IPFS provides distributed storage to ensure data redundancy and availability [84-89]. This system will empower patients to securely store and manage their medical records while giving them full control over their data [90]. It will also provide doctors and healthcare providers with a secure platform to access patient records and collaborate on patient care, thereby improving the quality of healthcare services [91-95]. Moreover, the system will be insurance fraud-proof, with all the services the user receives. This project aims to create an accessible healthcare record management system that will benefit all stakeholders, including patients, healthcare providers, and insurance companies [96].

Literature Survey

Shahnaz et al. [1] explored how blockchain technology can transform the healthcare sector's Electronic Health Record (EHR) systems by addressing data security, integrity, and management issues. Our proposed framework aims to implement blockchain technology for EHR and provide secure storage of electronic records with granular access rules. We also address scalability concerns by using off-chain storage. The framework offers a scalable, secure, and integral blockchain-based solution for EHR systems [97-101].

Oliveira et al. [2] present a blockchain-based approach to address the challenge of providing security, privacy, and availability to Electronic Medical Records (EMRs) in healthcare applications. Our patient-centric access control proposal involves keeping encrypted EMRs in the blockchain and allowing patients to share decryption keys only with trusted healthcare professionals. Blockchain enables secure interaction between untrusted nodes in a distributed peer-to-peer network without a reliable intermediary. We conducted simulations to investigate the scalability of our approach, and the results demonstrate linear scalability and low insertion time for new EMRs, even with an increase in the number of nodes in the network.

Azhagiri et al. [3] aim of the "Secured Electronic Health Record Management System" project is to safeguard the database containing patients' medical records. The current system for maintaining patient records is problematic, as they are often managed manually and not readily accessible to doctors, negatively impacting patient care quality, increased costs and treatment time. Additionally, criminals can easily hack and exploit the sensitive information contained in such records. This project seeks to address this issue by providing a highly secure database for confidential medical information. By doing so, patients can disclose their health issues without fear of losing their privacy. The project is cost-effective and efficient in reducing the time and resources required for such tasks, allowing healthcare providers to allocate their resources more effectively. The project also aims to protect healthcare records from hackers and other security threats, such as viruses and Trojan horses.

Kissi Mireku et al. [4] increased information and communication technology usage has led to a growth in data that organizations can access. Digitalizing health records has made sensitive health data more accessible, threatening patient privacy. Most research on big data privacy preservation overlooks patient input. This paper surveys patients and record officers to investigate their knowledge of healthcare data privacy and the relationship between privacy knowledge and big data protection. The study combines technology and social factors to mitigate the risk of healthcare record breaches, providing new directions for research in data privacy.

Traditional record keeping in its digital form has been improved by Nasaruddin et al. [5]. Most third world countries now employ EHRS because it is more efficient than their previous methods. The evolution of EHRS is also anticipated to yield a universally applicable health record system. This study suggests building a web-based EHRS with a stronger emphasis on building user confidence in the system via feedback. Specifically, the suggested prototype will integrate features including feedback and review pages, an allergy section, doctor background information, and record sections. Laravel, a PHP framework written in HTML and CSS, is used for this project, and My SQL serves as the database backend on the cloud. In addition, testing and validation of the entire system will be performed once development is complete to ensure that everything works as intended. The ultimate goal of this study is to design a feedback-based electronic health record system that can address the credibility crisis in healthcare record-keeping.

System Analysis

Currently, there exist multiple software and database solutions for storing medical information. However, a major issue with these systems is that they are centralized and controlled by a single authority [102-106]. Additionally, patient data is often distributed across various organizations, resulting in accessibility problems when needed. Patients must collect their medical information from multiple sources when seeking further treatment. Furthermore, the security of the data is not guaranteed, making it vulnerable to tampering and misuse by third parties. More often, it causes insurance fraud and other such heinous crimes [107-112]. Consequently, patients lack control over their data. Moreover, managing this information is complicated, as a significant portion is still paper-based [113].

Technique:

- ✓ Centralized access
- ✓ Stored in paper format
- ✓ Disadvantage:
- ✓ The data can be used without the patient's consent.
- ✓ Unavailability of data when in need
- ✓ The data is mutable

Proposed System Concept

The proposed system comprises two parts: the backend and the front end. The backend will be implemented using blockchain technology, specifically the contract-based language "Solidity," which is specific to the Ethereum blockchain [114-119]. The new system is built on the third generation of the decentralized web and will be hosted on the Ethereum blockchain [120]. On the other hand, the front end of the application will be used by the end users to interact with the application directly. It will be a browser-based application developed using web languages such as HTML, CSS, and JS. To better manage the application and for testing purposes, we have utilized the Angular framework. The front end will communicate with the blockchain using the web3.js library [121].

Technique:

- ✓ Storing data on IPFS
- ✓ Integrating the hash for the data on the blockchain
- ✓ Advantage:
- ✓ The data will be immutable.
- ✓ The control of medical data will transfer to the patient from the organization.

System Specification

An operating system (OS) is system software that manages computer hardware and software resources. It provides common services for computer programs.

Languages Used- Solidity

Solidity is a high-level programming language for writing smart contracts on the Ethereum blockchain. It is similar to JavaScript in terms of syntax and has been specifically designed for Ethereum's Virtual Machine (EVM). Solidity is statically typed, which means that data types must be explicitly defined, and it supports inheritance, libraries, and complex user-defined types. Smart contracts written in Solidity can be used to automate the execution of transactions on the Ethereum blockchain, enabling the creation of decentralized applications (DAPPS). Solidity includes features such as event logging, which allows developers to track the execution of contracts and identify errors, and modifiers, which can be used to add preconditions to function calls.

- Smart contract development: Solidity is primarily used to develop smart contracts on blockchain platforms like Ethereum.
- Decentralized application development: Solidity is used to develop decentralized applications (DAPPS) that run on the blockchain.
- Secure programming: Solidity has built-in security features designed to help developers write secure and reliable code for blockchain applications.
- Interoperability: Solidity is designed to be compatible with other programming languages and tools, making integrating blockchain applications with other systems easier.
- Token creation: Solidity is often used to create custom tokens on blockchain platforms, which can be used for various purposes, such as crowdfunding, loyalty programs, and more.
- Governance mechanisms: Solidity can create decentralized governance mechanisms for blockchain-based systems, enabling stakeholders to participate in decision-making processes securely and transparently.

Languages Used- Django Frameworks

Django is a high-level web framework for building web applications in Python. It follows the Model-View-Controller (MVC) architectural pattern, emphasizing reusable code, rapid development, and clean design. Some key features of Django include:

- Object-Relational Mapping (ORM): Django provides a powerful ORM that allows developers to map Python classes to database tables, making it easy to work with data in a database without writing complex SQL queries.
- Admin interface: Django comes with a built-in admin interface that allows developers to manage data and perform CRUD (Create, Read, Update, Delete) operations without writing any code.
- URL routing: Django's URL routing system is easy to use and allows developers to map URLs to views and templates.
- A template engine: Django provides a template engine that allows developers to create dynamic HTML pages using Python-like syntax.
- Security: Django has built-in security features, such as protection against SQL injection and cross-site scripting (XSS) attacks.
- Scalability: Django is designed to handle high-traffic websites and can scale horizontally by adding more servers.
- Third-party packages: Django has a large and active community that has created many third-

party packages, making adding features to your application easy.

- Django is a powerful and flexible web framework that allows developers to create complex web applications quickly and efficiently.

Languages Used - Angular JS Frameworks

AngularJS is a JavaScript framework used for building dynamic, single-page web applications. Google maintains it and offers a declarative way of building complex applications by using HTML as a template language and extending its syntax to create reusable components. AngularJS has several built-in features, such as data binding, dependency injection, and directives, making it easy to create interactive and responsive applications. It also provides powerful tools for testing, debugging, and optimizing the performance of applications. One of the key benefits of AngularJS is its ability to create reusable components that can be easily shared across multiple applications, allowing developers to build complex applications quickly and efficiently. Additionally, AngularJS provides strong community support and a rich ecosystem of libraries and extensions, making it a popular choice among developers. Overall, AngularJS is a robust and versatile framework that offers many benefits for building modern web applications.

- Simplify the development and testing of complex applications by providing a structured framework that promotes modularization and code reuse.
- Provide a declarative approach to building user interfaces, making it easier for developers to create interactive web applications.
- Enhance HTML by adding new features like data binding, directives, and filters to enable a richer and more dynamic user experience.
- Provide powerful tools for building scalable and maintainable applications, including dependency injection, services, and controllers.

Sequence Diagram

In our sequence diagram specifying processes operate with one another and in order. In our sequence diagram, we first proposed this in our component diagram propose data in this proposed method, and we are using the Hash- Solomon Code Algorithm to encrypt the data (fig.3).

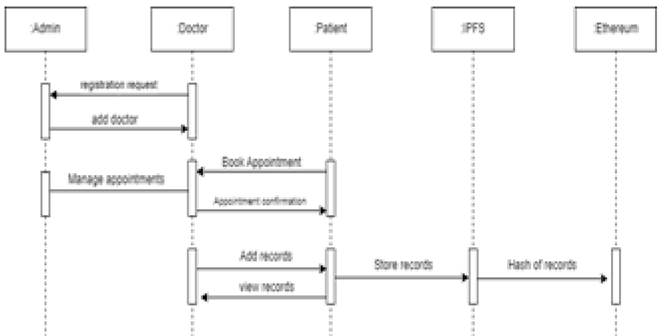

Figure 3: Sequence Diagram

Activity Diagram

With a broad definition that includes choice, iteration, and concurrency, activity diagrams depict workflows of sequential activities and actions. Business and operational workflows of system components can be mapped out in detail using activity diagrams in UML. The inner workings of a complicated process might be modelled using UML activity diagrams. UML activity diagrams are

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the object-oriented counterpart to structural development's flow charts and data flow diagrams (DFDs).

State Diagram

Sometimes this is the case, and sometimes this is a reasonable abstraction, but state diagrams always demand that the system described is constituted of a finite number of states. Varied state diagrams have different meanings and there are many of them. We use the Hash-Solomon Code Algorithm to encrypt the information in our state diagram, which was initially recommended for this purpose in our component diagram. Object-oriented modelling relies heavily on the use case diagram. It's used for both high-level conceptual modelling (thinking through the big picture of how the application works) and low-level modelling (turning those models into actual code). Our component diagram first suggests this approach, with the data encrypted with the Hash-Solomon Code Algorithm.

System Architecture Diagram

The systems architect established the system's basic structure. Each user type has a unique set of permissions and access levels to ensure they can only perform tasks they are authorized to do.

User Layer: A user uses a system and its resources. This proposed system's users could be patients, doctors, or administrative staff. Their main job would be to use the system to create, read, update, and delete medical records. They will access the system using a web browser with a graphical interface showing them the different functions they can use. This interface is like a menu that lets them choose what they want to do. Each user has different permissions based on their role. Behind the graphical interface is the blockchain layer, the core technology that powers the system.

Blockchain Layer: This layer allows users to interact with the DAPP that operates on the blockchain. This layer has three essential elements.

Blockchain Assets: These are information that users can send to others or store for future use. They are treated as assets by the blockchain network.

Governance Rules: The blockchain network follows specific consensus rules, ensuring the transactions are secure and trustworthy. Ethereum uses a Proof of Work (PoW) algorithm to maintain blockchain governance. Network: Ethereum uses a peer-to-peer network where all the nodes have equal status and rights. This is because the platform aims to be distributed, not centralized. In simpler terms, the blockchain layer is where the magic happens. It lets users interact with the system and update their medical records securely. It uses special rules and algorithms to ensure the information is protected and cannot be tampered with. The network comprises different nodes that work together rather than having one central control. This means the system is decentralized, making it more secure and trustworthy.

Results

The user will land on the page that shows him his medical records that have been added by various providers and were accepted by him. The landing page has been made to provide access for the Admin, the doctors, and the patients. The user can navigate to all functions from one singular page through meta mask authentication (fig.4).

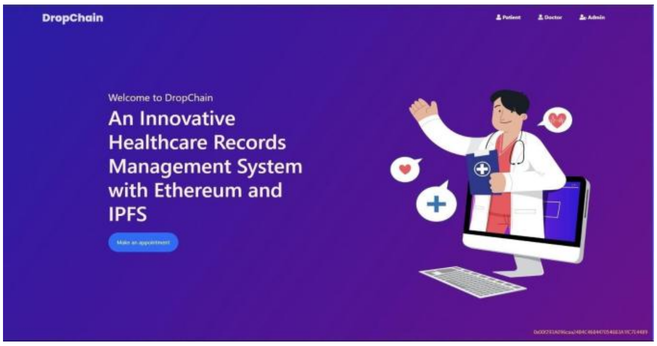

Figure 4: Landing Page

The patients can register from this page (fig.5).

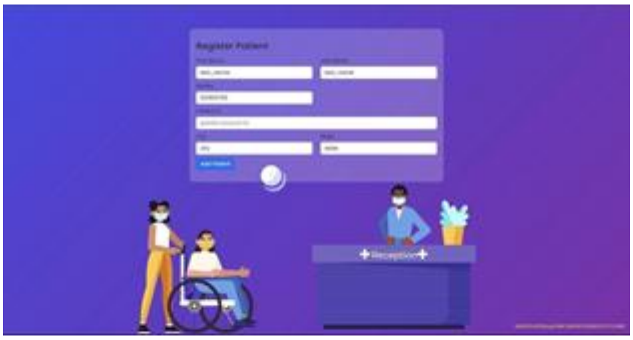

Figure 5: Patient Registration Page

For the back end, we use 'Ganache' as the local Ethereum test network to see the transactions, blocks, and more details. By default, Ganache provides us with 10 accounts with 100 eth each. As the transactions are approved, the blocks get created. We can also see which transactions were contact-creating and which were contract calls. The core purpose of testing is to find out unwanted errors and bugs. Testing is the methodology of figuring out or discovering every conceivable fault, defect, or weakness in a working project. It provides different methods to check the expected functionality of the components, sub-components, dependencies, integration mechanisms, security systems, etc. The basic form of testing that can be performed in a web application is unit testing and integration testing. Frontend Unit Testing. The front end is made using JavaScript and Angular. The unit testing for the logic of the front end is done using Jasmine. Jasmine is a JavaScript framework that follows BDD (behavior-driven development) procedure to ensure that all JavaScript statements, including functions, are properly unit tested. It provides spies and stubs for the service and other dependencies to properly test the components. In this project, all the components and services were unit tested with Jasmine. The back end is written using Solidity programming language. The Solidity codes can be managed with the help of the Truffle framework. Truffle tests the Solidity code with Solidity contracts, which are built on top of the Mocha framework. It uses assert statements from the Mocha framework. This kind of testing is done to ensure that the functions of the smart contract work as expected and that the values are modified according to the use case.

Conclusion And Future Enhancement

Our paper illustrates how blockchain technology can be utilized in healthcare to improve EHR management. Despite technological advancements in EHR systems, they face challenges like insurance fraud. Our proposed framework combines secure record storage with granular access rules to address these issues. We intend to implement an inventory management module within this framework. However, we must consider regulated policies and pricing of individual inventory elements to ensure effective management of each product. The system has only been tested using simulation software and test nodes provided by a third-party service. To fully understand the capabilities and limitations of the system, it needs to be tested on a real permissioned blockchain with a properly set up IPFS network. This will help evaluate how the system handles many users trying to store, access, and update data on the IPFS network and smart contracts simultaneously. The goal is to see how the system behaves with millions of users in real-world conditions. Our system implements blockchain only in the section for record management. However, to fully understand and utilize the power of blockchain and IPFS, a fully functional ERP system is needed to build, which will include inventory management to the billing system so that a fully immutable distributed application can be built. The ERP should be tested on a legitimate permissioned blockchain with a properly configured IPFS setup.

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