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Healthix: A DApp for Storing Healthcare Data

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Abstract - *Today's world includes heaps of healthcare data being generated every minute. It is impossible to know whether our data is safe on a centralized system. This is where blockchain comes into the picture. A Decentralized app to store all our healthcare data. It is safe, tamper-resistant, and most importantly, it is easily accessible to everyone. Healthix is going to make storing data easier in a user-friendly environment. Fragmented data across various systems will come together, finally bridging the gap between different hospitals. This unified system has the benefit of using the latest technology to deliver the best possible system.*

Key Words: health, healthcare, hospitals, doctors, patients, healthcare data, blockchain, decentralized, healthcare application, healthcare system, medical records.

1. INTRODUCTION

Healthcare systems that are currently used by hospitals are all different and mostly centralized. This leads to the fragmentation of data which may scatter a patient's data across different hospitals and clinics. The need for a unified system is paramount in such cases. With the use of a decentralized system, it is possible for us to create a tamper-resistant ledger of the data, mainly using blockchain. When patients switch doctors, it is impossible for them to keep track of all their past diagnoses. This makes it difficult for the doctors to provide the appropriate treatment. Healthix is going to help bridge the gap for patients making it easier for them to view their health-related data.

1.1 Aim

The main aim of the project is to develop an application that will address all the concerns that are pertaining to the fragmented distribution of healthcare information. This will help hospitals have better control over their health information. It will also help in sharing the data among various healthcare professionals. Due to the immutable nature of decentralized systems, it will also promote data security and assist with data protection. Some of the main objectives are:

1. Hospitals: Hospitals will have better access to their healthcare information along with better efficiency of handling sensitive information. This will provide a platform to exchange healthcare data in a safe and secure manner.

2. Doctors: When doctors have access to the patients' information in real-time, it gets easier for them to make the correct diagnosis. It helps to reduce their burden or order tests for something just to be sure of the treatment.

3. Patients: This platform aims to provide patients with access to view their medical history and current treatments. It will also include important information such as allergies to ensure proper diagnosis.

2. PROPOSED SOLUTION

The solution I would like to introduce involves decentralized data storage which makes use of distributed ledger technologies. This will help in storing the patient's data securely. I have chosen this technology to make sure that no unauthorized personnel will be able to have access to the data, which furthermore promotes data integrity to have a tamper-proof record of the healthcare information.

I propose to introduce a friendly user interface for patients to view their medical data at any time. Patients can scan through their entire medical history and any ongoing treatments if applicable. This information is shared with other healthcare providers as and when necessary. I have also included a few encryption mechanisms such as URL encoding to make sure that the data does not fall into the wrong hands.

It is also important to have security standards as healthcare data is sensitive. Which is why I have made the application as user-friendly as possible to make sure that these standards are upheld.

3. LITERATURE REVIEW

The initial evaluation of the literature [1] emphasizes a systematic mapping study procedure and uses the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) criteria. The blockchain healthcare literature does not address standardization, despite the fact that this method offers an organized analysis. Subsequent research

endeavours may focus on developing standardized approaches to assess blockchain-based healthcare applications, guaranteeing uniformity throughout various investigations and promoting a more thorough comprehension of the domain.

The other two literature reviews [2] [3] provide rich insights into potential applications and challenges but lack a specific emphasis on systematic review methodologies. The adoption of standardised frameworks such as PRISMA for more rigorous analysis could be a useful tool to further research. In order to contribute to a more coherent understanding of the role of blockchain in healthcare, it would be useful to combine research methods and improve comparability between studies.

The emergence of blockchain applications in the healthcare sector has been highlighted in the literature reviews [1][2][3], but there is a need for more emphasis on real-world implementation and industry adoption. The current situation of adoption and clinical outcomes in healthcare settings remains to be explored, although the reviews focus on use cases and projects. In future research, it is possible to bridge this gap by providing in depth case studies or empirical evidence of successful implementation of the Blockchain with a view to shedding light on problems encountered during integration and implications for healthcare practices.

Moreover, valuable insight could be gained from a deeper examination of factors that affect the industry's acceptance and resistance to decentralization in healthcare. It is important to understand the practical challenges of healthcare organizations and strategies for combating resistance so as to guide successful implementation.

The three literature reviews [1] [2] [3] recognize that blockchain technology in healthcare is still in its early stages of development. On the other hand, all acknowledge problems like resistance to change [2] and scalability issues [1]. To improve the scalability and usefulness of blockchain applications in healthcare, future research should explore the integration of cutting-edge technologies like edge computing, artificial intelligence, or the Internet of Things. This investigation may offer answers to current problems and open the door for more reliable and flexible blockchain technologies in healthcare environments.

Finally, the reviews briefly discuss the proposed workarounds, e.g. the encryption of health data "off-chain" [1], but further research is needed to assess the effectiveness of these solutions in real-world scenarios. Scalability solutions and practical strategies for overcoming resistance within the healthcare industry should be at the forefront of future investigations to ensure the successful integration of blockchain technology in healthcare settings.

4. SYSTEM DESIGN

The design of the system involves defining architectural elements, data flow and interaction in the system. A high-level overview of the system design can be found below:

4.1 Architecture

1. Decentralized Infrastructure: Utilized a blockchain-based decentralized ledger for secure and tamper-resistant storage of patient healthcare data. In order to ensure redundancy and availability, we use a distributed network of nodes.

2. Smart Contracts: Implemented smart contracts to automate and enforce rules related to data access, sharing, and consent management. Patients and healthcare providers can make arrangements for the efficient administration of their own affairs by means of smart contracts.

3. User Interfaces: Developed separate user interfaces for patients and healthcare providers, each tailored to their specific needs and roles. We are providing an easy and user friendly navigation interface with a view to improving the user experience.

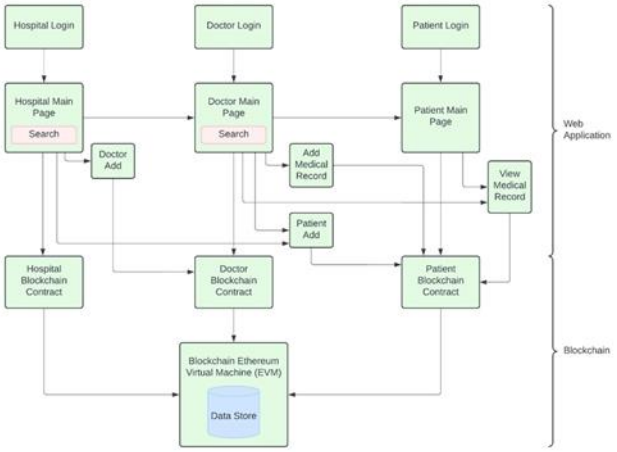

Fig -1: Architecture Diagram for the Application

4.2 Data Flow

1. Data Ingestion: Enabled the ingestion of safe and standardized data from a variety of healthcare sources, e.g. Electronic Health Records (EHRs), diagnostic systems or wearable devices.

2. Data Encryption and Tokenization: In order to ensure the confidentiality and integrity of patient data during transmission and storage, encryption and tokenization techniques have been applied to improve privacy, and tokenize sensitive data.

3. Consent Management: Implemented a consent management system that allows patients to specify who can access their data and for what purposes. For transparency, we integrate consent status into the blockchain.

4. Interoperability Layer: A layer of interoperability has been set up for the seamless exchange of data with current healthcare systems in order to guarantee compatibility and reduce integration problems.

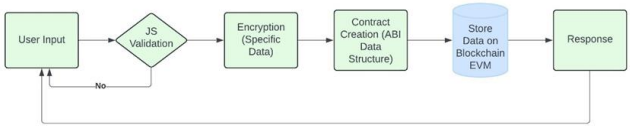

Fig -2: Generic Data Flow Diagram

4.3 Components

1. User Authentication and Authorization: Established a secure authentication mechanism for both patients and healthcare professionals. To control permissions according to user roles, we define a Role-Based Access Control.

2. Identity Management: To ensure the correct identification of users and to maintain the integrity of patients' identities, a strong identity management system has been set up.

3. Audit Trail: Established an audit trail system to record all interactions with patient data, providing a transparent and traceable history of data access.

4. APIs and Web Services: APIs and web services have been designed to ensure a seamless exchange of decentralised applications with outside healthcare systems.

5. Consensus Mechanism: The consensus mechanism was established for the validation and agreement of the state of the blockchain, to ensure data integrity and to avoid fraudulent activities within the decentralized network.

The aim of this system is to create a secure, interoperable, and user-friendly decentralized healthcare data management application that will empower patients, enhance the coordination of care and ensure health information's confidentiality and integrity.

5. SYSTEM IMPLEMENTATION

The User Interface of the Application is as follows:

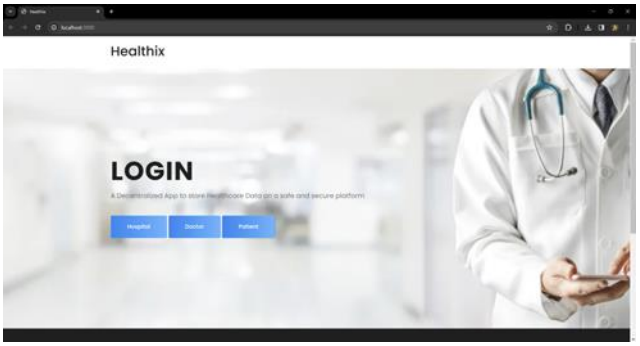

Fig -3: The main Hospital Landing Page

Upon entering the application URL, the user will be directed to the main page as depicted in Fig. 1. There are three levels of access available in the application. It is based on the role of the user. The first and foremost is the hospital access. The hospital will have access to details of the doctor as well as the patient's data.

Secondly, there is a doctor-level access in which the doctor may view their patients. They may add or view their medical records as well.

Finally, there is patient-level access in which patients will be able to view their medical records and their primary doctor. They will also be able to view the hospital that they are a part of.

As depicted in Fig. 2. The login page of the hospital includes a link for them to register themselves on the application if it is their first time. There is the option to reset their password and finally, the option to login.

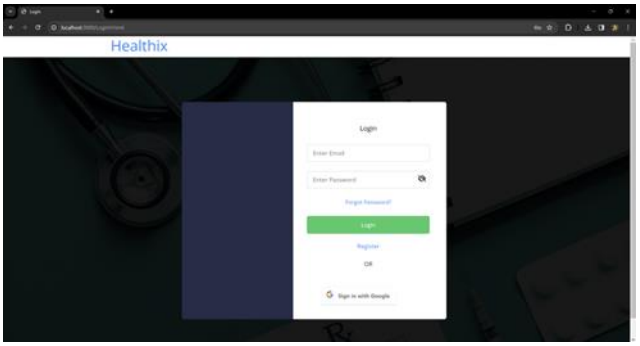

Fig -4: Hospital Login Page

The Hospital Registration page requires a few basic details of the hospital such as the company email, a new password, the hospital's name, address, specialty, and main phone number for patients to reach the hospital directly.

I have also given the option to go to the Login page for the hospital. This option is provided for users who may navigate to the registration page by mistake when they are meant to log in.

After a first-time registration, the hospital may now log in.

Fig -5: Hospital Home Page

Fig. 3. is the main page that the Hospital User will enter when their login is successful and their credentials are valid. The Login displays the name of the hospital in the top right corner. This page also can search for either Doctors or Patients that are pertaining to that hospital only. We have also included the Add Doctor button for the hospital to add a new doctor into the system as and when necessary. The user may log out at any time using the icon beside the hospital name. This is the same when the user login is a doctor or a patient as well.

Once the doctor with the letter 'S' is searched, all doctors containing that letter in the beginning are displayed. Now, the user may click on the Doctor's name for more information about the doctor or he/she may even click on Add Patient which will add a patient to that doctor.

If a patient search is done beginning with the letter 'J', all the patients containing that letter are displayed. The user has the option of clicking on a patient's name to get more details.

Fig -6: Doctor Details using Hospital Login

Fig. 4. displays the Doctor's Name, Specialty, Phone Number and Address. The option to add a new Patient is provided here also for the convenience of the user. The patient search provided here is limited to the patients of the doctor selected only. It will not display the patients of any other doctors. Only patients with the primary doctor as the selected doctor will be displayed in the search. If no Patients match the search criteria, the message "No records found" is displayed. Clicking on the home button takes us back to the hospital home page. Similarly, if there is no doctor found in the system, the message "No records found" is displayed.

The hospital User may also add a new doctor. All it requires is a few basic details such as the name of the Doctor, their specialization, phone number, address and email ID. Upon entering the details and clicking on add, a MetaMask prompt comes up. When the request is confirmed, a new Doctor is added to the system from the hospital's side. Now, with the Doctor registration URL obtained, the doctor must register themselves and create their account to access information about their patients. The URL leads to a page that automatically displays the Hospital Name and the user email that was registered at the hospital. These fields are unchangeable for security reasons as a doctor may claim to be from a hospital he/she may not be a part of. There may also be errors when the doctor enters their email ID, in which case the email ID with the hospital and the email ID with the doctor will not match which may lead to problems. In case the doctor realizes that he has already registered with the hospital, the option of directly logging in from this page is also provided for ease and convenience of the user. Entering the necessary details and clicking on register results in a MetaMask pop-up which upon confirmation will successfully register the new Doctor. The doctor may now login to their account by using the Login hyperlink. This page for Doctor Login may also be accessed from the main page by clicking on the "Doctor" button. As the doctor is new, he will not have any patients yet. A new patient may be added at any point.

Fig -7: A Doctor Adding a New Patient

The doctor's name is already pre-populated in Fig. 5. This may not be changed for security reasons. It is done so that a doctor does not add patients for other doctors. This may otherwise be a potential security breach.

After entering the required details of the patient such as Name, Date of Birth, Gender, Height, Weight, Address, Phone

Number and email ID we click on Add which gives a MetaMask prompt. Upon confirming the transaction, the system generates a Patient Registration URL for the patient to have their own account and view their information. This URL may be copied and used at the Patient's convenience.

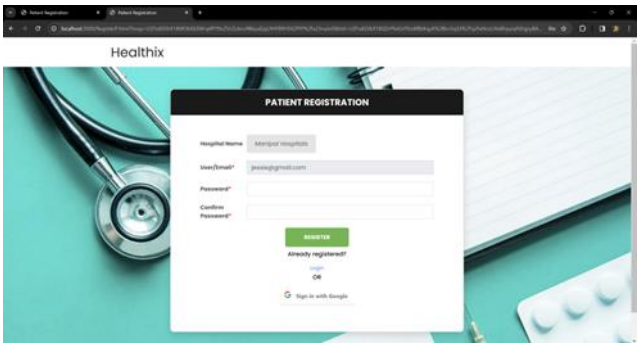

Fig -8: Patient Registration

The Patient Registration URL leads to the page shown in Fig. 6. The patient can now be registered with a new password for the patient's account. The Hospital Name and User Email cannot be changed as it may lead to complications and with wrong intent by malicious users. The patient may enter their desired password and register themselves on the system. Upon successful registration, they may login using the hyperlink provided. The patient may login natively through the application or they may sign in with Google also. In case the patient forgets their password, the option to change the password is also available for ease of use. In case the user is not registered yet, they may do so using the Register hyperlink provided.

Once the Patient has successfully logged in, all their details are displayed. This includes the Primary Doctor they are affiliated with along with their specialty. The patient details displayed are his/her name, date of birth, gender, height, weight, address, phone number, and email. The patient has the option to either log out using the icon beside the hospital name or they may view their medical records also.

The Patient's Medical records page is where they can check their prescription added by the doctor. If nothing has been uploaded, the prescription fields remain empty. This page displays the doctor, the name of the patient, their date of birth, and gender.

In the patient's search results, upon clicking on a particular patient, we get the patient's details with their Primary Doctor. The hospital user will have the option of editing the information of the patient in case there is an error. If the patient lost their Registration URL, it will be displayed here only if they have not registered yet. The hospital may also view the primary doctor of the patient from here. Finally, the hospital may view the existing medical records or add new records. After clicking on the edit button for patient details, and the necessary details are changed, the hospital user may click on save. This will lead to another MetaMask pop-up which prompts to confirm the changes. After clicking on confirm, the changes are made successfully.

In the View/Add Medical Records page, it is possible to navigate to view the doctor details in further depth by clicking on View Doctor. We can also have a look at the patient details by clicking on View Patient. We can also go back to the Hospital Home page by simply clicking on Home. Finally, we may also log out using the icon beside the hospital name. The date is auto-populated based on the present date.

Adding insurance details requires entering the insurance details such as Policy Number, Insurer, Policy Type and Policy Limit. After entering these details and clicking on save, a MetaMask pop-up comes up. Upon approving the MetaMask transaction, the Insurance Details that are now visible as soon as the transaction is confirmed. It is also possible to edit the Insurance Details if necessary or if there is a change in the future.

For Medical Synopsis, after entering all the required fields such as Illness, diagnosis, prescription, treatment, and allergies, the information is saved with confirming the transaction with the help of MetaMask.

In the case of the user forgetting their password, they may recover it using the Forgot Password option. Upon entering a valid email address, it is possible for the user to reset their password. Subsequently, they may log in using the newly reset password.

It is also possible for us to log in using Google. This was included by keeping in mind that not every user will have the patience to create a new account in the native application for every website they encounter. This is purely for the convenience of the users.

This Healthcare system mainly uses 3 different Contracts which are as follows:

1. hospital.sol – This contract is deployed to register new hospitals on the blockchain as a part of the healthcare system.

2. doctor.sol – This contract is used to register new doctors onto the blockchain as a part of the healthcare system.

3. patient.sol – This contract is used to add new patients into the system for easy information access by the hospital management.

These contracts interact with the blockchain with the help of MetaMask to confirm transactions in order to add data into the system which is immutable and safe from any tampering by a malicious user. This system enables a smooth

administration with a simple User Interface for the convenience of the hospital management.

The Application uses lite-server to deploy the front end of the Healthix system.

6. SYSTEM TESTING AND RESULT ANALYSIS

6.1 Testing Procedures

1. Unit Testing: In order to ensure the correct functioning of each module of the decentralised application and to meet its specified requirements, it carried out individual component tests. We tested each contract module separately, particularly for the hospital, doctor, and patient contracts. They were deployed separately and tested for every use case scenario. After we removed the bugs for the first module, we then moved on to the next one and so on. We finally got to a stage where all the bugs inside each module had been removed.

2. Integration Testing: In order to check the interaction and data flow of components, a set of application modules has been integrated that ensures uniform integration and compatibility with each component. We made sure that all the modules worked well together in the front end. Especially since the modules required that hospitals may add doctors and patients, and doctors may add patients. We needed to get the modules working seamlessly as the application must blend depending on the type of user wanting to log in.

3. Functional Testing: By testing user interaction, data storage, access control and data sharing features, the function of a decentralised application has been assessed. We enabled a few edit features and implemented their functionality. We added the option of signing in with Google as well for ease and convenience for the users. We wanted to make sure that the system is easy to operate without the user encountering any bugs.

4. Security Testing: To identify vulnerabilities and weaknesses in the security measures of the system, e.g. encryption, authentication or access controls, penetration tests have been carried out. We made sure to include URL encoding so as to not expose sensitive information on the web. We made sure that all the information passing through is encrypted to the required standard.

6.2 Results Analysis

1. Unit Testing Results: The functions and correctness of each component, including data storage, access control mechanisms as well as user interfaces, have been verified in the unit tests. Confidence was obtained that the system would work according to what was planned.

2. Integration Testing Results: In order to ensure a smooth flow of data throughout the system without any bottlenecks or inconsistencies, integration testing has validated a smooth interaction between different modules. We realized that the interactions must have a smooth flow with easy-to-use components.

3. Functional Testing Results: The functional tests have shown that the decentralised application can allow patients to view their medical information, securely exchange data with healthcare providers and gain access to comprehensive medical records, all of which meet its operational requirements.

4. Security Testing Results: Security testing has identified and addressed weaknesses, enhanced the overall security posture of the system, and ensured that healthcare data are protected from unauthorised access or breaches. These were mainly achieved by pre-populating the existing information, hence, reducing room for error and malicious users to harm the system.

The application is a robust and efficient solution for the management of health data through system testing and results analysis. In order to ensure that the application meets its objectives of empowering hospitals, doctors, and patients, it is important for us to enhance coordination of care and protect patient privacy. The comprehensive testing procedures have validated the application's functionality, security, and performance.

7. CONCLUSIONS

The creation and implementation of Healthix, a decentralized application for the storage of healthcare data have provided an interesting solution to the problems caused by the fragmentation of health information. In order to facilitate the coordination of care and to improve data security and privacy, the proposed decentralized system, based on blockchain technology and interoperability standards, aims to empower hospitals, doctors, and patients. The decentralized application aims at contributing to a more efficient and collaborative healthcare ecosystem, by providing doctors with control of health data and facilitating the seamless exchange of information between medical professionals.

The decentralized nature of the application ensures tamper-resistant storage, transparent audit trails, and adherence to privacy regulations. In order to increase trust between users, address ethics concerns, and comply with healthcare standards, consent management and interoperability features will be introduced.

The technical, regulatory, and user adoption challenges were carefully taken into account in the successful implementation. The need for improved healthcare has been made possible by constant monitoring, feedback mechanisms, and updating.

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We extend our sincere gratitude to everyone who assisted us in completing "Healthix: A DApp to Store Healthcare Data."

First and foremost, we would like to sincerely thank our respected leader, Prof. Amaresh A. M., for his unwavering guidance, support, and wisdom during this endeavor. This project has succeeded because of his leadership, which has been essential in shaping our concepts and perfecting our execution.

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We would like to sincerely thank our peers, families, and friends for their unwavering understanding, encouragement, and moral support along this journey. Their encouragement and belief in our abilities have given us bravery and motivation.

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