Securing Electronic Healthcare Records in Web Applications

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Abstract: *In such an unfortunate situation of a medical emergency, a lot of people tend to lose their lives which can be a result of misplaced/delayed paperwork. Thus it is essential to have the patient's medical record history before going into major surgery and it is often unavailable at the required time due to the chain of communication between different hospitals. As a possible solution to this problem we propose a central chain of all medical records of a patients in an electronic format. The electronic health records (EHRs) are patient-centered, real-time records that make information available to authorized users and help doctors diagnose cases more quickly, reduce medical errors, and deliver safer care. EHRs improve the communication gap and make the process of getting medical attention quicker. Our methodology includes an easy to use 2 module approach (doctor portal and patient portal) with multiple sub modules all linked to a common database. We create a secure and centralized database for EHRs with an easy approach and manageable methodology. Security is important in our use case and we thus include- Secure authentication (and verification of doctor's ID while creating a new account) , two factor authentication and OTP verification while accessing patient reports. We are using block chain for safely storing multiple patient records for maintaining a safe storage of multiple records. The doctors will be able to access the patients with few clicks and verification and understand the patient background. This will majorly help in maintaining records, accessing prescription and getting an overview of the patient's medical history while saving a lot of manual paper work.*

Keywords: *Electronic Health Records, Blockchain, 2 factor authentication, Database Management*

I. INTRODUCTION

Electronic health records will increase the efficiency, security and accessibility of healthcare records. Many healthcare organizations will have potential benefits by saving paperwork, knowing more about their patients and ease of accessing medical records. In situations of emergencies, easy access to health care records can result in the matter of life and death.

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Our goal is to create a solution for a very secure and safe electronic health record with easy data sharing and a centralized database of all patients and doctors. Existing methods have shown a lot of approaches relating to blockchain however, it being a technology which is yet to be widely adopted, proposes technological barriers to its implementation. Various other limitations were seen in other methods relating vendor adoption and infrastructure costs.

To tackle these limitation we propose a simple implementation of a decentralized network which can be tested on a national level where authentication can be done through national identification protocols such as social security numbers or Aadhar Cards in case of India and access is given prior verification using extremely user friendly double verification methods like OTP verification via mail or phone number.

The most important aspect of Electronic health records is data security. We are thus providing an end to end solution with different layers of security. First layer of security includes 2 factor authentication for the patient as well as the doctor.

Additionally the doctor has to get his doctor id approved. For the second layer of security, the doctor cannot directly access any patient's medical record. We are implementing an OTP verification where the doctor has to request for the patient data and the patient has to confirm the request via OTP verification. This ensures the patient data can be accessed by approved users only.

We are using blockchain for storing and securing patient medical records to maintain a safe storage of records. A Blockchain is a distributed ledger protocol that was originally associated with the world's first crypto currency, Bitcoin. Blockchain provides a possible future solution for data sharing and unlike other traditional approaches, Blockchain eliminates the need for any centralized control and instead, all the transactions (records) are decentralized and verified by the Blockchain participants themselves in the distributed ledger, thereby bringing in a sense of trust in the data management.

II. RELATED WORK

Ra et al. developed healthcare applications with a general - purpose framework on cloud platforms using Node.js. This study primarily focuses on developing an efficient and unique software design, APIs and rules to create a fast, expandable and well-structured cloud based healthcare application – Health Node. The application developed in this paper is made by using two software design processes.

To couple and decouple the modules the top - down approach is used and the developers uses the divide and conquer approach to divide the tasks into unique and simpler task oriented modules. The divide and conquer technique helped to reduce redundancy by dividing the modules and sub modules into groups of reusable functions. A hierarchy structure connects the modules that allow data flow. This approach enabled the development of multiple modules concurrently. The results showed that the platform enables system understanding and promotes software evolution.Their method enables addition of new functionalities without applying any major updates to the existing architecture. [1]

In Thakur et al.'s paper, a strong and secure watermarking approach is dis- cussed which uses transform domain techniques. The work presents how the fusion of DWT, DCT, and SVD can be used to implement co-joint cryptographic and watermarking- based hybrid techniques. The study primarily focuses on embedding medical records into the main medical image for the purpose of authentication, annotation, identification and saving the basic requirements for health applications. The Chaos- based encryption algorithm on the watermarked image using a two-dimensional logistics map is also studied for improving confidentiality. The results provide evidence that the employed technique is sound and sufficiently secure from various attacks without any major disruption between image and watermarked cover. Also, their method was found to be better than existing under studies that use state-of-the-art watermarking- based hybrid techniques. [2]

A hospital's rapid and correct dissemination of statistics to their patients may be very crucial. The researchers designed and evolved a machine to cope with several concerns diagnosed inside the hospital official files, and solve the dissemination of facts of sufferers' tests outcomes from Laboratory and Radiology Departments. In the study, online clinic report management gadget, had been made of different file interfaces for various stakeholders that now not most effective addressed the present day problems however additionally target to minimize tour and cost costs to the sufferers, and permit a better overall physician/patient interaction and reaction to ailments, leading to higher nice healthcare whilst still complying to authorities requirements and requirements. The overall performance of the system offers a protracted-time period impact and direct effect on the medical institution and its sufferers and opens extra possibilities in thinking about the sources available. This study focused on the business process improvement of a health facility via imposing powerful records. [3]

Studies show that in recent times digital medical records are highly prone to data breaches, interoperability and information asymmetry which leads to inefficient and poor access to one's medical records. To address this issue, A. Mukherjee et al. proposes the permission blockchain implementation of Electronic Health Record (EHR). The system architecture provides a safe, cost- efficient and decentralized, platform to store medical records. The paper has focused on improving the ascendancy of block- chain used in electronic health record system to securely obtain a patient's health record. The architecture is evaluated to analyse certain issues involved with the block-chain which includes cyber security, latency, scalability, and feasibility. A comparative analysis of four blockchain frameworks - Ethereum on chain/off chain with Inter-Planetary File System (IPFS), Hyper-ledger with edge nodes are with IPFS gives an overview of how these mechanisms affect the latency and scalability of blockchain. This paper focuses on the importance to improvise the existing EHR system and also addresses the issues involved in the implementation of EHR using blockchain framework. [4]

An ordinary way of life of the twenty first Century is a very hurried one. Human's warfare to discover time for themselves and take care of their fashionable fitness. Neglecting health problems, suspending treatments, and self- diagnosis are common amongst human beings nowadays, and their unwell results are not well known. Human beings administer medicines to deal with their fitness problems on their very own, without consulting a physician. In an effort to combat the problem, and concept become proposed to expand a medical database for patients that can be accessed by a health practitioner from everywhere around the arena. The database contains statistics regarding the drug(s) prescribed to the affected person. It additionally consists of information about touchy pills and specific hypersensitive reactions associated with the patient, in addition to the file of the prescription history of the patient. Customized Radio Frequency identity (RFID) cards ensure the security of the system as it consists of distinctive IDs for unique customers that could most effective be altered by the worried doctor the use of the medical database, for this reason authenticating the medical statistics of the patient. The product may be used everywhere in the world helping more than 70% of the population. [5]

G.S. Reen et al. make use of permissioned ethereum block-chain which enables the hospitals and patients internationally to talk with every other. Their methodology uses an aggregate of symmetric and uneven key cryptography to ensure the safety and safety of the garage and get admission to of the facts. This approach uses IPFS (inter planetary file machine) to save records that may be dispensed and it additionally ensures immutability of patient data. This version maintains the information of illnesses without compromising the private-ness of the affected person. The interface of this system is created using React js and the back-end is created using java-script. Despite the fact that this structure is able to keeping affected person confidentiality but it fails to save you the health center from taking a image or copying the contents of the document whilst importing it or while gaining access to it. [6]

Garets et al. argue how EHR is more than a dependent of semantics. Digital scientific facts and digital fitness records aren't the equal aspect. The acronyms represent totally unique standards, so insisting that they're used correctly is more than quibbling over words. Except you are fairly well versed in advanced clinical facts technologies, you are probable careworn, because the press, vendors, authorities officers and enterprise experts every so often unintentionally use the terms incorrectly.

Most care shipping corporation selection makers, clinicians, legislators, bureaucrats and participants of the press aren't specialists in healthcare IT.

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If they may be observant, however, and examine the endless press releases that try and pass for information, they recognize that the trendy rage is local healthcare statistics organizations purporting to percentage precise facts from affected person information. [7]

Prableen Kaur et al. study the significance of big statistics and its function in healthcare programs has been observed. It mentions that the use of huge records architecture and techniques are helping in dealing with the expeditious records growth in the healthcare industry. An experimental take a look at is accomplished to observe the function of large facts in the healthcare industry. It turned into seen that wonderful effort has been made the usage of huge information in the healthcare region. It turned into discovered that the use of system studying and big statistics analytics in analysis has not given extensive weight-age to the privacy and safety of the statistics. A layout of clever, relaxed healthcare information structures the usage of system getting to know and superior protection mechanisms has been proposed to address the huge facts of healthcare. The use of most efficient garage and facts safety layers to maintain safety and private-ness. The hybrid four- layer healthcare version appears to be a way greater effective massive information gadget. [8]

III.   PROPOSED METHODOLOGY

We propose to have a central chain of all the medical history of our registered users. This will include test reports, diagnosis reports as well as prescriptions. This works like a digital locker that shall be only be accessed by the patient and patient authorized doctors. The only function available with the doctor would be adding and viewing reports that too with the patient's authority. Modification/Deletion won't be available to either party to decrease the chance of altered reports.

In Figure 1 the centralized chain will be secured using smart contracts and for authentication and authorization we use OTP services. In Figure 2 we also propose a detailed database structure that can search user query on multiple parameters and with ease link both clients i.e. Patients and Doctors.
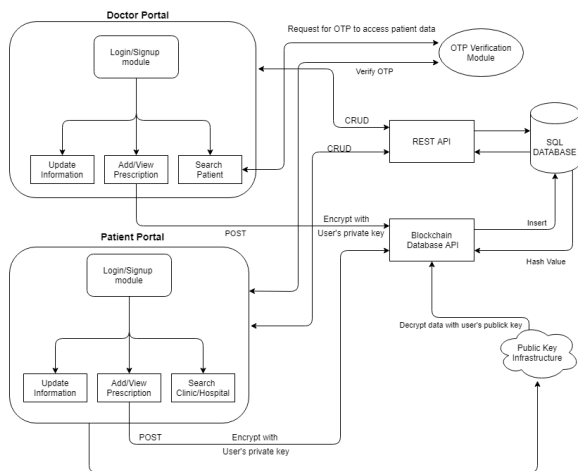

Figure 1

A.   Patient Section

•   Registration Portal- The patient has to create his account and submit a few important details (like his blood group, create password, date of birth etc.). This is one time

registration and after the patient has created his account that he will be logged in. Once the account is created the user can log in with his mobile number/email and password.

•   Give access to the doctor via OTP- Once the doctor wants to access the patient's record, he cannot do so unless the patient approves it. This ensures privacy and authorization. The doctor will have to send a request to the patient, whose records he wants to access, and the patient will receive an OTP.

•   Add medical records- If the patient is new, he/she will have to add all his past medical history. The patient can dynamically add his records in which he has to enter the name of doctor, medicines prescribed, reason of illness, and name of illness and upload the prescription document.

•   Update medical records- If the patient has to make changes to his records, he can do so using the update rest api and make changes to his records that he/she had once created. While making the changes the doctor who was consulted then will have to verify and approve the changes.

•   Search doctors and hospitals- Since all doctors, clinics and hospitals are registered on our database, the patient/user can search up for hospitals near to him and apply filters. He can give access to his location and get nearby hospitals. If the patient is having a cold and cough, he can apply filters for the type of illness and can see nearby doctors with relevant details. The patient can manually search exactly the doctor or hospital he wants to visit. The patient can get the location this way and visit the doctor.

•   Digital Prescription/QR code- Once the patient gets the checkup done, the doctor will have to upload the patient prescription digitally. This means the doctor will not have to do any paperwork and has to digitally type the prescription and upload it to the patient account. He can do so by scanning a QR code on a patient account. This way the data remains secure and saves a lot of paperwork. The doctors submit this and this data gets pushed to the patient database and the patient can view it whenever he wants on any device by logging in.

B.   Doctor's Section

•   Registration Portal- The Doctor has to create his account and submit a few important details (like his Doctor Degree and qualifications, unique doctor id, create password, date of birth etc.).

This is one time registration and after the Doctor has created his account he will be logged in. Once the account is created the Doctor can log in with his mobile number/email and password. This form is longer and takes more details about the doctor.

•   Authorization via Medical License- The doctor has to get his license verified as a next step if he is registering for the first time. After this verification only he can move ahead and access his portal. This is done only once when a new account is created. This ensures authorization.

•   All patient records- Now the doctor has a list of all patients with patient name and image. He can add search filters or directly search for the names. The doctor doesn't have complete access to patient data at this stage.

• Access Patient data via OTP verification- To get the complete access and view data, the doctor has to send requests to the patient via OTP. The patient will get the OTP and then the doctor will use that OTP and can then move to the next page which has complete user details and past records.

• Prescribe digital prescriptions- After the checkup the doctor goes to the next page to add a prescription. This is digitally entered with dosage, name of meds, quantity to be taken etc. After all his prescription is given, he has to put his digital signature and then submit the data to the backend database.

• Access past records- The doctor can access the patients past data and his previous illness, doctors etc. and analyze the data. This way he would get a better idea about the patient.
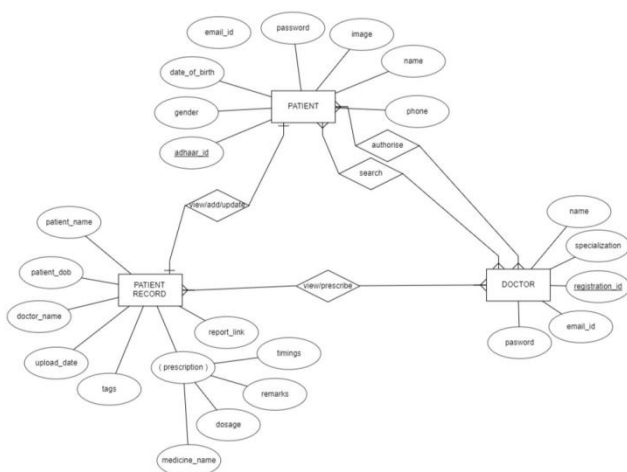
Figure 2

IV. IMPLEMENTATION

The proposed methodology is implemented into a web app using various back-end technologies which include deploying the actual smart contracts where the user data is stored, the Application Programming Interfaces (API) linking the blockchain to the user end, and the database management for user authentication and authorization. We also create a user friendly web front-end. This allows us to test the web app with real users which help us determining the server load and refine the user experience of the entire application we used API calls using Axis for linking the back-end to the front end. After this was completed we added some front end logic and added authentication for doctors as well as users. We used firestore for image uploading and OTP verification using firebase.

We used API calls using Axis for linking the back-end to the front end. After this was completed we added some front-end logic and added authentication for doctors as well as users. We used firebase for image uploading and OTP verification. For decentralized health record storage, we use the capability of the Ethereum blockchain [9] for storing medical data and sharing it for doctors to view at any time. The primary composition of the website has three parts:

· **Authentication**, which is done by OTP generation and encrypted password.
· **Data Storage**, where the medical data is stored, and

the storage address is cached in the blockchain for retrieval.
· **Retrieval**, where any validated user can obtain the stored data on the system and use it.

We study the system made using Node.js to see how to collect medical data, receive the address and compose functions to record that address into and recover it from a blockchain using the Solidity programming language. Smart contracts hold an essential part of this study as they are utilized for performing elementary operations such as granting access to the users on the website and executing CRUD operations on the records of the subject.

The pseudo-code illustrates the functioning of the smart contract for saving patient records. This algorithm possesses five functions that happen to create users, add, view, update and delete patient records. The first function defined is used to create users and assign roles of either doctor or patient, and it includes variables for the new account. The second function is to add patient records which are to be completed by the doctor after they have been designated the compliance relation. This function also notes if the task is being performed by the authenticated public address of a doctor's account only. The msg. sender used by Ethereum is utilized for identifying the address of the user for applying validity check. The doctor can then, append the records of the patient and after doing so would end the function by saving that record. The third function is to view patient records that employ the patient's unique id such as Aadhar to be stated as a variable to look up the records and after doing so reflect in the application.

The function also incorporates the validation for the user's indicated roles. The fourth function is to update patient records and is ratified for executing any alterations in the protected records of the patient. The subsequent function is to delete patient records which takes the unique id of the patient as input and after certifying that the doctor is the one operating this function it would eliminate those records. Role-based admittance would ensure security is practiced and only the validated users of the system would have admittance to these functions. After the functions are implemented, the system saves the data on the Ethereum Blockchain that would execute transactions. Once the action is confirmed, the system receives the communication of success from the blockchain layer that users can observe on the web application. [9]

Algorithm 1 Calculate Smart Contract to Store Patient Records (Create Operationss)

Create User:
Function Define Doctor (New UserDetails):
add UserDetails in database
end Function
Function Define Patient (New UserDetails)
add UserDetails in database
end Function

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Algorithm 2 Calculate Smart Contract to Store Patient Records (Add Operations)

Add Data:
Function Add PatientRecord (variables containing data to be added) :
if (*initiatedBy == doctor*) **then**
    add data to the patient record database
else
    Abort Session
end if
end Function

Algorithm 3 Calculate Smart Contract to Store Patient Records (Retrieve Operations)

Retrieve Data:
Function GetPatientRecord (AadharId)
if *initiatedBy == doctor patient* **then**
    if (*AadharId*) *== true* **then**
        retrieve data from patient (AadharId)
        return patientRecord
    else
        Abort Session
    end if
end if
end Function

Algorithm 4 Calculate Smart Contract to Store Patient Records (Update Operations)

Update Data:
Function UpdatePatientRecord (variables containing data to be updated)
if *initiatedBy == doctor* **then**
 if *id == AadharId* **then**
        update data in patient record database
        return success
else
        return fail
end if
else
    Abort Session
end if
end Function

Algorithm 5 Calculate Smart Contract to Store Patient Records (Delete Operations)

Delete Data:
Function DeletePatientRecord (AadharId)
if *initiatedBy == doctor* **then**
if *id == AadharId* **then**
        delete patient's record
        return success
    else
        return fail

    end if
 else
    Abort Session
end if
end Function

V.   SOFTWARE REQUIREMENTS

On the front end side, this project is built using React, which relies on a component-based architecture. Ant Design is a react UI library that helps in building these components. On the back-end side, this project uses Node.js and Express framework for rapid performance. We have used SQL database to store data i.e. patient records, hospital data, and medical history. This data is retrieved and transferred through the usage of smart contracts. We have additionally used firebase for file uploading and OTP Verification. For authentication we have used JSON Web Token (JWT) and BcryptJS.

A.   Backend Technologies

• Node.js - It is a platform developed on Chrome's JavaScript runtime to build rapid and scalable network applications. Node.js uses an event-driven, non-blocking I/O model that makes it efficacious and lightweight, ideal for comprehensive data, real-time applications that deploy across distributed devices.

• Express.js - Express is a lightweight and adaptable Node.js web application framework that gives a solid set of features for web applications. Express gives a meager layer of fundamental web application features, without clouding Node.js features.

B.   Frontend Technologies

• HTML/CSS - Hypertext Markup Language (HTML) and Cascading Style Sheets(CSS) are the core technologies used for building frontend web applications. HTML acts as the structure of the web page while the CSS is the styling and the visual layout.

• Javascript - Javascript is a high level programming language that runs on the client side. Its implementation as a client side script allows user to interact with the web pages and make it dynamic. It acts as a brain to the front end web applications.

• React - React.js is a front end javascript library made by facebook. It is used for building fast and dynamic user interfaces. It uses components where elements of the user interface are broken into small chunks of code and can be reused.

• Ant Design - Ant Design or AntD is a React UI library which has high and rich quality components for building supreme and interactive user interfaces for the front end.

C.   Databases

• SQL Database - It is a relational database where we can store data with a fixed schema. SQL offers both data definition and manipulation syntax which makes it easy to add, update and delete data using simple queries.

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• Firebase - Firebase is a real-time database that is hosted on the cloud. JSON format is used for data storage and is synchronized in real-time queries of every connected client.

VI.   RESULT AND DISCUSSION

After completing our prototype of the proposed model, we deployed the website on heroku's platform and had users test it. Our survey covered a lot of metrics which proved that the proposed solution would bring ease in their lives and would make them switch to online tracking of records instead of manual labor. Our testing audience contained 500 different users from various backgrounds, age groups and occupations. In **Figure 3**, we analyze how users find it better to switch from a manual recording system to an online database. In **Figure 4**, we see if users find it more secured to use a blockchain based online database for their health records. In **Figure 5**, we get an overview of how users find it more accessible than other generic methods. [10] [11]
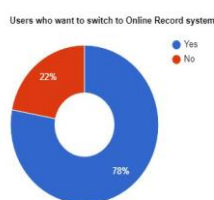
Fig. 3. Users who want to switch to online record system
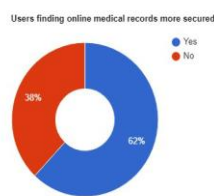
Fig. 4. Users finding online medical records more secured
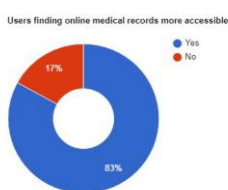
Fig. 5. Users finding online medical records more accessible

VII.   CONCLUSION

In this paper, we have primarily discussed the full stack web architecture for the implementation of Secured storage of medical records which will be useful in the healthcare system. By this approach we are not only securing the patient medical records but also making the records easily accessible, helping doctors understand the patient more closely in detail by analyzing his/her past records, patients can skip going through piles of paperwork before seeking treatment and hospitals won't have to maintain their individual patient records. This could revolutionize hospital management by providing digital access and paperless

documentation. In case a patient is unconscious and won't be able to give access to records, secondary access could be provided by listed emergency contacts.

Our main aim is to make the process of making the medical history of a person easily available so that their life can be saved in time. At the same time, we want a secure place where the record can be saved securely without leaking any private information of the patient. This system makes the work easy for both doctor and patient.

FUTURE SCOPE

For the future, we plan to incorporate a couple of features. Firstly we plan to implement the payment module in our application so the patient can give the payment for consultation directly on the platform after booking his/her slot. This way we want to make the process completely hassle-free (i.e. cashless and paperless). Secondly, we plan to make navigation easier and faster by incorporating a chatbot to assist the user as we are targeting a wide age group of users. The chatbot can guide the user on how to add his/her prescription, book a slot and guide the user regarding what type of doctor he/she should consult based on the symptoms and his/her record history.

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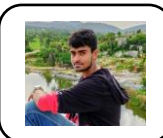
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