JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Transforming Healthcare: Electronic Health Records Implementation using Blockchain

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Abstract : The advent of emerging and innovative technologies, such as Blockchain has garnered massive attention from academia and subsequently, a multitude of sectors have begun to jump onto the trend. Blockchain's decentralized structure, security, and privacy can be applied to a vast number of sectors, especially in healthcare. On the other hand, EHR systems frequently experience issues with data administration, security, and integrity. We set the foundation in this study for a potential blockchain-based EHR implementation in the Indian healthcare setting. Our proposed approach aims to enable blockchain technology to be used with EHRs. Moreover, its goal is to safeguard the protection of record storage through implementing access controls, for users within the framework. This approach offers the benefits of a protected and cohesive blockchain driven resolution, for the electronic health records system

IndexTerms **- Blockchain, health records ,scalable, electronic health records, decentralization, Decentralized application. EHR, DApp, Proof-of-Work.**

I. Introduction

Technology has a profound and understated impact on our day-to-day lives. The current technological landscape, which is ever-changing, is altering our perceptions and practices in every area of our lives. The healthcare industry is one which is undergoing radical changes with the assistance of technology. The current medical systems in place have major drawbacks. The paper-based medical record system is clumsy, unsafe, and vulnerable to damage. Data redundancy and duplication are other problems plaguing the system because many healthcare facilities keep multiple copies of each patient's medical record. These obvious issues have the potential to cause grave mistakes, financial loss, and even fatalities. For this EHR concept was presented.

II. Introduction to EHR

The term Electronic Health Record (EHR) is commonly used to describe a patient’s history in form. In terms EHR serves as a version of a patient’s health records offering secure and instant access to authorized individuals. This digital record promotes connections and cooperation across the healthcare sector leading to progress in sharing knowledge and information. When properly executed, it possesses the capacity to evolve into an all-encompassing unified system, thereby offering a multitude of benefits. This technology provides an impermeable and secure method for storing healthcare data, including medical records. The electronic health record (EHR) systems were conceptualized with the main objective of bringing about a paradigm shift in the healthcare industry by eliminating the need for laborious paper records and reinstating them with a streamlined and paper-free electronic system [3]. EHRs play a key role in the ongoing advancement of healthcare. By lowering the frequency of errors in records, they have increased the clarity and accuracy of health information. EHRs can also be helpful for obtaining health information at any time and from any location, which lowers the likelihood of repeat testing, treatment delays, and educating patients so they can make wiser judgments. EHRs have improved the relationship between physicians and patients by enabling instantaneous communication whenever necessary. They have improved care coordination and raised patient participation. Due to the data's easy accessibility, healthcare professionals were also able to act quickly and decisively, giving patients better care as soon as feasible. However, as information technology has developed, these electronic data are now more susceptible to intrusions from unapproved users. Using sophisticated software or hacking tools, these malevolent individuals obtain access to patient personal data and alter records in order to damage patients or utilize the data for their own gain. It is therefore imperative to safely preserve patient health records and sensitive information and stop hackers from accessing them.[11]

III. Challenges in EHR

Electronic health record (EHR) systems are developed with the f objective of furnishing permanent, secure, and cross-platform medical records. But scaling EHR in India has been a challenge dude to technological limitations. Most of the health records are still managed in report formats and scaling EHR in India is posing to be a challenge. Electronic health records (EHRs) are widely implemented, but the Finnish nurses experiences with EHRs uncovered concerns related to the dependability and efficiency of the systems [3]. Although there is a growing corpus of data on the benefits of various EHR capabilities, there are possible disadvantages of this technology. These include monetary challenges, workflow modifications, temporary productivity drops brought on by the adoption of EHRs, privacy and security concerns, and a host of unanticipated effects. Hospitals and doctors are prevented from adopting and implementing an EHR due to financial barriers such adoption and implementation costs, ongoing maintenance costs, declining profitability associated to momentary loss of productivity, and revenue declines. Another disadvantage of an EHR is the disturbance of provider and medical staff workflows, which results in brief productivity reductions. There will be a decline in performance while end users adjust to the new system, which could lead to monetary losses. [10] Electronic health record (EHR) systems have some further restraints that are linked to them. They are:

3.1. INTEROPERABILITY

The seamless sharing of health information between health systems is a key functionality of EHR systems. This process, called Health information exchange (HIE), mainly focuses on how information flows and it can used for activities that improve patient care as a whole. Truly achieving interoperability, however, remains a challenge due to multiple factors. Standardization is one of the glaring challenges, as the widespread use of EHR systems in healthcare organizations has led to a lack of terminology and data formats. Technical incompatibility: EHR systems may differ in functional and technical aspects, in addition to data formats. Even if the data follows a standard format, this can possibly hinder the smooth exchange of data. The capabilities of electronic health record (EHR) systems can be maximized with the help of healthcare industry, by effectively removing interoperability barriers to improve provider communication and collaboration.

3.2 INFORMATION ASYMMETRY

A popular concept which delineates unbalanced transfer of information from providers to patients is called Information Asymmetry. It is a critical aspect of healthcare systems today. Electronic health records (EHR) and health care as a whole contain traces of the source of this asymmetry, as patient records are primarily under the control of hospitals and physicians. Attempting to access personal health information records is a daunting challenge with many procedures for patients trying to access those records. The implementation of centralized control, where all information is stored exclusively in health facilities, limits the ability of patients to access and understand their medical history.

3.3. DATA BREACHES

The frequency of data breaches in the healthcare sector requires an advanced platform. Researchers have identified an emerging pattern in this field, supported by extensive research in this particular field [5]–[7]. In addition, a sizable number of electronic health records (EHR) systems are inadequately built to meet the demands and expectations of patients, leading to inefficiencies and inadequate customization of said systems [12]. In order to address these obstacles, it is crucial to consider a solution that can support the shift towards a patient focused healthcare system, like Blockchain technology. This platform guarantees security, transparency, and accuracy of patient’s medical information.

IV. EHR IN INDIA

Whilst EHRs are well implemented and functional around the world, the Indian Subcontinent paints a different picture. India is an upcoming giant in the technological sector as well as medical sector due to its immense population strength.[12] Digitizing healthcare is one of the government's key goals to provide equal opportunity for medical treatment at affordable costs. The Government of India is also eager to use domestically generated data to enable affordable drug discovery and health research.[12] India has recognized the superior advantages of the EHR system in terms of revamped patient coordination, surge in patient engagement, refined medical research and reduced healthcare costs. The Indian Government has also made active efforts to implement EHR by implanting various schemes for the general public. They launched the Universal Health Coverage scheme, known as the Ayushman Bharat Yojana in 2018.[8] This national insurance scheme in the health sector has two main schemes- • The Pradhan Mantri Jan Arogya Yojana (PM-JAY), which arranges to supply a Rs 5,00,000 cover to the lower 40% of the Indian populace for secondary and tertiary care. • The inception of around 1,50,000 health and wellness centers across the Indian subcontinent for primary care, with a focus on underdeveloped regions. As a result, there are government mandates to take enforce the necessary measures to ensure that beneficiary health records are collected on a timely basis, these records are digitized and EHR systems are implemented.[12] In 2019, National Digital Health Blueprint, to create pan-India EHR was proposed. The 'National Health Stack', an ingenious digital structure, has been suggested by the National Institution for Transforming India (NITI Aayog), with the objective of creating a virtual health record for all inhabitants of India by 2022.[8] Hence, we can observe that multiple notable attempts have been initiated for the medical wellbeing of India in a virtualized format, but no concrete system is in place as of now. In the successive sections, we discuss a proposed system to overcome the challenges faced by the currently present EHR systems in India.

V. EHR USING BLOCKCHAIN

Blockchain technology presents a potentially robust solution for handling and storing sensitive patient health data in the current advanced and developing healthcare landscape. The operation of Blockchain is similar to a distributed ledger system, in which numerous interconnected blocks store data that is constantly and permanently connected. In the digital era, although we easily store different data on our smartphones, organizing medical records is still difficult because data is spread out among different healthcare providers. Blockchain technology provides a hopeful answer to simplify Electronic Health Records (EHRs) by guaranteeing the integrity, confidentiality, and compatibility of data. Utilizing blockchain and smart contracts allows patients to manage their healthcare data and safely share it with approved parties. Blockchain technology has been developed to solve the restrictions of existing EHR platforms, allowing for smooth sharing of data and control over access. Nevertheless, hurdles like scalability, standardizing data, high operational expenses, and integrating with older systems need to be addressed in order for broad acceptance. In spite of these difficulties, it is undeniable that blockchain has the potential to transform healthcare data management by guaranteeing security, interoperability, and patient-focus.[9]
Following blockchain characteristics should be understood to better understand the proposed system:

5.1 Distributed Ledger

Transactions are added to a distributed system over the network, which creates system recovery by eliminating a single point of failure or centralized entity. All transactions in a blockchain network are recorded, while the shared distributed ledger cannot be altered or tampered with. [13]

5.2 Smart contracts

Smart contracts are a major implementation of blockchain technology and allow a user or agent to create a legal document through the use of the blockchain system. Smart contracts are autonomous agents that are stored in blockchain technology that encodes and transforms transactions into a contract or legal documents to provide legal services.

5.3 Authentication

It is accomplished by requiring a specific private key linked to a public key to initiate the creation, modification or viewing of information stored in the blockchain.

5.4 Consensus Mechanism

The consensus of a blockchain is defined from its creation by its founders. Transactions are only updated when all verified users on the network accept the condition of the transaction. This depends on the type of blockchain used, public, private or consortium. [4]

VI. Proposed methodology

The related work area includes the research conducted in the field of healthcare whose execution is brought forth through the utilization of Blockchain. As previously stated, they offered specific remedies for addressing the prevailing issues in blockchain technology. The studies mostly focused on resolving the issues of scalability and data sharing using blockchain technology. The authors suggest the utilization of a foundational database that addresses specific ONC needs and other established standards as a potential option. Our suggested approach addresses the issue of scalability by utilizing the offchain scaling mechanism of IPFS, which sets it apart from other alternatives. Furthermore, Ethereum serves as the primary platform for the comprehensive execution of the suggested framework. The preceding portions of this paper have also addressed Ethereum and its associated dependencies.

5.1 System Design

Decentralized EHR System Design-An effective framework requires a well-defined system design that translates theory into a functional architecture. The following section elaborates the proposed system's building blocks, including its architecture, modules, and overall structure. A framework aims to create a secure, tamper-proof, and decentralized electronic health record (EHR) system that is resistant to disruptions. This is the aim of the system, and this is done with the help of Blockchain. Core Components and User Access Control-As illustrated in Fig. 2, the proposed system comprises three key components working together to ensure its efficient and continual operation. These components will be elaborated on in detail later. However, it is important to acknowledge the various user groups this framework caters to, including patients, physicians, and administrative staff. Each user group will have designated access levels within the system, reflecting their specific roles and responsibilities.

5.1.1 User Interface

The term "user" refers to an individual who proficiently utilizes a system and its associated resources. A user has several roles and functions in the system, which allows them to be identified.

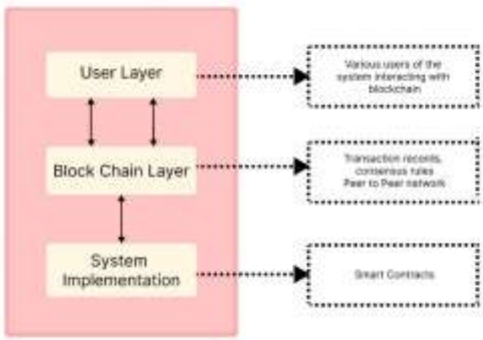

Figure 1 : system design of proposed framework

Doctors, physicians, and patients are just some of the possible end users of this system. The primary responsibility of these users would be to interact with the system and perform basic operations such as creating, reading, and updating patient data. The system's functionalities can be accessed by users via a browser—specifically, a DApp browser. The graphical user interface (GUI) of the decentralized application (DApp), which is modified and edited by us, is hosted on this browser. The graphical user interface (GUI) includes all the features that can be accessed by a particular user. In accordance with their assigned function, the user may utilize this graphical user interface (GUI) to interact with the blockchain layer of the system.

5.1.2 Layer of Blockchain

Assigning the code or mechanism that facilitates user interaction with the blockchain-based decentralized application (DApp), the blockchain layer represents the subsequent stratum of the system. Any digital object that is a component of the Ethereum network constitutes a blockchain asset. As part of transactions, third-party users have the ability to alter the state of data or documents stored on the blockchain. These transactions are considered assets by the Ethereum blockchain because they involve information that users may exchange or store for future use. Consensus standards are frequently employed by blockchain technology to process and carry out transactions. The Ethereum blockchain sees these transactions as assets as they include data that users may share or store for later. Blockchain technology frequently uses consensus standards to compute and execute transactions. The crux of blockchain technology is maintaining security and integrity, especially when it comes to patient's medical records, and this is done via consensus algorithms. The Ethereum network uses Proof of Work (PoW) consensus mechanism to provide reliable blockchain governance. The consent of each and every reliable node in the blockchain network makes this feasible. The Ethereum blockchain is powered by a decentralized network. When every node in the network is not under the control of a master node, every node in this network talks to every other node as peers. The idea behind adopting this network was to provide a decentralized platform instead of a centralized one. With this technology, using a network where all nodes are linked and have the same rights would have been the ideal course of action.

5.1.3 Implementation of the system

As mentioned before, the system was built with Ethereum and its dependencies. In order to have a thorough grasp of the system's many responsibilities, this section goes deeper into how it was implemented.

5.1.4 Smart Contracts

Smart contracts are essential for decentralized apps (DApps) because they make basic operations easier. The following contracts are included in the framework:

- Medical records
- Duties

These contracts are used to provide users with decentralized application access and allow them to perform CRUD actions on patient records. The Patient Records smart contract exists just to make it easier to put the features of the proposed framework into action. This library allows for the building of customized smart contracts by containing several smart contracts that carry out various functions. The goal of using this library was to make use of its features, particularly the tested and communityreviewed code. A part of the Asset library, which is a subset of the OpenZeppelin library, is the Rolessmart contract. There are several more contracts that are included in the asset collection that help with creating access rules. Still, the main consideration in selecting this specific smart contract was the roles library's more comprehensive role-defining mechanism.

VII. Performance and implementation

6.1 Evaluation of performance

To assess the performance of our proposed framework in real world scenarios, we conducted performance evaluations using Apache JMeter software.

6.2 Average time of execution

There is a positive association between the number of transactions added and the execution time. The expected execution times for the Assigning Roles, Adding Patient Records, and Viewing Patient Records functions in the case of a single user using the system are 18.30 seconds, 1 minute and 48 seconds, and 50 seconds, respectively. If one hundred users are using the system at once, the time will have increased.

6.3 Average latency

Latency, also known as response time, refers to the time it takes for a system to respond to a request. In simpler terms, it is the delay between sending a request and receiving a response. JMeter, a popular performance testing tool, was employed to evaluate the average latency of the proposed framework. This evaluation involved simulating a specific number of users and measuring the framework's response time under that load. JMeter measures latency in milliseconds(ms). Fig. 2 visually represents the system's throughput (requests processed per unit time) alongside its average response delay. The experiment observed a maximum latency of 14 milliseconds within the framework.

6.4 Transaction Size and cost evaluation

Another key performance metric considered is transaction size and cost. Transaction size refers to the amount of data involved in a single interaction between the user and the system. However, before calculating the transaction size, it is crucial to verify the payload, which is the actual data being transmitted within the transaction. A detailed assessment of transaction size and cost is presented in the following section.

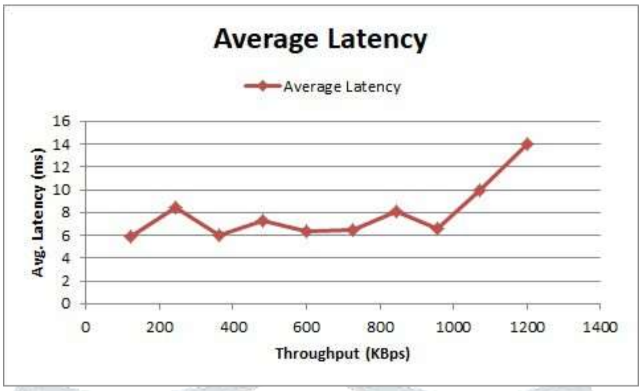

Figure 2. average latency of the proposed framework.

Fig. 3 illustrates the workflow of the system. The user and the administrator make up the two main components of the system. This proposed model caters to two primary user types: patients and doctors. How these users are assigned tasks is decided by the hospital's administrative staff member, the system administrator. Our two most critical users—the patient and the doctor—have different rights that must be granted by the system administrator.

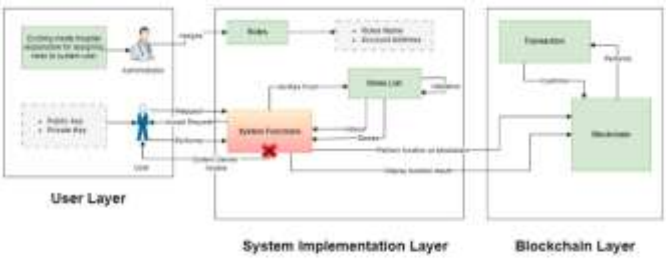

Figure 3. user interaction with Dapp.

After roles are assigned, users will request to carry out certain actions on the proposed system. Upon successful validation, the user will be granted access to the designated functions as the system authenticates their role name and account address in the Roles List. Once done , it will store the data it has gathered on the Ethereum Blockchain, enabling transactions incorporating that data. The DApp browser allows users to examine the whole proposed architecture, and the blockchain layer sends a success message to the system when a transaction is completed.

- A patient's medical records would be created by adding records to the DApp. Included are the IPFS hash, blood group, ID, name, and associated fields. Together with the help of IPFS hash, the medical records are preserved. This includes the uploaded file containing the patient's test results or other relevant medical data.
- The medical records of a patient must be changed as part of the updating procedure. The IPFS hash cannot be changed; only the patient's basic data is. The IPFS hash is intended to be non-updatable in order to safeguard the security of documents.
- The "View records" function gives the user access to patient's medical records. The see records function is used by both patients and physicians. The technology allows the patient to examine their medical records, confirming that they are permitted to view just their own information. To accomplish this goal, the system makes use of the patient's public account address to ensure that the patient only sees relevant medical information.

The system ensures secure data control through user roles and permissions. Physicians, acting as authorized users, can add new patient data or modify existing records. Patients retain the right to access their own medical history stored on the blockchain. However, to maintain data integrity and prevent accidental modifications, patients cannot directly edit their health information. The ability to permanently remove records is also restricted, ensuring a complete and immutable medical history on the blockchain. Specific user roles will be assigned access rights for different system transactions, such as adding data, modifying records, or viewing patient information. This granular control ensures only authorized users can perform these actions.

Figure 4: admin side dashboard

The patient can schedule an appointment via the distributed app's home page upon accessing it. If the patient is registered on the blockchain network, they may select the doctor they want to see and schedule an appointment here; if not, they can do so after successfully registering as a patient. Patients can schedule a visit with any of the following physicians. Once the user's identity has been verified, they may examine their past medical records and scheduled appointments.

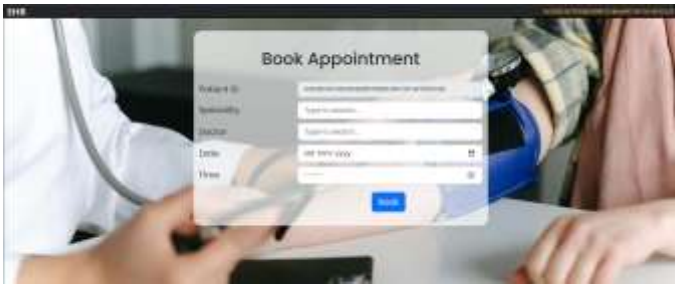

Figure 5 : book appointment page

Once the user's identity has been verified, they may examine their past medical records and scheduled appointments.

Figure 6: upcoming appointments

The admin may review all scheduled appointments and patients who have already been consulted by the doctor who has registered on the blockchain network. After speaking with the patient, the physician can update the medical record with the patient's information, prescriptions, doses, suggested testing, and any related reports.

Figure 7 : patient consultation page

During the subsequent visit, the physician can access the patient's past records by looking up the patient's public identification number. The doctor can view, update, or delete the medical record if it is no longer needed. Any patient can view patient information.

Figure 8 : patient records page

VIII. Conclusion

The transformative potential of electronic health record (EHR) blockchain technology in the healthcare industry has been explored in this study. A unique solution to the obstacles to current EHR systems is offered by Blockchain, ensuring patient, transparent and secure data management. The architecture proposed by us uses two main pillars to address these challenges: Fine-grained access control: Equipped with a comprehensive authorization system, access to and modification of patient data is restricted to authorized users only. Role-based access reduces the potential for unauthorized access and data asymmetry, giving patients more autonomy and control over their health information. Secure and Immutable Record Storage: Patient data has to be immutable and immutable and the use of blockchain technology ensures the same. A permanent and audible ledger created from medical data stored on the blockchain promotes transparency and trust in the healthcare ecosystem. The framework integrates the off-chain storage mechanism of IPFS to address data storage scaling challenges. By using this hybrid approach, efficient data management is maintained along with the basic security benefits of blockchain technology. In summary, blockchain technology offers a compelling solution for future electronic health record (EHR) systems. By prioritizing patient empowerment, access control and information security, blockchain technology can revolutionize health information management and improve patient care.

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