

A Survey: Blockchain-based Electronic Health Record System

Gaurang Awatade¹, Gaurav Kasure², Suyog Padole³, Yash Choudhary⁴, Shital Sungare⁵, Anil Kumar Gupta⁶

^{1,2,3,4}Student, Department of Computer Engineering, Dr. D. Y. Patil Institute of Technology, Pune, India

⁵Professor, Department of Computer Engineering, Dr. D. Y. Patil Institute of Technology, Pune, India

⁶Senior IEEE Member

Abstract - The emergence of new technologies brings in lots of features, which can increase the efficiency of existing systems. One such system which needs improvement is the management of health record. The existing Electronic Health Record (EHR) system faces some challenges regarding data security, interoperability, management, etc. Therefore, hospitals must use more efficient and secure technology to implement Electronic Health Record system. This can be achieved by Blockchain technology. Blockchain Technology is a very interesting research area, and now it is at its peak in revolutionizing the way in which we used to handle the data regarding healthcare while storing it and finally during its utilization. Various blockchain-based solutions have been proposed for the same. The motive of this literature is to put forward a comprehensive survey of these solutions.

Key Words: Electronic Health Record, Blockchain, Decentralized, Interoperability, Immutability, Scalability, Hyperledger Fabric.

1. INTRODUCTION

The earlier hand-written mechanism, i.e. paper-based system, was used to store the patient's health record [1]. This system was not efficient as it had some issues, out of which one was; this system was a time-consuming process as each record was required to be stored manually. Other issues include: if any patient visited multiple hospitals, then multiple records would have to be maintained for the same patient, which leads to data redundancy, this system was not tamper-proof, which means it wasn't secured system if any record got misplaced, then its recovery was a difficult task. All these problems state that this was insecure and inefficient. Therefore, the need for a digital system arises to overcome such challenges. Hence, the Electronic Health Record System was introduced to store the medical records of patients.

Many hospitals are using this Electronic Health Record system due to its benefits such as security and high efficiency than the paper-based system. It efficiently stores the health records like lab reports, MRI reports, etc. Though this system is more efficient than earlier, one issue that still occurs in this system is data redundancy. It also has some other issues related to Interoperability, Information Asymmetry, Security, etc. [1] that are explained below:

- **Interoperability:** Exchange of data between different organizations or hospital must be effective. Records that are stored must be exchangeable so that they can be used further. As there is not a universally defined standard various hospitals may have systems with different technical and functional capabilities, which may lead to a lack of interoperability [2].
- **Information Asymmetry:** It refers to one party having better access to the system than other parties [1]. As this is a centralized system, if patients want to access their records, they would have to follow a long process which is time-consuming because only the hospitals or organizations have access to the patient's record.
- **Security:** One of the significant drawbacks of an EHR system is data security. Hospital database systems are often the target of hackers. Hence the security of EHR is compromised.

Due to these challenges, the need for a more secured and efficient health record system arises. One such technology which is secured and can overcome these challenges is Blockchain.

1.1 Overview of Blockchain:

Blockchain is a decentralized system created by Satoshi Nakamoto [3] as the technology behind Bitcoin, a popular cryptocurrency. Soon this backend technology became popular and began to spread its branches in various fields, starting from digital currency to finance, supply chain management, healthcare, market monitoring etc. Blockchain technology contains a chain of blocks that are consecutively connected. In each of these blocks, a specific number of transactions are stored. This chain can continuously grow in one direction as more transactions are added. This chain is stored in a decentralized manner, meaning each node in the blockchain network holds these records. The blockchain contains transactions in groups that are hashed together. Thus any change in any of the transactions will change the hash code generated by each of the consecutive blocks. Therefore hackers have to change the whole series of blocks in the chain. This is not possible, given the number of blocks in the chain is massive. Hence security is provided, and they are managed by a peer-to-peer network. Blockchain has three types: private, permissionless and hybrid. Cryptocurrencies like Bitcoin and Ethereum are

permissionless(public) blockchains. A private blockchain is not accessible to all, and an individual/organization owns it. Hybrid(consortium) blockchain has permissioned, and public properties as public members have only read access, and it is partially decentralized in nature.

1.2 Features of Blockchain:

In short, blockchain is a database system that provides security, immutability and privacy of data stored in it.

- 1) **Immutability:** This property indicates, records can only be retrieved and appended in the system. It cannot be changed in any case. This property makes it ideal for maintaining the digital ledger of cryptocurrencies.
- 2) **Security:** Data can be appended to the blockchain only by authorized people who are nodes in the chain. Transactions are first validated by a number of nodes in the blockchain network by a consensus algorithm; only then it is appended in the chain. Consensus algorithms like Proof of Work(PoW) and Proof of Stake(PoS) are commonly used to authenticate transactions in the block to avoid illegitimate alteration of data by unauthorized personnel.
- 3) **Privacy:** This property can be seen in a private blockchain, unlike a public blockchain, where anybody can join the network and read, write within the blockchain. A private blockchain is

owned by an organization. It uses access control to restrict people from entering the network. Hyper ledger fabrics is an example of private blockchain.

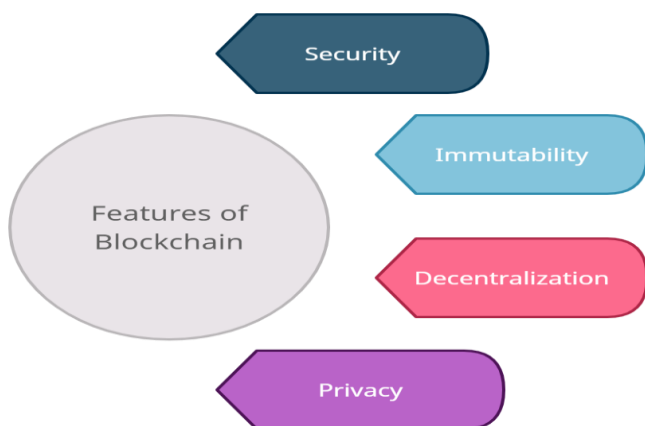


Fig -1: Features of Blockchain.

- 4) **Decentralized:** It is not owned by a single authority; instead, it is handled by a group of nodes, each of which possesses a replica of the ledger.

2. Related Work:

The challenges related to security, redundancy, interoperability, etc., faced by existing EHR systems leads to the need for blockchain-based EHR, which is one solution to overcome current challenges. In [1], the author proposes a blockchain-based Electronic Health Record system using Ethereum blockchain where users can add, update and delete records based on their roles. For example, patients can only view their records, and the hospital staff can add and update the records. When a user performs any transaction, it is first sent to other nodes for validation which is done using a consensus algorithm, and then the block gets added.

Paper [4] introduces blockchain, describes its features and discusses its applications in the healthcare sector. This paper discusses that how the blockchain technology can be used in the storage of health records. It gives an overview of how blockchain can be implemented in the healthcare sector.

Medrec [5] is a system that fully decentralizes access rights using the Ethereum blockchain in which patients have control over the distribution of the records. Medrec uses Smart contracts to connect patients and providers with the addresses of already stored medical records. Three smart contracts, namely Registrar Contract (RC), Patient-Provider relationship contract (PPR) and Summary contract (SC), are used. RC is used to map identification strings of a participant to their Ethereum address identity. It identifies directly based on an already existing form of ID. PPR contract is issued between provider and patient where one node stores medical records for the other. SC is used as a breadcrumb trail by participants to find their record history. It contains a list of references to PPR contracts. SC is also used for backup and restore as it is stored in a distributed network.

Medrec stores metadata in an encoded format that contains access rights, ownership of the record being requested. Medrec used data to incentivize the mining of the blockchain in its initial version. Medical researchers used to perform complex hashing problems to gain access to medical data. In the current design, providers maintain the blockchain. The consensus algorithm of "proof of authority" is used by providers to append blocks.

Medblock [6] is a decentralized medical data-sharing platform that makes sharing of EMRs among hospitals easy and efficient. Patients are unable to produce their medical history whenever they visit a hospital as their medical records are stored in some other hospitals' database. Storing complete details in EMR on a blockchain is not feasible, so only summaries are stored in the blockchain, and the rest is stored in the hospitals' database. This system uses the

SHA256 hashing algorithm, and the hash is stored in the form of Merkel Tree, similar to that of Bitcoin ledger.

Medrec and Medblock both use a breadcrumb trail mechanism for quicker retrieval of information. Users can search their records in the blockchain by comparing the encrypted keywords, but to achieve this, users have to search the entire ledger making it a time-consuming process. A user directory for retrieval is maintained. Breadcrumbs stores the hash value of the

block of records department wise in a tabular fashion. Whenever a patient needs to access their past records, he can find the desired block quickly from the crumbs. This method will increase efficiency at the cost of storing and maintaining additional data compared to the standard way of data retrieval. The traditional way of retrieving data is effective when the number of users is less, but as this number of users grows, the breadcrumb method proves to be efficient.

Generally, patients visit hospitals at a specified time of the day. This puts a tremendous load on the system to upload records on the chain in real-time. So, data is uploaded asynchronously to avoid congestion and smoothen the system load.

In [7], the author proposed a scalable blockchain-based framework using the Hadoop database. Along with the decentralization feature of blockchain, the scalability provided by the Hadoop database is used to overcome the scalability issue of blockchain. To improve the scalability, blocks were stored on the Hadoop database, and SHA3-256

was used for hashing. Java was the programming language that was used in this architecture.

In [8], the author proposed an efficient solution to the blockchain for clinical records. The fundamental goal of this study was to establish an architecture that falls in with the Office of National Coordinator (ONC) for Health Information Technology requirements. This study recognized the hurdles that this technology faces, including issues regarding privacy, security of blockchain, issues regarding a considerable volume of data being transmitted on this platform, and lastly, there is no universal standard enforced for data being exchanged on the blockchain. This study also incorporates proof of a decentralized application based on the design of the ONC requirements.

In [9], the author proposed an EHR system using Hyperledger Fabric. As the medical data is too big to store in the Ledger, therefore it is stored in EHR, and only the address is stored in the Ledger. The Ledger also holds the hash values of data.

One commonly used term in using blockchain as a backend technology is Smart Contract. Smart Contracts are like an agreement between two parties written in the form of code without the involvement of any third party. These are self-executing contracts. One such implementation of deploying smart contracts through a

Paper	Technology/Functions used	Key features
[1]	Ethereum Blockchain, Smart Contract	Provides role-based access
[5]	Ethereum's smart contracts	Allows storing new medical records as well as integrate with existing records from the database of hospitals.
[6]	Blockchain, the local database of hospitals and smart contracts	Provides a decentralized system for hospitals to store and retrieve a summary of patients' medical data on the blockchain.
[7]	Blockchain, Hadoop Database	Hadoop Database improves Scalability
[8]	Blockchain, Smart contracts, decentralized app and Digital Health Identity	Provides a decentralized system for efficiently sharing clinical records on the blockchain
[9]	Blockchain, Hyperledger Fabric	Storing hash values of data on Ledger and actual data in EHR
[10]	Blockchain and Smart contracts deployed using dApps.	Able to store medical data of patient, eg. Reports in textual format.
[11]	Blockchain and Smart contracts.	Makes it easy to share medical data of patients in the form of questionnaires.

Table -1: Summary table representing the technologies used with its features.

decentralized application (dApp) is [10]. It is a similar system of managing and storing health records on the blockchain network, but it is limited to storing data that is in textual format and does not support storing X-rays, MRI

scans, CT scans. It is able to store only reports of such scans in the form of text.

In [11], the author designed medical questionnaire storage and management system which uses blockchain. This system

intends to share the health records of patients with the patients' consent. Blockchain ensures that the data remains confidential and untampered. Patients can also make use of this system for their personal health records. This system also includes a validator that checks whether the patient's data is in the correct format. After validation, the patient's personal information is stored locally on the hospital's database, and the result of the questionnaire is stored on the blockchain.

3. CONCLUSION

This survey tries to explain the issues in current and past systems for managing Health Records and how they can be overcome using a secured technology like Blockchain. Also, to overcome the issue of scalability in blockchain, the use of a Hadoop database can be one solution. The application of Blockchain is not limited to EHR but has many applications in the Healthcare sector like secure Drug Supply Chain Management (SCM), etc. Also, other confidential records can be stored using blockchain. In future implementations, permission-based access to third-party can be added to the EHR system. On the basis of this survey, it can be concluded that blockchain technology has the ability to be implemented in the healthcare sector for application such as Electronic Health Record (EHR) system using Hyperledger, Smart Contract, Hadoop Database, etc. thereby increasing the efficiency.

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