



## A Scoping review of Data Storage and Interoperability in Blockchain based Electronic Health Record's (EHR)

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### Abstract

*In the current era of technological smart world blockchain technology has brought revolution in Electronic Health Record's (EHR's) data exchange, which is important within medical research and healthcare. The healthcare industries are overlooked with problems in secure data exchange and privacy protection. The scoping review aims to identify the Blockchain technology used in healthcare organization could help in addressing privacy and accessibility issues. The distributed ledger technology is integrated with IPFS-Interplanetary file system helps in accomplishing firm controllable blockchain-based Electronic Health Records (EHR) data exchange scheme. To share and save large health record files between healthcare institutions the Electronic Health Records (EHR) with IPFS-Interplanetary file system is a promising solution. The decentralized block storage and integrated Electronic Health Records (EHR) with Interplanetary File System (IPFS) achieve failure of accessing health records. The study designate that personal health documents and Electronic Health Reports are the bulk chosen areas, using distributed ledger technology. Interoperability, data integrity and authentication are the major concern need to be refined by blockchain technology. The most used platforms in EHR blockchain are hyperledger fabric and ethereum. The study also inspects the reliable data share of EHRs among mobile users through mobile cloud to ensure high security levels. The combination of distributed Interplanetary file system and mobile cloud blockchain platform is reliable data exchange mechanism by applying smart agreements for efficient Electronic Health Records data sharing among distinct medical providers and patients to access control mechanism.*

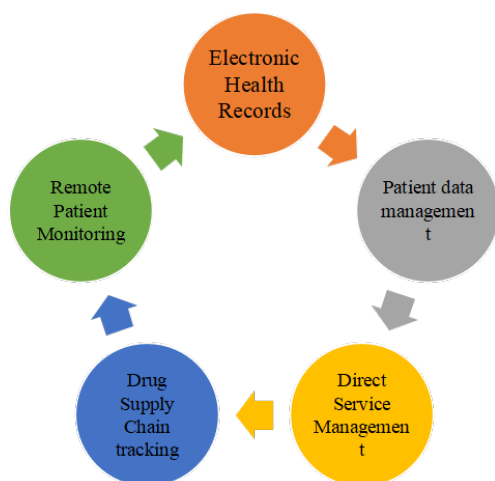
## 1. INTRODUCTION

The expeditious growth of information technology in the world replaced the traditional patient's health records on paper by Electronic Health Records (EHRs) which solves the problem of easy to lose papers and saving data for a longer period. (Gordon and Catalini) The identity verification and authentication

of all participants in healthcare is a major issue. The applications of blockchain in healthcare industry facilitates the uniform authority to retrieve electronic health documents. In 2008, the Satoshi Nakamoto, introduced Blockchain technology was implemented as a key element of the bitcoin digital currency. The functions and approaches of

blockchain technology in healthcare industry is extensive. Decentralized storage of data in blockchain technology facilitates the confidentiality, security, privacy and scalability. The shared database system of blockchain keeps record of all the transaction between two parties in a fixed way. The block in the blockchain are created by tracking the transactions through cryptography validation by the other participants or each node in the network. (Siyal et al.) A block contains the details of the complete transaction and the information about the time the previous transaction. The blocks of the blockchain is created

chronologically according to the transactions and cannot be altered.



**FIGURE 1. The application and benefits of Blockchain in healthcare industry**

The integrated and embedded hardware, network access, sensor or actuators and system software is Internet of Medical things in healthcare. The reliability and data privacy issue raises because of these complicated systems and obstructed critical operations in healthcare. The majority of devices are constrained with resources which restricts us from choosing the high end mechanism for privacy and security outlook. (Shamshad et al.) Though there are many standards and protocols for IoMT, it lacks in privacy and security issues. The traditional cloud-centric healthcare systems have fundamental problems like lack of transparency, high latency, single point failure and low level of control over personal data. The health industries are unable to give healthcare services to large number of patients due to lack of availability of professionals in medical

service. (Naz et al.) The service unavailability problem is encountered due to DoS attacks. Decentralized framework gives solution for unavailability problem, as a result healthcare switch to decentralized documentation. These are more efficient to patient-centric and enables decentralized architecture transparency. Event traceability, cost maintenance and security issues are achieved through current cloud-centric IoMT healthcare architecture but still deficit in privacy, data ownership and control mechanism. To overcome these issues, advanced robust technologies like distributed data storage systems, hybrid computing and blockchain technologies are utilized.

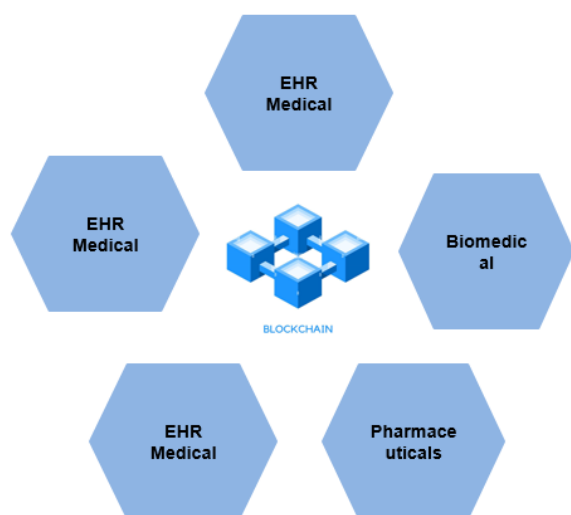
## 2. Blockchain Technology

### 2.1. Significance of blockchain in health care

Blockchain protects against tampering or corruption of data due to its immutable nature. The blockchain is designed with cryptographic hash value and each block is linked to each other, the changes made to each block results in the disruption of cryptographic link. (Shamshad et al.) authors probe that centralized data system in health care is inappropriate for data sharing in the growth of Electronic-medical records. Privacy preserving data sharing schemes can be achieved with the blockchain technology, since blockchain allows sharing of confidential data in real-time to participants by securing the communication channels from malicious attacks. (Soltanisehat et al.) express that according to the prediction of IBM healthcare leaders, impact of blockchain will be improvement in Electronic Health Records (EHR's) distributed framework. They state Medicare industry is anticipated to cut across \$500 million by 2022 in the global blockchain technology.

(Sookhak et al.) authors states that blockchain is expected to have a significant impact in healthcare industry. PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analysis is a fact-finding method used in systematic mapping and searching databases. Blockchain gained its popularity for its decentralized distributed ledger, where it does not require centralized method or trusted third party. The third generation of blockchain are adapted to other areas then the finance industry.

Blockchain can be adopted in publicized healthcare management, medical exploration and



**FIGURE 2. Significance of blockchain in health-care**

medicine counterfeiting in the Biopharmaceutical industry. According to World Economic Forum report, blockchain technology is likely to implement in storing global gross domestic product. Blockchain technology promotes digital health initiatives and digital business models by eliminating trusted third party for market services.

(Gordon and Catalini) data sharing is a patient-moderated privacy in patient-pointed interactivity is the biggest challenge. The blockchain facilitates data aggregation, identity and immutability. The two types of healthcare interoperability are patient-driven and organization-driven. The organization-driven interactivity depends on exchanging data with different entities of healthcare. The data of electronic health records of patient-driven is made accessible to the individual patient through Application Program Interfaces.

### 3. Challenges of Blockchain in EHR

(Siyal et al.) states that hospitals, medical workers and medical apparatus needs augment in digitizing health records which enables in easy access and sharing of healthcare data. It is difficult for the patients to maintain data among various institutions, to keep a track of easy access to the past data, blockchain is introduced by many researchers to maintain the Electronic Health Records (EHRs). Data trailing, auditing and loss of control over data are the major challenges in the time of implementation of EHR. MeDShare is the secure blockchain system used to secure medical data exchange



**FIGURE 3. Challenges of blockchain in HER**

between trusted parties like cloud service providers, hospitals and researchers of healthcare.

(Ismail, Materwala, and Hennebelle) before the implementation of blockchain technology, the interoperability between different institutions are grouped as push, pull and view models. Data transfer is possible only between two providers in push model. Example accessing data in the same hospital by different departments not by other hospitals and it fails to secure data integrity. The approach in view model is temporary, data sharing happens in informal way, without any standardized audit. Privacy, alteration of data, storage, scalability are the major challenges in healthcare big data though implementation of blockchain technology.

Attaran propose 18% of GDP spent on healthcare by U.S healthcare industry which is the world's largest. Healthcare data is a heterogeneous and large volume, through the course of patient's life get to interact with various health care providers, those data are maintained by providers and create data fragmentation trail for patient's access which is not in uniform and difficult to understand. Blockchain records continuous growth of transactions, storing DNA data, information of patients through blockchain can be accessed by patients and doctors directly on blockchain network anywhere and anytime.

Salah, et al, states interoperability, reversibility, navigate scalability, tokenization quantum computing and ensuring accuracy of healthcare data are the major challenges in adoption of blockchain technology traditional transactions like Visa can process

around 1900 transactions per second, the ethereum blockchain can process 20-25 transactions per second. Lightning network can tackle scalability issue in private blockchain by appending the second layer to it. Healthcare needs transformation from paper registry, digital registry to blockchain which avoids Immutability issue. It's inflexible for patients to verify the correctness of data, since hospitals and pharmaceuticals don't share their information, this can be overcome with tokenization. Tokenization enables patient to share their medical data with anyone.

Soltanisehat, et al, assert usage of blockchain construct a peer-to-peer assured smart contract. In general, all the proposed blockchain use private cloud and ethereum platform. Decentralized mechanism and cartographic algorithms solve several challenges in transaction system. Implementation of blockchain reduce the cost of transactions in peer to peer network. blockchain validates every transaction by recording history of transaction and each transaction are time stamped.

#### 4. System Architecture of Blockchain

Yang, Li (Li et al.) proposed architecture is based on the present databases. The blockchain keeps the track of all the access in the SQL server databases. Important metadata like access rights and ownerships are added to the chain with the logs. Each logs are related to the previous logs hence it guarantees the misuse of user's record.

Hennebelle, et al, (Ismail, Materwala, and Hennebelle) The blockchain network are of four types (i) Public (ii) Private (iii) Consortium (iv) Hybrid. No prior permission is required for the entity in public network to view the transaction. The participation in private network is prior taken to access the transaction. The view of data in hybrid network can be done by any network participants but modifications are access controlled, the hybrid blockchain recline in the middle of private and public. The ledger of the blockchain consisting health records are managed by access provider of the cloud; the metadata is recorded in the blockchain. IPFS are used to stored medical data in cloud. The ledger of the blockchain is duplicated across multiple databases of healthcare organization. The communication between cloud and blockchain platforms are permitted by integrator.

Dinh C. et al, (Nguyen et al.) proposed mobile cloud platform of an e-health care, the local gateways gather medical data and stores on public cloud which is shared among healthcare providers. Patient are given with PID (patient ID) and their living area with area I D AID. The wearable networks are private and maintained by patient. The mobile application incorporated in patients' smartphone. The patient address is formulated as PAddress = (PID, AID). storing of medical data in blockchain is not feasible hence address of patients PAddress. Large medical records are saved in decentralized cloud, the retrieval of medical records are attained by cloud EHR managers and retrieval entity must know the PAddress of patient and visible on the network of blockchain. The health providers are provided with HPID to access medical history on cloud storage to provide genuine health services. An ethereum platform is opted to develop a cloud blockchain network for electronic health Records sharing.

Pratap Singh, et al (Chelladurai, Pandian, and Ramasamy) The modules and smart contracts are defined in the presented patient-focused blockchain are designed to trace the functionality. The appointment registers by the patient over the communication network using chain code client interface. To avoid query raised by unauthorized stakeholders, data modification, deletion prevention, the transactions are made available on distributed ledger with hash value and timestamp. The authorized stakeholders and patients may rise query to the healthcare providers about their medical, reports, appointment and clinical diagnosis, etc.

Kencana Sari, et al (Puspita Kencana Sari), Access control, data sharing and data security are the EHRs problems overcome by blockchain, the EHR system create a record when patients visits to the hospital. The medical information such as history of drugs, information of nursing care, medical imaging and laboratory results maintained in decentralized database and cloud storage. In the new blockchain based EHRs business process the entities need to exchange data must be recorded as platform group, smart contract and the acknowledged access right records addresses the given blockchain. The provider's database stores health data recorded in EHR. Patients get information on approve or reject changes made by smart contract. The patient also gets notified when another stakeholder, such as labo-

ratory, insurance company, pharmacy etc., make any changes.

### 5. Data block Structure of blockchain

The blocks of the blockchain has the hash value and cannot be altered. Cryptography techniques are used to secure the data in the blockchain. Decentralized nature of blockchain enables high speed processed data. The transparency nature of blockchain ensures unrestricted availability on both private and public blockchain.

The blockchain headers identifies individual blocks and hash value (H) is created for the block header data.

The hashed block consists of three metadata block sets.

The targeted value (F) is compared with generated hash value (H).

The nonce value is kept incremented if the target value is greater than hash value

If the state (F > H) is positive, the blocks add the minor data.

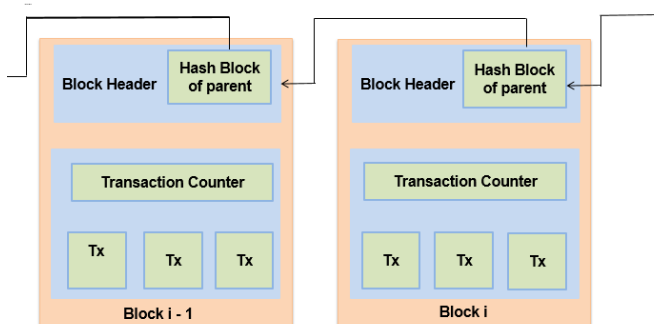


FIGURE 4. Structure of Blockchain

The data block of blockchain contains components like transaction records, Merkle tree. To aim the digital signature, the request is accessed only after providing patient information signed by private key of users (time stamp).

Block header: To prove the block data, block header contains the metadata.

Hash Value: SHA256 algorithm, to generate the hash vale  $H_{12} = H[(H_1 + H_2) = H( T_1.H) + (T_2.H)]$

The block validation is carried by previous block.

Merkle Tree: Stores the transaction in every block.

Nonce: A number created for an evidence of work on miner nodes.

Time stamp: previous transaction time in the block.

Hashing process starts once the creation of health reports. The arbitrary length of data is taken by hash function and fixed length data size alphamerical string as a hash value is generated. SHA-256 can compute on 64-bit and 32-bit words. The genuine data are saved in the IPFS-Inter Planetary File System or distributed servers, blockchain does not store original data instead stores the hashes to secure the data and acts as securing protocol. For Example: Patient P requests doctor D through providing patient ID or some credentials for an appointment at hospital H. After the patient consultation entire details are stored in the blockchain. The generated block consists of nonce, block number, digital signature and block hash. The created block is added to the chain.

The data of the patients are might generated from various sources like laboratories, radiology, technological devices and verified by medical team and private blockchain networks.

(Hasib et al.) proposed blocks of the node are interconnected with two fagments block's body and the header. Each node in the network receives a copy of the chain, there is some mechanism inside the blockchain it consists of previous block hash, hash root, signature, nonce and timestamp. the root hash in the block body, root hash is found and every source node is associated with each block in figure T1, T2 etc... T1 implies transaction occurred and so on. The doctor diagnosed information, date of diagnoses, hospital, and stamp are found distinctive.

### 6. Technical Blockchain

#### 6.1. Distributed Ledger

Houtan (Houtan, Hafid, and Makrakis) Blockchain is an asymmetric encryption network and decentralized in nature. In asymmetric encryption, every peer in the network has public and a private key. The private key is applied for decrypting the transactions related to public key. Public key is used for the peer identification address. The distributed ledger is a timestamp of all the transactions.

The assumption made as every data blocks are saved on each client node in the blockchain deployment. The rate of transactions per second is approximately 7, which hold the latency of blockchain web and reflects on transparency and authenticity of data

transactions.

All peers are identifiable in the hyperledger Fabric and it is a permission based blockchain. Hyperledger consists of three services (a) Membership service: privacy, identity and confidentiality of all the peers are used to manage by membership service. participants get identity, Attribute Authority to generate their secret keys after the registration on the Hyperledger. (b) Blockchain service: it includes point to point protocols, distributed ledger and consensus managers to manage the ledgers. (c) Chain code service: is a program to validate the nodes and secure sandbox.

### 6.2. *Interplanetary File System (IPFS)*

Honglei Li proposes IPFS is distributed system accesses and stores application, websites and large files on off-chain and puts immutable, permanent links in transactions.

The below are the features of proposed system :

(a) IPFS holds encrypted data of EHRs in distributed access, which can improve efficiency and privacy of data.

(b) Medical data can be accessed by only authorized users, authorized organizations can track if data is leaked.

(c) IPFS provide address to EHR files with hash-valued ensures security and integrity of EHR.

(d) If the patient forgets the private keys finger vein technology optimizes data authorization.

### 6.3. *Blockchain and cloud storage*

Muqaddas Naz states blockchain assures reliable secure and trusty worthy data sharing by recording sustainability. Distributed nature of networks diminishes the managing ability of networks. Blockchain's unchangeable identity can induce major attacks on networks. To overcome these issues, authors presented blockchain controlled data management system CBDM designed for cloud infrastructure. Trusted authority is introduced in a system to attain high level control on the network. Sharing of resources is achieved by cloud service, decentralization blockchain based cryptocurrency requires huge computational power. To tackle this issue authors working on cloud servers for efficient allocation of resources. Data stored on cloud are centralized servers, sharing of data among hospital and patient is protected through blockchain. To control fraud by third party, data needs to be

encrypted in end-to-end delivery. The blockchain based data exchange is created for cloud service providers.

### 6.4. *Blockchain and IOT*

The automation of IOT plays special character in everyday lives. Electronic tools exchange and share information through internet. authentication and data integrity of digital tools needs mechanism for appraising the confidentiality and security for sustainability. Existing schemes using IOT based blockchain for data exchange has some ambiguity such as cost of maintenance, administration of big data, security risks from IOT network. To overcome those challenges authors proposed mechanism of Shamir's secret sharing algorithm to secure fabric based data transmission.

## 7. Conclusion

Technology development can ameliorate the coherence in the implementation of EHR systems in various ways. Deep Learning, machine-learning, natural language processing techniques can extricate information from clinical narratives and unstructured data locked in EHRs. In the Health Information Systems EHRs are anticipated to be the prime beneficiaries of blockchain technology. This study indicates that privacy, Security, low performance, poor scalability, lack of trust, high cost and low performance remain the most critical challenges for implementing these technologies. The aspire of implementing blockchain technology is increasing exponential in healthcare industry. The health domain areas are potentially impacted by blockchain technology. Healthcare organizations are in expository request for latest and upgraded confidentiality solutions. This review reveals that research is basically focused on the utilize of blockchain technology to address the present challenges of EHR. Despite of the fact that blockchain presents remarkable potential for disrupting health organizations.

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#### CONFLICT OF INTEREST:

The authors Divyashree D and Dr. Chitra Ravi hereby declare that we have no conflict of interest.

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All authors expressed as there is no conflict of interest

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