BLOCKCHAIN INTEROPERABILITY 1.0: REVIEW ON HEALTHCARE INTEROPERABILITY AND DATA SECURITY

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Abstract: *The paper explores how blockchain technology can transform the healthcare industry by improving data management, security, provenance, and integrity. It explains the main features of blockchain technology and how they can be applied to various healthcare scenarios and existing solutions. Blockchain technology can enable a new paradigm of Electronic Health Records (EHR) delivery models that are more efficient and secure. The paper discusses the methods and applications of blockchain interoperability in the healthcare sector. The patient data management system on the blockchain ensures that the health records are stored safely and only authorized parties can access and modify them. Smart contracts are used to automate healthcare processes and enforce access control policies, eliminating the need for intermediaries and increasing system performance.*

Keywords:*healthcare, blockchain, interoperability, EHR, health records, semantic, syntactic;*

INTRODUCTION

The healthcare industry relies on a lot of accurate and reliable information flow among all parties [1]. However, this information is often scattered and isolated, making it hard to access enough of it to support decision-making and care delivery. This is because each medical facility keeps health information in a separate and centralized way, limiting the medical staff's view of the patient's full history and leading to errors in medical care and diagnosis. These factors create a need for methods that help to achieve interoperability among the information systems that support care delivery [2].

Interoperability is the ability of healthcare systems and software applications to exchange, share, and use data securely and effectively with each other [11]. This data can include patient records, clinical information, diagnostic images, and more. Blockchain technology can offer a new way of improving healthcare interoperability by enhancing data security, integrity, and patient control. It allows healthcare stakeholders to share and access data more easily and transparently while complying with industry standards and regulations. As the technology evolves, its influence on healthcare interoperability is expected to grow even more. Blockchain's distributed, immutable, and transparent nature provides unique benefits that can change the way data is shared and secured in the healthcare industry [3].

1. Blockchain Technology

Blockchain is a way of storing and sharing a record of all transactions that is made up of a series of linked databases called "blocks" and "chains" [3]. Blockchain technology uses distributed, decentralised, and peer-to-peer networks. This kind of database is also known as a digital ledger. The owner of the ledger signs each transaction with their digital signature, which protects and verifies the data. The data in the digital ledger is very secure. Blockchain technology can be applied to many areas, such as the bitcoin market, supply chain management, electoral systems, and more. Its features of immutability, transparency, and security make it a potential solution for businesses that want to increase trust, security, and efficiency.

There are different types of blockchain networks that have different levels of access and control. They are:

(i) Public blockchain: This is a blockchain network that is open to anyone who wants to join without any restrictions. Most cryptocurrencies use a public blockchain network that follows certain

rules or consensus algorithms. As more public blockchain networks are developed over time, they can be used for various commercial applications [4].

(ii) Private or restricted blockchain: This is a blockchain network that only allows authorized parties to access and view the data. Some data sets are kept confidential and can only be seen by people who have permission. An example of a private, permissioned ledger is Oracle's Blockchain Platform [4].

(iii) Consortium or federated blockchain: This is a blockchain network that is controlled by a small group of nodes or stakeholders who have the power to decide the mining and consensus processes.

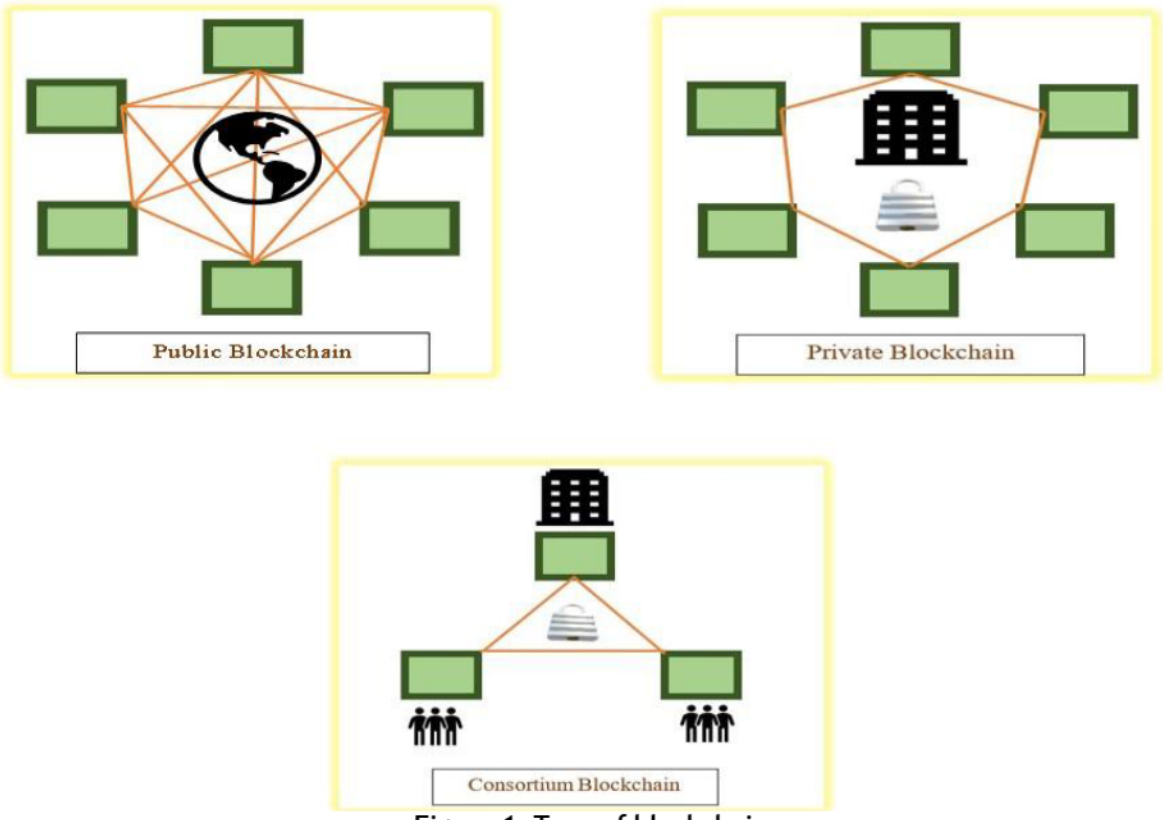

Figure 1. Type of blockchain

2. CONSENSUS MECHANISM

To add new nodes to the chain, blockchain uses some mechanism that ensures consensus among the participants. There are different types of consensus mechanisms that can be applied for this purpose, but the most common ones are [5].

Proof of Work (PoW)

A type of consensus algorithm in which participants, called miners, must solve hard mathematical problems (hash functions) to verify and append transactions to a blockchain. The miner who solves the problem first gets cryptocurrency tokens as a reward and has the power to suggest the next block of transactions, making it a key element of blockchain's security and decentralization [6].

Proof of Stake (PoS)

It does not use a mechanism that is efficient for computational tasks to choose nodes in a blockchain network. Instead, it uses a mechanism that chooses nodes based on how much they have invested in the system, which is measured by the amount or length of the assets they own related to that blockchain [7].

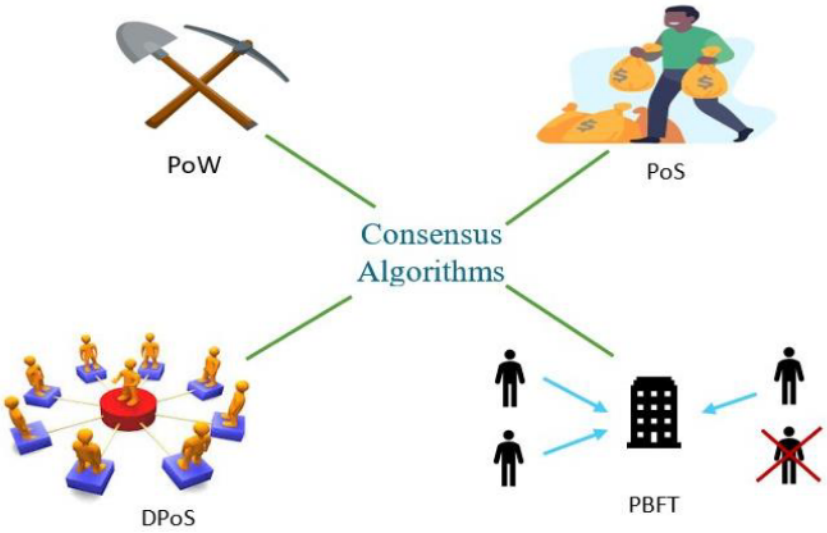

Figure 2. Types of Consensus Algorithms used in Interoperability

Delegated Proof of Stake (DPoS)

In a DPoS blockchain, token holders can vote for block producers, with their votes being more powerful if they have more tokens; the block producers with the most votes oversee block production. Also, users can give their voting power to another user, called proxy voting, which allows for a flexible and democratic system where token holders can either take part or delegate their voting influence to trusted representatives [8].

Practical Byzantine Fault Tolerance (PBFT)

PBFT is a consensus algorithm that is famous for its ability to guarantee the security and reliability of distributed systems, especially when some of the nodes may be malicious or faulty. PBFT provides a strong framework for reaching consensus among a group of replicas or nodes. Using a three-phase protocol, PBFT allows these replicas to collectively decide on the order and validity of incoming transactions, even when some of them may act arbitrarily or maliciously [9].

This paper is organized as follows: Section 2 describes feature of blockchain in healthcare interoperability. Section 3 explains the different types of blockchain interoperability in healthcare. Section 4 discusses the importance of interoperability in healthcare. Section 5 reviews the related work that has been done. Finally, section 6 summarizes the research conclusion and future scope of the research.

Blockchain Features used in Healthcare Interoperability

A blockchain allows a decentralized and distributed ledger that enables independent participants or actors to record and share digital assets, transactions, and information in a secure and trust less way without depending on a central, trusted third party. This technology could change and replace various intermediary functions in economic, social, and technological systems by providing a tamper-resistant and transparent record-keeping system. Blockchain's decentralized nature and cryptographic security make it useful in applications from cryptocurrency to supply chain management, voting systems, and more [10].

Blockchain Features	Explanations
Data security & integrity	Data cannot be changed once it is recorded on blockchain, which is decentralized and requires consensus among participants. This improves data security and integrity, which are essential in healthcare where patient data must be kept confidential and accurate [3].

Standards for Interoperability	Blockchain can help create common standards for data exchange and interoperability among healthcare systems. Smart contracts can follow these standards, ensuring that data is consistent and formatted correctly [2].
Patient centric health data control	Blockchain can allow the creation of a patient-centric health record that is immutable, secure, and can be shared with various healthcare providers with the patient's consent. Patients would have more power over their data and can choose which providers to give access to, ensuring that their healthcare information is available when needed [9].
Streamed line data exchange	Data can be shared in real-time on blockchain, which provides a distributed ledger. This reduces administrative costs and improves the speed of data access [9].
Reduced error & risk	The unchangeable nature of blockchain records reduces the chance of errors and fraud in healthcare. By ensuring that data is reliable and accurate, it becomes more trustworthy for diagnosis, treatment, and billing processes [39].
Smart contracts	Smart contracts on blockchain platforms can automate various healthcare processes, such as insurance claims processing, appointment scheduling, and prescription verification. These self-executing contracts can ensure efficiency and accuracy in healthcare operations [19].

Table:1.Blockchain features enable healthcare interoperability

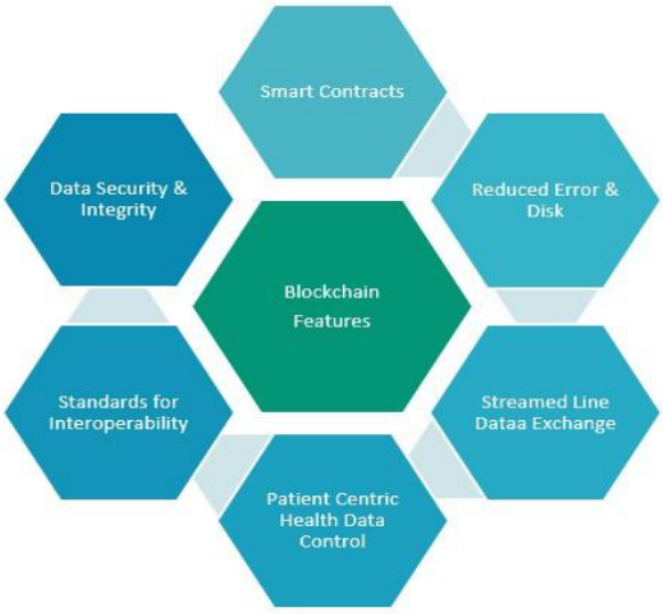

Figure 3: Blockchain Features

Blockchain solutions often have predefined governance rules that regulate access and control permissions. These rules are designed to balance privacy and transparency. They ensure that only authorized parties can see specific data, transactions, or records, which is important in healthcare, where patient data privacy is essential. Healthcare organizations can use various privacy-enhancing technologies, such as tokenization, pseudonymization, or data masking. These techniques allow

sensitive data to be stored or transmitted in a way that preserves individual privacy while still allowing legitimate users to access necessary information when needed.

Blockchain technology provides a strong framework for securely managing data, identities, and transactions in healthcare and various other domains. It allows organizations to comply with regulatory requirements, protect patient privacy, and maintain data integrity while enjoying the benefits of decentralized and transparent record-keeping [10]. In a blockchain network, additional parties (peers) can help verify the identity and actions of participants. This distributed consensus mechanism improves the reliability and integrity of the network by requiring multiple parties to agree on the validity of transactions.

Types of Blockchain Interoperability in healthcare

Interoperability is the smooth sharing and utilization of information between different systems, applications, or entities. The use of blockchain technology can enhance many forms of interoperability within the healthcare industry. The following are some important interoperability in healthcare applications that blockchain can enable:

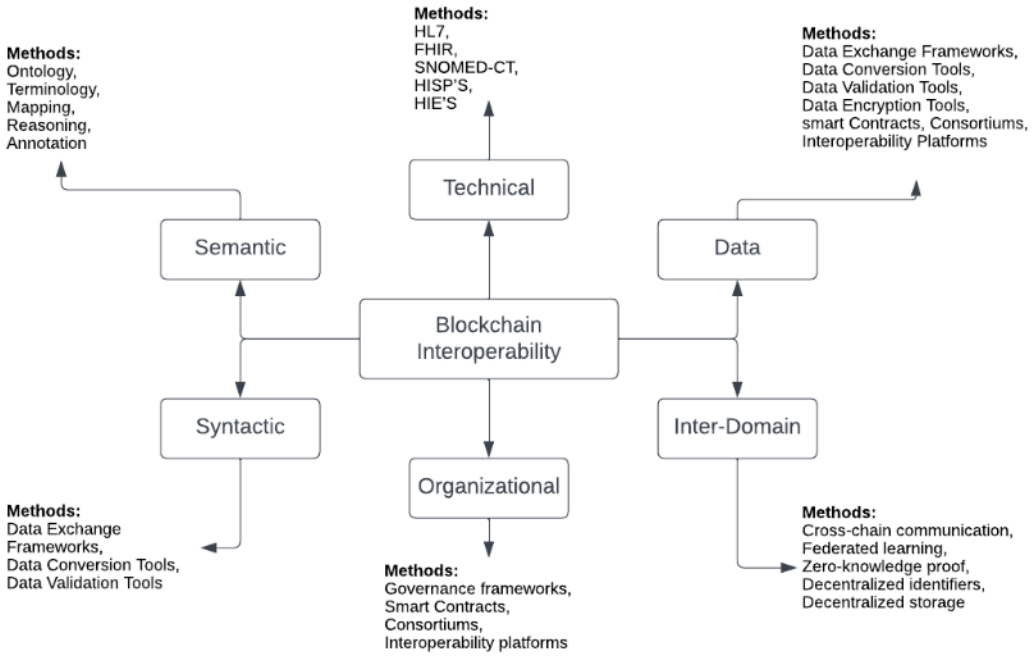

Figure 4: Different types of blockchain interoperability and methods used

Technical Interoperability: It focuses on the compatibility of data formats, protocols, and infrastructure across different systems [43]. Blockchain can provide a common and standardized data structure, ensuring that data is uniformly formatted and accessible across various systems. It can also enable data exchange through standardized APIs and interfaces [39][40].

Semantic Interoperability: This involves ensuring that data shared between systems is not only syntactically correct but also has shared meaning and context. Blockchain can improve semantic interoperability by using standardized terminology systems and ontologies. Smart contracts on the blockchain can follow semantic agreements, ensuring that data is consistently understood across different parties [11].

Organizational Interoperability: It addresses the alignment of policies, processes, and workflows between different healthcare organizations. Blockchain can enable secure data sharing and collaboration between organizations while preserving data ownership and privacy. Smart contracts can automate and follow agreements, enabling efficient cross-organizational processes [39].

Data Interoperability: It involves ensuring that data can be accurately and meaningfully shared across different systems. Blockchain can keep a distributed ledger of data transactions, ensuring data reliability, integrity, and auditability [44]. This improves the trustworthiness of data exchange between systems.

Inter-domain Interoperability: It involves connecting different healthcare domains, such as clinical, administrative, and public health, to enable comprehensive data sharing. Blockchain can serve as a secure and standardized platform for cross-domain data exchange, ensuring that data is shared in a secure and consistent manner [40].

Integrating blockchain technology can improve various aspects of interoperability in healthcare, enabling more secure, transparent, and efficient data exchange [11]. The interoperability uses different types of methods as shown in figure 4 which we will discuss in our next paper as Blockchain interoperability2.0.

1. The Importance of Interoperability in Healthcare

Healthcare interoperability means the ability of different computer platforms and software applications to communicate, exchange data, and use each other. It is important to enable information technology to work together inside and outside of organizational boundaries to improve the effective delivery of healthcare to people everywhere. It is important for providing efficient shared healthcare for patients to choose to share data in a flexible and secure way [43]. Sharing information supports better diagnosis accuracy and avoids limitations and inconsistencies in medical plans and medicine. In fact, in today's healthcare system, patients often participate in collecting and sharing their healthcare data with various service providers. This process usually involves the use of physical copies or electronic copies. This type of sharing medical data is inefficient and insecure due to following reasons:

Time Wasting: As the patient collects and submits the medical records every time, it takes more time which cause inefficiencies and delays in care-conditions.

Security Risks: The medical records are carried by patient in physical mode from one place to another, it may be lost or stolen.

Inefficient Data: Healthcare data often exists in multiple locations and formats, making it hard for patients to combine their complete medical history. Many patients face difficulties in keeping complete and accurate historical health records, and this can indeed lead to treatment problems and potential health issues.

The interoperability can be divided into three different levels [44]. These are:

Foundational Interoperability: Foundational interoperability depends on common data exchange formats, standards, and transport protocols.

Structural Interoperability: Structural interoperability ensures that data can be understood correctly by the receiving system, reducing the need for manual data mapping or transformation.

Semantic Interoperability: Semantic interoperability is the highest level of interoperability and represents the ability of systems to exchange data in a way that both the sending and receiving systems have a common understanding of the meaning and context of the data. This level enables smooth communication and decision support, as the data exchanged is not only structurally compatible but also semantically consistent.

Related Work

Many research works have been done on interoperability and EHR. Several authors have used different applications and methodology for EHR and interoperability for the improvement of the system. Some of them, used smart contracts and cryptographic algorithm for security. The below table has comparisons of such research works on EHR.

Sn	Author	Year of publication	Method used	Application Used	Issues and challenges
1	Ahmed N. Gohar [19]	2022	Theoretical analysis	Smart contracts	EHR interoperability

2	Edgar R. Dulce Villarreal [21]	2023	Model Driven Engineering	API & Smart Contracts	Lack of infrastructure
3	Suzanna Schmeelk [20]	2022	OVID Database	-	Security Challenges
4	Kensaku Kawamoto [18]	2021	Shared Infrastructure & Used Fast Healthcare	-	Improve Patient Care
5	S. Tanwar [12]	2020	BFT	Hyperledger Fabric	No standard in EHR & Cost
6	A.A. Alomar [13]	2019	Hash & Cryptography	Ethereum	Transition Cost
7	K. Fan [14]	2018	Digital Signature		Security & Efficiency
8	A. Dubovitskaya [15]	2020	Hyperledger	BFT	No performance Matrices
9	A.R. Rajput [16]	2021	Hyperledger	BFT	Transaction Response Time
10	Y. Zhuang [17]	2020	Blockchain Simulation	Smart Contracts	Access time to receive permission & Access Data

Table:2. Work done on EHR and interoperability by using different methods

There are some standards that are used in interoperability and data sharing in healthcare such as HL7, DICOM etc. While standards in semantic interoperability refer to representations for conveying data between two separate systems, semantics serve as dictionaries with medical terminologies. They are the most important foundational pieces for sharing interoperable EHR data. Standards might be of one of three types: document, communications, or terminology. To support efficient EHR sharing, messaging standards put a strong emphasis on structure, content, and other data needs. Terminology standards deal with codes that are specific to diseases and medications. Document standards can be used to determine the type and position of information.

HL7 standards used messaging and document type of standards which are helpful for healthcare stakeholders for sharing of patients' information's and it is compliant to CDA [39][43].

ICD-10-AM (The International Statistical Classification of Diseases and related Health Problems, Tenth Revision, Australian modification) standard used terminology standard type which offers codes for medical terms in the illness terminology of the medical decision-support system [39].

DICOM (Digital imaging and communications in Medicine) and SNOMED used messaging standard type used for the transmission, interpretation and storing of biological images [40].

ICPC2 (International Classification of Primary Care) used terminology standard. Symptoms, diagnostics, testing, administrative suggestions, and therapy are some of the categories [41].

CCD (Continuity of Care Document) used document type of standard which makes it easier to share patient information when they move from one type of treatment to another [42].

RIM (Reference Information Model) used conceptual type of standard which uses USAM (Unified Service Action Model) [44].

During the process of interoperability, it must be mandatory to check the security issues because the data sharing between different stakeholders could be critical medical data in various format which has patients' health records. Authors of a few research papers used various encryption and security approaches to secure personal data during the transfer of data. We studied many authors'

research work, and the selected authors' work, which used various security approaches and algorithms, is listed in Table 3. It listed the proxy-re-encryption, Nu-cypher network, encrypt access keys, IPFS etc. used for data security.

All these securities can be maintained by using blockchain technology in which sensitive healthcare data can be encrypted before being stored on the blockchain. Encrypted data could be only accessible to authorized parties with the necessary decryption keys. Blockchain employs strong cryptographic algorithms to secure data [13]. This includes hashing to ensure data integrity and public-key cryptography for identity verification and access control. Blockchain uses consensus mechanisms to validate and agree upon transactions. The consensus helps prevent malicious activities and ensures that only valid transactions are added to the blockchain.

Smart contracts are self-executing code on the blockchain that can enforce predefined rules and automate transactions. They enable secure and automated healthcare processes, reducing the need for intermediaries [21].

Authors	Methods	Remarks
A. Dubovitskaya [22], M. Abouali [30], R.H. Hylock [31], Q. Wang [32], G. Dagher [23]	Proxy Re-encryption	To increase the security and privacy of sensitive data, it entails executing encryption on already encrypted data.
M. Abouali [30], R.H. Hylock [31]	Nu-Cypher Network	Encryption and key management for reciprocation are enabled by NuCypher. A design for access authorization based on the development of access policies is also provided.
S.N. Dass [26], Q. Wang [32]	Zero Knowledge	It refers to a method whereby one part unconditionally validates another part.
V. Patel [27], A. Margheri [34], H. Wu [35]	Encrypt access Key	A set of cryptographic keys is created for the entity and the picture owner separately in order to exchange medical images.
G. Carter [36]	Multi-layer Encryption	To increase data security, two or three layers of encryption are utilised.
X.Du [28]	Authenticate Users	Users must first authenticate themselves in order to access certain system resources.
Y. Liu [33]	SNDC	SQL/NoSQL Data Converter: Used for SQL/ NoSQL data conversion
S.N. Dass [26], V. Malamas [24]	Data Orchestrate	A control mechanism coordinates, manages, and orders the activation of services to convey data from within to outside the chain.
Y. Liu [33], Y.S. Lo [25], M. Abouali [30]	IPFS	The Interplanetary File System offers an efficient content address block storage paradigm with content address hyperlinks, resulting in a hash that leads to on-chain information.

O. Musa [29]	Encrypt Information	It is the process of converting data from an accessible format to an unreadable one using an algorithm like SHA-256.

Table:3Security and Interoperability Methods.

CONCLUSION

Ensuring that entities with security features for sharing patient data is one of the biggest challenges facing the current healthcare systems. Blockchain technology has recently shown enormous potential in the field of healthcare. The main contribution of this paper concludes the use of blockchain technology to develop a patient data access and interoperability mechanism for a hospital use case. The interoperability in this paper is discussed with different methods used and application areas. To improve the efficiency of healthcare interoperability blockchain technology offers different types of interoperability which help us to keep the patient data secure. Thus, this paper gives the scope for future semantic and syntactic interoperability related to various applications of healthcare and different methods can be used for data secure sharing.

REFERENCES

[1] *A. Roehrs, C. A. da Costa and R. da Rosa Righi, "OmniPHR: A distributed architecture model to integrate personal health records", J. Biomed. Inform., vol. 71, pp. 70-81, Jul. 2017.*

[2] *T. Benson, Principles of Health Interoperability HL7 and SNOMED, New York, NY, USA:Springer, pp. 1-316, 2012.*

[3] *A. Kumar et al., "A Novel Decentralized Blockchain Architecture for the Preservation of Privacy and Data Security against Cyberattacks in Healthcare," Sensors, vol. 22, no. 15, Aug. 2022, doi: 10.3390/s22155921.*

[4] *Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, ''An overview 1544 of blockchain technology: Architecture, consensus, and future trends,'' 1545 in Proc. IEEE Int. Congr. Big Data (BigData Congr.), Jun. 2017, 1546 pp. 557-564, doi: 10.1109/BigDataCongress.2017.85.*

[5] *C. Agbo, Q. Mahmoud and J. Eklund, "Blockchain technology in healthcare: A systematic review", Healthcare, vol. 7, no. 2, pp. 56, 2019.*

[6] *L. Ismail and H. Materwala, ''BlockHR: A blockchain-based framework for health records management,'' in Proc. 12th Int. Conf. Comput. Modeling Simulation, Jun. 2020, pp. 164-168*

[7] *S. Wang, J. Wang, X. Wang, T. Qiu, Y. Yuan, L. Ouyang, Y. Guo, and F. Wang, ''Blockchain-powered parallel healthcare systems based on the ACP approach,'' IEEE Trans. Computat. Social Syst., vol. 5, no. 4, pp. 942-950, Dec. 2018.*

[8] *M. Snider, K. Samani, and T. Jain, ''Delegated proof of stake: Features & tradeoffs,'' Multicoin Capital, Austin, TX, USA, Tech. Rep., 19, 2018.*

[9] *A. Dubovitskaya, Z. Xu, and S. Ryu, ''Secure and trustable electronic medical records sharing using blockchain,'' in Proc. AMIA Annu. Symp., 2017, p. 650*

[10] *Brodersen, C., Kalis, B., Leong, C., Mitchell, E., Pupo, E., Truscott, A. and Accenture, L., 2016. Blockchain: securing a new health interoperability experience. Accenture LLP, pp.1-11.*

[11] *Villarreal, Edgar R. Dulce, et al. "Blockchain for healthcare management systems: A survey on interoperability and security." IEEE Access 11 (2023): 5629-5652.*

[12] *S. Tanwar, K. Parekh, and R. Evans, ''Blockchain-based electronic healthcare record system for healthcare 4.0 applications,'' J. Inf. Secur. Appl.,vol. 50, Feb. 2020, Art. no. 102407.*

[13] *A. A. Alomar, M. Z. A. Bhuiyan, and A. Basu, S. Kiyomoto, and M. S. Rahman, ''Privacy-friendly platform for healthcare data in cloud based on blockchain environment,'' Future Gener. Comput. Syst., vol. 95, pp. 511-521, Jun. 2019.*

[14] *K. Fan, S. Wang, Y. Ren, H. Li, and Y. Yang, ''MedBlock: Efficient and secure medical data sharing via blockchain,'' J. Med. Syst., vol. 42, no. 8, p. 136, Aug. 2018.*

[15] *A. Dubovitskaya, F. Baig, Z. Xu, R. Shukla, P. S. Zambani, A. Swaminathan, M. M. Jahangir, K. Chowdhry, R. Lachhani, N. Idnani, M. Schumacher, K. Aberer, S. D. Stoller, S. Ryu, and F. Wang, ''ACTIONEHR: Patient-centric blockchain-based electronic health record data management for cancer care,'' J. Med. Internet Res., vol. 22, no. 8, Aug. 2020, Art. no. e13598.*

[16] *A. R. Rajput, Q. Li, and M. T. Ahvanooey, ''A blockchain-based secret data sharing framework for personal health records in emergency condition,'' Healthcare, vol. 9, no. 2, p. 206, Feb. 2021.*

[17] *Y. Zhuang, L. R. Sheets, Y.-W. Chen, Z.-Y. Shae, J. J. P. Tsai, and C.-R. Shyu, ''A patient-centric health information exchange framework using blockchain technology,'' IEEE J. Biomed. Health Informat., vol. 24, no. 8, pp. 2169-2176, Aug. 2020.*

[18] *Kawamoto K, Kukhareva PV, Weir C, Flynn MC, Nanjo CJ, Martin DK, Warner PB, Shields DE, Rodriguez-Loya S, Bradshaw RL, Cornia RC, Reese TJ, Kramer HS, Taft T, Curran RL, Morgan KL, Borbolla D, Hightower M, Turnbull WJ, Strong MB, Chapman WW, Gregory T, Stipelman CH, Shakib JH, Hess R, Boltax JP, Habboushe JP, Sakaguchi F, Turner KM, Narus SP, Tarumi S, Takeuchi W, Ban H, Wetter DW, Lam C, Caverly TJ, Fagerlin A, Norlin C, Malone DC, Kaphingst KA, Kohlmann WK, Brooke BS, Del Fiol G. Establishing a multidisciplinary initiative for interoperable electronic health record innovations at an academic medical center. JAMIA Open. 2021 Jul 31;4(3):ooab041. doi: 10.1093/jamiaopen/ooab041. PMID: 34345802; PMCID: PMC8325485.*

[19] *A. N. Gohar, S. A. Abdelmawgoud and M. S. Farhan, "A Patient-Centric Healthcare Framework Reference Architecture for Better Semantic Interoperability Based on Blockchain, Cloud, and IoT," in IEEE Access, vol. 10, pp. 92137-92157, 2022, doi: 10.1109/ACCESS.2022.3202902.*

[20] *Schmeelk S, Kanabar M, Peterson K, Pathak J. Electronic health records and blockchain interoperability requirements: a scoping review. JAMIA Open. 2022 Jul 27;5(3):ooac068. doi: 10.1093/jamiaopen/ooac068. PMID: 35911668; PMCID: PMC9329659.*

[21] *E. R. D. Villarreal, J. García-Alonso, E. Moguel and J. A. H. Alegría, "Blockchain for Healthcare Management Systems: A Survey on Interoperability and Security," in IEEE Access, vol. 11, pp. 5629-5652, 2023, doi: 10.1109/ACCESS.2023.3236505.*

[22] *A. Dubovitskaya, Z. Xu, and S. Ryu, ''Secure and trustable electronic medical records sharing using blockchain,'' in Proc. AMIA Annu. Symp., 2017, p. 650.*

[23] *G. Dagher, J. Mohler, and M. Milojkovic, ''Ancile: Privacy-preserving framework for access control and interoperability of electronic health records using blockchain technology,'' Sustain. Cities Soc., vol. 39, pp. 283-297, May 2018.*

[24] *V. Malamas, P. Kotzanikolaou, T. K. Dasaklis, and M. Burmester, ''A hierarchical multi blockchain for fine grained access to medical data,'' IEEE Access, vol. 8, pp. 134393-134412, 2020.*

[25] *Y.-S. Lo, C.-Y. Yang, H.-F. Chien, S.-S. Chang, C.-Y. Lu, and R.-J. Chen, ''Blockchain-enabled iWellChain framework integration with the national medical referral system: Development and usability study,'' J. Med. Internet Res., vol. 21, no. 12, Dec. 2019, Art. no. e13563.*

[26] *S. N. Dass and R. Chinnaiyan, ''A blockchain based electronic medical health records framework using smart contracts,'' in Proc. Int. Conf. Comput. Commun. Informat. (ICCCI), Jan. 2021, pp. 1-4.*

[27] *V. Patel, ''A framework for secure and decentralized sharing of medical imaging data via blockchain consensus,'' Health Inform. J., vol. 25, no. 4, pp. 1398-1411, 2018.*

[28] *X. Du, B. Chen, M. Ma, and Y. Zhang, ''Research on the application of blockchain in smart healthcare: Constructing a hierarchical framework,'' J. Healthcare Eng., vol. 2021, pp. 1-13, Jan. 2021.*

[29] *O. Musa, L. S. Yun, and R. Ismail, ''UPLX: Blockchain platform for integrated health data management,'' in Proc. Int. Conf. Reliable Inf. Commun. Technol., in Lecture Notes on Data Engineering and Communications Technologies, vol. 72, 2021, pp. 10-18.*

[30] *M. Abouali, K. Sharma, O. Ajayi, and T. Saadawi, ''Blockchain framework for secured on-demand patient health records sharing,'' in Proc. IEEE 12th Annu. Ubiquitous Comput., Electron. Mobile Commun. Conf. (UEMCON), Dec. 2021, pp. 35-40*

[31] *R. H. Hylock and X. Zeng, ''A blockchain framework for patient-centered health records and exchange (HealthChain): Evaluation and proof-of-concept study,'' J. Med. Internet Res., vol. 21, no. 8, Aug. 2019, Art. no. e13592.*

[32] *Q. Wang and S. Qin, ''A hyperledger fabric-based system framework for healthcare data management,'' in Proc. Int. Conf. Inf. Secur. Cryptol., 2021, pp. 132-137.*

[33] *Y. Liu, G. Shan, Y. Liu, A. Alghamdi, I. Alam, and S. Biswas, ''Blockchain bridges critical national infrastructures: E-Healthcare data migration perspective,'' IEEE Access, vol. 10, pp. 28509-28519, 2022.*

[34] *A. Margheri, M. Masi, A. Miladi, V. Sassone, and J. Rosenzweig, ''Decentralised provenance for healthcare data,'' Int. J. Med. Informat., vol. 141, Sep. 2020, Art. no. 104197.*

[35] *H. Wu, Y. Shang, L. Wang, L. Shi, K. Jiang, and J. Dong, ''A patient-centric interoperable framework for health information exchange via blockchain,'' in Proc. 2nd Int. Conf. Blockchain Technol. Appl., Dec. 2019, pp. 76-80.*

[36] *G. Carter, H. Shahriar, and S. Sneha, ''Blockchain-based interoperable electronic health record sharing framework,'' in Proc. IEEE 43rd Annu. Comput. Softw. Appl. Conf. (COMPSAC), vol. 2, Jul. 2019, pp. 452-457.*

[37] *S. D. Cannoy and L. Iyer, ''Semantic web standards and ontologies in the medical sciences and healthcare,'' in Semantic Web Technologies and e-Business: Toward the Integrated Virtual Organization and Business Process Automation. Hershey, PA, USA: IGI Global, 2007, pp. 405-420.*

[38] *(2013). Overview of Healthcare Interoperability Standards. Health Information and Quality Authority. Accessed: Nov. 12,2020.[Online]Available:https://www.hiqa.ie/sites/default/files/2017-01/Healthcare-Interoperability-Standards.pdf*

[39] *ICPC2PLUS.Wikipedia.Accessed:Nov.12,2020.[Online].Available:https://en.wikipedia.org/wiki/ICPC_2_PLUS#:~:text=ICPC%20is%20being%20developed%20by,in%201998%20as%20ICPC%2D2.*

[40] *M. Michelle. (2012). 5 Things to Know About CCD. HealthcareITNews. Accessed: Nov. 21, 2020. [Online]. Available:https://www.healthcareitnews.com/news/5thingsknowaboutccd#:~:text=What%20exactly%20is%20a%20CCD,v3%20standards%2C%22%20Brull%20said*

[41] *HL7 International. Accessed: May 2, 2021. [Online]. Available:http://www.hl7.org/implement/standards/product_brief.cfm?product_id=233*

[42] *Lyniate. Rim Reference Information Model. Accessed: Nov.21,2020.[Online].Available:https://www.lyniate.com/knowledge-hub/rim-reference-information-model/*

[43] *P. Zhang, J. White, D. C. Schmidt, G. Lenz, and S. T. Rosenbloom, "FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data," Comput. Struct. Biotechnol. J., vol. 16, pp. 267-278, 2018, doi: 10.1016/j.csbj.2018.07.004.*

[44] *Gohar, Ahmad, Sayed AbdelGaber, and Marwa Salah. "A proposed patient-centric healthcare framework for better Semantic interoperability using blockchain." International Journal of Computer Science and Information Security (IJCSIS) 19.11 (2021).*

[45] *Interoperability Requirements for Blockchain-Enabled Electronic Health.... https://www.hindawi.com/journals/scn/2022/9227343/.*