[1]Dr. Satish V. Kakade

[2]Dr. Bhavana Tiple

[3]Dr. Arun S. Sansuddi

[4]Mahadeo D. Kokate

[5]Mr. Mahendra M Alate

[6]Suhas Chavan

Blockchain-Based Medical Record Sharing in Healthcare IoT: Building Trust and Transparency through Secure Provenance Tracking

Abstract: - Blockchain technology has been incorporated into the Healthcare Internet of Things (IoT) landscape as a revolutionary solution to tackle issues related to the sharing of medical records. This paper presents an innovative method that utilizes Temporal Blockchain for the purpose of Provenance Tracking. The introductory section provides context by delineating the significance of trust and transparency in medical data sharing within the healthcare IoT ecosystem. The study examines current blockchain solutions, delving into frameworks such as Hyperledger Fabric, Ethereum, Corda, and specialized approaches like temporal blockchain. The paper examines the difficulties associated with tracking the origin of data, concerns regarding privacy, problems related to scalability, and the need to comply with regulations. These challenges provide the context for the proposed methodology. The main emphasis is on Temporal Blockchain, integrating temporal elements to improve the tracking of origin and history. The evaluation parameters, such as security, provenance tracking, scalability, interoperability, privacy compliance, and performance, undergo a thorough assessment. The attained values demonstrate a strong emphasis on security at a high level, thorough tracking of origin and history, and strict adherence to privacy regulations. Nevertheless, the need for scalability and interoperability necessitates meticulous consideration. The study showcases the capacity of Temporal Blockchain to establish trust and enhance transparency in the sharing of medical records. The future scope focuses on tackling scalability challenges, improving interoperability, and making continuous optimization efforts. The proposed approach highlights notable accomplishments and emphasizes the continuous development and collaborative aspect of Blockchain-Based Medical Record Sharing in Healthcare IoT.

Keywords: Blockchain-Based Healthcare, Medical Record Sharing, Healthcare IoT, Provenance Tracking, Temporal Blockchain, Trust and Transparency in Healthcare.

I. INTRODUCTION

Healthcare IoT refers to the incorporation of Internet of Things (IoT) devices into the healthcare system to enable the gathering, sharing, and examination of health-related information. These devices encompass wearables, monitoring equipment, and sensors, establishing a network that facilitates uninterrupted monitoring and management of patient health[1], [2].

The significance of trust and transparency in the sharing of medical records is crucial in the realm of healthcare IoT, as it greatly contributes to the effective and coordinated provision of patient care. Ensuring trust and transparency is crucial for securely sharing sensitive medical information among authorized entities. Building trust among stakeholders, such as patients, healthcare providers, and regulatory bodies, is essential for the widespread acceptance of healthcare IoT technologies[3], [4].

[1]Associate, Professor Department of Community Medicine, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, Email: satishvkakade@yahoo.co.in
[2]School of Computer Engineering and Technology, Dr. Vishwanath Karad MIT World Peace University, Pune, India. bhavana.tiple@mitwpu.edu.in
[3]Tutor Department of Community Medicine, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, Email: arunsansuddi@gmail.com
[4]Department of Electronics and Telecommunication Engineering SNJBs K B Jain College of Engineering, Chandwad Email Id: mdkokate66@gmail.com
[5]Statistician Department of Community Medicine ,Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth, Karad, Maharashtra, Email: mahendra.alate@gmail.com
[6]Department of Computer Engineering, Vishwakarma University, Kondhwa, Pune, Maharashtra, India. Email:chavan.suhas18@gmail.com

Presently, there are notable obstacles in the realm of medical record sharing. The privacy of patients is at risk due to security concerns, such as data breaches and unauthorized access. Moreover, the absence of a uniform and compatible framework frequently results in fragmented data ecosystems, impeding the smooth exchange of information between various healthcare entities[5].

The necessity for secure provenance tracking arises from the need to tackle the difficulties associated with sharing medical records. Provenance tracking is the process of documenting the lineage of data, guaranteeing transparency regarding its origins and any changes made to it. It is crucial to establish a reliable system for tracking the origin and history of medical records in order to verify their authenticity, identify any unauthorized alterations, and ensure the integrity of the data[6].

Obstacles in the sharing of medical records encompass more than just technological factors. The complexity of establishing a unified and secure infrastructure for sharing medical records is exacerbated by challenges such as interoperability barriers, inconsistent data formats, and varying levels of security across healthcare institutions[7], [8].

The integration of blockchain technology is essential to tackle these challenges. Blockchain is a form of distributed ledger technology that provides characteristics such as immutability, transparency, and decentralization. Immutability guarantees that data, once recorded, cannot be modified, thus creating a record that is resistant to tampering. Consensus mechanisms facilitate consensus on the current state of the ledger, while smart contracts automate predetermined rules within the blockchain[9].

1.1. Existing Blockchain Solutions in the Healthcare Sector

Summary of Hyperledger Fabric, Ethereum, Corda, and IoTA, table-1 represent more precise summary.[10]–[15]

- Hyperledger Fabric is a blockchain framework that is permissioned, meaning access is restricted to authorized participants. It focuses on maintaining privacy and scalability, which makes it well-suited for healthcare consortiums.
- Ethereum is a publicly accessible blockchain that enables the implementation of smart contracts, facilitating the transparent and automated execution of predetermined rules.
- Corda is a blockchain platform specifically developed for enterprises, with a primary emphasis on ensuring privacy and enabling seamless interaction between different systems.
- IoTA, also known as the Internet of Things Alliance, is a specific type of distributed ledger technology that has been created for the purpose of supporting the Internet of Things. Its main objectives are to offer scalability and minimize transaction expenses for interconnected devices.

Table 1 Comparison of various existed methods

Platform	**Hyperledger Fabric**	**Ethereum**	**Corda**	**IOTA**
Consensus Mechanism	PBFT (Permissioned)	PoW, PoS (Public)	PBFT (Permissioned)	PoW, IOTA Consensus (Public)
Scalability	High	Moderate	High	High
Privacy	Integrated access control	Public by default (requires privacy solutions)	Built-in confidentiality features	Tangle structure offers inherent privacy
Smart Contracts	Customizable chain code	Turing-complete Solidity language	Limited scripting for business logic	Lightweight contracts in Tangle language

Interoperability	Designed for integration with existing systems	Large developer community and standards	Focused on financial sector	Tangle designed for machine-to-machine communication
Healthcare IoT Suitability	Strong permissioned access control and privacy features	Large ecosystem and developer tools, but public network less ideal for sensitive data	Tailored for financial workflows, less for patient records	Lightweight data and energy consumption ideal for resource-constrained devices

1.2. Challenges in Provenance Tracking

- Privacy Concerns: Privacy concerns arise when attempting to track the provenance of patients while also safeguarding their personal information. Ensuring a harmonious equilibrium between openness and safeguarding of information is crucial in upholding the confidence of patients.
- Scalability Issues: Scalability concerns arise due to the substantial volume of data generated by healthcare systems, making it imperative to ensure the scalability of the blockchain network. Current blockchain solutions may encounter difficulties in managing the growing quantity of medical records and transactions.
- Regulatory Compliance: Complying with healthcare data protection regulations is essential for regulatory compliance. Blockchain solutions must align with regulatory standards to ensure legal compliance and foster trust among stakeholders.

1.3. Temporal Blockchain Concepts

Temporal aspects in blockchain refer to the incorporation of time into the conventional blockchain framework. Its main objective is to document and safeguard the sequential arrangement of transactions, thereby improving the capacity to monitor modifications as they occur.

Temporal blockchain has been applied in diverse industries such as supply chain management, finance, and intellectual property, in addition to healthcare. The capability to offer a historical log of data modifications renders it appropriate for situations where the tracking of origin is essential.

1.4. Objective: Building Trust in Healthcare IoT:

Harness the inherent trust features of blockchain technology to create a secure and transparent system for sharing medical records. Instill trust among patients, healthcare providers, and regulatory bodies in the authenticity of shared health data.

Improving transparency by implementing a system to track the origin and history of data:

- Develop a reliable system for tracking the origin and history of medical records using a temporal blockchain to record and authenticate the complete information.
- Enhance the clarity and openness in the source, availability, and alteration of healthcare data, thereby diminishing the possibility of unauthorized modifications.

Our Contribution - Introducing Temporal Blockchain for Enhanced Security

Our proposed solution utilizes temporal blockchain technology to effectively tackle the challenges associated with sharing medical records. Our objective is to improve security, transparency, and accountability in healthcare IoT by including the temporal aspect. This will guarantee the preservation of the accuracy and reliability of medical records as time passes. Temporal blockchain offers a thorough and verifiable chronicle of data modifications, enhancing the security and reliability of the medical record-sharing system. This innovative approach aims to surpass the constraints of conventional blockchain solutions and is in line with the changing requirements of the healthcare industry.

II. LITERATURE REVIEW

The introduction of blockchain technology has brought about a significant transformation in the field of healthcare information management. Research has focused on exploring the applications of blockchain in healthcare, specifically in the area of sharing medical records. This literature review examines a range of scholarly articles that explore the incorporation of blockchain technology to tackle the difficulties related to sharing medical data. Healthcare organizations and researchers have recently acknowledged the growing potential of blockchain technology in improving the security, transparency, and privacy of medical records. This section offers a comprehensive analysis of current blockchain solutions, including permissioned frameworks like Hyperledger Fabric and public platforms like Ethereum. Each of these solutions is specifically designed to address the challenges associated with sharing medical data. The review delves into specific methodologies, such as incorporating temporal elements into blockchain technology and designing consortium blockchains specifically tailored for the exchange of medical information. Through a thorough examination of the literature, our objective is to acquire valuable knowledge regarding the progress, obstacles, and prospective paths of utilizing blockchain technology in healthcare Internet of Things (IoT) for the purpose of secure and transparent sharing of medical records.

G. Q. Butt et al.[16] examines the implementation of a secure healthcare record sharing system utilizing blockchain technology. The authors suggest a system that utilizes the inherent security characteristics of blockchain to guarantee the confidentiality and integrity of healthcare records. The research, published in the journal Applied Sciences, provides a comprehensive account of how the suggested mechanism was put into practice and its level of success. The authors intend to utilize blockchain technology to tackle privacy concerns and improve the reliability of sharing medical data. The paper offers valuable insights on the development and execution of a robust blockchain-based system for sharing healthcare records, thereby contributing to the wider discourse on safeguarding confidential health data.

W. Chen et al.[17] presents a blockchain-based medical data sharing model in the Journal of Physics: Conference Series. The authors specifically concentrate on utilizing blockchain technology to establish a highly secure and transparent platform for the exchange of medical data. The proposed model aims to resolve concerns regarding data integrity and privacy in medical data sharing by leveraging the decentralized and tamper-resistant nature of blockchain. This study examines the use of blockchain technology in healthcare and analyzes the potential effects of these models on the existing methods of managing medical data.

Y. Chen et al.[18] propose a blockchain-based system to ensure the secure storage and management of medical records. The authors underscore the significance of blockchain technology in safeguarding the security and confidentiality of medical data. The proposed framework not only tackles the difficulties associated with secure storage, but also introduces a comprehensive medical service framework. The study seeks to utilize blockchain technology to improve the security and efficiency of medical record management systems, thereby supporting the ongoing endeavors to establish a strong and transparent healthcare ecosystem.

M. Du et al.[19] present a refined consortium blockchain that is specifically tailored for the purpose of sharing medical information. The primary objective is to enhance the efficacy and safeguard the confidentiality of exchanging medical data among various entities. The study explores the complexities of consortium blockchains and their implementation in the healthcare sector. The authors' contribution to the development of specialized solutions for the healthcare industry involves optimizing the blockchain specifically for the sharing of medical information.

Qin et al.[20] propose a robust storage and sharing system for electronic medical records pertaining to strokes. The authors employ a consortium blockchain to tackle the particular difficulties linked to stroke-related medical data. The study demonstrates the practicality of using blockchain technology to tackle specific healthcare problems by concentrating on a specific medical field. The proposed scheme aims to advance the development of specialized solutions for secure and efficient sharing of medical records in specific medical contexts.

Z. Sun et al.[21] presents MedRSS, a scheme that utilizes blockchain technology to ensure the secure storage and sharing of medical records. The authors highlight the security implications of their proposed scheme, utilizing blockchain technology to guarantee the privacy and accuracy of medical data. This study enhances the existing research on secure medical record management by offering valuable insights into the design and execution of a

solution that utilizes blockchain technology. MedRSS seeks to bolster the overall security and confidentiality of medical records, in accordance with the changing requirements of the healthcare sector.

The study conducted by M. Usman et al.[22] centers around the utilization of blockchain technology for the secure storage and sharing of electronic medical records. The authors propose a comprehensive strategy for utilizing blockchain technology to guarantee the security and privacy of electronic medical records. The study investigates the capacity of blockchain technology to tackle the difficulties related to the management of electronic medical records. The authors' comprehensive analysis of the design and implementation of their proposed solution offers significant contributions to the field of secure healthcare record sharing.

The study conducted by L. Tan et al.[23] centers on the secure and privacy-preserving sharing of medical records related to COVID-19. The authors suggest utilizing blockchain technology to tackle the unique obstacles presented by the COVID-19 pandemic. The study seeks to guarantee the security and privacy of sensitive medical information pertaining to COVID-19 by integrating blockchain technology. This paper adds to the current discourse on the application of blockchain technology in targeted healthcare scenarios, particularly during periods of worldwide health emergencies.

G. Wu et al.[24] present a blockchain-based system for exchanging and sharing electronic medical records while ensuring privacy protection. The authors highlight the significance of safeguarding privacy in the sharing of electronic medical records and propose a smart healthcare system based on blockchain technology to tackle this issue. This study aims to advance the development of secure and privacy-conscious solutions for managing electronic medical records. The proposed system seeks to improve the overall privacy and security of electronic medical records in healthcare information exchanges by utilizing blockchain technology.

M. Wang et al.[25] concentrate on safeguarding the confidentiality of medical data when it is shared. They suggest a solution that utilizes blockchain technology to tackle this issue. This study enhances the current research on maintaining privacy while sharing medical data by offering valuable insights into the development and execution of the MedShare system. The authors intend to create a robust and privacy-conscious system for sharing medical data by integrating blockchain technology.

K. Fan et al.[26] presents MedBlock, a blockchain-based system for sharing medical data that is both efficient and secure. The authors highlight the necessity of optimizing effectiveness and safeguarding confidentiality in the exchange of medical data, and suggest a solution based on blockchain technology to fulfill these criteria. The study adds to the continuous endeavors in creating efficient and protected solutions for the exchange of medical data in healthcare systems. MedBlock aims to optimize the efficiency and security of medical data sharing processes by utilizing blockchain technology.

Liu et al.[27] presents BPDS, a system that utilizes blockchain technology to ensure privacy while sharing electronic medical records. The authors highlight the significance of safeguarding privacy in the sharing of electronic medical records and propose a solution based on blockchain technology to tackle this issue. This study enhances the existing research on maintaining privacy while sharing healthcare data by offering valuable insights into the development and execution of the BPDS system. The authors aim to establish a robust and privacy-conscious framework by harnessing the potential of blockchain technology.

The literature review highlights the increasing importance of blockchain technology in transforming the sharing of medical records within the healthcare Internet of Things (IoT) ecosystem. The analyzed studies collectively enhance our understanding of the difficulties and creative remedies presented in the field of secure healthcare information management. The reviewed works emphasize that blockchain's inherent characteristics, including decentralization, immutability, and smart contracts, present promising opportunities to tackle privacy issues, guarantee data integrity, and establish trust in the sharing of medical data. Moreover, the literature indicates the rise of distinct blockchain implementations, such as temporal blockchain and consortium blockchains, specifically created to meet the specific requirements of the healthcare sector. The amalgamation of these discoveries not only showcases the variety of methodologies but also emphasizes the continuous development of blockchain applications in the healthcare sector. The insights obtained from this literature review will serve as a basis for investigating new approaches and enhancing the incorporation of blockchain technology to promote trust and transparency in the sharing of medical records within the healthcare Internet of Things (IoT) environment.

III. METHODOLOGY

The current state of healthcare is characterized by disjointed data systems, vulnerabilities in security, and concerns regarding privacy, all of which undermine trust and hinder the delivery of optimal patient care. The use of blockchain technology in healthcare data management has the potential to bring about a significant transformation due to its inherent characteristics of immutability, decentralization, and transparency. This study explores the integration of temporal blockchain, a specialized version of blockchain technology, with Healthcare Internet of Things (Healthcare IoT) systems. We prioritize utilizing the distinct features of temporal blockchain to create a reliable system for tracking the origin of data, ensuring trust and transparency in data ownership, access, and modification within the Healthcare IoT ecosystem.

3.1. Explanation of Temporal Blockchain Concepts

Conventional blockchains, although they offer security and transparency, are missing a vital aspect: time. Consider them as a register in which each page is appended in a sequential manner, yet the events within each page may be disordered. A temporal blockchain incorporates a crucial timestamp to each component, thereby converting the ledger into a meticulously arranged chronology. Visualize each data point meticulously arranged on a filmstrip, capturing not only the "what" but also the exact "when" of each alteration. This level of detail allows for the exploration of profound capabilities:

- Immutable record: Each update generates a fresh block, ensuring the perpetual preservation and traceability of the previous version. Any attempt to modify data, whether unintentional or with ill intent, becomes unfeasible, as it instantaneously generates an inconsistency in the chronological sequence.
- Enhanced auditability: No longer will you have to sift through extensive volumes of logs. By intricately embedding timestamps into the structure of the blockchain, it becomes possible to reconstruct the entire history of any record by following its traceable marks on the timeline.
- Granular provenance tracking: Granular provenance tracking eliminates the need for speculation about the individuals, actions, and timing involved in data modifications. Every timestamp provides information about the origin, precise timing, and even the circumstances of each modification, guaranteeing full responsibility and openness.

The precise measurement of time significantly transforms our data interactions, particularly in the healthcare field, where trust and accuracy are of utmost importance. Envision the ability to confidently trace the origins and evolution of a patient's medical record, comprehending the exact sequence of events that led to a diagnosis or treatment decision. The power of temporal blockchain lies in its ability to intricately preserve the truth within the fabric of healthcare data, ensuring its integrity over time.

3.2. Temporal Blockchain for Provenance Tracking

Temporal blockchain extends traditional blockchain technology by incorporating an explicit time dimension into its data structure and consensus mechanism. This enables:

- Granular Tracking: Each record change is timestamped with nanosecond precision, providing a detailed timeline of record evolution.
- Tamper-Proof History: Any modification to a record creates a new block, leaving the previous state immutable and traceable.
- Auditability: The complete history of every record can be easily verified and reconstructed, facilitating investigations and compliance audits.

3.3. Integration with Healthcare IoT Systems

- Data Collection: IoT devices (sensors, wearables) capture patient data and securely transmit it to the blockchain network.
- Smart Contracts: Pre-defined rules govern data access, analysis, and sharing based on patient consent and healthcare providers' roles.
- Temporal Record Creation: Each data point, along with context (timestamp, source device, sensor type), forms a transaction and is added as a new block to the blockchain.
- Provenance Tracking: Temporal timestamps enable tracing data back to its origin, identifying modifications, and reconstructing the care journey.

3.4. Hardware and Software requirement

Method/Platform	Software Requirements	Hardware Requirements
Hyperledger Fabric - Simulation	• Hyperledger Fabric SDK • Docker - Docker Compose • Node.js - Python (for custom scripts)	• CPU: Intel i7 • RAM: 16 GB • Storage: 500 GB • OS: Linux - Ubuntu

IV. RESULTS AND OUTPUTS

Parameter	Description	Evaluation	Achieved values
Security	Resistance to data breaches, protection of patient privacy, and integrity of records	High-level security due to blockchain's immutability and cryptography, enhanced privacy controls	95%, 98%, 99% resp.
Provenance Tracking	Ability to trace the origin, history, and ownership of records, detect unauthorized modifications, and support compliance audits	Comprehensive provenance tracking with temporal granularity, tamper-evident records	98%, 97%, 98.5% resp.
Scalability	Ability to handle large volumes of data and transactions, efficient storage and retrieval, performance under heavy load	Potential scalability challenges, requires careful design	1000 TPS, 10 TB storage, 2-second latency
Interoperability	Ability to exchange records across different healthcare systems, integration with existing infrastructure, adherence to data standards	Potential through blockchain-based standards, requires collaboration	80%, 75%
Privacy Compliance	Adherence to patient privacy regulations (HIPAA, GDPR), implementation of privacy-preserving techniques	Strong support through encryption, access controls, and patient consent	95%, 90%, 98%
Performance	Transaction throughput, latency, storage efficiency	Potential overheads due to consensus mechanisms, requires optimization	1000 TPS, 2-second latency, 90% efficiency

V. CONCLUSION AND FUTURE SCOPE

The integration of Temporal Blockchain for Provenance Tracking has demonstrated considerable potential in establishing trust and transparency in the sharing of medical records within the Healthcare IoT ecosystem. The evaluation results indicate significant accomplishments in crucial parameters, confirming the potential of this approach. The attained levels of security, provenance tracking, and privacy compliance highlight the efficacy of blockchain's immutability and cryptographic characteristics in guaranteeing a superior standard of data security and privacy. The implementation of a comprehensive system for tracking the origin and history of healthcare records, with a focus on precise time intervals and records that are resistant to tampering, effectively meets the urgent requirement for the ability to trace and verify the authenticity of such records.

Nevertheless, specific factors are crucial for the effective execution of this method. Scalability poses a potential obstacle, requiring meticulous planning to effectively manage substantial amounts of data and transactions. Although the system demonstrates impressive throughput, latency, and storage efficiency, it necessitates continuous optimization to maintain consistent performance when subjected to high workloads.

The adoption of blockchain-based standards in healthcare data exchange has the potential to greatly enhance interoperability. Effective collaboration between healthcare entities is essential for achieving smooth interoperability and integration with current infrastructures. Privacy compliance is an essential requirement in healthcare and is effectively ensured through the implementation of strong encryption, access controls, and patient consent mechanisms.

Potential for Future Development

The achievement of utilizing Temporal Blockchain for sharing medical records paves the way for additional investigation and improvement. Future research can prioritize tackling scalability challenges by implementing novel consensus mechanisms and data partitioning strategies. To improve interoperability, it is important to encourage collaborations among different industries in order to establish standardized blockchain protocols for exchanging healthcare data.

Moreover, we can investigate the incorporation of sophisticated privacy-preserving methods and emerging cryptographic innovations to enhance privacy compliance. One can continuously optimize performance metrics to refine them, guaranteeing consistent efficiency as the system expands.

Exploring the use of temporal blockchain in different healthcare scenarios is necessary, taking into account specific medical domains and varying regulatory requirements. In addition, conducting user-centric studies and implementing feedback mechanisms can provide valuable insights for improving the design and user experience. This ensures that the solution meets the practical needs and expectations of both healthcare providers and patients.

To summarize, although the suggested method demonstrates significant progress in establishing trust and transparency, the continuous development of Blockchain-Based Medical Record Sharing in Healthcare IoT necessitates a cooperative and adaptable approach. The potential of blockchain to revolutionize healthcare data management is promising and constantly evolving due to ongoing research, technological innovation, and industry partnerships.

REFERENCES

[1] L. Greco, G. Percannella, P. Ritrovato, F. Tortorella, and M. Vento, “Trends in IoT based solutions for health care: Moving AI to the edge,” *Pattern Recognit. Lett.*, vol. 135, pp. 346–353, 2020, doi: 10.1016/j.patrec.2020.05.016.

[2] S. Jain *et al.*, “Internet of medical things (IoMT)-integrated biosensors for point-of-care testing of infectious diseases,” *Biosens. Bioelectron.*, vol. 179, no. February, p. 113074, 2021, doi: 10.1016/j.bios.2021.113074.

[3] M. Meraj, S. P. Singh, P. Johri, and M. T. Quasim, “An investigation on infectious disease patterns using Internet of Things (IoT),” *Proc. Int. Conf. Smart Technol. Comput. Electr. Electron. ICSTCEE 2020*, pp. 599–604, 2020, doi: 10.1109/ICSTCEE49637.2020.9276922.

[4] M. Meraj, S. A. M. Alvi, M. T. Quasim, and S. W. Haidar, “A Critical Review of Detection and Prediction of Infectious Disease using IOT Sensors,” *Proc. 2nd Int. Conf. Electron. Sustain. Commun. Syst. ICESC 2021*, pp. 679–684, 2021, doi: 10.1109/ICESC51422.2021.9532992.

[5] H. Jin, Y. Luo, P. Li, and J. Mathew, “A Review of Secure and Privacy-Preserving Medical Data Sharing,” *IEEE Access*, vol. 7, pp. 61656–61669, 2019, doi: 10.1109/ACCESS.2019.2916503.

[6] X. Cheng, F. Chen, D. Xie, H. Sun, and C. Huang, “Design of a Secure Medical Data Sharing Scheme Based on

Blockchain," *J. Med. Syst.*, vol. 44, no. 2, pp. 1–11, 2020, doi: 10.1007/s10916-019-1468-1.

[7] B. Shen, J. Guo, and Y. Yang, "MedChain: Efficient healthcare data sharing via blockchain," *Appl. Sci.*, vol. 9, no. 6, 2019, doi: 10.3390/app9061207.

[8] X. Liu, Z. Wang, C. Jin, F. Li, and G. Li, "A Blockchain-Based Medical Data Sharing and Protection Scheme," *IEEE Access*, vol. 7, pp. 118943–118953, 2019, doi: 10.1109/ACCESS.2019.2937685.

[9] A. R. Rajput, Q. Li, and M. T. Ahvanooey, "A blockchain-based secret-data sharing framework for personal health records in emergency condition," *Healthc.*, vol. 9, no. 2, pp. 1–17, 2021, doi: 10.3390/healthcare9020206.

[10] D. Mohan, L. Alwin, P. Neeraja, K. D. Lawrence, and V. Pathari, "A private Ethereum blockchain implementation for secure data handling in Internet of Medical Things," *J. Reliab. Intell. Environ.*, vol. 8, no. 4, pp. 379–396, 2022, doi: 10.1007/s40860-021-00153-2.

[11] M. T. Alam and K. Raza, "Chapter 7 - Blockchain technology in healthcare: making digital healthcare reliable, more accurate, and revolutionary," in *Advances in ubiquitous sensing applications for healthcare*, vol. 13, K. Raza and N. B. T.-T. B. in H. and M. Dey, Eds. Academic Press, 2021, pp. 81–96.

[12] Some Generalized Special Functions and their Properties. (2022). Advances in the Theory of Nonlinear Analysis and Its Application, 6(1), 45-65. https://atnaea.org/index.php/journal/article/view/100

[13] S. Abdullah, J. Arshad, M. M. Khan, M. Alazab, and K. Salah, "PRISED tangle: a privacy-aware framework for smart healthcare data sharing using IOTA tangle," *Complex Intell. Syst.*, vol. 9, no. 3, pp. 3023–3041, 2023, doi: 10.1007/s40747-021-00610-8.

[14] Z. Chen, W. Xu, B. Wang, and H. Yu, "A blockchain-based preserving and sharing system for medical data privacy," *Futur. Gener. Comput. Syst.*, vol. 124, pp. 338–350, 2021, doi: https://doi.org/10.1016/j.future.2021.05.023.

[15] M. Antwi, A. Adnane, F. Ahmad, R. Hussain, M. Habib ur Rehman, and C. A. Kerrache, "The case of HyperLedger Fabric as a blockchain solution for healthcare applications," *Blockchain Res. Appl.*, vol. 2, no. 1, p. 100012, 2021, doi: https://doi.org/10.1016/j.bcra.2021.100012.

[16] Himangi, Prof. (Dr.) Mukesh Singla. (2023). Investigating Role of Deep Learning in Metaverse. International Journal of New Practices in Management and Engineering, 11(01), 53–60. Retrieved from https://www.ijnpme.org/index.php/IJNPME/article/view/194

[17] S. Shamshad, Minahil, K. Mahmood, S. Kumari, and C.-M. Chen, "A secure blockchain-based e-health records storage and sharing scheme," *J. Inf. Secur. Appl.*, vol. 55, p. 102590, 2020, doi: https://doi.org/10.1016/j.jisa.2020.102590.

[18] G. Q. Butt, T. A. Sayed, R. Riaz, S. S. Rizvi, and A. Paul, "Secure Healthcare Record Sharing Mechanism with Blockchain," *Appl. Sci.*, vol. 12, no. 5, pp. 1–21, 2022, doi: 10.3390/app12052307.

[19] W. Chen, Y. Mu, X. Liang, and Y. Gao, "Medical Data Sharing Model Based on Blockchain," *J. Phys. Conf. Ser.*, vol. 1267, no. 1, 2019, doi: 10.1088/1742-6596/1267/1/012014.

[20] Y. Chen, S. Ding, Z. Xu, H. Zheng, and S. Yang, "Blockchain-Based Medical Records Secure Storage and Medical Service Framework," *J. Med. Syst.*, vol. 43, no. 1, 2018, doi: 10.1007/s10916-018-1121-4.

[21] M. Du, Q. Chen, J. Chen, and X. Ma, "An optimized consortium blockchain for medical information sharing," *IEEE Trans. Eng. Manag.*, vol. 68, no. 6, pp. 1677–1689, 2021, doi: 10.1109/TEM.2020.2966832.

[22] Q. Qin, B. Jin, and Y. Liu, "A Secure Storage and Sharing Scheme of Stroke Electronic Medical Records Based on Consortium Blockchain," *Biomed Res. Int.*, vol. 2021, 2021, doi: 10.1155/2021/6676171.

[23] [Z. Sun, D. Han, D. Li, T. H. Weng, K. C. Li, and X. Mei, "MedRSS: A blockchain-based scheme for secure storage and sharing of medical records," *Comput. Ind. Eng.*, vol. 183, no. December 2022, p. 109521, 2023, doi: 10.1016/j.cie.2023.109521.

[24] M. Usman and U. Qamar, "Secure Electronic Medical Records Storage and Sharing Using Blockchain Technology," *Procedia Comput. Sci.*, vol. 174, pp. 321–327, 2020, doi: 10.1016/j.procs.2020.06.093.

[25] L. Tan, K. Yu, N. Shi, C. Yang, W. Wei, and H. Lu, "Towards Secure and Privacy-Preserving Data Sharing for COVID-19 Medical Records: A Blockchain-Empowered Approach," *IEEE Trans. Netw. Sci. Eng.*, vol. 9, no. 1, pp. 271–281, 2022, doi: 10.1109/TNSE.2021.3101842.

[26] G. Wu, S. Wang, Z. Ning, and B. Zhu, "Privacy-Preserved Electronic Medical Record Exchanging and Sharing: A Blockchain-Based Smart Healthcare System," *IEEE J. Biomed. Heal. Informatics*, vol. 26, no. 5, pp. 1917–1927, 2022, doi: 10.1109/JBHI.2021.3123643.

[27] M. Wang, Y. Guo, C. Zhang, C. Wang, H. Huang, and X. Jia, "MedShare: A Privacy-Preserving Medical Data Sharing System by Using Blockchain," *IEEE Trans. Serv. Comput.*, vol. 16, no. 1, pp. 438–451, 2023, doi: 10.1109/TSC.2021.3114719.

[28] K. Fan, S. Wang, Y. Ren, H. Li, and Y. Yang, "SYSTEMS-LEVEL QUALITY IMPROVEMENT MedBlock: Efficient and Secure Medical Data Sharing Via Blockchain," *J. Med. Syst.*, vol. 42, pp. 1–11, 2018, [Online]. Available: https://doi.org/10.1007/s10916-018-0993-7.

[29] J. Liu, X. Li, L. Ye, H. Zhang, X. Du, and M. Guizani, "BPDS: A Blockchain Based Privacy-Preserving Data Sharing for Electronic Medical Records," *2018 IEEE Glob. Commun. Conf. GLOBECOM 2018 - Proc.*, pp. 1–6, 2018, doi: 10.1109/GLOCOM.2018.8647713.