Decentralized Personal E-Health ID Card in Sri Lankan Context using Blockchain

D.W.M.H. Wanasinghe and M.S. Shafana

Abstract In Sri Lanka, managing patient health information faces significant challenges due to centralized systems vulnerable to data breaches, inefficiencies, and record duplication. These issues hinder patient control over health information and complicate record sharing among healthcare providers, especially in emergencies. The research proposes a Decentralized e-healthcare ID Card utilizing Polygon blockchain technology to address these challenges. This system enhances the security, transparency, and immutability of health records, empowering patients with control over their medical data while allowing healthcare providers access to accurate information. Key benefits include improved data sharing, streamlined record management, and reduced administrative burdens, ultimately increasing healthcare efficiency. The proposed solution aims to modernize Sri Lanka's healthcare infrastructure, improve patient outcomes, and foster trust in the healthcare process. It also serves as a potential model for other developing countries, showcasing how blockchain can revolutionize the management and security of sensitive health information, ensuring a secure and patient-centric future for healthcare.

***Index Terms*— Decentralized, e-Healthcare, Blockchain, Digital Health, Data Privacy**

I. Introduction

THE study focuses on developing a Decentralized Personal e-healthcare ID Card using blockchain technology, specifically the Polygon blockchain, along with MetaMask for user interaction. This initiative addresses significant challenges in managing patient health information in Sri Lanka, where traditional centralized healthcare systems are plagued by inefficiencies, data breaches, and fragmented medical records that compromise patient care and trust. The reliance on paper-based records and inadequate digital infrastructure complicates the sharing of medical information among healthcare providers, particularly during emergencies. The research aims to create a secure, efficient, and patient-centric solution by leveraging blockchain's capabilities to enhance data integrity, privacy, and accessibility. Key objectives include designing a blockchain-based identification system that allows patients to control their medical records, ensuring the confidentiality of sensitive information, and facilitating seamless sharing of health data among providers. The scope encompasses various aspects of healthcare data management, focusing on security, privacy, and patient empowerment while addressing the need for improved efficiency in record management to reduce administrative burdens and eliminate duplicate records. However, the study acknowledges potential challenges, such as integrating blockchain with existing systems, resource requirements, scalability concerns, regulatory barriers, and the need for workforce training. Building trust among patients and healthcare providers is also crucial for successful implementation. The literature review of this paper examines existing research on e-healthcare systems and identifies knowledge gaps; the methodology describes the research design, blockchain selection (Polygon), MetaMask integration, data collection, and ethical considerations; the system design and implementation chapter details the architecture and integration of the decentralized e-healthcare ID card; and the findings and discussion chapter analyzes the system's effectiveness in enhancing data security and patient empowerment. The final chapter summarizes the findings, discusses implications for healthcare data management, and offers recommendations for future research and practical applications. Ultimately, this research aims to modernize healthcare data management in Sri Lanka, improving patient outcomes and establishing a model for other developing countries.

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II. Literature Review

A. Review Stage

The study [1] by Omar Ali et al. examines blockchain technology's benefits, challenges, and functionalities across various sectors, categorizing them into informational, technological, economic, organizational, and strategic aspects. It highlights functionalities like point-to-point transmission, data ownership, and transaction processing.

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Due to its decentralized nature, blockchain technology is gaining prominence in finance and social services. However, it is vulnerable to attacks. Arunima Ghosh et al. explore blockchain's taxonomies, transaction processing, consensus protocols, smart contracts, and forks. They discuss real-world applications, platforms like Hyperledger and Multichain, and emerging vulnerabilities related to Bitcoin and Ethereum attacks. The authors [2] also discuss defensive methodologies and future blockchain trends.

Agbo et al.'s [3] systematic review of blockchain technology applications in healthcare highlights the growing research but lack of prototype implementations and effectiveness studies. The review emphasizes the need for further investigation to better understand and evaluate blockchain's utility in healthcare.

Hayder Albayati et al.'s [4] paper explores blockchain technology usability and consumer intentions towards cryptocurrency transactions. They propose an integrated model combining TAM with external variables and conduct surveys among international users to understand their impact on adoption.

Ashok Gupta et al.'s [5] paper discusses integrating blockchain technology into cloud computing to address security concerns, highlighting its potential to improve integrity, authenticity, and confidentiality in cloud environments.

Aaron Wright and Primavera De Filippi's [6] article explores the potential of blockchain technology in decentralizing data storage and information management and reducing intermediaries' role in society. They introduce "Lex Cryptographia," a new legal framework for smart contracts and decentralized organizations.

Sharma and Jain's paper [7] discusses blockchain technology, its consensus algorithms, and their functions. It also discusses security and performance challenges and reviews the advantages and broader applications of blockchain technology.

The paper [8] by Mohammad Hashemi Joo et al. explores the applications of blockchain technology in finance, focusing on payment systems. They highlight cryptocurrency as the most significant application, with future growth requiring increased familiarity, trust, and legislative changes.

Jaideep Ghosh [9] discusses blockchain's potential to revolutionize financial services and healthcare industries. However, academic research in IS and IT has not kept pace. The authors suggest a comprehensive framework for studying public and private blockchain applications, focusing on sociocultural impacts, trust behaviors, IoT applications, and legal issues.

Sheping Zhai et al.'s [10] paper explores blockchain as a decentralized, secure application model that combines distributed data storage, peer-to-peer transmission, consensus mechanisms, and digital encryption technologies. The authors discuss the infrastructure, encryption principles, and existing security issues while suggesting future research directions.

The study by Namasudra et al. [11] highlights the importance of blockchain technology in enhancing data security in the IT landscape. It discusses its decentralization, immutability, transparency properties, applications in healthcare, digital voting, and IoT and outlines future research directions and challenges.

Maxime C. Cohen's [12] paper explores the transformative impact of big data on service industries like finance, transportation, hospitality, and online platforms. It highlights the mechanisms leveraging hidden information, risks, and pitfalls, including potential misuse, cybersecurity issues, and potential price discrimination, while highlighting the potential for highly personalized offerings.

Jeiyoung Lee's [13] article explores the transformative potential of blockchain technology, particularly as the foundation of Bitcoin, in creating a new economic system. It highlights its enhanced information security and transparency, fostering a token economy and establishing new business models, potentially leading to a new economic paradigm.

Golosova and Romanovs' paper [14] explores the potential of blockchain technology in addressing trust, transparency, security, and data processing reliability issues in various industries. They analyze its practical implications, success factors, and challenges in various sectors, evaluating its convenience and difficulties.

Islam et al.'s [15] study introduces a hybrid model combining LSTM and GRU units with secure multi-party computation and differential privacy techniques to improve supply chain management transparency, security, and efficiency. The model achieves an accuracy of 0.95, balancing privacy and data utility.

The study by Bakh et al. [16] explores the use of machine learning and blockchain technology to improve healthcare data management. Machine learning extracts relevant information from vast datasets, while blockchain enhances data exchange reliability and interoperability. This secure foundation is gaining traction in healthcare, supply chain management, and government agencies.

Shobana and Suguna [17] discuss blockchain's decentralized data storage and processing challenges, proposing a healthcare system combining blockchain with identity management for insurance transfers and social media networks.

Blockchain technology, developed by Nakamoto [18] in 2008, offers security, scalability, and efficiency improvements in various sectors. Demand for new techniques in India has led to industries adopting BC for growth.

The rapid growth of electronic health records (EHRs) [19] has increased demand for clinical decision support systems, but challenges like data breaches and thefts persist. Blockchain technology offers a solution, with deep learning techniques and cryptographic authentication improving security.

The healthcare industry is transforming with innovative blockchain technology, enabling secure patient data coordination and pre-approved constraints. This paper [20] proposes smart contract technology to facilitate access to healthcare records for patients and system users.

The paper [21] by R. Abid et al. discusses the potential of blockchain technology in improving the security and efficiency of sharing medical records in healthcare. It suggests that blockchain's decentralized framework can ensure patient data remains confidential and tamper-proof but also faces challenges like interoperability and regulatory compliance. Blockchain has

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numerous benefits and applications, but there is a need for empirical studies to validate these claims across various sectors. Existing literature often lacks concrete evidence of successful implementations in diverse fields, and other industries' unique challenges and opportunities should be explored.

Challenges and limitations include a critical gap in the literature regarding prototype implementations of blockchain in healthcare, a lack of practical case studies, and a lack of comprehensive surveys that capture diverse demographic insights. Future research should focus on understanding consumer acceptance and behavioral factors to foster wider adoption of blockchain technologies.

Security and vulnerabilities are also a concern, and there is a lack of comprehensive surveys that encompass both application and technical perspectives. Further exploration of security frameworks and their effectiveness against emerging threats is needed.

Integration with existing technologies, such as cloud computing, is also a concern, but case studies demonstrating successful implementations and lessons learned from those experiences could greatly benefit the research.

Regulatory and legal frameworks need further exploration to accommodate decentralized systems and foster innovation. Future research should focus on developing frameworks that leverage blockchain technology to address the challenges posed by big data and ensure secure and efficient data management.

III. Methodology

The Methodology chapter outlines the structured approach taken to achieving the research objectives of developing a blockchain-based e-healthcare ID system for secure and decentralized health data management. The methodology is divided into several key steps. The diagram Fig 1 below shows how the objectives are met.

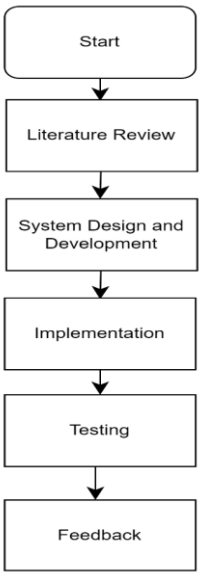

Fig. 1: Research Workflow

A literature review of existing healthcare systems and blockchain technology identified data security, privacy, and interoperability gaps. The research proposed a decentralized system architecture using the Polygon network, ensuring secure storage, sharing, and patient data access. The system was implemented using smart contracts and encryption algorithms and underwent rigorous testing for performance. Feedback from healthcare professionals and technical evaluations was collected to evaluate the system's effectiveness and identify areas for improvement.

A. System Design

The proposed system aims to create a decentralized application (dApp) for accessing and managing medical information using the Polygon network, leveraging MetaMask for user authentication and interaction.

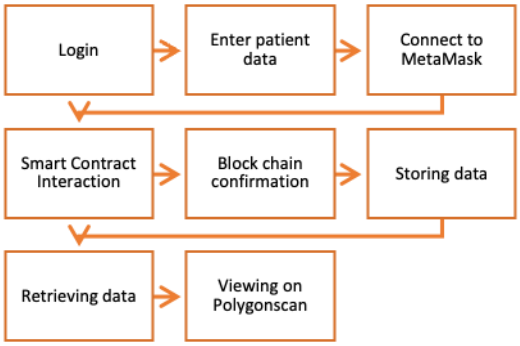

Fig. 2: System Architecture

The architecture diagram Fig. 2 outlines the flow of the blockchain-based e-healthcare ID system designed for secure management of health records using the Polygon network. This system leverages the Polygon network and MetaMask capabilities to create a secure, efficient, and user-friendly platform for accessing medical information. By prioritizing user control and data security, the proposed solution addresses key challenges in healthcare data management while harnessing the benefits of blockchain technology.

Login System

i. The process begins with a user logging into the system. Only authenticated personnel (like healthcare providers) can access patient data. The login system validates credentials and manages access control

ii. Entering Patient Data: After logging in, the user can input the necessary patient data into the system. This can include personal information, medical history, diagnoses, treatments, etc. The inputted data is structured in a format compatible with the blockchain storage protocol.

Connect to MetaMask

MetaMask is a browser-based crypto wallet that allows interaction with blockchain networks. Once the patient data is

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ready, the system connects to MetaMask. MetaMask facilitates secure communication between the local machine and the Polygon blockchain. The user signs the transaction via MetaMask, which ensures that only authorized individuals can push or pull data from the blockchain.

Smart Contract Interaction

After establishing the MetaMask connection, the system interacts with the smart contract deployed on the Polygon blockchain. Smart contracts are self-executing pieces of code that define how data will be stored, retrieved, and validated on the blockchain. The smart contract facilitates data storage and confirms that all actions follow predefined rules.

Blockchain Confirmation

Once the smart contract processes the transaction, the blockchain network validates and confirms it. This step ensures that the data is securely stored and immutable once it is written to the blockchain. Blockchain confirmation is essential for establishing trust and transparency, ensuring patient data cannot be altered without proper authorization.

Viewing on Polygons can

Polygonscan is a blockchain explorer that provides insights into transactions and data stored on the Polygon network. After blockchain confirmation, users can view the transaction and data status on Polygonscan. This adds another layer of transparency, allowing authorized parties to verify that the patient's data has been securely stored.

Retrieving Data

When data retrieval is necessary (e.g., to access patient history), the process begins with a request initiated through the smart contract. The user interacts with MetaMask to authenticate and confirm the retrieval action. The smart contract then queries the blockchain, ensuring that the requested data is fetched in a secure, traceable manner. This data can be viewed either locally or via tools like Polygonscan.

Storing the data

Data storage involves taking the structured patient data and pushing it to the blockchain. The smart contract verifies that all input conditions are met before committing the data to the Polygon network. The user is notified once the storage operation is complete, and the data becomes available for future retrieval.

B. Testing

A usability test involving 20 healthcare providers evaluated the effectiveness of a medical information management system integrated with MetaMask and the Polygon network. 90% of users successfully logged in, but many needed additional guidance. 85% could input patient data but requested more predefined fields and a "save as draft" feature. Intelligent contract interaction was successful, but users needed more explicit instructions about transaction costs. Data retrieval was successful, but users wanted a more intuitive search function.

IV. Results and Discussion

Our decentralized e-healthcare ID system, built on blockchain technology, has provided a trustworthy way to safely manage and share medical data. The approach protects privacy and restricts access to authorised healthcare providers by giving patients authority over their medical records. Many consumers gain from this protection, but the system's ability to operate with current healthcare frameworks also makes it easier for providers to share data.

During usability testing with 20 healthcare providers, 90% of users successfully logged in; however, some needed extra guidance for the authentication process. Although feedback indicated that more predefined fields and a "save as draft" option would improve usability, about 85% of users were able to enter patient data. Although interacting with smart contracts was successful, many users asked for more precise instructions regarding transaction charges. Although the system's data retrieval features worked well, several users thought that for better experience a user-friendly search engine could be included.

It has been guaranteed confidentiality and integrity of health data by encryption and consensus techniques. The management of Patient record without manual procedures and unnecessary paperwork is streamlined by these methods, which also lessen administrative burdens and eliminate duplication. The technology improves the entire delivery of healthcare services with the centralised repository.

The medical sector in Sri Lanka benefits greatly from our blockchain-based system, especially when contrasted with the current centralised solutions. The system offers robust protection for sensitive medical data due to the tamper-proof construction and resistance to data breaches. The ability of the patient to control access to their medical records is another factor contributing to the increased need for our patient-centered healthcare approaches. Telemedicine's global accessibility makes it conceivable, and our system is especially good for rural areas which has poor healthcare infrastructure.

The approach has obvious long-term advantages for Sri Lanka's healthcare industry, despite some barriers including the requirement for technical know-how and limited infrastructure. Usability input indicated areas that needed work, such making features and instructions simpler, although these changes might hasten uptake. The healthcare sector could be enhanced through this kind of blockchain-based approach if it is having a proper design. It would improve the security of health information systems across the country and address inefficiencies.

This blockchain-based system aligns with Sri Lanka's legal and ethical frameworks by ensuring compliance with data protection and privacy regulations, such as those outlined in the Personal Data Protection Act. Its patient-centric design supports ethical principles by giving individuals full control over their medical records, reinforcing informed consent and data ownership rights. Additionally, the system’s tamper-proof and transparent

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architecture promotes accountability, meeting ethical standards for secure and trustworthy handling of sensitive health information. These features position the system as a solution that respects both legal mandates and patient rights in Sri Lanka.

V. CONCLUSION

Increased productivity, improved data interchange, and improved security are just a few advantages of implementing our blockchain-based solution for the Sri Lankan medical industry. Blockchain technology keeps patient health records safe and irreversible by preventing unwanted changes. Additionally, it makes data sharing with MetaMask easier, increasing productivity and guaranteeing prompt access to correct medical records. The technology reduces administrative load and improves treatment quality by making patient record management simpler. MetaMask with the Polygon network offers a scalable and affordable data transaction solution. This forward-thinking approach positions the healthcare sector for future advancement.

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