Journal of Engineering, Science and Technology
ISSN: 2714-2396, Volume 7 Issue 1

A BLOCKCHAIN-BASED APPROACH TO DECENTRALIZED MEDICAL MANAGEMENT

T.T. Oyetayo [1], M.O Ayinde [2], K.O Jimoh[3] and E.M Osundina[4]

1,2,3 Department of Computer Science, Faculty of Computing and Information Technology, Osun State University, Osogbo, Nigeria.
4 Department of Electrical Electronics Engineering, University of Calabar, Cross River, Nigeria.

Received Date: 14th April, 2024 Accepted Date: 13th June 2024 Published Date: 15th Sept., 2024

ABSTRACT

Medical record management and security are crucial in today's healthcare system. Traditional approaches, such as manual paper-based recordkeeping and complicated electronic health records (EHRs), have enhanced data organisation, storage, and retrieval. However, these systems confront considerable hurdles, including data security vulnerabilities, inefficient data exchange protocols, and limited patient control over their health information. These concerns can lead to unauthorised access, data breaches, and poor coordination among healthcare professionals, jeopardising patient care. Blockchain technology, a decentralised and distributed ledger system noted for its immutability, transparency, and cryptographic security, presents a viable solution to these long-standing issues. This paper investigates the feasibility of incorporating blockchain technology into healthcare systems to address these concerns. Blockchain assures that data cannot be altered or destroyed without detection, addressing the security and integrity concerns associated with traditional EHR systems. Blockchain is a tamper-proof and transparent platform for handling medical data since it records and verifies transactions using consensus processes and cryptographic algorithms. The study aimed to create a blockchain-based platform to improve data security, interoperability, and patient involvement through a user-centred approach. The solution uses smart contracts to automate consent management and data sharing, giving patients precise control over who can access their medical information and under what conditions. Unified Modeling Language (UML) diagrams, including system architecture, use cases, and activity diagrams, were developed to illustrate the system's design and functionality. These diagrams provide a comprehensive system workflow overview, highlighting how patients and healthcare providers interact within the decentralised framework. Hyperledger Fabric's modular architecture and confidentiality features make it an ideal choice for this application, facilitating secure data sharing among authorised parties through smart contracts and consensus mechanisms.

Keywords: Blockchain, Electronic Health Records, Data Security, Hyperledger Fabric, permissioned blockchain

1. INTRODUCTION

Medical record management and security are essential in today's constantly evolving healthcare environment. Traditional medical management methods, from manual paper-based documentation to complex electronic health record (EHR) systems, have substantially improved medical data organisation, storage, and retrieval [1]. However, these systems have ongoing issues, such as data security flaws, inefficient data sharing procedures [2], and restricted patient control over their own health information. The introduction of blockchain technology presents a viable answer to these crucial concerns. Blockchain, a decentralized and distributed ledger

system, is known for its immutability, transparency, and cryptographic security [3][4]. Blockchain technology assures that data cannot be edited or deleted without detection since it records and verifies transactions using consensus mechanisms and cryptographic algorithms detection [5]. This fundamental characteristic addresses the security and integrity issues that plague traditional EHR systems [6].

In a traditional EHR system, data is frequently centralized, making it a tempting target for cyberattack. Breaches can result in illegal access, data alteration, and serious privacy problems. Furthermore, data concentration might lead to inefficiencies in information sharing, preventing healthcare practitioners from coordinating care seamlessly. Patients typically have limited control over their medical data, undermining their ability to actively participate in their healthcare decisions [7]. Recent research has investigated how blockchain technology might be integrated into healthcare systems to address these restrictions. [8] proved the feasibility of leveraging blockchain to create safe and interoperable EHRs by providing a system that protects privacy, accountability, and transparency. Their research found that blockchain technology might greatly improve the confidentiality and privacy of medical records, minimize administrative constraints, and enable patient-centered care. [9] used a blockchain-based system with Hyperledger Fabric and Docker containers to securely manage patient consent and data exchange. Their findings showed that such a system might effectively secure patient privacy while allowing for efficient data sharing among authorized parties.

Recent studies have explored the integration of blockchain technology into healthcare systems to overcome these limitations. [8] demonstrated the feasibility of using blockchain for secure and interoperable EHRs, proposing a system that ensures privacy, accountability, and transparency. Their study showed that blockchain could significantly enhance the security and privacy of medical records, reduce administrative burdens, and enable patient-centered healthcare. Another study by [9] implemented a blockchain-based framework using Hyperledger Fabric and Docker containers to manage patient consent and data sharing securely. Their results indicated that such a system could effectively protect patient privacy while facilitating efficient data sharing among authorized parties.[10] developed a blockchain-based EHR system to improve data security and interoperability. Their research highlighted the potential of blockchain to provide a decentralized solution that not only secures patient data but also promotes seamless access to medical records across different healthcare providers. [11] reviewed various blockchain applications in healthcare, emphasizing its potential to enhance data security, interoperability, and patient engagement. They noted that blockchain could address many of the existing challenges in EHR systems by providing a tamper-proof and transparent platform for managing medical data.

These research work underscore the growing recognition of blockchain's potential to revolutionize healthcare management. By leveraging blockchain technology, healthcare systems can achieve a higher level of data security, interoperability, and patient empowerment, ultimately leading to more efficient and effective care delivery [12][13]. Despite these advancements, there is still a need for a comprehensive, user-friendly solution that integrates blockchain technology into medical management [14] in a way that is accessible to both patients and healthcare providers. This paper addressed gap by developing a blockchain-based platform that not only secures medical records but also enhances data interoperability and patient engagement through a user-centric design. The system leverages smart contracts to automate consent management and data sharing, ensuring that patients have granular control over who can access their medical information and under what conditions. The platform also employs advanced encryption

techniques to safeguard patient data further, setting a new standard for security and privacy in medical management systems.

2. METHODOLOGY

2.1. System Architecture

The system architecture is a three-tier architecture consisting of an application layer, a network layer, and a blockchain layer. his architecture ensures secure, private, and efficient management of medical data.

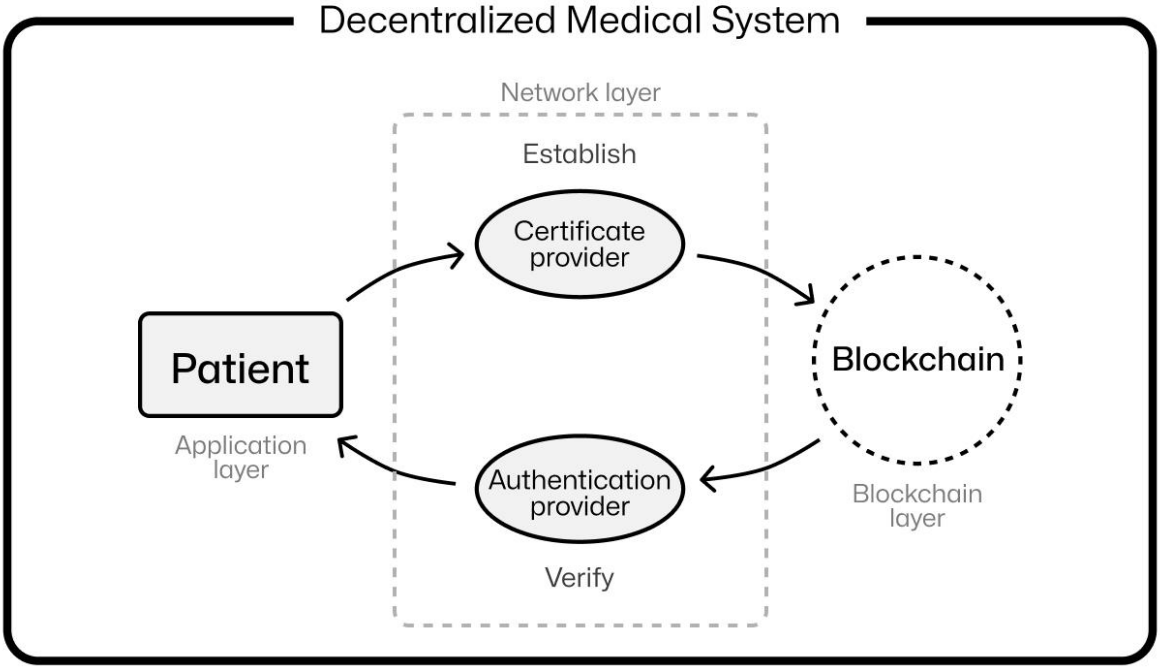

Figure 1: System Architecture Diagram for Decentralized Medical Management

i. **Application layer**: This layer represents the end-users of the system, which includes patients who will interact with the decentralized medical system to manage and access their medical records.
ii. **Network layer**: This layer is responsible for establishing secure communication by issuing digital certificates to verify the identities of the entities (e.g., patients, healthcare providers) interacting with the
iii. system. This layer ensures that only authenticated users can access the blockchain network. This layer ensures that all parties have access to the same copy of the patient data.
iv. **Blockchain layer:** This layer is where the patient data is stored. The blockchain is a distributed ledger that is tamper-proof and immutable. This means that patient data cannot be altered or deleted without the consent of all parties involved.

2.2. Blockchain Platform

This project employs Hyperledger Fabric, a permissioned blockchain technology

developed for enterprise use cases Its modular architecture enables customization to meet specific needs, and its emphasis on confidentiality is well aligned with our requirement for secure data sharing among authorized parties. Clients communicate with peers on the Hyperledger Fabric network, who keep a copy of the distributed ledger and conduct transactions using smart contracts (chaincode). These smart contracts specify the rules for processing transactions and modifying the ledger's state. An orderer service, which uses a pluggable consensus mechanism, maintains consensus on the order in which transactions are added to the ledger, ensuring data consistency and immutability. This secure and transparent platform serves as a solid foundation for our application, providing secure data sharing, tamper-proof record keeping, and faster cooperation among authorized parties.

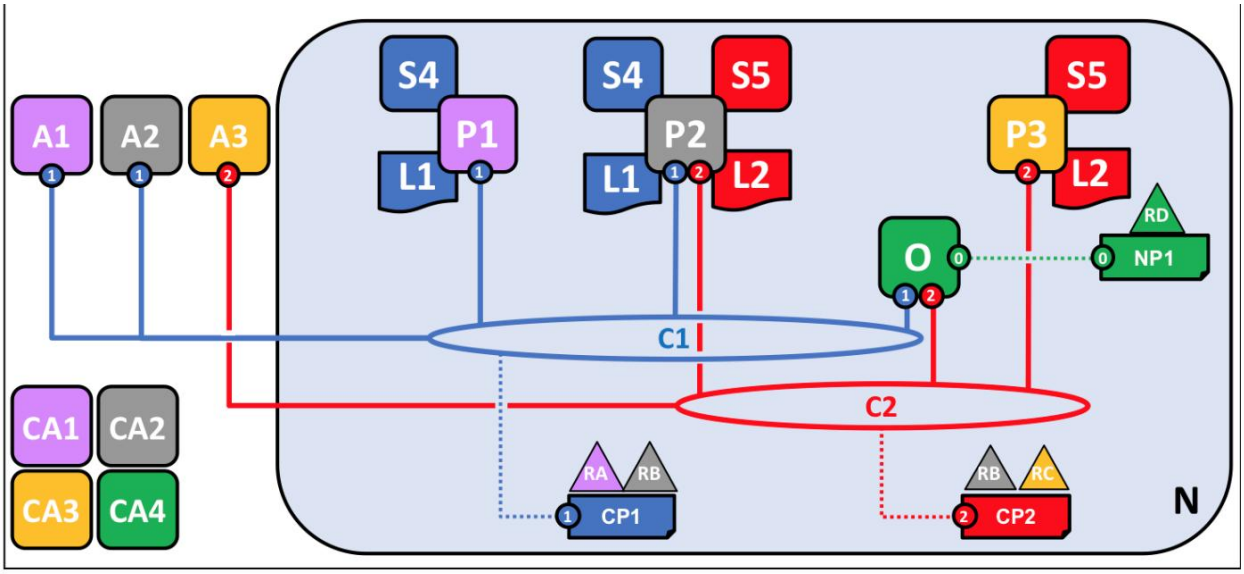

Figure 2: Hyperledger Fabric Network Diagram for Decentralized Medical Management

This decentralized medical management system leverages a Hyperledger Fabric network (denoted as N) to securely manage and share patient medical data. The network operates under a predefined network policy (NP1) and utilizes an ordering service (O) to ensure transaction ordering consensus. Within the network, a dedicated channel, Channel C1, is established specifically for medical data management. This channel is governed by its own channel policy (CP1), ensuring granular control over access and permissions. Channel C1 is created by a consortium of authorized healthcare organizations represented by RARB.

For secure and efficient communication within Channel C1, designated entities are granted permission to participate. These entities include:

- **Ordering Service (O):** Manages the ordering and sequencing of transactions within the channel.
- **Peers (P1 and P2):** These nodes maintain copies of the channel's ledger (L1 for C1 and potentially L2 for another channel C2). Peers also execute relevant smart contracts (chaincode) to process transactions on the channel. In this scenario, Peer P2 utilizes chaincode S4 and S5 for medical data management tasks.
- **Client Applications (A1 and A2):** These applications represent authorized participants that can initiate transactions on the channel. Within the Hyperledger Fabric network, authorized participants interact through client applications (A1 and A2). These applications act as interfaces for authorized entities to initiate transactions on Channel C1.

The specific functionalities of these applications will depend on the roles and permissions assigned within the channel policy (CP1).

- **A1 applications** could represent interfaces for patients to interact with the network. These applications would enable patients to manage their medical data according to the defined permissions.
- **A2 applications** could represent interfaces for healthcare providers or other authorized entities. These applications would allow authorized personnel to access and potentially update patient data relevant to their role and following the channel's access control policies.

2.3 System Design

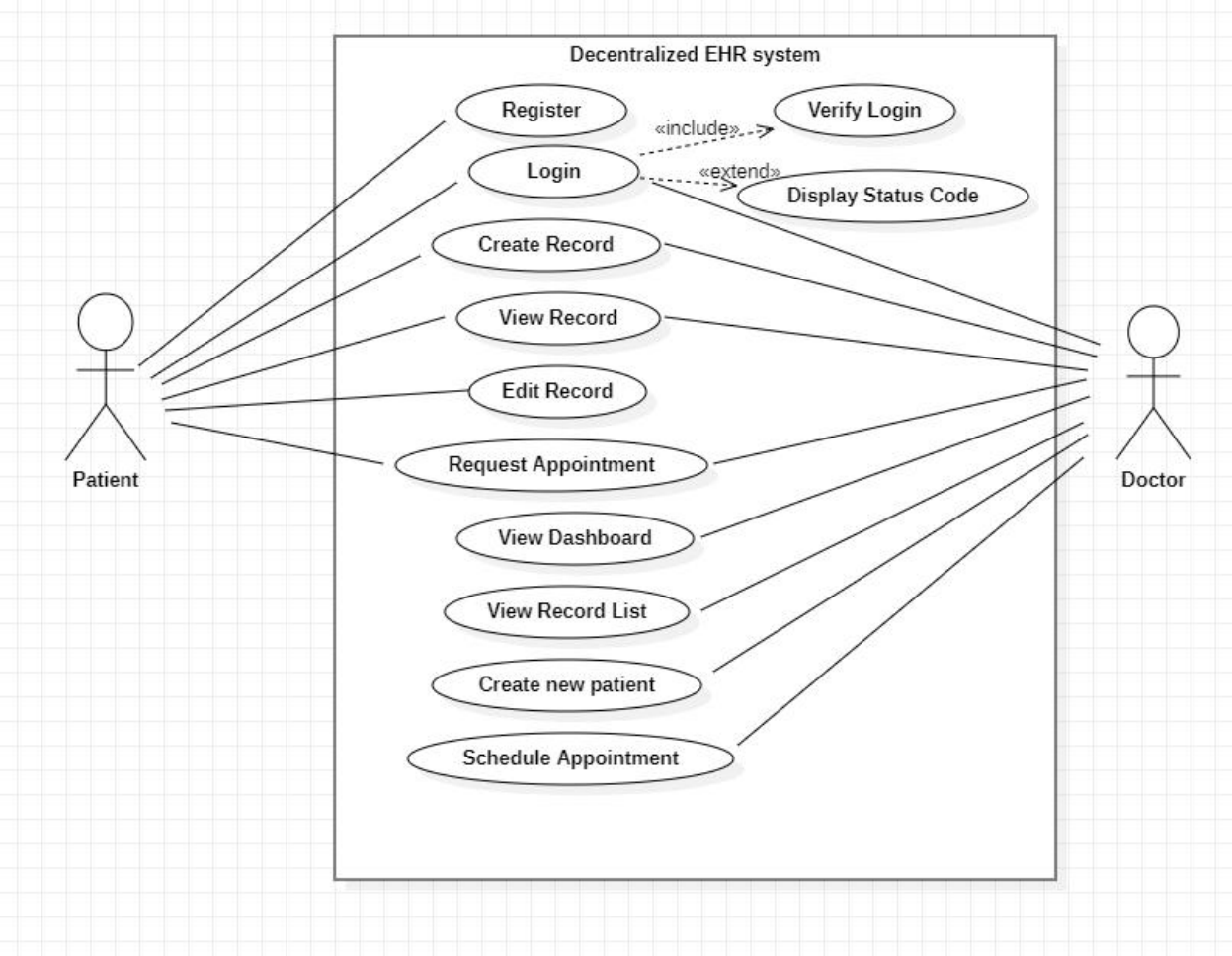

Figure 3: Use Case diagram for a medical decentralized system

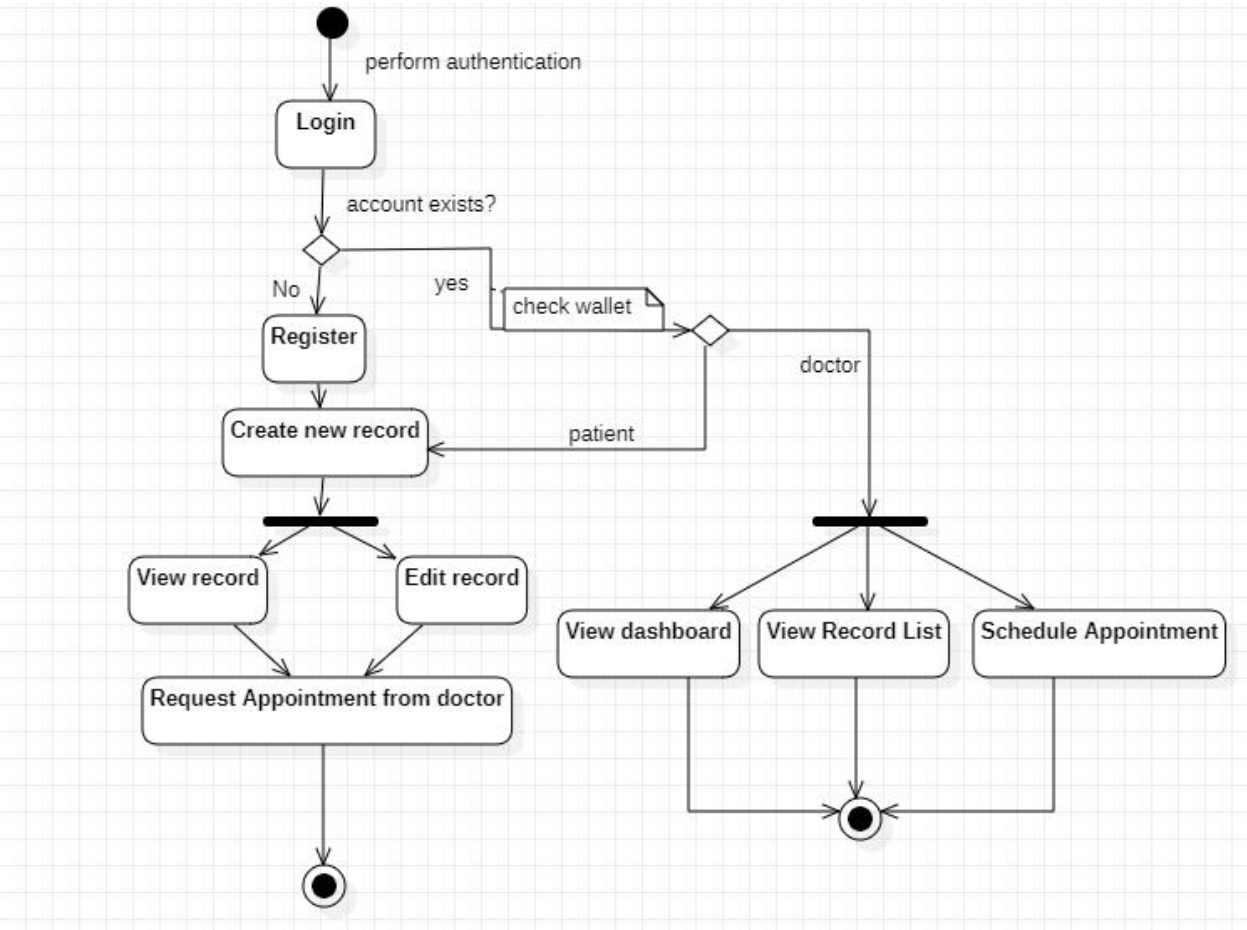

Figure 4: Activity Diagram

2.4 **Smart Contract Development**

3. RESULTS AND DISCUSSION

THE HOME PAGE

This is the homepage of the website. Patients can create an account in the system by clicking on the register button or login with their metamask wallet by clicking the connect wallet button if they already have an account. Doctors can also log into the system by clicking the '**connect wallet**' button.

THE PATIENTS PROFILE

This is the page of the website visible only to a patient after he/she has logged into the system successfully. The patient can view his/her medical records by clicking on the **record list** button. The patient can edit his/her record by clicking on the edit profile that pops up in the **Patient** Dropdown button. A patient can also view his or her details, such as: Weight, Blood group, Date of Birth on the page. The details that have been registered on the system by the admin.

THE ADMINS DASHBOARD

The admin dashboard displays comprehensive system data, including the total number of registered patients and doctors, the count of appointments, and metrics on appointment growth month-over-month.

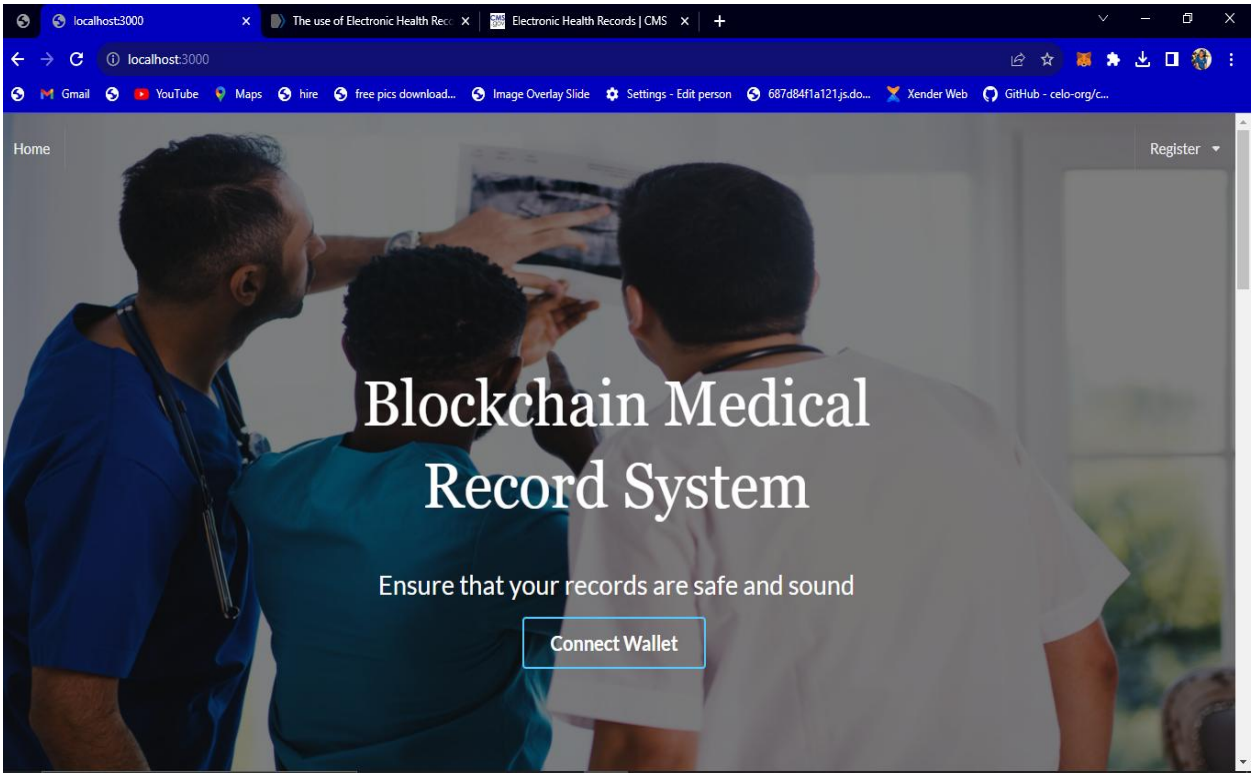

Figure 5: Home page of the Medical Decentralized Application

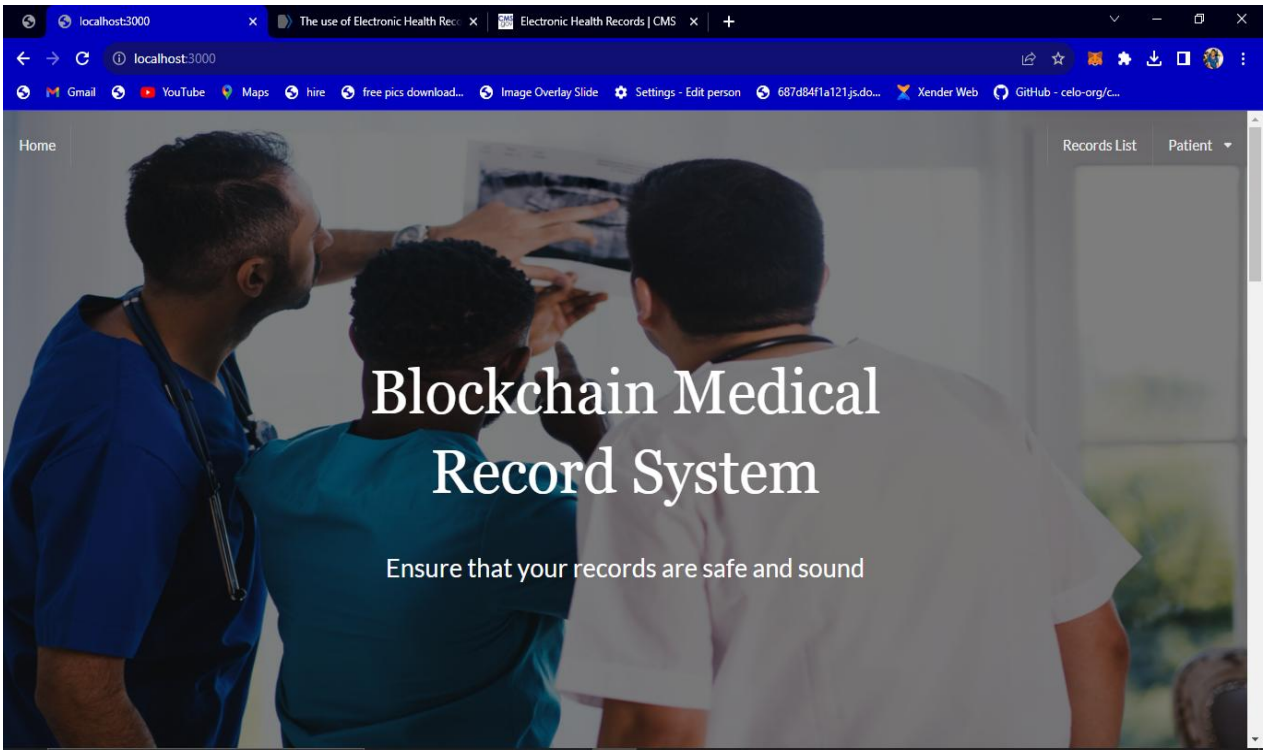

Figure 6 : Patient Profile activity of the cloth recommendation application

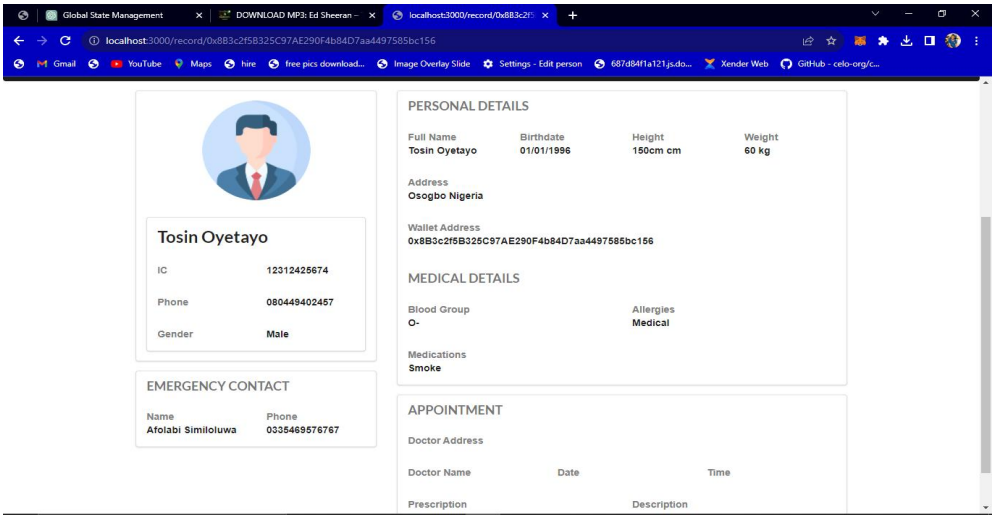

Figure 7: Patient Profile of the Decentralize medical application

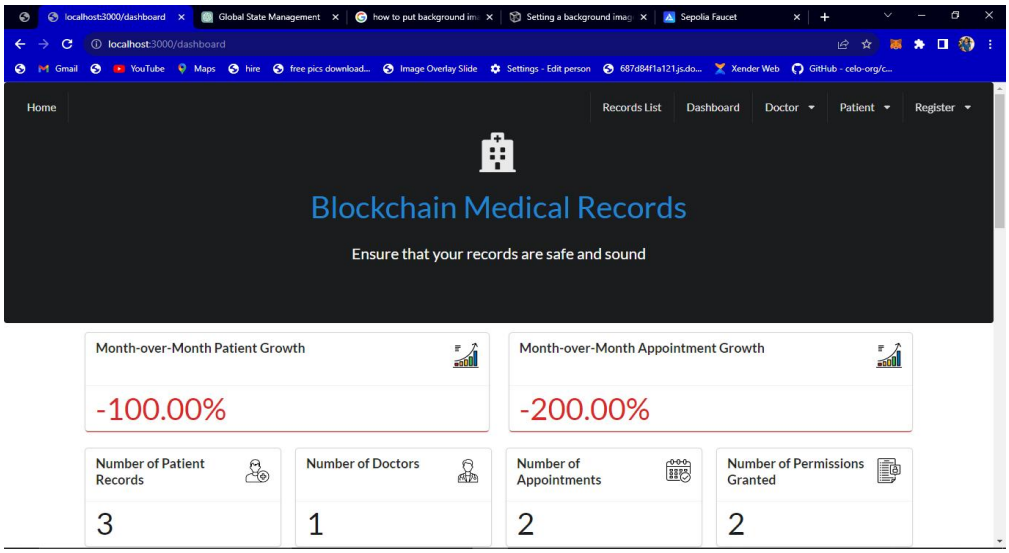

Figure 8: Dashboard of the Decentralize medical application

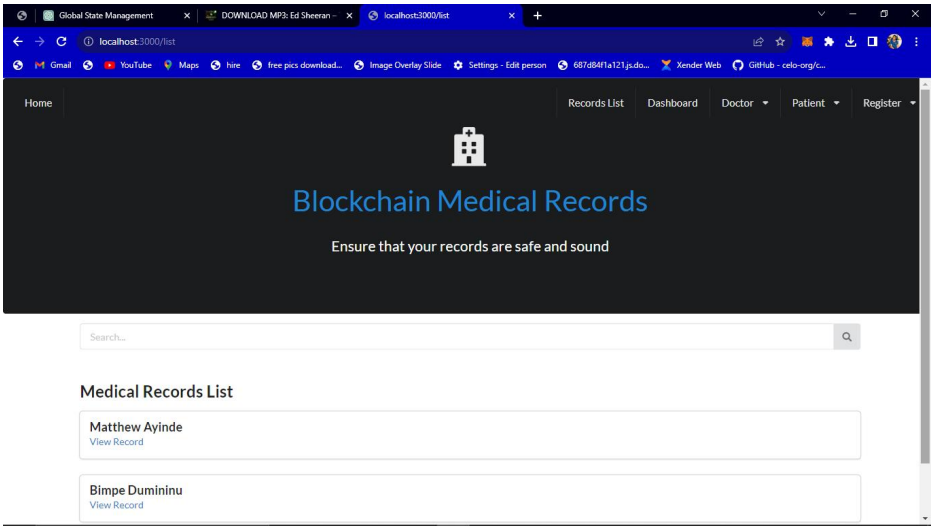

Figure 9: Patient List of the Decentralize medical application

DOCTOR PROFILE

This page shows the profile of a doctor registered on the system. It shows the essential and personal details of the doctor such as his/her educational details, phone number, and Birthdate.

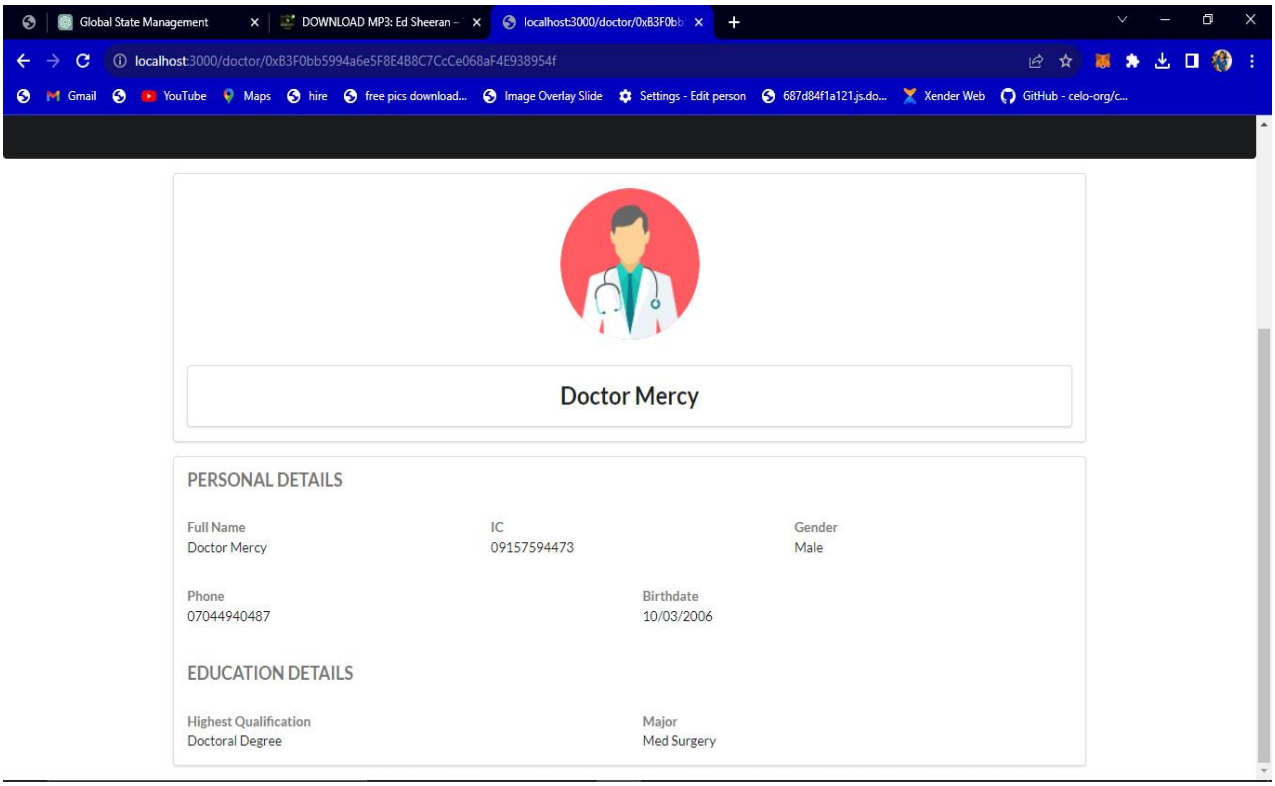

Figure 10: Doctor's Profile of the Decentralize Medical Application

4. CONCLUSION

The decentralised medical management system described in this paper leverages blockchain technology to provide a secure and efficient solution for handling medical data. The system ensures the integrity, privacy, and immutability of patient data by employing a three-tier architecture that includes an application layer, network layer, and blockchain layer. The use of Hyperledger Fabric's modular and confidential platform enables secure data sharing among authorised parties through smart contracts and consensus mechanisms. The system's design, illustrated through UML diagrams, demonstrates the effective interaction between patients and healthcare providers within the decentralized framework. This innovative approach promises to enhance data integrity, privacy, and operational efficiency in healthcare settings.

REFERENCES

[1] Al Mamun, A., Azam, S. and Gritti, C., 2022. Blockchain-based electronic health records management: a comprehensive review and future research direction. *IEEE Access*, *10*, pp.5768-5789.

[2] Subashini, S. and Kavitha, V., 2011. A survey on security issues in service delivery models of cloud computing. *Journal of network and computer applications*, *34*(1), pp.1-11.

[3] Yap, K.Y., Chin, H.H. and Klemeš, J.J., 2023. Blockchain technology for distributed generation: A review of current development, challenges and future prospect. *Renewable and Sustainable Energy Reviews*, *175*, p.113170.
[4] Arora, P. and Nagpal, R., 2022, May. Blockchain technology and its applications: a systematic review of the literature. In *Proceedings of the International Conference on Innovative Computing & Communication (ICICC)*.
[5] Leng, J., Zhou, M., Zhao, J.L., Huang, Y. and Bian, Y., 2020. Blockchain security: A survey of techniques and research directions. *IEEE Transactions on Services Computing*, *15*(4), pp.2490-2510.
[6] Keshta, I. and Odeh, A., 2021. Security and privacy of electronic health records: Concerns and challenges. *Egyptian Informatics Journal*, *22*(2), pp.177-183.
[7] Menon, S., Entwistle, V.A., Campbell, A.V. and Van Delden, J.J., 2020. Some unresolved ethical challenges in healthcare decision-making: navigating family involvement. *Asian Bioethics Review*, *12*, pp.27-36.
[8] Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. (2016). MedRec: Using Blockchain for Medical Data Access and Permission Management. In *Proceedings of the 2nd International Conference on Open and Big Data*.
[9] Dubovitskaya, A., Xu, Z., Ryu, S., Schumacher, M., & Wang, F. (2017). Secure and Trustable Electronic Medical Records Sharing using Blockchain. *AMIA Annual Symposium Proceedings*, 2017, 650-659.
[10] Xia, Q., Sifah, E. B., Asamoah, K. O., Gao, J., Du, X., & Guizani, M. (2017). MeDShare: Trust-Less Medical Data Sharing among Cloud Service Providers via Blockchain. *IEEE Access*, 5, 14757-14767.
[11] Agbo, C. C., Mahmoud, Q. H., & Eklund, J. M. (2019). Blockchain Technology in Healthcare: A Systematic Review. *Healthcare*, 7(2), 56.
[12] Abbate, S., Centobelli, P., Cerchione, R., Oropallo, E. and Riccio, E., 2022. Blockchain technology for embracing healthcare 4.0. *IEEE Transactions on Engineering Management*, *70*(8), pp.2998-3009.
[13] Gohar, A.N., Abdelmawgoud, S.A. and Farhan, M.S., 2022. A patient-centric healthcare framework reference architecture for better semantic interoperability based on blockchain, cloud, and IoT. *IEEE access*, *10*, pp.92137-92157.
[14] Agrawal, K., Aggarwal, M., Tanwar, S., Sharma, G., Bokoro, P.N. and Sharma, R., 2022. An extensive blockchain based applications survey: Tools, frameworks, opportunities, challenges and solutions. *IEEE Access*, *10*, pp.116858-116906.