



A Blockchain-Based Medical Record Storage System for Healthcare Data Management

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Abstract. The healthcare sector faces significant challenges in securely managing and storing patient data. This paper introduces a Blockchain-based Medical Record Storage System (BMRS), which provides a decentralized and secure framework for healthcare data management. Utilizing blockchain's decentralization and immutability, BMRS offers a robust solution for storing and sharing sensitive medical data. In this model, patients have full control over their medical records and can grant or revoke access to other stakeholders. Healthcare professionals gain secure, real-time access to patient information, improving diagnosis and treatment, while insurance providers benefit from enhanced data integrity and reduced fraud through tamper-proof records. Each medical interaction is recorded as a transaction on the blockchain, creating a secure and unalterable record of patient history. Key features include cryptographic access control, compliance with regulations like HIPAA and GDPR, and smart contracts to automate data access. The system has been implemented and evaluated based on security, scalability, and transparency, demonstrating its potential to enhance privacy, trust, and collaboration in healthcare.

Keywords: Blockchain · Decentralized Healthcare System · Electronic Health Records (EHR) · Medical Data Security · Smart Contracts

1 Introduction

The healthcare industry increasingly depends on digital solutions to efficiently and securely manage patient information [1]. Electronic Medical Records

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C. Iwendi et al. (Eds.): ICACTCE 2024, LNNS 1312, pp. 273–285, 2025.

https://doi.org/10.1007/978-3-031-94620-2_24

(EMRs) have become integral to modern healthcare, enabling providers to access patient data, improve diagnosis, and ensure coordinated care across institutions. However, traditional EMR systems face challenges such as data fragmentation, privacy concerns, and susceptibility to cyberattacks due to their centralized nature. Therefore, a robust, secure solution is essential to protect sensitive medical data and ensure it is accessible only to authorized parties.

Blockchain technology, known for its decentralized and immutable features, offers a transformative solution for secure healthcare data management [2]. By using distributed ledger technology, blockchain ensures medical records are tamper-resistant and accessible only to authorized users, providing enhanced security and transparency compared to centralized systems. The decentralized structure also eliminates single points of failure, making the system more resilient to attacks, while the immutable ledger ensures the integrity of stored data, which is crucial in managing sensitive healthcare information [3].

Despite its potential, integrating blockchain for medical data storage presents several challenges. Scalability issues, including slow transaction speeds and high energy consumption, can hinder the performance of blockchain-based systems [4]. Additionally, integration with existing healthcare infrastructure and compliance with regulations such as HIPAA and GDPR pose significant hurdles. Addressing these limitations requires innovative solutions to harness the benefits of blockchain without compromising system performance or regulatory adherence [5].

In this paper, we propose a Blockchain-based Medical Record Storage System (BMRS) to address the limitations of traditional EMR systems and current blockchain solutions. Our model empowers patients with control over their medical records, allowing them to grant or revoke access to healthcare providers and insurance companies. BMRS ensures secure, real-time access to patient data for doctors, enabling accurate diagnosis and treatment, while insurance companies benefit from increased data transparency, reducing fraud. The system is designed to be scalable, secure, and efficient, providing a comprehensive solution for healthcare data management. The key contributions of our work include:

- **Patient-Controlled Access:** Patients control who can access their medical records, granting or revoking permissions.
- **Secure Data Sharing:** Provides real-time, secure access to medical data, enhancing diagnosis and treatment.
- **Enhanced Data Integrity:** Ensures tamper-proof and transparent medical records.
- **Scalable Design:** Uses cryptography and smart contracts for secure, scalable data management.

The remainder of this paper is organized as follows: Sect. 2 provides a literature review of existing blockchain-based healthcare systems and their limitations. Section 3 describes the architecture and design of the proposed BMRS. Section 4 discusses the implementation of the system, including smart contracts and cryptographic methods. Section 5 presents the results of our performance analysis,

and comparison with existing system. Finally, Sect. 6 discusses the limitations of our model, offers concluding remarks, and suggests directions for future work.

2 Literature Review

Swetha *et al.* (2024) [6] proposed SecureMed, a decentralized framework using blockchain and IPFS to manage EHRs securely. The system ensures privacy, security, and transparency, with smart contracts automating access control through role-based permissions. While it improves execution time and data management, its reliance on Ethereum's PoW consensus poses scalability issues due to slow transaction times and high computational costs. Zakzouk *et al.* (2023) [7] proposed a blockchain-based EMR management framework for smart healthcare infrastructure, enhancing security, privacy, and data accessibility. While the framework improves execution time, latency, and throughput, its reliance on Proof of Work (PoW) leads to higher energy consumption and slower transactions.

Ismail and Materwala (2020) [8] introduced BlockHR, a blockchain-based EHR management system that offers tools for patients to manage their data and predict chronic diseases. S. Liu *et al.* (2023) [9] developed a blockchain-based PHR system with searchable proxy signcryption, improving data sharing, access control, and search efficiency while reducing storage and computation costs. Sun *et al.* (2023) [10] proposed MedRSS, a blockchain-based solution for medical record storage and sharing using Hyperledger Fabric. Butt *et al.* (2022) [11] proposed a blockchain-based secure healthcare record-sharing mechanism to improve data accessibility and security for patients, particularly during international travel. Rahman *et al.* (2024) [12] proposed a blockchain-enabled patient-centric agent for remote patient monitoring in 5G networks. By integrating SDN with blockchain, the system improves data handling, security, and network performance in IoMT-based healthcare solutions. Zaabar *et al.* (2021) [13] introduced HealthBlock, a decentralized healthcare data management system using OrbitDB and IPFS for secure EHR storage. The system enhances privacy and security by leveraging Hyperledger Fabric.

In contrast, our BMRS model addresses these limitations by combining a scalable, multi-peer Hyperledger Fabric setup with cryptographic access control and compliance with HIPAA and GDPR regulations. BMRS improves on existing solutions by offering better scalability, lower transaction costs, and more robust privacy controls.

3 Proposed Model

The proposed Blockchain-based Medical Record Storage System (BMRS) is designed to address the challenges in securely managing healthcare data while empowering patients with control over their medical records. Integrating blockchain with current healthcare systems, such as Electronic Medical Records (EMR), presents technical challenges, including ensuring interoperability, data

standardization, and managing the costs of transitioning from centralized to decentralized architectures. Our solution utilizes smart contracts to facilitate seamless communication between legacy systems and the blockchain network. The model integrates blockchain technology, cryptographic mechanisms, and decentralized storage (IPFS) to ensure the privacy, security, and transparency of sensitive medical information. The system incorporates three key stakeholders: patients, doctors, and health insurance providers. Each plays a crucial role in interacting with the medical records, and all interactions are governed by the blockchain and smart contracts which is shown in Fig. 1.

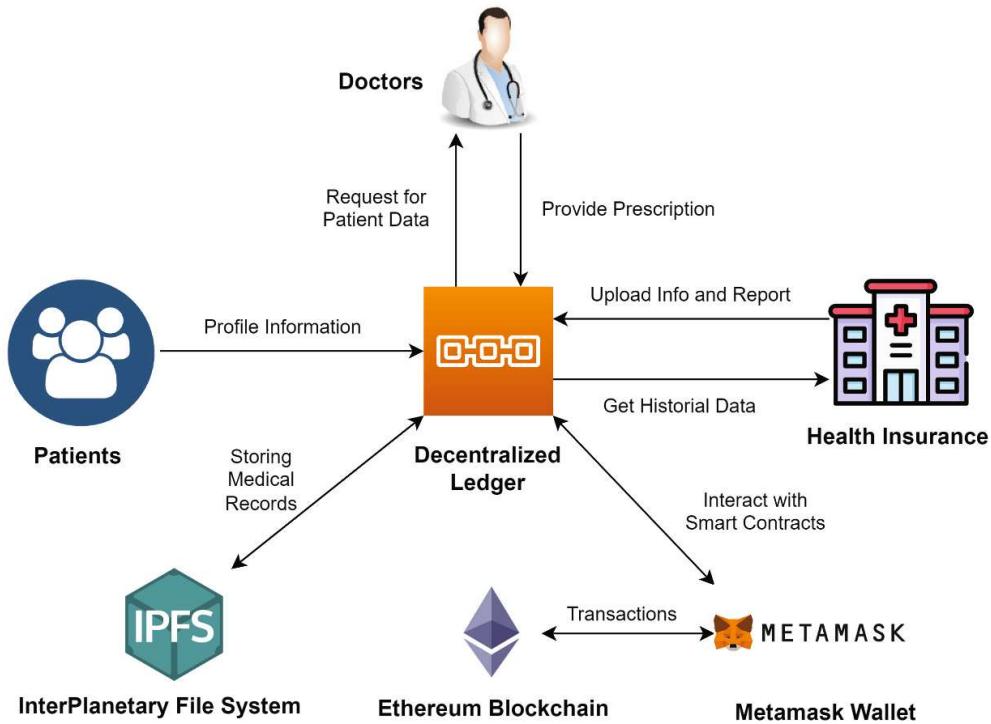


Fig. 1. System architecture of the proposed model

3.1 Patient

At the core of the system, patients retain full control over their medical records. The patient's journey begins with profile registration, where they securely store their personal and medical information on IPFS. Using MetaMask, the patient verifies their identity and interacts with the blockchain to manage permissions. The patient can selectively share medical records with healthcare providers. The work process of the patients entities is shown in Fig. 2.

Through the blockchain, patients can monitor all interactions with their data in real-time, ensuring that any data access is recorded immutably. The patient also interacts with the health insurance provider by making secure payments for coverage through blockchain-based transactions. These payments are stored on

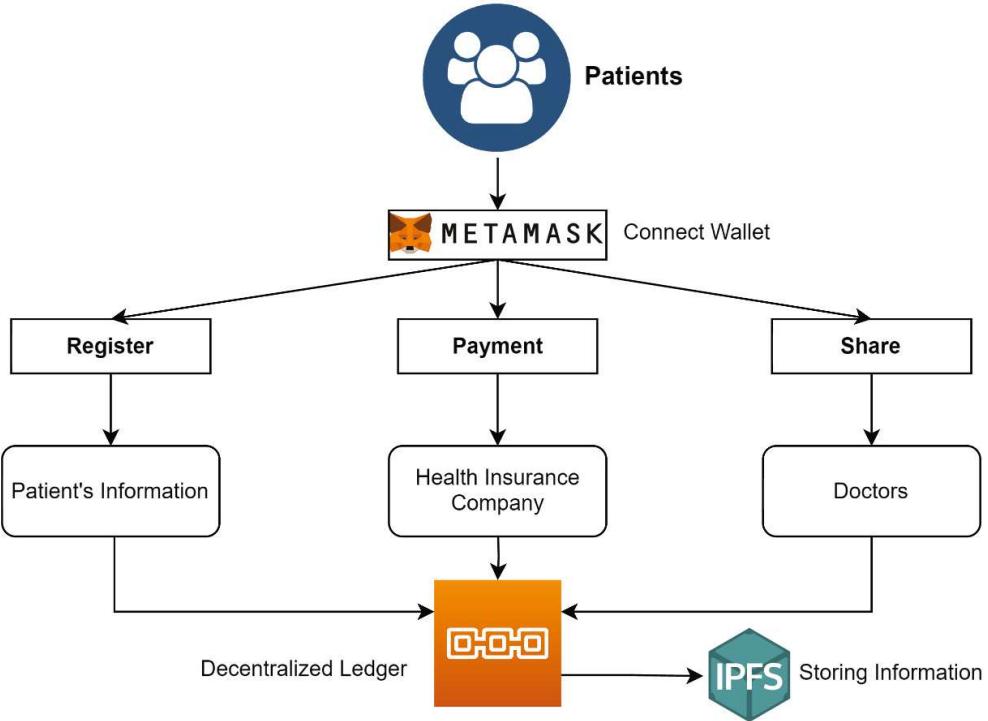


Fig. 2. Patient workflow for medical record management and insurance transactions

the blockchain for transparency, with the actual transaction records stored on IPFS. Patients have the ability to share their medical records with insurance companies when necessary.

3.2 Doctor

Doctors, as another key stakeholder, interact with the system to access patient records and update medical information. After profile registration and secure verification via MetaMask, doctors are granted access to a list of patients who have authorized them to view or modify their medical records. Doctors can diagnose patients and view their medical history, ensuring accurate treatment planning. The work process of the doctor's entity is shown in Fig. 3.

Doctors interact with the blockchain, where smart contracts enforce access control. This ensures that doctors can only view the data for which they have permission, and any updates made to a patient's records (such as new diagnoses, treatments, or prescriptions) are securely stored on IPFS and tracked via the blockchain. Every interaction with patient data is auditable, ensuring transparency and preventing unauthorized access.

3.3 Health Insurance Provider

Health insurance providers use the system to manage policies, customers, and claims. After secure authentication via MetaMask, the insurance provider can view a list of patients (customers) and their associated policies. The insurance

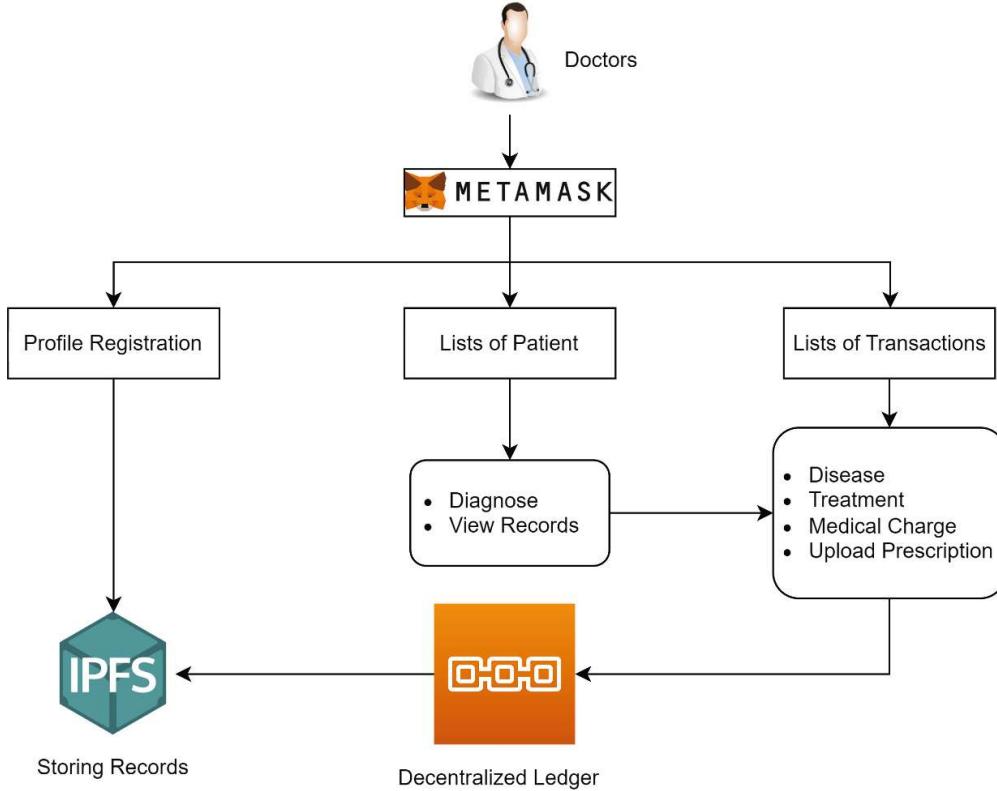


Fig. 3. Doctor workflow for patient diagnosis and medical record management

company interacts with the blockchain to verify the authenticity of patient claims and monitor the status of payments. The blockchain ensures that all claims and policy transactions are tamper-proof and fully auditable.

Patients can share relevant medical records with the insurance company to support their claims, and the insurance provider can process payments and update claims statuses. The actual medical records and claims-related data are stored on IPFS, while the blockchain stores only the cryptographic hash for verification purposes. The work process of the health insurance companies' entity is shown in Fig. 4.

4 Implementation

The implementation of the BMRS platform focuses on providing a decentralized, secure, and user-friendly healthcare data management solution. The system is built on a stack of technologies, including ReactJS for the frontend, Solidity for smart contracts, and Ethereum as the blockchain platform. The following subsections outline the technology stack, user interaction flow, and the use of blockchain in securing patient records.

4.1 Technology Stack

The BMRS system integrates a range of modern technologies that ensure efficiency, security, and scalability.

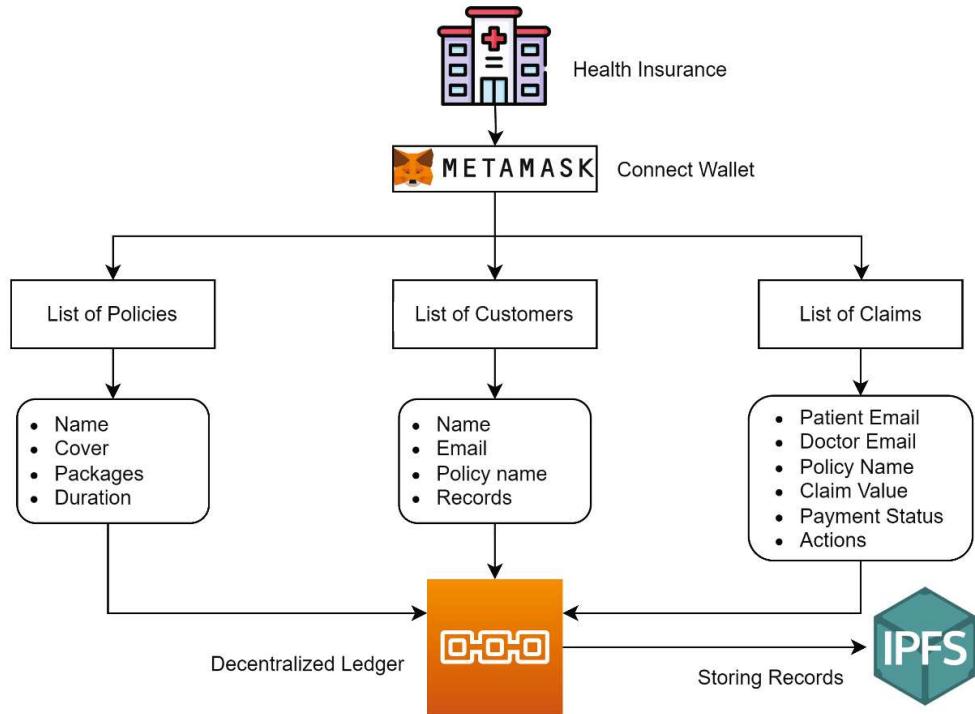


Fig. 4. Health insurance workflow for managing policies, customers, and claims

- **Frontend:** Built using ReactJS, which provides a dynamic and user-friendly interface for patients, doctors, and insurance providers.
- **Blockchain:** Ethereum serves as the underlying platform, leveraging smart contracts to govern interactions between stakeholders.
- **Smart Contracts:** Developed using Solidity to manage access control, record updates, and insurance claims.
- **IPFS (InterPlanetary File System):** It is utilized for decentralized and secure storage of patient records, keeping sensitive medical data off-chain while ensuring integrity through blockchain-generated hashes.
- **MetaMask:** The MetaMask wallet is used for secure authentication and transaction signing, allowing users to interact seamlessly with the Ethereum blockchain.
- **Truffle:** Employed for smart contract development and testing, ensuring a reliable and efficient development cycle.
- **Testing Frameworks:** Mocha and Chai are used for unit testing smart contracts, ensuring all functions behave as expected.

4.2 Entities Workflow

The BMRS platform provides a streamlined interface for the three key stakeholders: patients, doctors, and insurance providers. The following steps demonstrate the work at each stage, supported by figures.

4.2.1 Patient Workflow

- Home Page and Registration:** The homepage introduces the platform, highlighting blockchain-secured medical data. Patients connect their MetaMask wallet and register by providing basic information, securely stored on IPFS.
- Profile Management:** Patients view their profile with personal info and medical record addresses on IPFS. They control data access, securely sharing records with doctors via blockchain.
- Insurance Policy Management:** Patients browse and purchase insurance policies with Ethereum, and transactions are securely recorded on the blockchain. Figure 5 illustrates the workflow for data sharing and policy purchases.

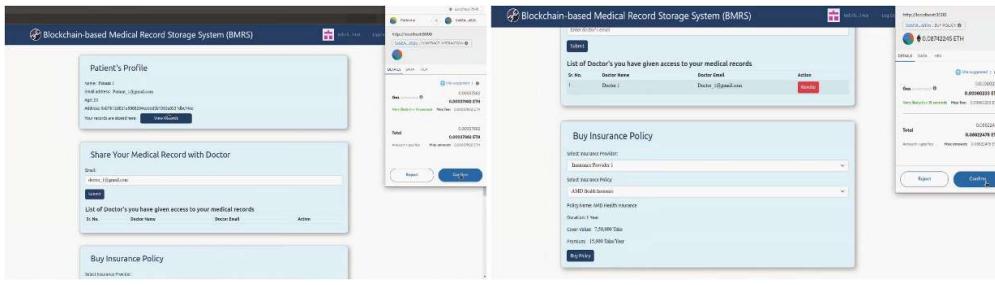


Fig. 5. Patient workflow for profile and insurance policy management

4.2.2 Doctor Workflow

- Doctor Registration and Profile:** Doctors register on the platform similarly to patients, by connecting their MetaMask wallet and providing details. Once registered, doctors can view their profile and the list of patients who have granted them access to their medical records.
- Medical Record Access:** Doctors can securely access patient medical records that have been shared with them. Through the dashboard, they can view, diagnose, and update medical records. The doctor workflow is depicted in Fig. 6, showing the process from viewing the patient list to accessing and updating medical records.

4.2.3 Insurance Provider Workflow

- Registration and Claims Management:** Insurance providers register on the platform by connecting their MetaMask wallet and entering relevant details. Once registered, they can access the list of customers, view their records, and process claims.

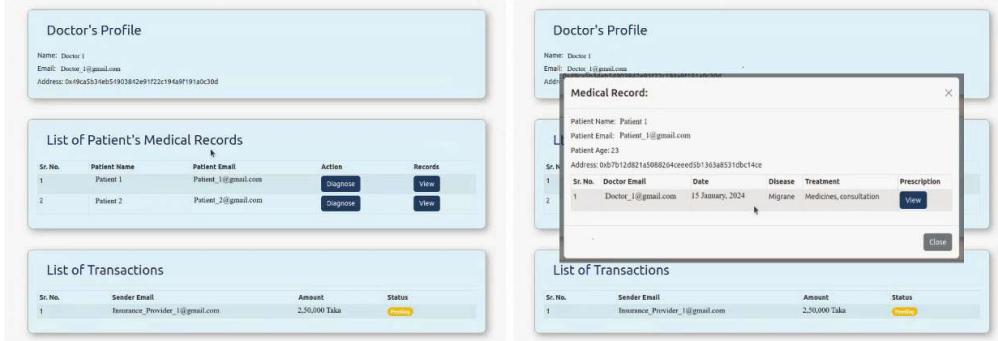


Fig. 6. Doctor workflow showing profile management and access to patient medical records

- Approving or Rejecting Claims:** The insurer reviews claims and can either approve or reject them based on patient records shared by doctors where all claim approvals and payments are processed via the Ethereum blockchain.
- Final Payment Processing:** After verifying a claim, insurance providers can securely approve the claim, and payments are processed through Ethereum-based transactions. The insurance workflow is shown in Fig. 7, outlining the steps from claims management to approval and payment processing.

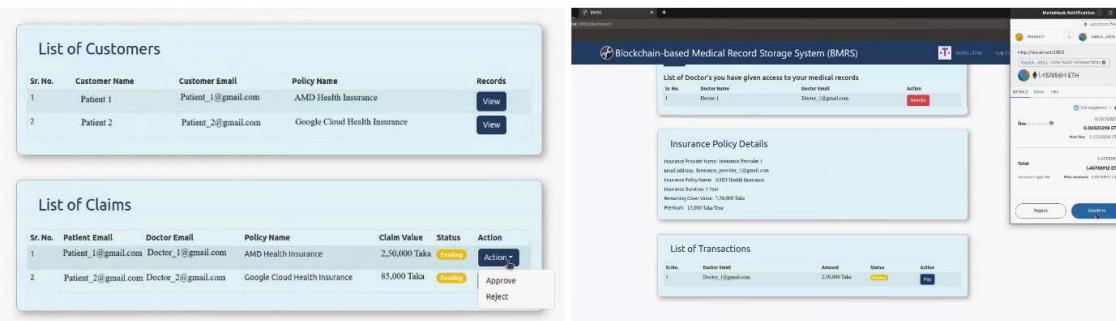


Fig. 7. Insurance workflow outlining claims management, approval, and payment processing

5 Performance Analysis

The performance evaluation of the BMRS system focuses on key metrics such as scalability, transaction speed, throughput, and gas costs. These aspects are crucial to understanding the system's efficiency in managing interactions among patients, doctors, and health insurance providers within a decentralized healthcare data management platform.

5.1 System Efficiency

The integration of blockchain in large-scale healthcare settings faces significant challenges, particularly in transaction times and energy consumption. Addressing these issues requires optimization of consensus algorithms and the adoption of more energy-efficient protocols, such as Proof of Stake (PoS) or Layer 2 solutions like sharding, to reduce latency and power use. Scalability is vital for BMRS to handle increasing users and transactions. In a single-peer setup, bottlenecks arise as the peer's capacity is exceeded, especially when patients register, share records, or process insurance claims [14]. The multi-peer setup, however, distributes the load across nodes, efficiently managing higher transaction volumes. This configuration also improves transaction speed, enabling parallel processing for faster data access and smoother claim handling, as illustrated in Fig. 8. The graphs show that the system scales well, with insurance providers handling more load, while patients and doctors have faster transaction speeds as volume increases.

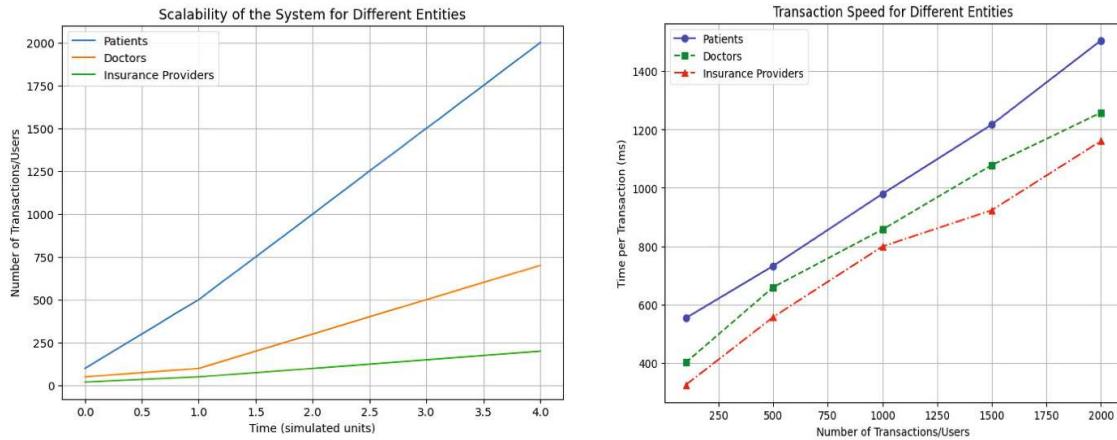


Fig. 8. Comparison of system scalability and transaction speed across various transaction volumes

To validate the system's effectiveness, a performance analysis was conducted, comparing transaction speed, gas costs, and throughput under various workloads. Our implementation demonstrated improved scalability, especially in multi-peer setups, enabling more efficient transaction processing and minimizing bottlenecks in healthcare environments. Gas cost and throughput are essential for evaluating BMRS efficiency. Gas fees vary by task complexity, with routine operations like patient registration incurring lower costs, while more complex tasks, such as insurance claims, are higher. Throughput assesses the system's capacity to manage increasing transactions for patients, doctors, and insurers. As shown in Fig. 9, a multi-peer setup significantly enhances throughput, enabling the system to process more transactions in parallel, improving scalability and reducing response times across healthcare interactions. Gas cost analysis shows

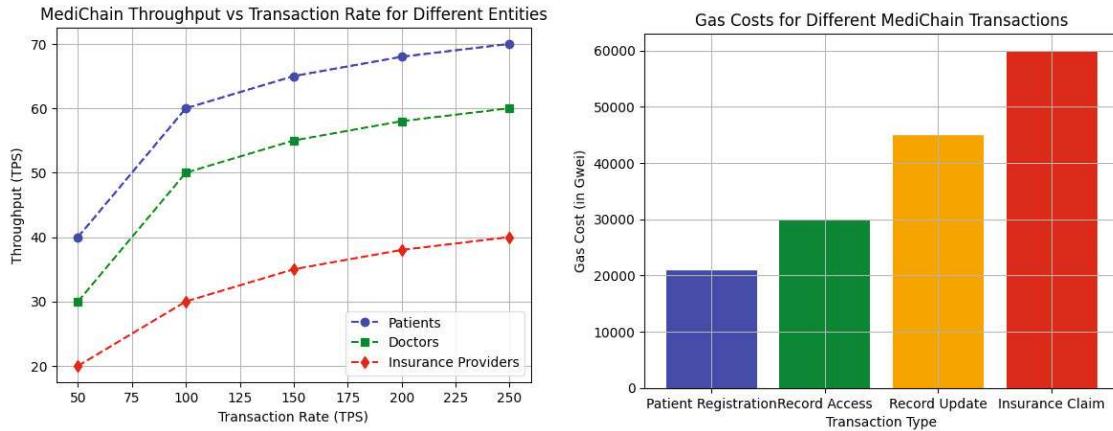


Fig. 9. Gas cost and throughput comparison for different transaction types

that insurance claims are the most expensive, while patient registrations are the least costly, reflecting the complexity of the transactions.

Overall, the performance analysis demonstrates that BMRS is well-suited for healthcare data management, providing a scalable and efficient solution for various stakeholders.

5.2 Comparison with Related Systems

The performance of BMRS is compared with other blockchain-based healthcare systems from the literature. As shown in Table 1, BMRS offers better scalability and efficiency through its multi-peer architecture, optimized gas costs, and low latency. In contrast to Ethereum's Proof of Work (PoW) systems, BMRS's use of Hyperledger Fabric enables faster transaction speeds and reduced gas costs.

Table 1. Comparison of BMRS with other blockchain-based healthcare systems

Criteria	Swetha et al. (2024)	Sun et al. (2023)	Zakzouk et al. (2023)	Zaabbar et al. (2021)	BMRS (Proposed Model)
Blockchain Platform	✗	✓	✗	✓	✓
Storage System	✓	✓	✓	✓	✓
Access Control	✓	✗	✓	✓	✓
Consensus Mechanism	✗	✓	✗	✗	✓
Performance Metrics	✗	✗	✗	✓	✓
Network Scaling	✗	✓	✗	✗	✓
Gas Costs Usage	✗	✗	✗	✗	✓
Security Features	✓	✗	✓	✓	✓
Regulatory Compliance	✗	✓	✓	✗	✓

6 Conclusion

In this paper, we introduced the Blockchain-based Medical Record Storage System (BMRS) to enhance healthcare data management with a decentralized, secure, and transparent framework. BMRS leverages blockchain, smart contracts, and IPFS for seamless interactions between patients, doctors, and insurers, ensuring data integrity, privacy, and regulatory compliance. The system allows patients to manage records, securely share data with providers, and maintain immutable records for insurance claims. However, BMRS faces challenges such as Ethereum's high gas costs and blockchain scalability issues. Future work will focus on reducing transaction costs using Layer 2 solutions, improving scalability, enhancing interoperability, and strengthening data privacy.

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