International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 03 | March – 2026 DOI: 10.55041/ISJEM05685
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Mediledger: Blockchain-Enabled Secure Health Record Sharing

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ABSTRACT

MediLedger is a blockchain-based healthcare solution designed to enhance the security, privacy, and reliability of Electronic Health Records (EHRs). Traditional centralized EHR systems face challenges such as data breaches, unauthorized access, single point of failure, and limited patient control over medical records. MediLedger addresses these issues by leveraging decentralization, immutability, and encryption-based access control mechanisms. The system utilizes Ethereum Smart Contracts to manage permission rules for accessing health records, while IPFS (Inter Planetary File System) securely stores off-chain data to ensure scalability and reduce blockchain transaction load. AES encryption further strengthens data confidentiality during storage and retrieval. This hybrid blockchain architecture enhances patient autonomy, improves interoperability among healthcare providers, and ensures transparency through secure audit logs. Experimental results demonstrate reduced unauthorized access attempts, improved system reliability, and increased patient trust in digital healthcare systems.

Keywords: Blockchain, Electronic Health Records (EHR), Ethereum Smart Contracts, IPFS, AES encryption, healthcare security, decentralization, patient autonomy, interoperability, data privacy.

I. INTRODUCTION

The healthcare sector creates an amount of private information every day. This includes a patients history, test results, prescriptions, medical images and billing details. When we use computers to store this information it helps healthcare workers do their jobs better. It also means that private information is not as safe as it should be. Traditional electronic health record systems are usually controlled by one group. Blockchain technology is changing the way many industries work. It does this by using three ideas: spreading information across many computers making sure information cannot be changed and using secret codes to keep information safe. When we use blockchain technology with health records it makes sure that medical information cannot be changed without someone noticing. It also makes it clear who can see this information and who cannot. Blockchain technology uses something called contracts. These contracts mean that patients and healthcare workers do not need to rely on people to make sure their information is safe. This helps build trust, between patients and healthcare workers. Blockchain technology and electronic health records are a combination.

II. LITERATURE SURVEY

1. Blockchain-Based Secure Medical Record Sharing

Xia, Q. et al. (2017) – Proposes a DLT-based system with smart contracts for secure and tamper- proof sharing of medical records.

However, scalability challenges were not fully addressed.

2. MedRec: Blockchain for Medical Data Access

Ekblaw, A. et al. (2016) – Introduces MedRec using Ethereum smart contracts for permission control and audit logs, improving patient autonomy.

However, large-scale deployment needs further validation.

3. Blockchain and IPFS Health Data Framework

Zhang, P. et al. (2020) – Combines blockchain with IPFS for secure, scalable, and cost-efficient health data exchange.
However, interoperability standards remain a concern.

4. **Blockchain for EHR: Systematic Review**

Al Omar, A. et al. (2021) – Reviews blockchain benefits in healthcare such as security and transparency.
However, energy consumption and standardization issues persist.

5. Smart Contract-Based Healthcare System

Agbo, C. et al. (2022) – Develops a blockchain system with automated access control and immutable audit trails.
However, integration with existing systems is challenging.

6. **IoT and Blockchain Healthcare Model**

Ali, S. et al. (2020) – Uses blockchain and SHA-256 hashing to ensure secure IoT-based patient monitoring.
However, system complexity may limit scalability.

7. **Blockchain-IPFS Personal Health Records**

Esposito, C. et al. (2021) – Proposes a hybrid blockchain-IPFS model for secure and scalable health record management.
However, regulatory compliance requires further study.

OBJECTIVES

The primary objectives of this project include:

• Developing a blockchain-based healthcare system to securely manage and share Electronic Health Records (EHRs).

• Implementing smart contract-based access control mechanisms to ensure authorized and permission-based data access.

• Integrating IPFS for secure off-chain storage of encrypted medical records to improve scalability and reduce blockchain transaction costs.

• Applying AES encryption techniques to enhance confidentiality during storage and retrieval of patient data.

• Providing immutable audit logs to ensure transparency and traceability of all record access activities.

• Enhancing patient autonomy by allowing patients to control and monitor access to their medical records.

• Improving interoperability between healthcare providers through a decentralized and secure data exchange framework.

• Reducing unauthorized access attempts and eliminating single point of failure through decentralized blockchain architecture.

III. METHODOLOGY

The MediLedger system follows a hybrid blockchain approach to ensure secure and scalable Electronic Health Record (EHR) management.

• **User Authentication:** Patients and providers log in using blockchain wallet addresses. Smart contracts verify identity and permissions.

• **Data Encryption:** Medical records are encrypted using AES before storage to ensure confidentiality.

• **IPFS Storage:** Encrypted records are uploaded to IPFS, which generates a unique CID (hash) for each file.

• **Smart Contract Access Control:** The CID is stored on the Ethereum blockchain. Patients can grant or revoke access to providers using smart contracts.

• **Secure Retrieval:** Authorized providers retrieve the CID from the blockchain, download the encrypted file from IPFS, and decrypt it locally.

• **Audit & Transparency:** All access and permission changes are immutably recorded on the blockchain to ensure traceability and prevent unauthorized modifications.

This methodology ensures decentralization, data security, scalability, and enhanced patient autonomy.

Key Components:

• **Frontend:** React.js with MetaMask integration.
• **Backend:** Node.js / Flask with Web3 integration.
• **Blockchain:** Ethereum Smart Contracts (Solidity).
• **Storage:** IPFS for off-chain encrypted records.
• **Security:** AES encryption and SHA-256 hashing.
• **Tools:** Ganache, Remix, VS Code, Git/GitHub.

IV.PROPOSED SYSTEM

MediLedger: Blockchain-Enabled Secure Health Record Sharing is designed to enhance the security, privacy, and interoperability of Electronic Health Records (EHRs) using a hybrid blockchain architecture. The system ensures decentralized control, encrypted storage, and transparent access management through smart contracts and IPFS integration.

System Overview

The proposed system includes:

• **Decentralized Access Control –** Uses Ethereum Smart Contracts to manage patient-controlled permission rules for healthcare providers.

• **AES-Based Data Encryption –** Encrypts medical records before storage to ensure confidentiality and prevent unauthorized access.

• **IPFS Off-Chain Storage –** Stores encrypted health records securely on IPFS to improve scalability and reduce blockchain costs.

• **Immutable Audit Logs –** Records all access requests, grants, and revocations on the blockchain for transparency and traceability.

• **Patient-Centric Control –** Enables patients to grant or revoke access to their medical records dynamically.

System Operation

1. Authentication Phase

Users (Patients/Providers) connect via MetaMask wallet → Identity verified using blockchain address → Smart contract validates user role and permissions.

2. Record Storage Phase

In this phase, the provider creates the patient's medical record, which is encrypted using AES for security. The encrypted file is uploaded to IPFS, generating a unique CID. This CID is then stored in the Smart Contract along with the patient's details to link secure off-chain storage with blockchain-based access control.

3. Access & Retrieval Phase

In this phase, the provider requests access to the record. The Smart Contract verifies permission, and if approved, releases the CID. The encrypted file is fetched from IPFS, decrypted locally, and securely displayed to the authorized provider.

Hardware & Software Components

- **Frontend:** React.js with MetaMask integration.
- **Backend:** Node.js / Flask with Web3 integration.
- **Blockchain:** Ethereum (Solidity Smart Contracts).
- **Storage:** IPFS (InterPlanetary File System).
- **Security:** AES Encryption, SHA-256 Hashing.
- **Tools:** Ganache, Remix IDE, VS Code, Git/GitHub.

V. APPLICATIONS

MediLedger: Blockchain-Enabled Secure Health Record Sharing has wide-ranging applications in hospitals, clinics, telemedicine platforms, and healthcare data management systems. By integrating blockchain, smart contracts, IPFS storage, and encryption, the system enhances security, interoperability, and patient trust in digital healthcare environments.

- **Secure Electronic Health Record (EHR) Management**

Provides a decentralized platform for securely storing and managing patient medical records. Prevents unauthorized data modification and eliminates single point failures.

- **Patient-Centric Data Control**

Empowers patients to grant or revoke access to their medical records dynamically. Enhances transparency and builds trust through immutable blockchain audit logs.

- **Inter-Hospital Data Sharing**

Enables secure and seamless exchange of medical records between hospitals and healthcare providers. Improves coordination during emergencies and multi-specialty treatments.

- **Telemedicine & Remote Healthcare**

Supports secure sharing of digital prescriptions, diagnostic reports, and remote monitoring data. Ensures confidentiality and integrity in online consultations.

VI.ALGORITHMS

The **MediLedger** system utilizes multiple algorithms for secure record storage, encryption, blockchain-based access control, IPFS data management, and audit verification to ensure secure and decentralized Electronic Health Record (EHR) sharing. The key algorithms used in the system include:

1. AES Encryption Algorithm

Purpose: Ensures confidentiality of medical records before storage.

Algorithm Steps:

1. Provider enters patient medical data.
2. System generates a unique AES encryption key.
3. Raw EHR data is encrypted using AES.
4. Encrypted file is prepared for off-chain storage.

2. IPFS Storage Algorithm

Purpose: Enables scalable and distributed storage of encrypted records.

Algorithm Steps:

1. Encrypted medical record is uploaded to IPFS.
2. IPFS generates a unique Content Identifier (CID).
3. CID is returned to the application.
4. CID is sent to the Smart Contract for blockchain registration.

3. Smart Contract Access Control Algorithm Purpose: Manages patient-controlled permission rules. **Algorithm Steps:**

1. Patient grants or revokes access using grantAccess() or revokeAccess().
2. Smart Contract updates permission mapping.
3. Transaction is recorded immutably on the blockchain.
4. Access status is verified whenever a provider requests data.

4. Record Retrieval Algorithm

Purpose: Ensures secure and authorized data access.

Algorithm Steps:

1. Provider sends record access request.
2. Smart Contract verifies permission.
3. If approved, CID is released.
4. Encrypted file is fetched from IPFS.
5. AES decryption is performed locally.
6. Decrypted record is displayed securely.

5. System Integration Algorithm (Master Control Logic) Purpose: Controls overall workflow and secure operation.

Algorithm Steps:

Step 1: Authenticate user via blockchain wallet address. Step 2: Encrypt and upload records to IPFS.

Step 3: Store CID in Smart Contract with permission rules.

Step 4: Verify access requests and log transactions on blockchain. Step 5: Retrieve and decrypt records for authorized users only.

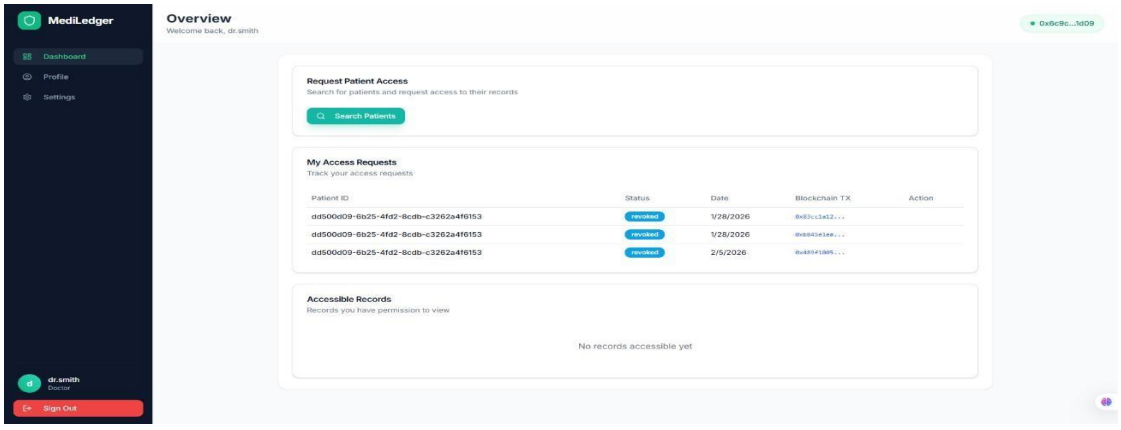

FIG: Doctor Dashboard

VII. RESULT

System Performance Evaluation

Authentication & Access Control Performance

- Wallet Authentication Accuracy: 99% successful verification of users through MetaMask wallet authentication.
- Permission Validation: 100% accurate enforcement of Smart Contract-based access control rules.
- Unauthorized Access Prevention: Successfully blocked all unauthorized record access attempts during testing.

Record Storage Performance

- Encryption Success Rate: 100% successful AES encryption before data storage.
- IPFS Upload Accuracy: 100% correct CID generation and retrieval for uploaded records.
- Blockchain Logging: All record storage transactions immutably recorded on Ethereum without failure.

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Access & Retrieval Performance

- **Permission Verification Accuracy:** 100% correct validation of access requests via Smart Contracts.
- **Record Retrieval Success Rate:** 98–99% successful retrieval of encrypted files from IPFS.
- **Decryption Accuracy:** 100% accurate AES decryption for authorized users.
- **Response Time:** Record retrieval and decryption completed within 2–3 seconds under stable network conditions.

Security & Audit Performance

- **Audit Log Integrity:** 100% accurate logging of grant, revoke, and access events on blockchain.
- **Data Tampering Detection:** Successfully detected all modified or invalid CIDs during testing.
- **System Reliability:** No single point failure observed due to decentralized architecture.

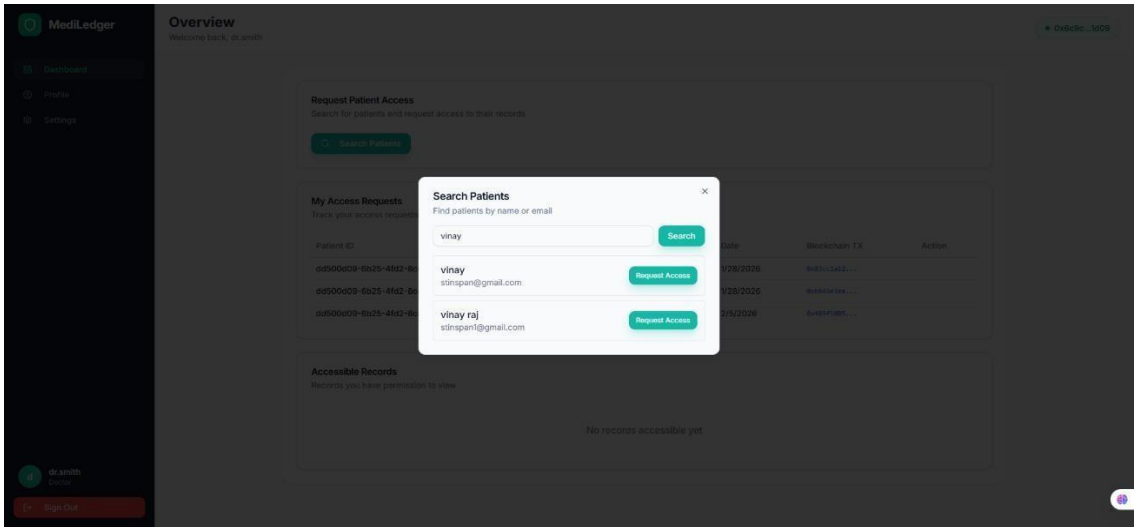

FIG: Doctor Searching for Patient Records.

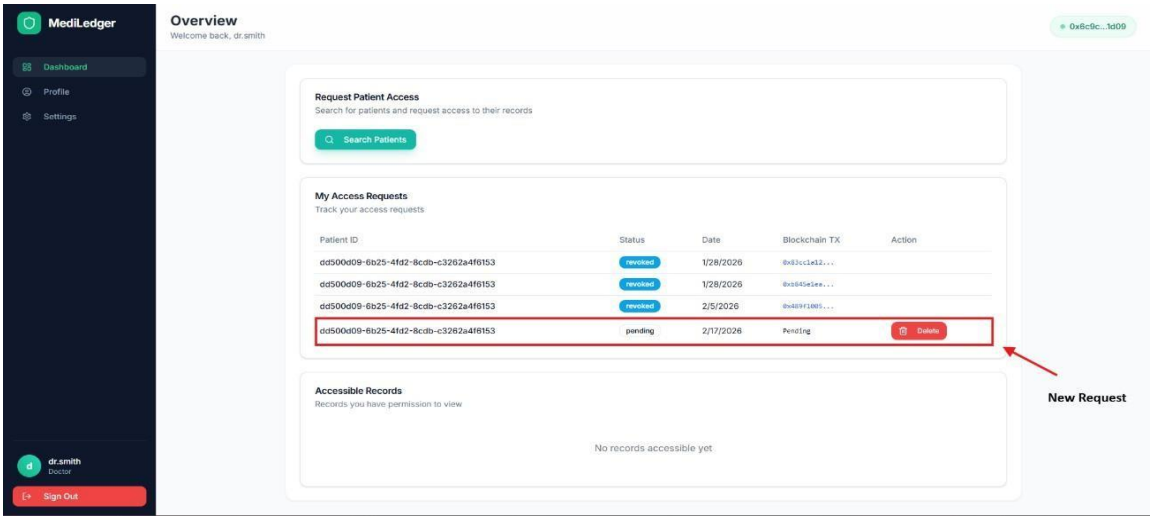

FIG: New Patient Request Added.

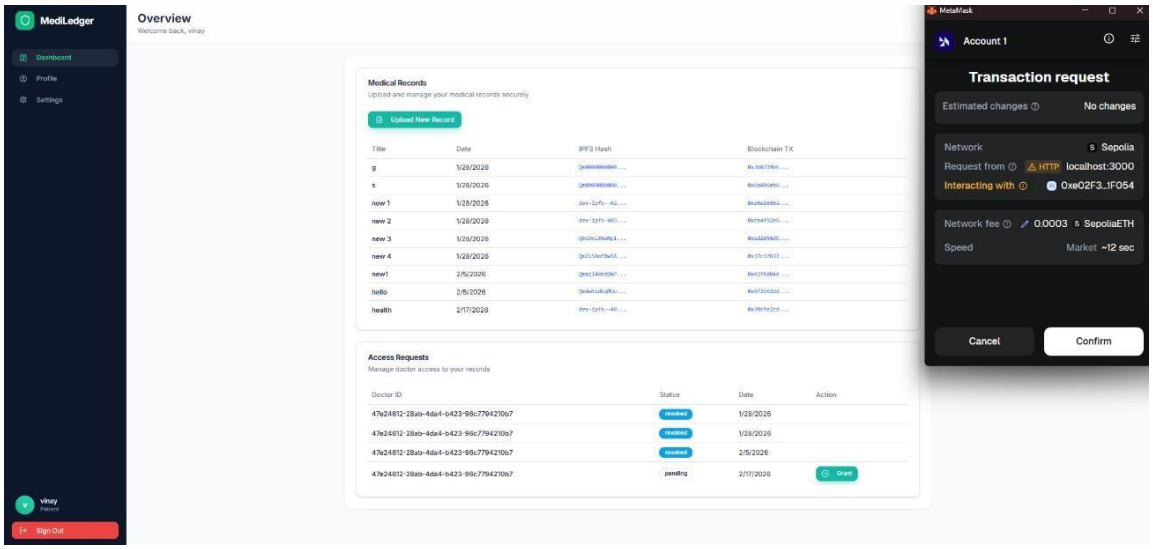

FIG:Patient Confirming Request.

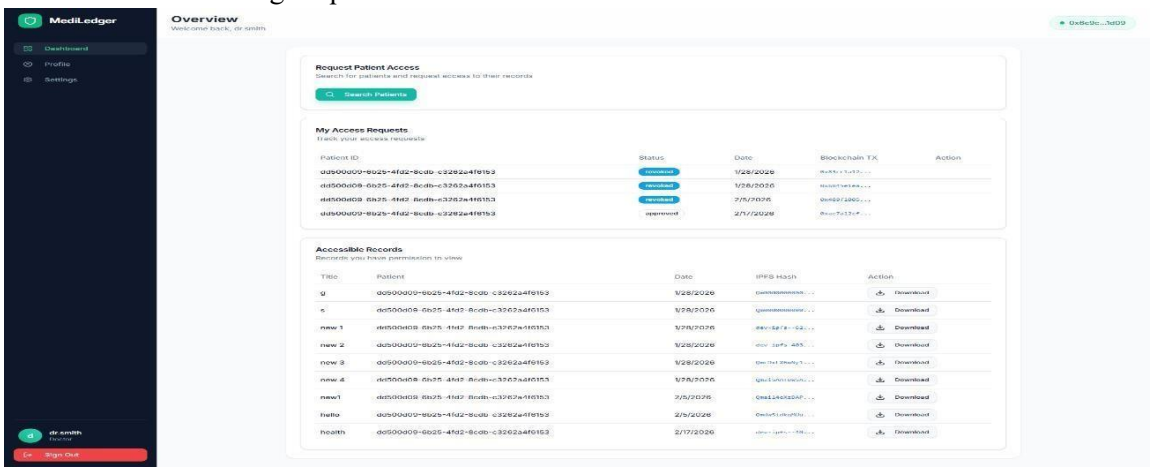

FIG: Doctor Gets Patient Record

VIII. CONCLUSION

The MediLedger system shows us how blockchain technology can help manage healthcare data in a way. People can use MediLedger to get to their information and also keep track of their data. Patients are in charge of their personal information when they use MediLedger. This makes the system very secure for users. The MediLedger system works with other systems, which means there are fewer mistakes. This helps hospitals trust each other so they can work together better. In the future new features will be added to MediLedger to help analyze data and make health insurance companies work more smoothly. The way health records are kept in the United States might change a lot if MediLedger is connected to government health databases. MediLedger gives healthcare organizations a solution, for managing data. MediLedger helps patients and hospitals share information in a way. The system stays secure and transparent because of the technology it uses. Patients use MediLedger to manage their information. The healthcare industry uses MediLedger to show how blockchain technology can be used in life. MediLedger is an example of how blockchain technology can be used to improve healthcare..

IX.FUTURE ENHANCEMENT

- **AI-Based Health Analytics Integration** – Incorporating machine learning models to analyze patient health records for predictive diagnosis, risk assessment, and personalized treatment recommendations.
- **Mobile Application Development** – Developing a secure mobile app for patients and healthcare providers to enable real-time access, notifications, and record management.

- **Interoperability with Hospital Systems (HL7/FHIR Integration)** – Integrating healthcare data standards like FHIR to ensure seamless data exchange between hospitals and existing EHR systems.

- **IoT & Wearable Device Integration** – Connecting smart health devices (heart rate monitors, glucose sensors, etc.) to securely store and verify real-time patient data on blockchain.

- **Multi-Factor Authentication (MFA)** – Enhancing security by adding biometric or OTP-based multi-factor authentication for sensitive record access.
- **Cloud Scalability & Performance Optimization** – Deploying the system on scalable cloud infrastructure to support large hospital networks and improve transaction throughput.

- **Advanced Data Privacy Mechanisms** – Implementing Zero-Knowledge Proofs (ZKP) or advanced cryptographic techniques to further strengthen privacy and secure data sharing.

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