Metamedica: A Blockchain-Based Platform for Secure and Interoperable Electronic Health Records

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Abstract -

Abstract – The management of personal medical records presents a global challenge, especially in ensuring privacy, interoperability, and secure access. Traditional electronic health record systems are centralized, lacking transparency and efficient communication between healthcare entities. Metamedica is a decentralized web-based platform designed using Ethereum blockchain, MetaMask, IPFS, and smart contracts to empower patients with full control over their health data. The system enables secure uploading, sharing, and retrieval of records, while also allowing doctors and diagnostic centers to interact seamlessly through role-based permissions. By incorporating blockchain technology, Metamedica ensures data integrity, traceability, and protection against unauthorized access. The integration of IPFS for decentralized storage further strengthens the system's efficiency and reliability. The use of smart contracts automates access control, enhancing trust and eliminating redundant processes in the healthcare workflow. Metamedica not only addresses the limitations of conventional EHR systems but also paves the way for a patient-centered, secure, and interoperable future in healthcare.

Keywords – Blockchain, electronic health records, Ethereum, interoperability, IPFS, MetaMask, smart contracts

I. INTRODUCTION

The increasing digitization of the healthcare sector necessitates a secure, interoperable, and patient-centered system for managing medical records. Traditional electronic health record (EHR) systems are often centralized, lacking in transparency and secure data sharing mechanisms. This results in fragmented data, redundant diagnostic efforts, and delayed medical responses, especially when patients interact with multiple healthcare providers. Blockchain technology presents a transformative opportunity to overcome these limitations by decentralizing data control and introducing immutability, transparency, and access control through smart contracts.

Metamedica is designed as a decentralized web-based platform that utilizes the Ethereum blockchain, MetaMask for secure wallet interactions, InterPlanetary File System (IPFS) for distributed file storage, and smart contracts written in Solidity to govern user permissions and data integrity. The platform empowers patients by giving them direct control over who accesses their medical data and under what conditions. This model not only promotes trust among stakeholders but also enhances the overall efficiency and quality of healthcare delivery.

By leveraging blockchain's decentralized ledger and the distributed nature of IPFS, Metamedica addresses critical challenges in current EHR systems. It serves as a blueprint for implementing secure and interoperable health data systems capable of transforming modern healthcare into a truly connected and patient-driven ecosystem.

II. BACKGROUND AND MOTIVATION

Centralized EHR systems are prone to fragmentation, lack auditability, and are often limited in communication. Blockchain, through its immutable and transparent ledger, provides a secure alternative [5]. Ethereum's support for smart contracts allows automated access control and interoperability across healthcare providers [6]. Our motivation is to build a platform that ensures secure and seamless data exchange [7].

III. OBJECTIVES

Ensure secure, tamper-proof storage of electronic health records

Empower patients with full ownership and access control of their health data

Facilitate seamless, permissioned data sharing with doctors and diagnostic centers

Achieve interoperability among diverse healthcare entities and systems

Eliminate redundancy and enhance care coordination through automation

Enable traceability and transparency using blockchain audit trails

IV. SYSTEM SCOPE

Metamedica is a decentralized healthcare platform that targets three primary user roles: patients, doctors, and diagnostic centers. Each user group interacts with the system based on assigned smart contract permissions.

Patients can register, upload encrypted health records to IPFS, manage access to their data, and monitor who has viewed or modified their files. They are in full control of granting and revoking permissions via the blockchain.

Doctors can request access to patient records, generate consultancy reports, and add diagnosis details—only with patient authorization.

Diagnostic centers are allowed to upload medical test reports and associate them with verified patient IDs. These reports are visible to both the doctor and the patient.

All interactions (uploads, accesses, edits) are logged immutably on the Ethereum blockchain.

The frontend is powered by ReactJS and MetaMask integration for transaction signing and secure user identity management.

The backend is driven by Solidity smart contracts and decentralized file storage using IPFS, ensuring high security and data integrity.

V. LITERATURE REVIEW

Several studies have explored the integration of blockchain with healthcare data systems, highlighting its potential to resolve key limitations of conventional EHRs. Azaria et al. introduced MedRec, an early prototype for blockchain-based medical data access and permission management, which demonstrated how smart contracts can empower patients and automate provider interactions [1]. Linn and Koo emphasized the value of decentralized control and tamper-resistant data sharing for health research and personalized care [2].

A systematic review by Agbo et al. categorized blockchain applications in healthcare into data sharing, clinical trials, and insurance, validating its cross-domain utility [3]. Research by Zhang et al. proposed hybrid architectures using IPFS for off-chain storage and blockchain for metadata management, optimizing scalability without compromising decentralization [4]. Additionally, Peterson et al. presented a model for blockchain-based health information exchange networks, which influenced the design logic behind Metamedica's interoperability modules [5].

Metamedica builds on these foundations but advances the state of the art by offering a role-specific, Ethereum-based platform with decentralized storage and full patient control, implemented using modern development tools like MetaMask, Truffle, and ReactJS.

VI. Architecture and Design

The architecture of Metamedica follows a modular, role-based structure and is built on decentralized principles. The platform consists of the following core components:

Frontend Interface: Developed in ReactJS, the interface is dynamic, responsive, and tailored to each user role (patient, doctor, diagnostic center). It connects to Ethereum via Web3 and MetaMask.

Smart Contracts: Built with Solidity, contracts include:

PatientRegistry – for registering patients and managing ownership of medical records.

DoctorRegistry – for validating doctors and recording their interactions.

EHRManager – to control permissions, uploads, and access logs using mapping structures.

Blockchain Layer: Ethereum provides the immutable ledger where hashes of uploaded EHR files, user credentials, and access history are stored. Ganache is used locally for development and testing.

Storage Layer: IPFS is used for storing actual medical reports and documents. IPFS hashes (CID) are stored on-chain via smart contracts.

Authentication: MetaMask handles wallet-based authentication and transaction signing, ensuring every write operation is user-authorized and traceable.

Data Flow:

1. Users log in through MetaMask.

2. Patients upload documents to IPFS; the hash is sent to a smart contract.

3. Doctors request access, which patients must approve.

4. Every access and upload is recorded on-chain for full auditability.

This architecture ensures decentralization, security, transparency, and patient-first access control.

VII. IMPLEMENTATION

Metamedica's implementation integrates several modern web and blockchain tools to ensure secure, scalable, and decentralized handling of electronic health records.

Smart Contracts: Developed using Solidity and tested through the Truffle framework. These contracts define the logic for user roles, access permissions, and medical data registry. Functions such as granting/revoking access, adding reports, and verifying user identities are handled on-chain.

MetaMask Integration: MetaMask serves as the gateway for user authentication and transaction authorization. Every interaction with the blockchain (e.g., uploading records, granting access) requires MetaMask approval, ensuring user consent and traceability.

Ganache: Ganache is used as a personal Ethereum blockchain for local development and testing. It provides deterministic account and transaction control during the smart contract deployment and debugging phase.

IPFS Storage: Actual medical files (e.g., reports, scans) are uploaded to IPFS. The returned hash (CID) is stored in smart contracts to link on-chain records with off-chain content, optimizing scalability without compromising data integrity.

Frontend Application: Built with ReactJS, the user interface is responsive and role-specific. Patients can upload files and manage access, doctors can request and consult records, and diagnostic centers can contribute medical test reports.

VIII. USE CASE DEMONSTRATION

Metamedica is structured around three key user roles—patients, doctors, and diagnostic centers—each with distinct capabilities and access levels governed by smart contracts.

Patient Role:

Patients register using MetaMask, ensuring a secure and blockchain-linked identity. They can upload their medical documents (e.g., prescriptions, lab results) to IPFS and receive a content hash (CID) which is linked via the blockchain. Patients can view their medical history and manage who can access their data by approving or revoking doctor or diagnostic center requests directly from their dashboard.

Doctor Role:

Doctors can register and be verified through the system's smart contracts. They can request access to a patient's records. Upon approval by the patient, the doctor can view the documents and add consultation notes or prescriptions. The entire interaction is logged on the blockchain for transparency.

Diagnostic Center Role:

Diagnostic centers can create and upload test reports to IPFS, linking them with a patient's ID. These reports become instantly accessible to both the patient and any authorized doctor. Diagnostic users cannot view unrelated data unless explicitly granted permission.

Each transaction—including file uploads, access requests, approvals, and data viewing—is logged immutably on the Ethereum blockchain. The interface built with ReactJS makes these processes seamless, while IPFS ensures fast and reliable decentralized storage. The role-based design ensures secure interactions without the need for centralized control or third-party verification.

IX. RESULTS AND DISCUSSION

The Metamedica platform was extensively tested in a simulated Ethereum environment using Ganache, enabling real-time interaction across all user roles. The system's performance was measured based on access control efficiency, data integrity, transaction auditability, and user satisfaction.

Access Control Validation:

Only users with verified roles could interact with the system. Doctors could access patient data strictly after receiving permission, and access logs were accurately recorded and viewable on-chain. Unauthorized access attempts were automatically rejected by smart contract logic.

Decentralized Storage Reliability:

IPFS successfully managed decentralized file storage. All uploaded reports returned unique content identifiers (CIDs), which were permanently linked on the Ethereum blockchain. Retrieval of files using the CID proved fast and reliable during testing.

Audit Trail and Transparency:

Every action, from file upload to record access and approval events, generated an immutable transaction. This blockchain-based log not only proved useful for debugging and analysis but also enhanced user trust.

Frontend and User Experience:

The ReactJS interface allowed intuitive navigation. Role-specific dashboards provided clarity, and MetaMask integration ensured secure logins and transaction confirmations. Feedback from test users highlighted the platform's transparency, simplicity, and sense of control.

The results validate that blockchain and decentralized technologies can form a robust foundation for secure, patient-centric EHR systems. The seamless integration of smart contracts and IPFS creates an ecosystem where healthcare data is protected, accessible, and governed by the user, without relying on central authorities.

CONCLUSION:

In this paper, we presented Metamedica, a revolutionary platform designed to provide secure and decentralized healthcare services using blockchain technology. By leveraging Ethereum blockchain, MetaMask, IPFS, and smart contracts written in Solidity, we built a transparent, immutable, and trustworthy system for managing patient data and medical records. The use of decentralized technologies ensures that sensitive health information is stored securely and can be accessed only by authorized parties, providing a higher level of privacy and security compared to traditional centralized systems.

The ReactJS frontend offers an intuitive user interface, while Ganache and Truffle facilitate smooth development and testing of the blockchain-based platform. Through this integrated ecosystem, Metamedica addresses critical challenges in healthcare, such as data privacy, security, and the lack of interoperability between different healthcare providers.

FUTURE WORK:

While Metamedica lays the foundation for decentralized healthcare systems, several areas can be improved or expanded for better performance and adoption in the real world:

1. Scalability and Performance: As the healthcare data grows, the platform needs to be optimized for scalability. Future work includes researching solutions like Layer 2 scaling or off-chain storage mechanisms to handle large amounts of data without affecting transaction speed or increasing costs.

2. Interoperability: Expanding Metamedica's compatibility with existing healthcare systems and Electronic Health Records (EHRs) will enable seamless data exchange across different institutions, fostering collaboration and improving the overall patient care experience.

3. AI Integration: Incorporating Artificial Intelligence for data analysis and prediction models can enhance decision-making processes, such as diagnosing diseases or predicting patient outcomes based on historical data.

4. Regulatory Compliance: Ensuring that Metamedica adheres to healthcare standards and regulations, such as HIPAA in the U.S., or GDPR in the EU, is crucial. Future work will focus on aligning the system with these frameworks and providing automated compliance checks.

5. User Adoption and Education: For the platform to be widely adopted, educating healthcare providers and patients about the benefits and usage of blockchain-based healthcare systems will be essential. Future efforts should focus on user-friendly interfaces and educational resources.

6. Decentralized Autonomous Organizations (DAOs): Implementing DAOs in healthcare governance could enable a more democratized decision-making process, giving patients and healthcare professionals a voice in platform evolution.

By addressing these areas, Metamedica can evolve into a fully-fledged, real-world healthcare ecosystem that balances innovation with trust, privacy, and accessibility for all users.

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