Secure E-Healthcare Management System using AI and Blockchain

Syed Mujib Rahaman
Research Scholar
Department of Computer Engineering
PAHER University
Udaipur,
Rajasthan, India

Dilendra Hiran, PhD
Professor
Department of Computer Engineering
PAHER University
Udaipur,
Rajasthan, India

Priyanka Kumari Bhansali, PhD
Assistant Professor
Department of CS and SE
Andhra University College of Engineering (A)
Visakhapatnam, A.P, India

S.K. Hiremath, PhD
Associate Professor
Department of CSE
CMR University
Bangalore,
Karnataka

ABSTRACT
Blockchain technology presents a valuable opportunity for enhancing secure data sharing in the healthcare sector. Despite its potential, several challenges remain regarding the effective management and sharing of electronic health records (EHRs). To overcome these challenges a patient health monitoring platform utilizing blockchain technology, particularly smart contracts on Ethereum is being proposed. This paper aims to enhance data security, improve interoperability, and enable more efficient healthcare data management by leveraging blockchain's decentralized and transparent nature. Additionally, integrating AI modules with the healthcare system can offer advanced analytics and decision-making capabilities, further enhancing the value proposition in the healthcare domain. This research paper outlines the framework for a secure AI and blockchain-based e-healthcare management system, detailing the key features, the technologies employed, and the roles of both artificial intelligence and blockchain in healthcare management. Furthermore, it explores the synergistic application of AI-Blockchain in enhancing E-Healthcare outcomes and discusses potential future advancements in this field.

General Terms
Security, Artificial Intelligence, Blockchain, Electronic Healthcare Records

Keywords
E-healthcare, Data Security, Blockchain, AI

1. INTRODUCTION
In the evolving field of healthcare, the integration of advanced technologies has become imperative to address the persistent challenges that traditional healthcare systems face. The conventional methods of managing patient information, ensuring data security, and facilitating seamless communication among healthcare stakeholders are fraught with vulnerabilities, inefficiencies, and limitations. In response to these challenges, this research paper endeavors to introduce an innovative solution: the AI-Blockchain-Based E-Healthcare Management System [1]. The proposed system revolutionizes how healthcare data is handled by merging AI analytics with blockchain technology, it ensures secure, transparent, and efficient management of health records. Through blockchain, it maintains an immutable ledger, guaranteeing transparency and auditability of data access. Additionally, it incorporates advanced AI-powered insight tools can be used to predict health risks and diseases by analyzing large sets of patient data through machine learning algorithms. These tools provide valuable insights that enable healthcare professionals to intervene early and develop personalized treatment plans. By taking a proactive approach, healthcare providers can improve patient outcomes while also lowering healthcare costs.

2. KEY FEATURES OF E-Healthcare MANAGEMENT SYSTEM
The proposed E-healthcare Management system is poised to transform the healthcare industry by addressing critical challenges in data management, security, and operational efficiency. Its innovative use of blockchain and AI technologies provides a robust solution for improving patient care, protecting sensitive information, and enhancing the overall efficiency of healthcare systems.

2.1 Enhanced Healthcare Data Management
The proposed system revolutionizes the management of healthcare data, streamlining the process to ensure that patient care is significantly improved. By organizing and storing data more effectively, healthcare providers can access vital information swiftly, leading to better-informed decisions and enhanced patient outcomes.

2.2 Robust Data Security and Privacy
Utilizing the power of blockchain technology, the proposed system ensures that data storage is both secure and transparent. Blockchain's decentralized nature provides a high level of security against unauthorized access and data breaches, while its transparency allows for an immutable and verifiable record of all data transactions, ensuring privacy and compliance with regulatory standards.

2.2.1 AI-Powered Healthcare Analytics
It leverages artificial intelligence to perform sophisticated healthcare analytics. By integrating AI with blockchain technology, the platform can analyze vast amounts of healthcare data securely and efficiently. This combination allows for more accurate predictive analytics, personalized treatment plans, and improved patient outcomes through data-driven insights.

2.3 Streamlined Healthcare Processes
The proposed system introduces a more efficient framework for managing health records, optimizing various healthcare processes. By automating routine tasks and ensuring seamless data flow between different stakeholders, the platform reduces administrative burdens and operational costs. This efficiency leads to quicker access to patient information, more coordinated care, and an overall enhancement in the quality of healthcare services provided

3. TECHNOLOGIES USED

3.1 Blockchain Technology

Blockchain technology serves as the backbone of this system, offering a decentralized and immutable ledger that ensures secure storage of healthcare data. The decentralized nature of this technology enhances data integrity and security, making it an ideal solution for handling sensitive healthcare information. Notable blockchain platforms that can be employed include Ethereum, Hyperledger Fabric, Corda, and EOS. Each platform provides unique features that can be leveraged to meet the required needs of healthcare data management [2].

3.2 Artificial Intelligence (AI)

Artificial Intelligence significantly contributes to the enhancement of the healthcare system's capabilities by employing a multitude of specialized techniques:

3.2.1 Machine Learning (ML)

ML algorithms process and analyze healthcare data to derive insights, predict patient outcomes, and support clinical decision-making. Techniques such as supervised learning, unsupervised learning, and reinforcement learning are extensively applied to different healthcare scenarios, including diagnosis, treatment personalization, and resource allocation [3].

3.2.2 Natural Language Processing (NLP)

NLP is used to interpret and manage unstructured data found in medical records, clinical notes, and patient communications. This technology facilitates information extraction, automates documentation, and conducts sentiment analysis, improving the efficiency and accuracy of data processing.

3.2.3 Computer Vision

This subset of AI focuses on interpreting medical images like X-rays, MRI scans, and pathology slides. Computer vision algorithms assist in diagnostic procedures, treatment planning, and monitoring disease progression, offering valuable support to radiologists and pathologists.

3.2.4 Predictive Analytics

By analyzing historical healthcare data, predictive analytics models can forecast patient outcomes, disease progression, and healthcare resource needs. This predictive capability supports the development of personalized treatment plans and preventive healthcare measures, ultimately improving patient care and operational efficiency.

3.3 Cryptographic Techniques

With the goal of preserving the confidentiality and safety of the medical records that are stored on the blockchain, robust cryptographic techniques are employed. Public-key cryptography ensures secure data sharing and access control, while hashing guarantees data integrity. Digital signatures further authenticate data transactions, safeguarding sensitive information from unauthorized access and tampering.

3.4 Cloud Computing

Integrating cloud computing services is essential for effectively running our healthcare system. Leading cloud service providers like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) offer a variety of flexible resources. These include computing power, data storage solutions, and networking options, all designed to meet diverse business needs. These platforms supply the infrastructure required to adapt to changing system demands, ensuring that businesses can maintain reliability, scale their operations as needed, and manage costs effectively.

The architecture of the system is designed using APIs and microservices to enable modular development and facilitate integration with external systems. RESTful APIs or messaging protocols like MQTT and AMQP are used to enable seamless communication between different components of the system. This modular approach enhances scalability, flexibility, and ease of maintenance, allowing for efficient updates and expansions.

3.5 DevOps Tools

Adopting DevOps practices and utilizing tools such as Docker, Kubernetes, Jenkins, and GitLab CI/CD streamline the entire software development lifecycle. The tools used in DevOps streamline the process of continuous integration and continuous delivery (CI/CD), allowing for the automation of testing and deployment. This automation helps keep systems updated and running smoothly with minimal manual intervention. By adopting DevOps practices, development and operations teams can work together more effectively, resulting in faster rollouts of high-quality software updates and new features.

The incorporation of cutting-edge technology in the healthcare system leads to enhanced security, efficiency, and effectiveness, resulting in improved patient outcomes and optimized operating procedures.

4. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) refers to the capability of machines, such as computers and robots, to execute tasks that typically necessitate human cognitive abilities. This encompasses the development of systems designed to replicate cognitive functions like reasoning, comprehension, generalization, and learning from past experiences—traits commonly observed in human behavior. [5].

Automatically accessing large volumes of data generated on a daily basis and then analyzing them, identifying inherent patterns, testing the newly learnt knowledge on existing corpus, utilizing this feedback to modify the strategy used to solve problems lies at the core of Artificial Intelligence. Machine learning algorithms facilitate the processes of knowledge representation, reasoning and discovery. Although AI has been used to assist humans in various contexts, the wide potential that AI and Machine Learning offer on a real-time basis make them the ideal candidate to be used in the development of E-Healthcare Management System.

For this purpose, Google Gemini AI Pro has been chosen for the current implementation as the scope of the current paper is being limited to textual data.

4.1 Gemini AI and Flask

Google Gemini AI is a multimodal AI which can handle different types of data including text, images, audio, video etc., Flask is a Python API that can be used to build web applications. It has been chosen because it is easy to customize and extend depending upon user requirements.

From a front-end, requests may be sent to Flask which then forwards it to Gemini. Since Gemini Pro is being used the responses which are in the form of text are sent back in JSON format. CORS is used in order to allow the API to be accessed from different types of applications at the front end.

5. BLOCKCHAIN

Blockchain technology is transforming how we store data by providing a decentralized, secure, and transparent option [6]. Unlike traditional databases controlled by a single entity, blockchain spreads information across a network of computers, meaning that each participant has their own copy of the data. This approach enhances security and transparency, as it reduces the risk of data manipulation and increases trust among users. This decentralized structure, combined with cryptographic

techniques, makes it extremely difficult to alter or delete information. Furthermore, the absence of a centralised authority eliminates the need for reliable intermediaries and reduces the possibility of manipulation. These characteristics make blockchain appropriate for a broad range of uses beyond cryptocurrencies, such as voting procedures, supply chain management, and intellectual property protection. They also portend a transparent and safe future for the recording and tracking of information.[7].

5.1 Components of Blockchain

5.1.1 Node

A blockchain node is a computer or device that operates the blockchain software, participating in transaction validation and network security. Nodes communicate with each other, and a higher number of nodes increases network decentralization.

a) Full Node: It maintains a complete copy of the blockchain, validating and managing transactions.

b) Partial Node (Lightweight Node): It holds only transaction hash values, accessing full transactions via these hashes, requiring less storage and computational power.

5.1.2 Ledger

It is a digital database for transaction information. There are three types:

5.1.2.1 Public Ledger

Open and transparent, accessible for reading and writing by anyone in the network.

5.1.2.2 Distributed Ledger

Each node has a local copy of the database, collectively verifying transactions and adding blocks.

5.1.2.3 Decentralized Ledger

No single node or group controls the ledger, with every node participating in transaction verification.

5.1.3 Wallet

It is a digital tool for storing cryptocurrency, using public and private key pairs to ensure privacy.

5.1.4 Nonce

This is a 32-bit number used once, added to a hashed block to aid in block creation or transaction validation.

5.1.4 Hash

The data is mapped to a fixed size using hashing.

5.2 Process of Blockchain

Blockchain technology functions like a secure, transparent, and shared ledger where everyone holds a copy and changes need collective approval. Imagine sending something valuable and both parties get identical, publicly visible receipts. This is the core of blockchain.

5.2.1 Initiating a Transaction

A buyer starts a transaction to send or receive an asset like cryptocurrency. This transaction is then broadcasted to the network.

5.2.1.1 Validation

The network validates the transaction, ensuring the buyer has sufficient funds or ownership of the asset.

5.2.1.2 Hashing

Validated transactions are grouped into a block, which undergoes cryptographic hashing, creating a unique digital fingerprint for data integrity.

5.2.1.3 Distribution

The new block is distributed to all network nodes, which verify its validity using the hash.

5.2.1.4 Commitment

If a majority of nodes agree on the block's validity, it's added to the blockchain, completing the transaction.

5.2.1.5 Mining Rewards

In proof-of-work systems, miners engage in a competition to crack cryptographic puzzles to add new blocks to the blockchain. Those who successfully solve these puzzles are rewarded with cryptocurrency. In Proof-of-Stake systems only those participants who stake Ether existing in their accounts are allowed to participate in the consensus, thereby reducing energy consumption to a large extent. From the perspective of energy consumption PoS based blockchains such as Ethereum are considered to be better when compared to PoW based blockchains.

5.2. Ethereum Blockchain

Ethereum Blockchain has been chosen as a viable option for the implementation of E-Healthcare application as it combines the advantages of security, scalability and ease of tracking of transactions. Ethereum uses smart contracts and Proof of Stake which provides significant improvement in the number of transactions that can be executed per second. Combined with the ease of development of smart contracts using Solidity programming language, Ethereum seems to be the appropriate choice for implementation of E-healthcare management system.

6. AI & BLOCKCHAIN IN HEALTHCARE MANAGEMENT

6.1 Blockchain in Healthcare

Blockchain technology offers a secure, decentralized framework for managing patient data, granting patients full control over their medical records and ensuring resistance to tampering. This allows healthcare providers to access patient information securely and transparently, potentially reducing medical malpractice and errors[8].

6.2 AI in Healthcare

Artificial Intelligence assists healthcare providers by identifying patterns and trends within medical data. AI algorithms can recommend suitable treatments and medications based on a patient's diagnosis, medical history, and other relevant factors. Moreover, AI can predict future health outcomes and identify patients at risk for specific diseases.

6.3 Blockchain in Electronic Health Records (EHR)

Decentralized Data and Control: Blockchain technology empowers patients to own and manage their medical records, enabling secure and interoperable data sharing among healthcare providers. Platforms such as MedRec and Gem Health Network utilize blockchain to incentivize data access and streamline care coordination.

6.4 Blockchain in Health Monitoring for IoT Devices

Secure and Scalable Communication: Blockchain provides a secure and scalable platform for communication between medical IoT devices and healthcare providers[9]. The lightweight nature of certain blockchain models reduces operational costs and ensures reliable data transmission [10].

6.5 Blockchain In Neuroscience

Blockchain ensures the integrity and security of neuroimaging data used in research. By maintaining data accuracy, it fosters trust and reproducibility in scientific studies. This breakthrough is particularly promising for advancing personalized medicine in diseases such as Parkinson's and Alzheimer's.

6.6 Blockchain in Genomic Medicine

Blockchain empowers patients by granting them secure ownership of their genomic data. Through blockchain, patients can control who accesses their data, enabling their participation in research while safeguarding their privacy. This data can then be leveraged for personalized risk assessment and the development of targeted drugs.

6.7 Blockchain in Biomedical and Pharmaceutical Sectors

Blockchain brings transparency and efficiency to clinical trials by enabling real-time tracking of drug efficacy and safety data. This capability minimizes the risk of data manipulation, accelerates research progress, and ensures the integrity of clinical trial outcomes.

7. E-HEALTHCARE MANAGEMENT SYSTEM

The proposed system of integrating artificial intelligence with blockchain technology can significantly transform and benefit the health care industry by enhancing data security, interoperability, and patient care.

7.1 E-Healthcare Management System Functions

7.1.1. Patient Management

7.1.1.1 Registration and Identity Management

Patients can securely register and manage their identities on the blockchain, guaranteeing data integrity and privacy.

7.1.1.2 Medical Records

Employ blockchain technology to store immutable medical records, accessible only to authorized healthcare providers, ensuring patient privacy and consent.

7.1.2. Appointment Scheduling

7.1.2.1 Smart Contracts

Utilize smart contracts on the blockchain to automate appointment scheduling, minimizing administrative burdens and ensuring transparency [11].

7.1.2.2 AI-Powered Scheduling:

AI algorithms can optimize scheduling by considering patient preferences, physician availability, and the urgency of medical conditions.

7.1.3. Diagnostic Assistance

7.1.3.1 Symptom Analysis

AI algorithms can evaluate patient symptoms and medical history to assist healthcare providers in diagnosing conditions, enhancing accuracy and efficiency.

7.1.3.2 Data Sharing

Patients can securely share diagnostic data with healthcare providers through encrypted channels, facilitated by blockchain technology.

7.1.4. Treatment Planning

7.1.4.1 Customized Treatment Plans

AI has the ability to examine individual patient data to develop tailored treatment strategies. This process considers factors such as the patient's medical history, genetic makeup, and the efficacy of various treatments.

7.1.4.2 Blockchain Traceability

Record treatment plans and medical interventions on the blockchain to ensure traceability and auditability, thereby enhancing accountability and quality of care.

7.1.5. Medication Management

7.1.5.1 Supply Chain Integrity

Utilize blockchain to monitor the pharmaceutical supply chain, ensuring the authenticity of medications and preventing counterfeit drugs from entering the market.

7.1.5.2 Medication Adherence

AI-powered reminders and monitoring systems can enhance medication adherence among patients, reducing the risk of adverse health outcomes.

7.2 System Workflow

7.2.1 Telemedicine and Remote Monitoring

7.2.1.1 Virtual Consultations

Facilitate secure virtual consultations between patients and healthcare providers, using blockchain for enhanced privacy and AI for real-time diagnostic support.

7.2.1.2 Remote Monitoring Devices

Integrate AI-powered remote monitoring devices to continuously track vital signs and health metrics, enabling proactive healthcare interventions.

7.2.2 Insurance and Billing

7.2.2.1 Claims Processing

Utilize smart contracts to automate claims processing, reducing administrative delays and enhancing transparency in insurance transactions.

7.2.2.2 Fraud Detection

Deploy AI algorithms to analyze insurance claims data, identifying fraudulent activities to reduce financial losses for insurers and ensure fair premiums for policyholders.

7.2.3 Research and Development

7.2.3.1 Data Sharing for Research

Leverage blockchain technology to facilitate secure data sharing among researchers, ensuring that patient privacy and consent are respected at all times.

7.2.3.2 AI-driven Insights

Apply AI to analyze extensive healthcare datasets, uncovering patterns, trends, and potential treatments to expedite medical research and innovation.

7.2.4 Regulatory Compliance

7.2.4.1 HIPAA Compliance

Implement robust security protocols and strong data management practices to ensure compliance with the HIPAA and other regulations. These measures are essential for safeguarding sensitive health information and maintaining regulatory adherence.

7.2.4.2 GDPR Compliance

Comply with the General Data Protection Regulation (GDPR) requirements for data protection and privacy, especially in processing personal health information.

7.2.5 Continuous Improvement

7.2.5.1 Feedback Mechanisms

Gather feedback from healthcare providers, patients and others to continuously enhance the system's usability, effectiveness, and safety.

7.2.5.2 Iterative Development

Embrace an iterative development approach, integrating new technologies, standards, and best practices in healthcare management.

8. ARCHITECTURE OF E-HEALTHCARE MANAGEMENT SYSTEM

The layered architecture includes IPFS Inter Planetary File System, Google Gemini AI as the bottommost layer. IPFS is used as persistent storage. Google Gemini AI is a multimodal generative AI which can be used with different types of data including text, audio, video etc., Django is a python based web framework whereas Flask is a light weight web framework based on Python. Flask is used because it is flexible where as Django is used because it provides better performance and multiple templates that ease implementation. Angular is used to create the Front-end for the application. Once the single page web application has been created, Metamask is used to perform transactions on the blockchain.

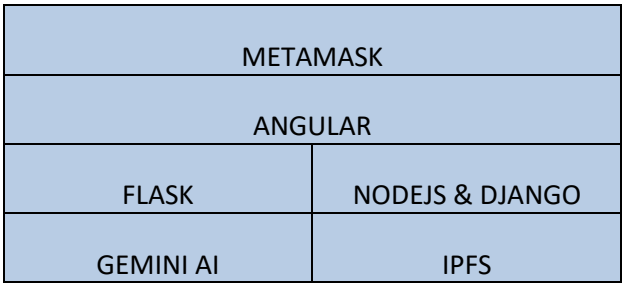

Figure. 1. Architecture

9. IMPLEMENTATION OF E-HEALTHCARE MANAGEMENT SYSTEM

The implementation methodology of E-healthcare management system involves creation of a single page distributed web application using Ethereum blockchain and integrating it with Gemini AI for the purpose of further analysis.

Step 1: Create Backend using NodeJS and Django

Step 2: Create Single Page Web Application using Angular.

Step 3: Create Distributed Ethereum Blockchain Application using Solidity, Truffle and IPFS.

Step 4: Integrate this web application with Gemini AI and Flask App in order to enhance the web application with advanced machine learning features.

Step 4.1: Create the Flask Server to handle requests and run it in virtual environment

Step 4.2 Activate the virtual environment once it has been created

Step 4.3 Create a file called requirements.txt containing the packages needed on the server side. The packages include google-generativeai, Flask and flask_cors

Step 4.4: Install packages using the command pip install -r requirements.txt

Step 4.5: On the server side, create a file called “main.py” and import the packages including google. generativeai, Flask, request, jsonify, CORS

Step 4.6: Create a function to handle the request. Here a POST request is sent to Google Generative AI. Since Gemini Pro is being used, the input is given the form of text.

Step 4.7: The response is sent back to the front end in a JSON Format.

Step 5: Use Metamask in order to perform Blockchain transactions.

10. IMPLEMENTATION OF BLOCKCHAIN

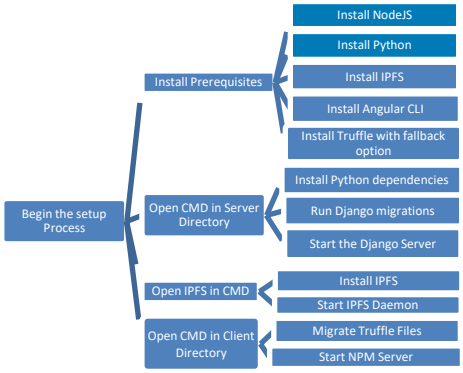

Figure 2. Implementation of Blockchain

11. RESULTS

Results indicate that the proposed methodology of integrating Blockchain with the AI can be used for enhancing the performance of E-Healthcare Management Systems. While Blockchain provides the benefit of security of data, AI provides the benefit of advanced analytics which informs and assists in automated decision making.

12. FUTURE ADVANCEMENTS

Future advancements in AI-blockchain-based e-healthcare management systems can significantly optimize their functionality. A primary area for enhancement is interoperability, which can be achieved by developing standardized protocols and APIs to enable seamless data exchange between diverse healthcare systems and devices. Additionally, employing advanced AI algorithms for predictive analytics will allow healthcare providers to anticipate disease outbreaks, tailor treatment plans to individual patients, and improve resource management. Implementing real-time monitoring solutions that utilize AI and blockchain technology can facilitate continuous patient health monitoring and early detection of anomalies [12]. Decentralized clinical trials on the blockchain, supported by

smart contracts, can streamline processes like insurance claims, appointment scheduling, and billing, thereby reducing administrative burdens. Blockchain-based patient-centric health records can empower individuals to securely manage their health data and engage in research initiatives.

Furthermore, strengthening security measures, such as zero-knowledge proofs and decentralized storage, is essential to protect sensitive healthcare information and ensure patient privacy. Joint endeavors involving researchers, healthcare practitioners, and technology. vendors, and regulatory bodies are crucial for driving innovation, validating solutions, and establishing industry standards for AI & blockchain e-healthcare systems.

13. CONCLUSION

The integration of AI and blockchain technology in e-healthcare management systems offers significant potential to transform healthcare delivery. This combination could change how services are provided, enhancing efficiency and improving patient care. By examining current research, we can identify both the major advantages and the hurdles that come with integrating these technologies in the healthcare sector. AI-driven systems enhance healthcare operations through advanced analytics, predictive modeling, and personalized patient care, resulting in greater efficiency, accuracy, and cost-effectiveness. Blockchain technology offers a reliable and transparent way to manage data, helping to protect patient privacy and ensure data remains secure and accurate. It also makes it easier for healthcare providers to share information smoothly across different systems.[13].

Although AI and blockchain technologies bring numerous advantages to the e-healthcare sector, several critical challenges must be tackled to guarantee their seamless adoption and broader use. These include adhering to regulatory guidelines, ensuring data standardization, resolving interoperability issues, and addressing ethical concerns, all of which present notable hurdles. To unlock the full potential of AI-blockchain solutions in healthcare, it's vital to overcome these obstacles. While these technologies could transform healthcare by enhancing efficiency, accessibility, and patient-centered care, thoughtful planning and careful navigation of these challenges are key to ensuring their successful implementation.

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