



THE BLOCKCHAIN RELIES ON DONATED BLOOD MONITORING

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ABSTRACT Currently, many blood monitoring management systems lack essential features such as traceability, immutability, transparency, auditing, privacy, and security. Moreover, their centralized nature makes them susceptible to single points of failure. To address these limitations, this paper introduces a decentralized and secure blood monitoring management solution based on a private Ethereum blockchain. Our approach ensures transparency, traceability, auditability, privacy, and trust while automating the overall process. To handle non-critical and large datasets, we leverage the decentralized InterPlanetary File System (IPFS) for off-chain storage. The paper outlines the system architecture, sequence diagrams, entity-relationship diagram, and key algorithms to illustrate the solution's operational flow. We also assess the system's performance in terms of efficiency and security. Additionally, our smart contract code is made publicly accessible on GitHub¹.

Keywords: Blood Monitoring Management, Blockchain, Private Ethereum, Decentralization, Transparency, Traceability, Immutability, Security, Privacy, Auditability, IPFS, Off-chain Storage, Smart Contract, System Architecture, Sequence Diagrams, Entity-Relationship Diagram, Security Analysis.

I. INTRODUCTION

Effective blood monitoring and management are critical components in healthcare systems, ensuring the timely and safe delivery of blood to patients in need. However, many existing blood monitoring systems struggle to offer essential features such as traceability, immutability, transparency, auditability, privacy, and security. These limitations are primarily due to the centralized nature of current systems, which makes them vulnerable to data breaches and single points of failure. Traditional technologies like RFID (Radio Frequency Identification) have been employed to track blood bags within supply chains, but these systems suffer from security vulnerabilities, lack of scalability, and low customization potential for broader industrial applications.

To overcome these challenges, this paper introduces a blockchain-based solution using a private Ethereum network, designed to automate and secure blood monitoring processes. By leveraging the decentralized and tamper-resistant nature of blockchain, the system ensures a high level of data integrity, privacy, and accountability. Furthermore, the solution integrates the InterPlanetary File System (IPFS) for efficient off-chain storage of large and non-critical data. Smart contracts are used to define the rules and logic of blood monitoring operations, making the system more reliable and transparent. This proposed system is also adaptable, enabling easy customization for other industrial applications with minimal effort. Through security analysis and performance evaluation, this approach demonstrates

significant improvements over traditional methods, offering a robust and scalable framework for modern blood monitoring management.

II. Need of the Study

A large number of traceability solutions use a central server to handle the visibility and traceability problems. One popular solution for tracking and monitoring blood bags is using the radio frequency identification (RFID) technology. The RFID is a standing out technology because of its high significance in supply chain management. In industrial applications, this technology is used to transfer data utilizing radio frequency waves and further identifies tagged items. Davis et al. proposed the RFID-based dynamic blood information management system to track blood products in blood centers.

The RFID chip is added to the blood bags as part of the recognition procedure during the preparation period. When an order is issued from a healthcare center, the delivery operator picks the bag and encodes the RFID chip to its destination. The central information system keeps the track record of each blood bag using the RFID reader/encoder that automatically reads the product code registered on the chip and the blood Monitoring number. This solution allows several tags to be read simultaneously, stores information on the chip, provides condition tracking sensors such as time and temperature, and facilitates automated detection and data collection.

III. LITERATURE SURVEY

To enhance productivity and safety, the RFID technology is integrated with supply chain processes. Although the integration has shown sufficient performance in healthcare supply chains, it can also be used for the traceability and transportation of blood components. However, the RFID technology suffers from security and privacy problems. For example, tags can be read from a distance in a range of inches to some yards with a high-gain antenna reader, which can enable anyone to see the contents. Also, some tags can be turned off, and since the RFID-based systems use electromagnetic spectrum, they can be easily disrupted [1]. Eskandari-Khanghahi et al. created a multi-period and multi-objective blood supply chain optimization model. The model accounts for uncertain data due to disaster and post-disaster rough conditions. The solution includes blood transfer between several blood facilities, transferring vehicles, blood centers, and hospitals. It also employs linear programming that considers location, allocation, and delivery of blood. The authors of also proposed a supply chain solution to manage critical blood supply requests in crucial situations.[2]Healthcare supply chains are complex structures spanning across multiple organizational and geographical boundaries, providing critical backbone to services vital for everyday life. The inherent complexity of such systems can introduce impurities including inaccurate information, lack of transparency and limited data provenance. Counterfeit drugs is one consequence of such limitations within existing supply chains which not only has serious adverse impact on human health but also causes severe economic loss to the healthcare industry. [3]Consequently, existing studies have emphasized the need for a robust, end-to-end track and trace system for pharmaceutical supply chains. Therein, an end-to-end product tracking system across the pharmaceutical supply chain is paramount to ensuring product safety and eliminating counterfeits. Most existing track and trace systems are centralized leading to data privacy, transparency and authenticity issues in healthcare supply chains. In this article, we present an Ethereum blockchain-based approach leveraging smart contracts and decentralized off-chain storage for efficient product traceability in the healthcare supply chain.[4] The smart contract guarantees data provenance, eliminates the need for intermediaries and provides a secure, immutable history of transactions to all stakeholders. We present the system architecture and detailed algorithms that govern the working principles of our proposed solution. We perform testing and validation, and present cost and security analysis of the system to evaluate its effectiveness to enhance traceability within pharmaceutical supply chains.

III. METHODOLOGY

To build a secure and decentralized blood monitoring management system, our methodology focuses on leveraging blockchain technology, decentralized storage, and smart contract logic. The overall design emphasizes transparency, traceability, auditability, and privacy. The architecture consists of a private Ethereum network, which facilitates

secure and tamper-proof transactions between stakeholders, and the InterPlanetary File System (IPFS) for storing large non-critical data off-chain. The system is designed to be scalable and adaptable to meet the needs of not just blood banks but also other medical and industrial domains.

3.1 Dataset used

The dataset used in this system includes metadata related to blood donations such as donor details (excluding sensitive personal information), blood type, quantity, collection and expiry dates, blood bag ID, and location data. It also includes transaction records between blood banks, hospitals, and transportation entities. While critical transaction logs and rules are stored on the Ethereum blockchain for immutability, large datasets such as scanned documents or temperature logs during transportation are stored in IPFS and linked via blockchain using content-addressable hashes.

3.2 Data preprocessing

Before storing data on the blockchain or IPFS, the system performs several preprocessing steps. First, sensitive information is anonymized or encrypted to protect user privacy. Data consistency checks are performed to ensure no duplicate or corrupt records are uploaded. Each record is formatted into a structured JSON format that smart contracts can interpret easily. Large files or images are pre-processed, compressed, and hashed before being uploaded to IPFS. These hash links are then associated with the appropriate blockchain transaction, ensuring complete traceability.

3.3 Algorithm used

The system employs Ethereum smart contracts as the core logic for managing blood monitoring activities. Two key algorithms are implemented in Solidity: one handles the registration and verification of blood donations, and the other manages the tracking and transfer of blood units. These smart contracts enforce rules such as validation of blood expiry, authorized access, and condition-based transfer approvals. Rolebased access control (RBAC) is implemented within the smart contracts to ensure that only authorized users (e.g., hospital staff, transport agents, blood bank admins) can interact with specific parts of the system.

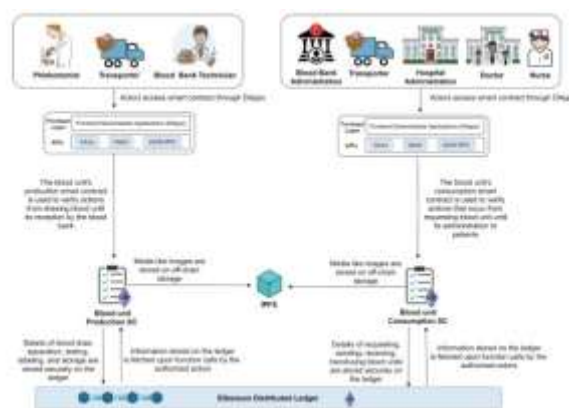


Figure 3.3.1 : System Architecture

3.4 Techniques

Several innovative techniques are employed to enhance system efficiency and security. Firstly, blockchain ensures tamper-resistance, immutability, and auditability of transactions. Secondly, IPFS provides decentralized storage, reducing on-chain data size and associated gas costs. Role-based permissions and cryptographic hashing ensure data

privacy and secure access control. Additionally, smart contracts automate workflows and minimize human error. The system's modular design allows for easy customization and integration into various medical and supply chain infrastructures. Security analysis is also conducted to identify and mitigate potential vulnerabilities, ensuring a robust and reliable solution.

3.5 Flowchart

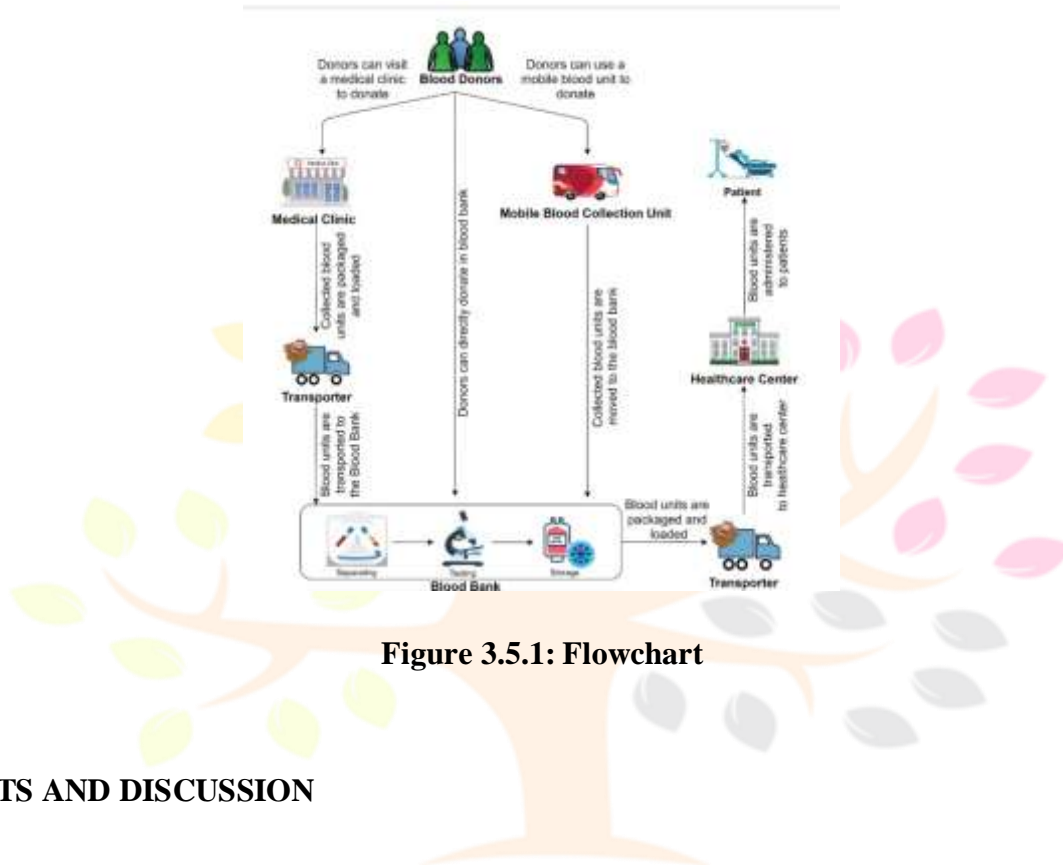


Figure 3.5.1: Flowchart

IV. RESULTS AND DISCUSSION

4.1 Graphs

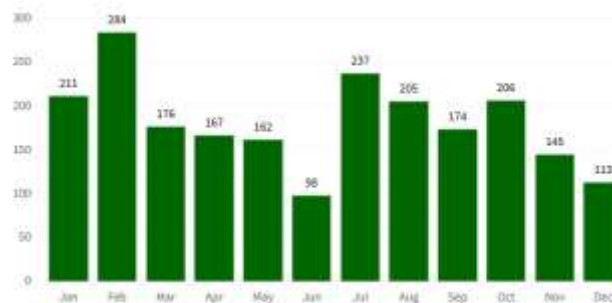


Figure 4.1.1 : Resultant Graph

4.2 Screenshots

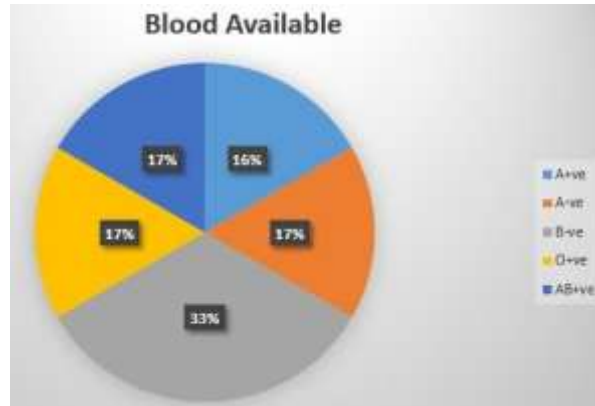


Figure 4.2.1 Blood Available Details in pie chart

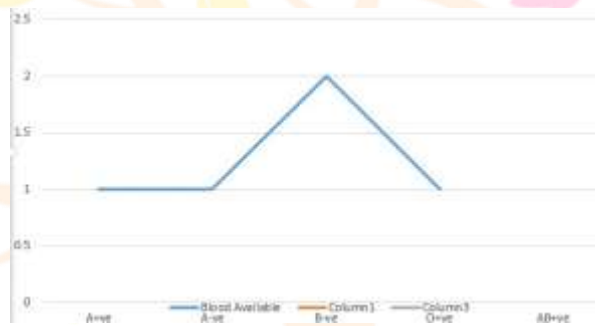


Figure 4.2.2 : 1 Blood Available Details in line chart

V. CONCLUSION

This paper presents a blockchain-based approach to blood monitoring management using a private Ethereum network, aiming to resolve the critical limitations of existing centralized systems. By integrating blockchain with the decentralized InterPlanetary File System (IPFS), the proposed solution ensures secure, transparent, traceable, and tamper-proof management of blood supply data. The use of smart contracts enhances automation and enforces predefined rules for efficient and reliable operations. Compared to traditional RFID-based systems, the proposed model addresses privacy, security, and single-point-of-failure concerns effectively. The system is not only decentralized and secure but also adaptable, offering the flexibility to be customized for various industrial applications beyond healthcare. The performance evaluation and security analysis demonstrate that the proposed framework improves the integrity, scalability, and trustworthiness of blood monitoring systems. As a result, this solution represents a significant step forward in modernizing blood management processes through emerging technologies like blockchain and IPFS.

VI. REFERENCES

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