

MANAGING BLOOD DONATION EFFECTIVELY USING BLOCKCHAIN

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ABSTRACT

Many of today's blood donation management systems aren't up to pace when it comes to providing for auditability, privacy, traceability, and security for donors and recipients. Additionally, the centralization they use makes them susceptible to the "single point of failure" issue. We propose a secure Ethereum network in this study. Blood donation management automation using blockchain technology in a way that is public, verifiable, auditable, private, secure, and reliable. Off-chain, in the decentralised interplanetary File System, is where the suggested system stores massive, non-critical data (IPFS). In order to provide a concise explanation of how our blood donation management solution works, we describe its system architecture, sequence diagrams, entity-relationship diagram, and algorithms. Through a series of security analyses, we determine how well our solution performs in terms of efficiency and efficacy.

1. INTRODUCTION

A human body's blood is a vital fluid. It helps provide the body's vital organs with the nutrients they need to function. Considering that blood is in more demand than any other medical supply, governments often host awareness campaigns to encourage blood donation among their residents. According to estimates [1], [2], there will be a total of 216,639 gifts made in 2018–2019 from a total of 136,908 contributors. The average healthy person donates blood once every 56 days [3]. The yearly volume of blood donations collected is estimated by the WHO to be 112.5 million units, or around 50 million litres [4]. The advent of new illnesses, however, has resulted in a greater demand for dependable and effective blood donation management [5]. The field of Patient Blood Management (PBM) is extensive and complex. Unfortunately, the existing blood management system has several limitations and blind spots that prevent it from performing at its optimal level.

Logistics network. According to Hannon [6], blood component wastage rates are typically between 1% and 5%, and the quantity of disposal is neither communicated nor visible in order to shed light on the underlying causes. Consequently, each advancement or change is a crucial aspect in delivering efficient healthcare all over the globe.

First, blood units may be delivered from healthcare facilities to regional blood banks. The second option is to use blood collecting vehicles. Thirdly, by contacting blood banks straight. When blood is given to a blood bank, it is separated, tested, and stored. Centrifuges are used to separate whole blood units into their component parts, such as red cells, platelets, and plasma.

2. RELATED WORK

Several research and scientific fields have recognized the need of traceability. It is the extent to which products can be tracked from their point of manufacture or creation to the final consumer. Supply chain management is one of the most important areas where data traceability is required because of the many parties involved. As the algorithms employed in other supply chain networks may be relatively straightforward, the use case of controlling the supply chain of blood unit donation is more difficult.

The process of collecting blood, transporting it, storing it, distributing it, and finally giving it to patients involves a vast number of people. Information on the origin, storage conditions, and duration of transit in blood supply chain systems, as well as any pharmaceutical supply chain, is regarded highly confidential. Therefore, it is crucial to increase data transparency to ensure the safe transport and distribution of blood units and to build confidence in the quality of the blood itself. Here, we examine various solutions for blood supply chain visibility and traceability, including blockchain-based and non-blockchain-based methods.

A. NON-BLOCKCHAIN-BASED SOLUTIONS

Many available traceability options rely on a centralised server to solve issues of transparency and auditability. Using radio frequency identification (RFID) technology is a common method for keeping tabs on blood bags. Because of its immense value in managing supply chains, RFID stands out as a revolutionary technology. This method of transferring information in the workplace makes use of radio frequency waves and may also be used to identify tagged objects [22]. At order to keep track of blood products in blood centres, Davis et al. [23] introduced the RFID-based dynamic blood information management system.

As part of the identification operation, an RFID chip is implanted into the blood bags beforehand. After receiving an order from a medical facility, the delivery person will choose the appropriate bag and programme the RFID chip to the correct location.

A RFID reader/encoder automatically scans the product code registered on the chip and the blood donation number, and this information is then stored in a central database. This method promotes automatic detection and data gathering [24], as it allows several tags to be read at once, saves data on the chip, offers condition monitoring sensors like time and temperature, and more.

By incorporating RFID technology into supply chain procedures, efficiency and security may be improved. Despite the fact that the merged system has functioned well in terms of healthcare provision.

Chains, it may also be used to track blood and its components during transit. There are privacy and security concerns with RFID technology, however. A high-gain antenna reader can scan tags from a distance of a few inches to a few yards, allowing anybody to see their information. Moreover, certain tags are disableable, and since RFID-based systems rely on electromagnetic spectrum, they are vulnerable to interference [25].

Microservices-oriented software architecture for middleware that gathers, stores, and tracks data sources in a centralised way to give data analysts with a resource for fresh insights into an entire supply chain was provided by the authors in [26] to increase transparency for food customers. Additionally, in [27], a centralised system for managing blood donations is envisaged. By integrating various blood donation-related systems, it improves overall management efficiency. It shortens the time it takes to donate blood by collecting just the information that is necessary.

In order to optimise the blood supply system throughout many time periods and with multiple objectives, Eskandari-Khanghahi et al. [30] developed a model.

Data uncertainty caused by disasters and their aftermath is included into the model. Transfer trucks, blood banks, blood centres, and hospitals are all part of the answer. It uses linear programming to think about where blood should go and how to get it there. To handle demands for life-sustaining blood products during emergencies, the authors of [31] presented a supply chain approach. In their model, they proposed a method to cut down on the blood supply chain's overhead. Donors, blood banks, ambulances, labs, and blood centres all play a role in the model's circulation of blood units. In [32], the authors presented a unified strategy for managing the blood supply chain; it is based on a network that employs an optimization model. The created methodology is useful for pinpointing blood banks and distributing resources effectively during emergencies. The aforementioned options use cutting-edge optimization algorithms to better manage and choreograph the blood supply chain and the movement of blood units. However, they have a few major flaws that should be explored. In this article, we want to address the major problem, which is the inability to see data in the already deployed system. However, using a centralised system to do so might compromise data openness while still accounting for supply chain traceability. The central server is the sole source of information on the blood units being transmitted. Accordingly, the remainder of the system's members, most especially the physicians and their patients, will not have access to any data that was not captured or was disguised by the server.

The risk of a catastrophic failure due to reliance on a single server is another significant drawback of centralised server architectures. In the event of a data breach, the whole blood supply might be jeopardised if sensitive patient information was stored in a single area.

Considering the critical nature of blood supply chain solutions, this has serious implications for the system's availability since the inability to function due to a central server being down is unacceptable.

B.BLOCKCHAIN-BASED SOLUTIONS

Maintaining blood unit traceability necessitates that all relevant parties be kept abreast of the blood units' whereabouts at all times. Using a distributed ledger like the blockchain ensures that all data is visible to all participants in the network, providing the necessary transparency. Because information published in a blockchain transaction cannot be altered, no participant in the blood supply chain can claim they did not carry or receive blood units after that transaction has been recorded on the blockchain. Each participant's activities are recorded and available to every participant in the blockchain network, guaranteeing their responsibility. Due to the distributed nature of the blockchain, the identical data is stored on all the active nodes.

Given the critical nature of the data pertaining to the blood units and donors, this shows that the data is tamper-proof and cannot be manipulated. It was also indicated before that, without the employment of a very complicated probabilistic model, the algorithms utilised in the blood supply chain are often not extremely complex. A blood supply pipeline may be established using very simple algorithms. The need for low-overhead and straightforwardness in blockchain-based systems makes them well suited to this kind of application. This is due to the fact that implementing smart contracts on the blockchain incurs a much higher cost of operation for more complicated algorithms. Despite the fact that blockchain applications are favoured due to their low operational costs, they are also capable of processing a high volume of requests and transactions, which is required in the case of most supply chain networks. Thus, we can conclude that blockchain technology can be used to better employ a pharmaceutical supply chain, including the blood donation supply chain, by avoiding the problems associated with centralised solutions in terms of visibility, transparency, availability, and data integrity, thereby significantly improving the performance and reliability of tracking donated blood units from their origin to the patient recipients.

A Hyperledger Fabric-powered blood chilled supply chain was suggested by Kim et al. [5]. The suggested system helps confirm the transactions linked to temperatures, and it keeps track of timestamps to indicate when the temperatures were verified. In addition, it shows how the blood units are currently being stored, with players in the blood cold supply chain providing an explanation for any status changes. The authors also designed a business logic to facilitate the transfer of blood between medical facilities in the event of an emergency. This network is meant to disseminate data in real time as blood is transfused, used, and destroyed. To a similar end, Lakshminarayanan et al. [11] suggested a solution that runs on the Hyperledger Fabric platform. By keeping tabs on individual blood units, it guarantees the integrity of the blood supply.

Include hosting a market for transactions between blood banks and donors. Using the Electronic Product Code (EPC) encoded on each tag, Toyoda et al. [28] advocated for a more efficient RFID supply chain. Integrating monitoring and verification of product tags helps ensure dependability and prevents counterfeiting. However, these options are not without their drawbacks. For instance, [5]'s suggested system verification is unfinished since it doesn't include an evaluation analysis. For this reason, implementing the suggested concept in an operational blood information management system is essential for proving its viability.

Even so, a method of preventing hacking during blood donations is necessary. Additionally, [11]'s suggested tracking method was restricted to blood bag monitoring and would not guarantee the traceability of blood components. Given that various blood components have varying shelf lives and optimal storage temperatures, it's crucial to take these factors into account.

In [33], the benefits of blockchain technology for the pharmaceutical supply chain are highlighted.

In particular, they describe their results with reference to the supply chain for plasma derivatives. Key challenges in supply chain management are also emphasised, such as tracking down the source of the plasma and spotting low-quality blood donations. Therefore, the blockchain was validated as a viable option to address these issues. The report also discusses the role of incentives in inspiring benefactors to take action. In [19], another approach was described using the Hypeledger to construct a blockchain-based blood supply chain management system. Not only is this solution built on a private blockchain, but it also doesn't analyse the blood's constituents or record information about the donor. In [34], the authors presented a blockchain method similar to Ethereum for decentralised blood tracking. Only members of certified blood donation centres (CBDC) are given the ability to write on behalf of the organisation. An identifier, such a donor's SSN or password, is used to verify their identity.

Overall, none of the aforementioned blockchain-based solutions provide a secure method of monitoring the blood donation process while also protecting the confidentiality of user data. In contrast, the private Ethereum blockchain is used to solve the problems with performance outlined earlier in this study while also protecting user privacy and data integrity.

The collection, transport, request, and transfer of blood units are only some of the many facets of the blood donation system that are captured by our suggested solution. It guarantees that these details are recorded in a way that is auditable, safe, and decentralised. Beginning with the donation procedure and ending with consumption, our technology tracks the whole life cycle of a given blood unit. To guarantee honesty and transparency, our plan involves everyone who helps throughout the process of donating a blood unit. Importantly, we utilised a private Ethereum blockchain to keep all parties' data safe and secure.

Information kept on the private Ethereum blockchain is protected from being read by anybody except those who are allowed to access it. Finally, our approach is the only one of its kind to include the security of the smart contract, which is crucial to guaranteeing the integrity and invulnerability of the stored data at all times.

In addition, extensive research was conducted to guarantee the correct operation of the smart contract throughout its implementation, testing, and validation phases.

3. SYSTEM ANALYSIS

The majority of traceability systems rely on a centralised server to manage visibility and traceability issues. Radio frequency identification (RFID) technology is often used as a means of tracking and keeping tabs on blood bags. Because of its immense value in managing supply chains, RFID stands out as a revolutionary technology. This method of transferring data using radio frequency waves and identifying tagged goods is widely employed in industrial settings [22]. For the purpose of monitoring blood supplies, Davis et al. [23] presented an RFID-based dynamic blood information management system.

As part of the identification process, an RFID chip is implanted into the blood bags beforehand. The delivery person selects the bag and assigns the RFID chip's destination information based on the order issued by the medical facility. The RFID reader/encoder immediately scans the product code recorded on the chip and the blood donation number, allowing the central information system to maintain track of each blood bag. This method enables for automatic detection and data gathering [24], since several tags may be read at once, information is stored on the chip, and condition monitoring sensors like time and temperature are provided.

RFID technology is used into supply chain procedures to increase efficiency and security. The integration has already proven effective in healthcare supply chains, and it may be used to the tracking and delivery of blood components as well. Security and privacy issues also plague RFID technology. It is possible for anybody to see the information contained on a tag, for instance, by using a high-gain antenna reader from a distance of a few inches to a few yards. Additionally, some tags are disabled, and as RFID-based systems utilise electromagnetic spectrum, they are readily disrupted [25]. A multi-period and multi-objective model for optimising the blood supply system was developed by Eskandari-Khanghahi et al. [30]. Disaster and post-disaster tough circumstances are taken into consideration in the model, which makes the data more reliable. A network of mobile blood centres, blood banks, hospitals, and other transfer facilities make up the solution. The system uses linear programming to plan blood collection, distribution, and delivery. Furthermore, in [31], the authors developed a supply chain strategy to handle emergency demands for blood.

Disadvantages

- One common yet inaccuracy-inducing technique for identifying and monitoring blood bags is the use of radio frequency identification (RFID) technology.
- No simple modifications can make the system suitable for use in a wide variety of additional industrial contexts.

Proposed System

To solve these problems, this article suggests a blockchain-based blood donation chain management system. Specifically, this study contributes primarily in the following ways:

The system presents a private Ethereum block chain-based solution for automating blood donation management operations in a decentralised, traceable, transparent, auditable, private, safe, and trustworthy way.

To deal with data growth, the system combines the decentralised Interplanetary File System (IPFS) with the private Ethereum block chain.

In order to implement features and specify rules for blood donation management, the system creates two smart contracts and related algorithms.

The system uses security assessments to evaluate the efficacy of the proposed blockchain-based blood donation management solution and the produced smart contracts. We also contrast our method with the current options out there.

The suggested block chain-based system for blood donation management is general and may be adapted to the specific requirements of different industries with little further work.

Advantages

- The concept suggests a distributed ledger system (blockchain) to handle blood donation logistics. Organizations mostly create private Ethereum networks to boost network anonymity, and this is the foundation of our suggested architecture.
- Patient information and other medical supplies are considered confidential and may only be accessed by authorised individuals or organisations due to the delicate nature of blood management. That's why the proposed solution is better served by a private Ethereum blockchain.

4. IMPLEMENTATION

Admin

In this section, the Admin will be able to conduct things like approve blood donors and blood bankers, access all of the files pertaining to blood information, and do other tasks. Look At Potential Blood Donors And Get Approved, Learn About Blood

Hospitals

Transact Blood Groups, Browse Blood Donors, and More! Examine Information About Blood Donors Using Blockchain Technology, Information About Patients Using Blockchain Technology, and Donated Information Using Blockchain Technology.

Using this section, hospitals may register and log in, see blood donors, feed patient details, view blood bankers and requests for blood, view blood detail, and view patients.

Blood bankers

Register and Login, View Blood Donors, View Blood Detail Request, View Req And Sale Bottle, View Blood Available, and so on are some of the tasks that blood bankers will do in this module.

Blood donor

Donors of blood will do tasks in this module such as registering with a hospital and a blood bank in order to get blood transfusions, as well as logging into these respective websites and completing tasks such as donating blood to hospitals and blood banks.

5. CONCLUSION

In this work, we propose a blockchain-based system for tracking blood donations and determining where each unit of blood came from. Blood in a distributed system that is open, private, safe, reliable, auditable, and prone to transparency. The suggested method automated the recording and logging of occurrences using the smart contract functionality of a private Ethereum blockchain. To solve the problem of insufficient space, we combined the private Ethereum blockchain with IPFS. Using the Remix integrated development environment, we verified that our solution worked as intended. The source code for the smart contracts we built is accessible on Github. To prove that our proposed blood donation management system is safe enough against significant security flaws and threats, we performed a security study. We also compared our method to what has already been done. Our long-term goal is to create a fully functional decentralised application (dapp) that we can test and deploy on the live Ethereum network. The security of the blood-cold supply chain will be bolstered further with the addition of violation monitoring.

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