Blockchain-Based Management for Organ Donation and Transplantation

Dr. N. Sree Divya
Assistant Professor (IT)
Nsreedivya_it@mgit.ac.in

P. Bhuvana Reddy
Student : MGIT
pbhuvana_it201240@mgit.ac.in

Y. Pranavan Reddy
Student : MGIT
Ypranavanreddy_it201260@mgit.ac.in

G. Akanksha Reddy
Student : MGIT
gakankshareddy_it201222@mgit.ac.in

Abstract - Today's organ donation and transplantation systems pose different requirements and challenges in terms of registration, donor-recipient matching, organ removal, organ delivery, and transplantation with legal, clinical, ethical, and technical constraints. Therefore, an end to-end organ donation and transplantation system is required to guarantee a fair and efficient process to enhance patient experience and trust. We propose a private Ethereum blockchain based solution to enable organ donation and transplantation management in a manner that is fully secure, traceable, auditable, private, and trustworthy. We develop smart contracts that ensure the data provenance by recording events automatically. We present algorithms with their implementation, testing, and validation details. We evaluate the performance of the proposed solution by performing privacy, security, and confidentiality analyses as well as comparing our solution with the existing solutions.

Key Words: organ, donation, private, confidentiality

1. INTRODUCTION

Organ donation is a critical and compassionate process that aims to save lives by transplanting organs from willing donors to individuals in need. This selfless act can occur through two primary methods: deceased donation and living donation. The initial step in both scenarios involves a thorough examination by the hospital transplant team to ensure the donor's overall health and suitability for donation.

In the case of deceased donation, the process takes a different trajectory. After the donor's examination, a crucial brain death test is conducted to confirm the irreversible cessation of brain function. Once brain death is established, the donor is considered for organ donation. The family's consent is typically sought, respecting the wishes of the deceased or any prior registered intent to donate. Following consent, the matching process begins, where the available organs are matched with patients on the waiting list based on factors such as blood type, organ size, and medical urgency.

Living donation, on the other hand, involves individuals who willingly offer to donate an organ while still alive. This could be a kidney, a portion of the liver, or, in rare cases, a lung or part of the pancreas. The donor undergoes a comprehensive evaluation to ensure physical and psychological fitness for the procedure. Once approved, the donor may choose to donate anonymously, with the matching process facilitated by transplant authorities. Alternatively, if the donor has a specific recipient in mind, the data is expedited to the transplant surgeon for further planning.

When the donation is planned for a known individual, the process becomes more personalized. The transplant surgeon receives the relevant information, initiating the surgical procedures to remove the organ from the living donor and transplant it into the identified recipient. This meticulous coordination between medical professionals, donors, and recipients is vital to the success of organ transplantation and, ultimately, the enhancement of patients' quality of life and survival rates. The generosity of donors and their families, whether in life or posthumously, plays a pivotal role in this life-saving medical practice.

2. LITERATURE REVIEW

1. Decentralised and Distributed System for Organ/Tissue Donation and Transplantation: In today's era of digitisation, many technologies have evolved that every manual work can be digitally automatized. In the digital automatizing process, security and privacy are the most important and highly demanding aspects. Blockchain offers many features that can be used in almost every sphere of life. Features like decentralisation, transparency, privacy makes it an extremely useful technology. Therefore, by making use of all these features, several problems in healthcare sector can be solved like removing complex network of third parties and lack of traceability of transactions. This paper presents a decentralised, secure and transparent organ and tissue transplant web application (also called DApp), which not only nullifies the role of any third party involved in the organ transplantation, but also is a cost-effective solution that saves the patients from high cost of transplantation. The details and Electronic Medical Record (EMR) are hashed using the IPFS (a distributed file server), which reduces the cost of upload greatly as shown in the results section of this paper.

2. Organ Allocation Algorithms and Blockchain-based Systems for Organ Donation and Transplantation : The objective of the paper is to highlight the significance of organ donation and transplantation since the first successful kidney transplant in 1954. It emphasizes the complexities in the allocation of scarce kidneys, driven by the imbalance between supply and demand. The paper discusses the efforts made by organizations worldwide to enhance organ donation and transplantation, particularly focusing on the use of blockchain-based solutions to address existing challenges. The primary focus is on kidney allocation algorithms, given the high demand for kidney transplants. Additionally, the paragraph points out the variations in organ allocation policies among different countries and emphasizes the need for international regulations. The overarching goal is to shed light on the potential of blockchain technologies as a fundamental solution to improve organ donation systems and address existing issues in the field.

3. Using Blockchain Technology for The Organ Procurement and Transplant Network: Registration, donor-recipient matching, organ removal, organ delivery, and transplantation all present unique challenges and opportunities in modern organ donation and transplantation systems due to legal, clinical, ethical, and technical constraints. Because of this, a comprehensive organ donation and transplantation system is necessary to ensure a fair and efficient procedure that improves patients' experiences and their confidence in the system. We propose a private Ethereum blockchain-based solution in this paper to facilitate organ donation and transplantation management in a way that is fully decentralised, secure, traceable, auditable, private, and trustworthy. We present six algorithms for smart contracts along with information about how they were built, tested, and validated. We compare our solution to preexisting solutions and conduct privacy, security, and confidentiality analyses to determine how well our proposal performs.

4. Use of Forensic DNA Testing to Trace Unethical Organ Procurement and Organ Trafficking Practices in Regions that Block Transparent Access to their Transplant Data: This study proposes an approach to track unethically procured organs in particular countries or regions where investigations cannot be performed by utilizing forensic DNA methodology. Using China as an example, previous research has concluded that organs in China are in part unethically and extra-legally procured (so called "forced organ harvesting") from living prisoners of conscience without consent. Using forensic DNA-analysis, we propose building a DNA data bank from missing prisoners of conscience in China and comparing these results with DNA from donor organs in patients who received transplants in China. Biological materials collected in China will provide DNA directly or indirectly from potential victims of forced organ harvesting. Archival biopsies from transplant recipients' donor organs will provide DNA profiles of donors. Verified match between DNA profiles of transplanted organs and missing victims will establish proof of such connection, thus provides evidence despite a lack of transparency.

3. EXISTING SYSTEM

The current system in place for managing organ donation, which does not rely on blockchain technology, utilizes a sophisticated multi-agent software platform. This platform acts as a virtual hub, facilitating the exchange of information between donor hospitals, regulatory bodies, and recipient hospitals. Its primary aim is to streamline the various tasks that precede organ transplantation, thereby enhancing the overall efficiency of the process.

One of the key functionalities of this platform is its ability to centralize and organize potential donor information. It serves as a comprehensive repository for storing crucial data such as medical records, organ availability, and compatibility assessments. By consolidating this information in one accessible location, healthcare professionals can make more informed decisions and expedite the matching process between donors and recipients.

Furthermore, the platform significantly improves communication channels among all stakeholders involved in organ transplantation. Through direct and efficient communication channels integrated into the system, donor hospitals, regulators, and recipient hospitals can collaborate seamlessly. This enhanced communication not only fosters better coordination but also allows for quicker updates, decision-making, and logistical planning.

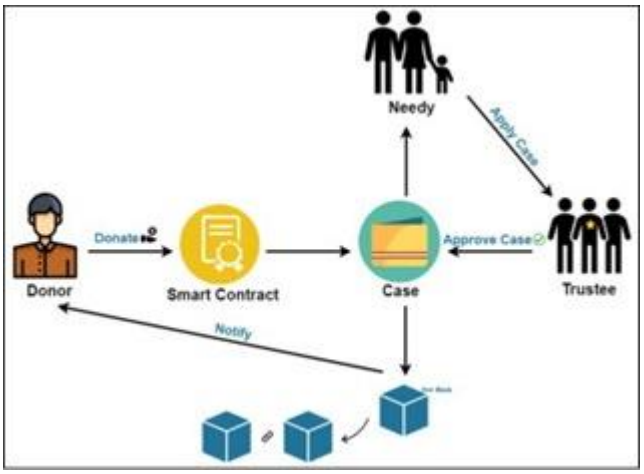
To assess the effectiveness of this system, an information workflow was simulated using the developed platform. The results of the simulation indicated a notable time-saving potential, estimated to be between three to five hours per transplantation process. This time efficiency is invaluable, as it not only accelerates the transplantation process but also increases the likelihood of successful outcomes for patients awaiting organ transplants.

4. PROPOSED SYSTEM

Our proposal introduces a private Ethereum blockchain-based system to manage organ donation and transplantation securely and reliably. By leveraging blockchain technology, we ensure that the entire process is traceable, auditable, and trustworthy. Central to our solution are smart contracts, which are programmed to register various stakeholders involved in the organ donation and transplantation process. These smart contracts meticulously record every action taken, creating

an immutable record of events. This ensures transparency and accountability throughout the entire process. Specifically, the Organ Donation Smart Contract plays a crucial role in managing the waiting list for organ recipients. It oversees the acceptance of potential donors after they pass rigorous medical tests. Once approved, the smart contract facilitates the auto-matching process, pairing donors with the most suitable recipients based on predetermined criteria.

In summary, our private Ethereum blockchain-based solution offers a secure and efficient way to manage organ donation and transplantation. By utilizing smart contracts and blockchain technology, we enhance data provenance, streamline processes, and ultimately improve the outcomes for patients awaiting life-saving organ transplants.



5. METHODOLOGY

Our proposed methodology for a blockchain-based management system for organ donation and transplantation incorporates blockchain technology, smart contracts, and secure data management to establish a robust and efficient ecosystem. This section delineates the essential components and procedures of our approach.

blockchain Infrastructure: We utilize a permissioned blockchain network to regulate access and adhere to regulatory standards. The network comprises nodes operated by medical institutions, organ procurement organizations, regulatory bodies, and other stakeholders. Each node maintains a copy of the distributed ledger to ensure redundancy and data accessibility.

Data Sharing and Privacy: Patient data is encrypted before storage on the blockchain, with access permissioned to authorized medical professionals. This balance between data sharing and privacy safeguards patient confidentiality while facilitating collaboration among stakeholders.

Smart Contracts for Process Automation: Smart contracts automate various processes, including donor-recipient compatibility matching, organ allocation based on medical urgency, and verification of prerequisites. These self-executing contracts reduce manual intervention, mitigate delays, and improve process accuracy.

Interoperability and Integration: Our system integrates seamlessly with existing electronic health record (EHR) systems and databases using standardized APIs and data formats. This facilitates smooth information exchange, prevents data silos, and provides a holistic view of patient health history.

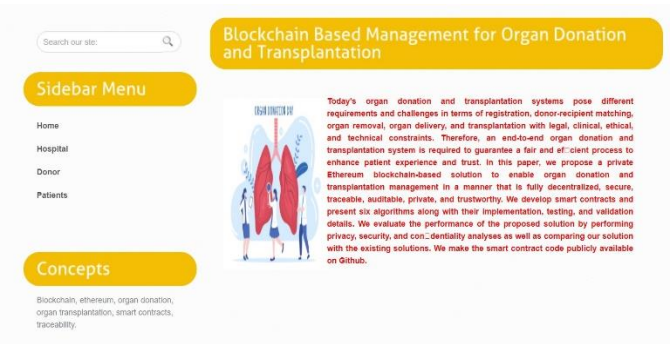
Security and Auditing: Blockchain's immutability and cryptographic techniques ensure data security. The blockchain's audit trail offers a transparent and tamper-proof record of all transactions and events, resolving disputes or discrepancies effectively.

In subsequent sections, we will delve deeper into the technical and operational aspects of our proposed methodology. This comprehensive approach addresses challenges in organ donation and transplantation management by leveraging blockchain's capabilities to enhance transparency, security, and automation.

6. RESULT

The execution and verification of the suggested blockchain-driven management system for organ donation and transplantation provided valuable insights into its operational capabilities, efficiency, and prospective influence. This segment showcases the outcomes derived from our experimental arrangement, emphasizing significant discoveries and results.

To document the organ donation procedure, vital details like the patient's name, organ specifics, blood type, and the current state of the organ need to be entered and securely stored on the blockchain. Continuous monitoring of the organ's status is imperative, with timely updates being crucial. Swift and secure transmission is necessary to prevent any delay that could compromise the organ's suitability for transplantation. The relevant migration files are stored in the assigned migration directory.



7. CONCLUSIONS

In this paper, we have proposed a private Ethereum blockchain-based solution that manages organ donation and transplantation in a decentralized, accountable, auditable, traceable, secure, and trustworthy manner. We developed smart contracts that ensure the data provenance by recording events automatically. We present six algorithms with their implementation, testing, and validation details. We analyze the security of the proposed solution to guarantee that smart contracts are protected against common attacks and vulnerabilities. We compare our solution to other blockchain-based solutions that are currently available. We discuss how our solution can be customized with minimal effort to meet the needs of other systems experiencing similar problems. In the future, our solution can be improved by developing an end-to end DApp. Furthermore, the smart contracts can be deployed and tested on a real private Ethereum network. Finally, the Quorum platform can provide better confidentiality because transactions among entities can only be viewed by specific participants and nobody else, which is not the case in our solution, where transactions between two participants are viewed by other actors authorized in the private blockchain.

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