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 [ijirset@gmail.com](mailto:ijirset@gmail.com)

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# Blockchain based Management for Organ Donation and Transplantation

Manasa G V Kumar<sup>1</sup>, P.Nischay<sup>2</sup>, Rakshitha N<sup>3</sup>, R Jagannatha<sup>4</sup>

Assistant Professor, Department of Computer Science & Engineering, Rajarajeswari College of Engineering, Bangalore, Karnataka, India<sup>1</sup>

U.G. Student, Department of Computer Science & Engineering, Rajarajeswari College of Engineering, Bangalore, Karnataka, India<sup>2,3,4</sup>

**ABSTRACT:** Organ transplantation has become a life-saving medicinal procedure for patients suffering from end-stage organ dysfunction. However, the inefficiencies Major difficulties with organ transplantation and donating procedures remain significant impediments to addressing the growing demand for organs. This publication presents a fresh approach leveraging blockchain technology to enhance the management of donation of organs and transplantation. Blockchain's inherent characteristics of transparency, immutability, and decentralization have the potential to streamline the complex organ procurement procedure, mitigate fraud, and enhance trust among In this article, we suggest a blockchain based framework that covers organ tracking, consent verification, and secure data sharing among medical institutes. The suggested approach automates procedures while protecting patient confidentiality and data privacy with smart contracts. Blockchain technology integration seeks to promote teamwork, lessen administrative load, and eventually boost organ transplantation systems' efficiency.

**KEY WORDS:** Blockchain, ethereum, organ donation, organ transplantation, smart contracts, traceability.

## I. INTRODUCTION

Organ transplantation plays a crucial role in extending the lives of patients with organ failures. However, the existing organ donation and transplantation ecosystem is marred by challenges such as lack of transparency, data fragmentation, and inefficiencies in the allocation process. The result is an inadequate supply of organ to meet the rising demand, leading to avoidable deaths!!! Blockchain-based technology has gained prominent beyond its initial application in cryptocurrencies due to its capacity to address issues related to data integrity, security, and trust in various domains. In the medical field, blockchain has shown promise in enhancing data sharing, reducing medical errors, and ensuring patient consent management. Leveraging these advantages, we propose a blockchain-based managing system for organ donation and transplantation. The remainder of this paper is arranged as follows: Section 2 provides an overview of related works in both the organ transplantation domain and the applications of blockchain using in healthcare. Section 3 details the proposed blockchain-based managing system, explaining its architecture and workflows. Chapter four discusses the potential benefits and challenges of adopting the proposed systems. Finally, section 5 summarizes the paper by summarizing the contributions and discussing future research directions. In recent years, blockchain technology has attracted much attention in different sectors because it offers a distributed and secured database without the need for a third party or a central authority. The main use cases for blockchains are its uses in cryptocurrencies. A significant portion of its development is focused on information architecture or how the database will be formed, distributed, and accessed with various degrees of permissions. Nakamoto created the first blockchain, which serves as the public ledger for bitcoin transactions. Later, the Ethereum blockchain architecture inserts computer programs into blocks to represent financial instruments. These are now commonly referred to as smart contracts. However, the purpose of blockchains is to enable the recording and distribution of digital data without the need for a central authority to modify it. In this sense, a blockchain serves as a ledger for immutable data that cannot be changed or deleted. By using blockchains, medical information may be stored securely, and patient data could be updated in real-time and across various entities. Managing organ donations and transplantations has become challenging due to the lack of data accountability, immutability, audits, traceability, and trust features in existing systems. The following are the paper's main contributions: We proposed a private Ethereum blockchain-based solution that ensures organ donations and transplantations management utilizing a decentralized approach, secured, reliable, traceable, auditable, and trustworthy. • We developed smart contracts that register actors

and ensure data provenances through producing events for every one of the necessities actions that 14936 occurred during the organ donations and transplantation stages. The code for the smart contracts is released to the public. On Github.1 • We develops an auto- matchings processes between the donor and recipients through a smart contracts based on certain criterias. • We provide six algorithms and their full imple- mentations, testings, and validations details. • We conducts security analysis to determine that the proposed solutions is security against common security attacks and vulnerabilities. We compares our solution in conjunction with the current ones to show it's novelty. Our proposed solutions is general and may be easy adjusts to meet the needs of a varies of related applications

## II. BACKGROUND

### A.PRIVATE PERMISSIONED ETHEREUM NETWORK

Private blockchains offer heightened privacy and security by restricting access to authorized entities, ensuring that transactions and data remain confidential. Enterprises can leverage the Using the Ethereum blockchain to build their networks with private permissions, enhancing privacy, security, and confidentiality. Organ transplantation details are highly sensitive, encompassing patients' health records and family histories. Therefore, utilizing a privately granted Ethereum blockchain proves optimal for safeguarding such information.

### B.BLOCKCHAIN INTEGRATION

Our suggested remedy depends on the Blockchain network. as its foundational infrastructure, ensuring permanent recording of transactions and events to uphold accountability and data provenance. To make our accessible smart contracts round the clock, they must be deployed within the blockchain. However, deploying them on the main network during testing isn't ideal. Hence, we suggest using a local blockchain environment, a JavaScript-based Virtual Machine, or a test network for testing Ethereum-based smart contracts. These smart contracts, developed using REMIX IDE, are deployed on a JavaScript-based Virtual Machine, which hosts an isolated Ethereum node within the browser for convenient testing. Once tested and verified, these smart contracts can be deployed on Ethereum's mainnet to evaluate their performance in a live blockchain setting. Notably, the deterministic nature of intelligent contracts ensures consistent outcomes regardless of the node executing the operation.

### C. PARTICIPANTS INTERACTIONS

The interaction among different participants within the matching intelligent contract can be categorized into three distinct phases. Phase 1 initiates with the production of a waiting list, where an authorized doctor adds a new patient with their ID, age, BMI, and blood type. Phase 2 involves receiving consented donors, with only authorized transplant team members able to approve tests, triggering an event upon approval. Following this, the procurement organizer evaluates and registers the donor, with an event signaling the registration announcement. Phase 3 manages the auto-matching between donors and recipients based on age range, blood type, and BMI, resulting in the announcement of a ranked patient list. Alternatively, Figure 4 depicts the interaction among various participants within the transplantation smart contract, encompassing the removal, delivery, and transplant processes. In Phase 1, the donated organ is removed from the donor's body. Once the donated organ is prepared for delivery, a transporter initiates the start delivery function. Phase 2 entails the transportation of the donated organ by an authorized transporter, who executes both the starting and ending delivery functions, ensuring safe delivery to the matched patient hospital, where it is acquired by the transplant surgeon. Finally, in Phase 3, the donated organ is transplanted, with an event signaling the conclusion of the transplantation process

### D. IMPLEMENTATION DETAILS

Below are the implementation specifics of our suggested blockchain-based organ donation and transplantation solution, in addition to the associated algorithms. Our system is constructed on using a private Ethereum network, enriched with validation nodes and restricted access to authorized participants.

Smart contracts, pivotal to our solution, are authored in Solidity and meticulously tested using the Remix IDE—an accessible web platform facilitating the development and administration of intelligent contracts. Our suggested remedy encompasses two primary components: organ donation and organ transplantation, each outlined below.

#### A. ORGAN DONATION

The organ donation smart contract involves four entities: the patient's doctor, hospital transplant team member, procurement organizer, and matching organizer. Each entity possesses a unique Ethereum address and engages with

using the smart contract by invoking specific functions. Various kinds of variables are incorporated within this smart contract. Firstly, Ethereum addresses are used for associate entities with unique addresses, such as the procurement organizer and matching organizer. Secondly, mapping is employed to link Ethereum addresses to Boolean values, signifying whether certain conditions are met. For instance, mapping ensures that authorized transplant surgeons and doctors are properly identified, moreover, it prevents patient duplication through patient validity checks. Additionally, an enumeration variable, "BloodType," encompasses different blood types—A, B, AB, and O—represented by uint8 inputs (0, 1, 2, and 3 respectively). Similarly, "OrganType," another enumerated variable, accepts uint8 inputs (0 for Heart, 1 for Lung, 2 for Liver, and 3 for Kidney).

The procurement organizer initiates the deployment of the organ donation smart contract, consequently assuming the role of the owner. This designation grants the procurement organizer the authority to assign the Ethereum address belonging to the matching organizer. Subsequently, the authorized doctor adds a new patient to the waiting list, which is subsequently disseminated to all participants. Following this, an authorized medical team member conducts necessary tests and announces their approval. The procurement organizer executes the donor registration process, announcing the kind of donated organ. Subsequently, the auto-matching process is executed, storing information regarding matched patients and potential donors. This matching process is contingent upon primary criteria such as age, blood type, BMI, and waiting time.

#### B. ORGAN TRANSPLANTATION

In the organ transplantation smart contract, which donors surgeon, transporter, and transplant surgeon are the main The intelligent contract involves multiple participants who interact by calling functions within it. It encompasses various types of variables, including public Ethereum addresses for donors and transplant surgeons, a mapping for authorized transporters responsible for organ transportation, and an enumerated variable called OrganStatus representing different types of the donated organ.

The transplantation process begins with the Transplant surgeon executing the smart contract, specifying the donor's surgeon's Ethereum addresses and the extracted organ's initial condition. After the smart contract is activated, the tracing process begins. deployed and authorized transporters are assigned. The surgeon removes the donated organ, which is subsequently transported by an authorized transporter from the donor's location to the recipient hospital. Notifications are sent for the start and completion of the delivery procedure. Subsequently, the transplant surgeon announces the reception of the donated organ and initiates the transplantation process. Finally, transplantation details, including patient ID, time, and date, are announced. The entity-relationship diagram depicts the main attributes and functions in each intelligent contract. The procurement organizer and matching organizer are declared as Ethereum addresses, as only one of each can exist. Meanwhile, mappings are used for the patients' doctor, transplant team member, and patient validity due to their plurality in the system. Blood type and organ type are declared as enumerations because of their distinct types. The main roles within the organ donation smart contract include Adding New Patient, Test Approval, Registering NewDonor, and Matching Process. The Organ Transplantation smart contract describes the transplantation process with attributes detailing the procedure. Only one surgeon is designated from the donor side and one from the recipient side, both declared as Ethereum addresses. Transporters are mapped as more than one can exist. The intelligent contract features five primary functions: Removing Donated Organ, Start Delivery, End Delivery, Receive Donated Organ, and Organ\_ Transplantation. The relationship between the organ donation and transplantation smart contracts is one-to-many, with one organ donation smart contract encompassing all patients and multiple transplantation smart contracts for various donation processes. Six algorithms elucidate the functions of both smart contracts. Algorithms 1, 2, and 3 outline the phases of the donor donation smart contract, while the remaining algorithms illustrate the functions of the Organ Transplantation smart contract.

### III. RELATED WORK

We discuss the existing blockchain and non-blockchain- based solutions that have been put forth to address the issues in the organ donation system.

#### A. NON-BLOCKCHAIN-BASED SOLUTIONS FOR ORGAN DONATION MANAGEMENT

In traditional non-blockchain-based processes, various methodologies and technologies are implemented to augment organ donation, transplantation management, and the matching process. For instance, a study by [17] introduced a multi-agent software platform designed to model the information workflow among donor hospitals, regulators, and

recipient hospitals. This platform streamlines pre- transplantation tasks, thereby enhancing overall process efficiency. Furthermore, it facilitates the storage of potential donor information and fosters direct connection between all parties concerned in the organ transplantation process. Simulation of the information workflow using this platform revealed potential time savings ranging from three to five hours. TransNet, as outlined in leverages scanning technology for barcodes during organ recovery to aid in labeling, packaging, and tracking organs and other biological materials intended for transplantation. This system integrates seamlessly with an application and a portable barcode printer synchronized with DonorNet. During organ recovery, procurement coordinators utilize the operating room's system to print labels and scan all organs for transportation. Similarly, numerous supply chain management solutions employ barcodes, RFID tags, and Electronic Product Codes (EPC) to identify and disseminate product information, thereby facilitating item tracking across various phases. Moreover, a manageable mechanism known as MIN, proposed by [19], aims to enhance efficiency and fairness in selecting patients for deceased organ matching within The existing framework in Australia. The MIN mechanism allocates an arriving organ for a patient by minimizing [KDPI-EPTS], with tie-breaking based on time on the waiting list and random selection. KDPI assesses the standard of the organ, while EPTS gauges the recipient's life quality post- transplant. Testing demonstrated that the MIN mechanism outperforms the current mechanism considered by the Organ and Tissue Authority in Australia.

#### B. BLOCKCHAIN-BASED SOLUTIONS FOR ORGAN DONATION MANAGEMENT

A blockchain-based kidney donation system named "Kidner" has been proposed, offering a kidney-pair donation module instead of the traditional kidney waiting list. In this system, when an individual wishes to donate their kidney to a family member but is incompatible with the intended recipient, the system matches the donor's kidney with another patient in a similar situation. The authors of introduced an organ donation decentralized app utilizing blockchain technology. Patients register their information, including medical ID, organ type, blood type, and state, through a web application. The system operates on a first-in, first-out (FIFO) basis, except for cases of critical patients, offering improved security, transparency, and faster processing. However, adaptation may be necessary when deploying the system in different regions to comply with local regulations and requirements. Similarly, in a web-based application was developed utilizing FIFO to select an organ donor for each patient seeking a transplant, with emergency cases given priority. Another organ donation and transplantation application leveraging blockchain technology was proposed in [12], where registered hospitals accept donors and recipients to match them based on requests. Additionally, presents a blockchain use case in organ donation. The process commences with the donor signing a smart contract for organ donation, followed by the patient filing a transplant request. Both documents are verified and hashed by a registered doctor or nurse, who then creates a verified mismatching pair and announces it over the network. The network subsequently finds a match and sends it to a doctor for approval. Upon approval, the doctor generates a hash, advancing the process.

### IV. DISCUSSIONS

In this part, we assess the privacy, confidentiality, and security aspects of our solution. Typically, Ethereum-based solutions outline the expenses related to implementing and executing smart contracts. However, in case, we utilize An exclusive Ethereum ledger where the cost of gas price is set to zero, thus eliminating any associated costs. Moreover, we conduct a comparative analysis between our solution and existing ones. Lastly, we explore the potential for generalizing our solution to other applications or systems.

#### A. SECURITY ANALYSIS

**Integrity:** The suggested organ donation management solution employs an event-based approach, recording each transaction and storing it on a ledger. This permits users to follow the donation and transplantation processes step by step. For instance, whenever a ranked list of matched recipients with available donors is generated, it is documented as an happening to confirm that the donated organ is allocated to the recipient with the highest priority.

**Authorization and Accountability:** The suggested fix makes use of Ethereum smart contracts created in Solidity language, leveraging the Modifier feature. This feature allows specific participants to execute particular functions, ensuring accountability for what they did. All unlawful behavior is documented. as events in an unchangeable ledger, facilitating the tracing of mistakes or illegal activities back to their sources. For example, only the organ matching organizer is authorized to carry out the matching function, which stores the matched list retrievable later by the DApp. Similarly, only a transplant surgeon can carry out the organ transplantation function. Consequently, these participants

accept accountability for their deeds and understand that manipulation will result in consequences. or errors in these processes.

**Availability:**The decentralization of the Ethereum blockchain entails the presence of numerous distributed nodes tasked with recording and logging all transactions within the network. This setup guarantees the availability and synchronization of the network, even inside the event of a node failure.

**MITM Attacks:** In the ledger, each transaction necessitates the sender's private key signature. As a result, attackers are prevented from manipulating the blockchain, greatly minimizing the likelihood of man-in-the-middle (MITM) attacks. This feature is paramount for improving the management of blockchain-based organ donation and transplantation, as it restricts access to trusted entities, making certain that only those with permission may receive information and execute actions.

#### B. ANALYSIS OF INTELLIGENT CONTRACT SECURITY

A specialized tool named Oyente was employed to test and confirm the organ donation and organ transplantation smart contracts for vulnerabilities. Oyente is adept at detecting various security issues: parity multisig problem, integer overflow, integer underflow, transaction-ordering dependence (TOD), call stack depth attack, timestamp reliance, and re-entrancy among the Ethereum blockchain's shortcomings. The results of using the Oyente tool show that the intended smart contracts are devoid of existing vulnerabilities, affirming their robustness and high security against common exploits. Additionally, the EVM code coverage was measured at 80.9% for the organ donation intelligent contract and 99.1% for the organ transplantation smart contract.

#### C. CONSIDERATION WITH THE CURRENT SOLUTIONS

A comparative analysis between our solution and current blockchain-based remedies is presented, utilizing important parameters such as the blockchain platform employed, mode of operation, smart contract development, tracing capability, real-time monitoring, implementation, and DApps development. Both our solution and the current solution made use of the Ethereum network's private mode of operation. However, other solutions did not specify the kind of blockchain platform used. Both our solution and the current solution proposed a smart contract-based approach. Notably, front-end decentralized applications for user utilization have not been developed.

#### D. GENERALIZATION

Our suggested blockchain-based remedy shows how blockchain technology may be used to aid in managing and tracing the procedure for donated organ transplantation across various phases, including registration, matching, removal, transportation, and transplantation. The intelligent contracts designed to represent these phases in the organ transplantation management system can be tailored to suit other systems involving highly sensitive items that require following, tracing, and accountability. For instance, delivery functions can find applications in numerous healthcare and other industries and domains. Similarly, the concept of comparison and auto-matching between donors and registered patients can be used to blood donation operations, medical device donation, or even industrial products. This delineates the modifications necessary to adapt the recommended solution to other systems or applications. Participants and their interactions may differ, and off-chain storage may be required if the application involves large-sized content. Furthermore, the algorithms developed for intelligent contracts can be adjusted to align with the prerequisites for any new system. While other applications may have a similar structure to our solution, careful consideration should be given to designations based on targeted use case.

We have introduced a private solution based on the Ethereum blockchain designed to manage organ transplantation and donation in a decentralized, accountable, auditable, traceable, secure, and trustworthy manner. Our solution involves the development of smart contracts that ensure data provenance by automatically recording events. Additionally, we have provided six algorithms, complete with implementation, testing, and validation information. Furthermore, we have conducted a thorough analysis of the security of our proposed solution to guarantee that smart contracts are safeguarded against common attacks and vulnerabilities. In comparison to other blockchain-based solutions currently available, we have outlined the distinguishing features of our solution. We have also discussed the potential for customization with minimal effort to address similar challenges encountered by other systems. Looking ahead, there are opportunities for improvement such as the evolution of an end-to-end DApp. Additionally, deploying and testing intelligent contracts on a real private Ethereum network could enhance the solution's efficacy. Lastly, we recognize that Quorum platform may offer enhanced confidentiality as transactions among entities are visible only to specific

participants. In contrast, our solution permits transactions between two participants to be viewed by other authorized actors in private blockchain..

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