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Decentralized Organ Donation and Transplantation Using Blockchain Technology

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Abstract

The management of organ donation and transplantation systems is confronted with numerous challenges, spanning registration, donor-recipient matching, organ logistics, and ethical considerations. In response, this paper proposes a decentralized solution leveraging a private Ethereum blockchain framework. This paper establishes a secure, traceable, and privacy-preserving environment by utilizing smart contracts and a suite of innovative algorithms. This approach's robustness and trustworthiness will be highlighted by implementation details, testing procedures, and thorough evaluations that cover privacy, security, and confidentiality. Through comparative analyses, this solution emerges as a promising avenue for enhancing equity, efficiency, and patient confidence in organ donation and transplantation management.

Keywords: Organ Donation, Ethereum Blockchain, Privacy, Security, and Confidentiality

1 Introduction

Failure of organ can result from various factors such as chronic illnesses, acute conditions, trauma, infections, toxicity, autoimmune disorders, and genetic conditions. For a transplant to succeed, the organ must be in good condition, compatible with the recipient, and the donor's removal should not endanger their life [1]. In 1954, the first successful organ donation and transplant operation in Boston occurred when Ronald Herrick donated one of his kidneys to his brother Richard Herrick [2]. Since then, the annual transplant rate has significantly increased. However, there is currently a greater demand for organ donations than there are donors [3]. Twenty individuals die each day while awaiting an organ transplant, and every ten minutes, a new patient becomes added to the waiting list. [4]. Access to the waiting list for organ donation is essential for organ allocation, but both socioeconomic and regional factors can influence a transplant referral. Therefore, specific patient categories should not be treated differently during the waiting list allocation process [5].

There are two methods for donating organs: living donation and donation from the deceased. The standard flow chart for organ transplantation and donation is shown in Figure 1. The transplant staff at the hospital examines the donor first, and if the donor is dead, a brain death test is carried out. In the interim, medical professionals assess the donor, if they are still alive, to make sure they are suitable for live donation. The procurement organizer receives a report on all medical records after that. In addition to making sure the donor is correctly recorded in the medical system, the procurement organizer's job is to evaluate the donor's health and determine if he is a good fit. Subsequently, in the event that the assessment indicates the donor's eligibility for donation, the organ transplant coordinator receives all of the information from the procurement coordinator. Only with the donor's permission may this step be carried out in order to gift to an anonymous recipient. The organ transplant coordinator then arranges for the pairing of patients on the waiting list with available donors. As a result, an output in the form of a ranked list is sent to the transplant doctors. The transplant surgeon then evaluates the organ's compatibility for the recipient based on the recipient's present health as well as the donor's medical history. Once the surgeon accepts the organ donated, the donor's surgeon is informed to remove the organ. The transplant surgeon then receives the donated organ once it has been brought to the recipient's hospital. On the other hand, the pertinent data is sent straight to the transplant surgeon when a live donor gives a transplant to a particular person [6, 7].

In the past, when a patient was close to passing away, the hospital and organ procurement organization worked together to do a preliminary medical examination to determine the patient's suitability for organ donation. The average time for this procedure was fifteen minutes, and just six percent of the assessments led to the identification of possible organ donors. However, an instant messaging system produced by central computer systems has rapidly supplanted this phone call-based method. All the information required for the organ donation procedure is stored in these systems [8]. However, a significant issue with this strategy is that the transplantation facilities' ability to keep safe systems and identify any risks to donors and recipients is the only thing that ensures the security and authenticity of the data.

Furthermore, a lack of transparency presents a challenge to the success of the organ donation process. When participants are not transparent, it can lead to illegal organ trade and purchases, as well as medical professionals engaging in unethical practices [10]. Additionally, some hospitals exploit patients' need for organs by offering to transfer organs to those willing to pay a higher amount, ignoring patients with the utmost ranking on the waiting list [11].

Furthermore, sluggish processes in the current transplant systems are a common problem that is unacceptable in urgent and life-threatening circumstances. Recent years have seen an increase in security lapses that jeopardize personal privacy and system integrity, and these systems frequently don't meet minimum security criteria. Though many health ministries, hospitals, and other medical facilities do not have a consistent data transmission method, most current systems manage data using standard databases [1].

Blockchain technology's potential to offer a decentralized and protected database, eliminating the need for a mediator, has attracted significant interest from numerous businesses in recent times. While the name "blockchain" is frequently linked to cryptocurrencies, its evolution has primarily concentrated on information architecture, or the organization, distribution, and varying degrees of authorization of databases [12]. Smart contracts, which are computer instructions encoded in blocks to represent financial objects, were later incorporated to the Ethereum blockchain design [13]. Blockchain's primary objective is to make digital data dissemination and recording more immutable.

The absence of data accountability, immutability, auditability, transparency, traceability, and trust elements in current systems presents issues for the administration of organ donation and transplantation. To tackle these issues, our paper presents the following contributions:

We propose a solution based on a private Ethereum blockchain with a Decentralized Application (DApp) to manage organ donation and transplantation. This solution ensures decentralization, security, reliability, traceability, auditability, and trustworthiness.

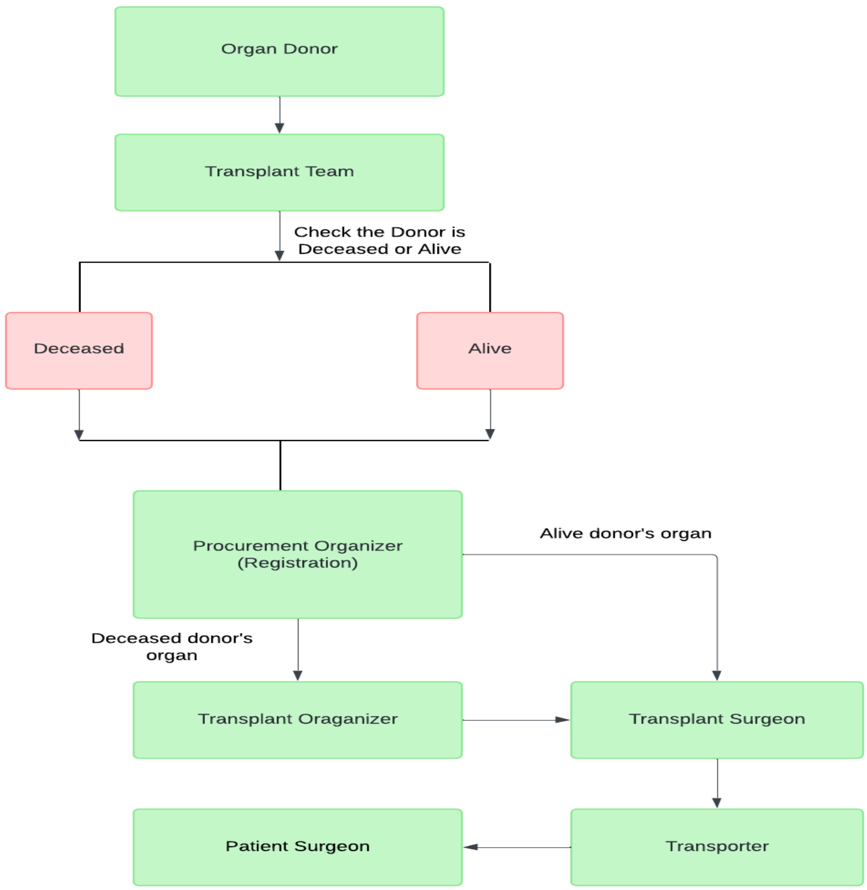

Figure 1: Flowchart for organ donation and transplantation

- We create smart contracts that record participants and track data authenticity by creating events for every step of the procedures.
- The system should be created to enhance organ allocation by excluding deceased patients from matching. This ensures a more efficient and equitable distribution of organs.

Our suggested approach is adaptable and simple to modify to fit the needs of different related applications.

2 Literature review

The authors of paper [15] propose a decentralized application (DApp) for organ donation using blockchain technology. Patients can register their details on the system using a web application, however weight is not included. Information requested to be registered includes medical ID, organ category, blood group, and current status. The system operates on a first-in first-out basis, except for patients in critical condition. On the other hand, paper [16] presents a decentralized, secure, and transparent web application for organ and tissue transplantation, also known as a DApp. This application eliminates the need for third-party involvement in transplantation and provides a cost-effective solution, reducing high costs for patients. As shown in the findings portion of the study, the information and Electronic Medical Records are hashed using the IPFS, greatly lowering the cost of uploading.

The paper [17] focuses on addressing organ trafficking by utilizing blockchain to securely store organ records, enabling tracking of changes and verification of entries to prevent black market activities. The system's performance is evaluated based on average response time and Ethereum Smart Contracts' gas usage, demonstrating low response times and cost-effective maintenance, indicating feasibility for real-time organ transplant networks.

In paper [18], the authors propose a web application that serves as a useful platform for all to connect. It allows users to interact with a smart contract without the need to manage their own keys, ensuring security and transparency. This approach provides a stability between decentralization and comfort. By incorporating off-chain databases, the system enhances accessibility, data security, and overall efficiency, offering solutions to several challenges in the healthcare sector. These include eliminating complex intermediary networks and enhancing transaction traceability. Moreover, this cost-effective solution helps patients avoid the high costs associated with transplantation.

The authors of study [19] examine the impacts of numerous listings on American organ transplant waiting list lines, considering the intricacy of the system and how it affects thousands of Americans. Present regulations let patients, with a physician's approval and the capacity to pay for extra testing expenses, to register at more than one Donor Service Area (DSA). However ethical concerns arise, particularly regarding perceived advantages for wealthier individuals. The authors create an agent-based, discrete event model to replicate several listings in transplant waiting list queues in order to investigate these impacts. Limitations or criticisms of the suggested agent-based, discrete event model for simulating multiple listings in organ transplant waiting list queues could be considered as drawbacks of this paper. These might include concerns about the accuracy or validity of the model, the assumptions made, or the generalizability of the findings.

Blockchain technology is thought to be a workable way to enhance EMR adoption, especially in terms of security and data integration. Blockchain can provide individuals more control over their medical records, according to recent studies. However, challenges such as ensuring data consistency and correctness during transmission remain important considerations. While decentralized data storage is often preferred for its scalability, the current organ management system relies on a client-server architecture, which can lead to data loss and difficulties in data restoration in the event of server failure. To address these issues, this study proposes a blockchain-based organ donation management system (ODMS) [20].

The Paper [21] offers a design for a private Ethereum-based organ donation and transplant administration system. They talk about the many obstacles and needs that contemporary systems must meet, including those related to organ removal, donor-recipient matching, delivery, and transplantation. These are impacted by clinical, legal, ethical, and technological considerations. The authors support a complete donation and transplantation system to solve these issues and guarantee a just and effective procedure that improves patient experience and trust. Complete decentralization, security, auditability, traceability, privacy, and trustworthiness are the main objectives of their suggested system. The lack of DApp, however, may be a disadvantage of this strategy and restrict the system's adaptability and compatibility with other blockchain-based systems.

To allow all parties concerned to track the flow of charitable donations from the time they are donated by donors to the time they reach the intended beneficiaries, the authors of the study [21] suggest a blockchain-based architecture for donation traceability. Every transaction is documented as a block in the public-permissioned blockchain that powers the system on the Ethereum platform. These unchangeable, publicly available information chunks enable prompt, traceable transactions. The complexity and expense involved in setting up and running a blockchain system, however, may be a disadvantage of this strategy. With a hybrid qualitative approach, the effectiveness of the proposed framework is assessed, showing an improvement in the traceability of charitable donations.

3 Proposed Methodology

We give a thorough explanation of our organ donation and transplantation solution in this section. A smart contract, created especially for donation of organ and transplant procedures, is used in our solution. Through a DApp connected by an API, users can engage with the features and events of the smart contract. Preauthorized individuals have access to certain smart contract features that provide them access to blockchain-stored data. Among these participants are doctors, members of the hospital transplant team, procurement coordinators, and organ matching coordinators. The smart contract takes up several important tasks, such as creating a waiting list, approving post-medical testing for donors, and facilitating automatic matching between donor's and recipient's ambiguity pertaining to the systems in place. Ethereum can act as a decentralized and distributed database, storing the state and transaction history of smart contracts.

Transparency, traceability, and verifiability are ensured by carefully documenting and storing each stage of the process on the blockchain ledger. Furthermore, our solution uses a private Ethereum to prioritize confidentiality, privacy, and authority. This ensures that only authorized entities can access sensitive information, maintaining confidentiality and trust within the system. By combining the security and immutability of blockchain technology with tailored smart contract functionalities, our solution offers a robust and transparent platform for organ donation and transplantation management.

3.1 Private Permissioned Ethereum Network

In contrast to public blockchains, where information is exposed to all parties, private blockchains do, in fact, offer higher security and privacy since they limit access to transactions and data to only approved entities. Businesses can create their own private-permissioned blockchain networks by utilizing the Ethereum blockchain, which will improve confidentiality, security, and privacy. The structure of the Ethereum Virtual Machine is shown in Figure 2. This network architecture eliminates the need to develop an entirely new blockchain for every DApp. Developers can work with the ready-made Ethereum system to fast-track onboarding and get their applications up and running sooner than other alternatives.

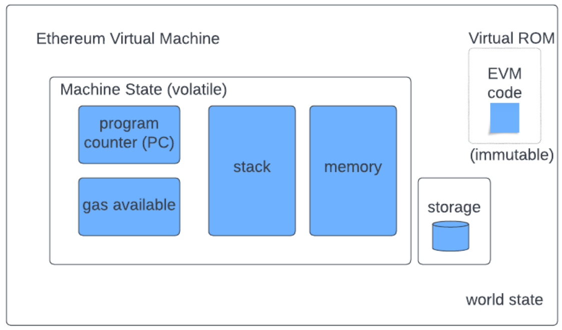

Figure 2: EVM (Ethereum Virtual Machine)

Ensuring the privacy of sensitive data, including medical records and family histories, is crucial when it comes to donated organ donation. For this reason, the best way to deploy organ donation and transplantation management systems is through a private permissioned Ethereum blockchain. This approach ensures that only authorized participants, such as medical professionals and relevant healthcare personnel, can access and interact with the sensitive data, thereby safeguarding patient privacy and maintaining the integrity of the transplantation process.

3.2 Blockchain Integration

Our suggested solution is based on the blockchain network, which offers a safe and unchangeable ledger for keeping track of events and transactions. Throughout the organ donation and transplantation procedure, this guarantees accountability and data provenance. In order to properly implement the created smart contracts, the right blockchain environment must be used. It might not be the best idea to implement smart contracts directly onto the primary network during the trial period. Ethereum-based smart contracts should instead be tested locally on a blockchain environment, in a virtual machine or on a specialized analysis network. Our solution uses a JavaScript-based Virtual Machine to host and execute smart contracts. This configuration makes it possible to operate a separate Ethereum node inside of a browser, which makes smart contract testing and verification more effective. After undergoing testing and validation, the smart contracts can be implemented on Ethereum's main net to assess their functionality in an authentic setting of blockchain. It's worth noting that the deterministic nature of smart contracts ensures consistent outcomes across different nodes. Therefore, regardless of the specific node executing the operation, the result remains the same. This reliability reinforces the trustworthiness and predictability of our solution's smart contract functionality.

3.3 Participants Interactions

Initial Phase begins with the creation of a waiting list, that is overseen by a licensed physician who adds new patients and obtains pertinent data from them, including ID, weight, age, and blood type. In Phase 2, donors who have consented to organ donation are received, and only authorized transplant team members can approve their medical tests, triggering an immediate event notification. Subsequently, the procurement organizer evaluates and registers the donor, prompting an announcement event. Phase 3 entails the organ transplant coordinator supervising the auto-matching procedure between donors and recipients. Following the release of a ranked list of matched patients, this matching is based on parameters from the donor, including blood type, age range, and weight range.

4 Implementation Details

Here, we get into the in-depth algorithms and implementation details of our blockchain - based organ donation and transplantation system. Because our solution is built on a private Ethereum blockchain, privacy and security are improved. This private blockchain network has validation nodes and only authorized users, strengthening confidentiality and trust inside the system.

4.1 Donation And Transplantation of Organ

The primary members in the smart contract are the matching organizer, the procurement organizer, a member of the hospital transplant team, and the patient's physician. Each entity has its own Ethereum address, which it uses to invoke certain functions on the smart contract. Two examples of the variables that are present in the smart contract and are used to link entities with unique IDs are the procurement organizer and matching organizer. Ethereum addresses are among the other variables. In order to ensure that patients are not selected twice and to link Ethereum addresses to Boolean values that indicate if specific conditions are met (e.g., authorization for transplant surgeons and doctors), mapping variables are used. Furthermore, listing characteristics like “Blood Type” and “Organ.”

The donation smart contract is deployed by the procurement organizer, who also takes ownership of it and has the power to designate the Ethereum address of the matching organizer. Then, approved medical professionals add new patients to the queue and notify everyone involved. After that, members of the approved medical team carry out testing and declare test approvals. Subsequently, the organ procurement coordinator notifies and registers donors, indicating the kind of donated organ. Following these steps, the auto-matching procedure starts, keeping records of patients who have been matched with potential donors according to important parameters like age, blood type, BMI, and waiting period. To clarify the specifics of the different operations included in our smart contracts, we provide three algorithms.

Algorithm 1: Adding new patient

```
Input: Patient_ID, Patient_Age, Patient_BMI,Bloodtype_, _OrganType_
Patient_ID is the ID of the patient on the waiting list.
Patient_Age is the age of the patient on the waiting list.
Patient_Weight is the weight of the patient.
Bloodtype_ is a particularized enumerate variable that represents types of blood.
OrganType_ is a particularized enumerate variable that represents types of the needed organ.
Output: An event announcing that a new patient is Added to the waiting list
assignedDoctorsToAddPaitients_list: A mapping of the patients doctors EAs
if caller == ProcurementOrganizer then
assigningDoctor_list[PatientDoctor] = true.
else
Revert.
end
/* The list of the assigned patients
doctors is ready */
if (caller == PatientDoctor) then
Patient_ID ← PatientsID [i]
_OrganType_ ← NeededOrganType [i]
```

Patient_Age ← Patients_age[i]
_BloodType ← Blood_type [i]
Patient_Weight ← Weight [i]
else
Revert.
end

The first algorithm depicts the process of starting a waiting list phase and adding new patients. The AddingNewPatient and AssigningPatientDoctors functions are represented by this algorithm. The patient ID, age, weight, blood group, and required organ category must all be added by the doctors because this data will be saved in an array and used in the matching step later.

Algorithm 2: Eligibility Test and Registration for Donor

Input: Donor_ID, _DonatedOrganType
Donor_ID is the ID of the organ donor.
OrganType is a particularized enumerate variable that
represents various types of the donated organ.
assignedTransplantMembers_list: A mapping of the transplant team
if caller == ProcurementOrganizer then
assigningmember_list[TransplantTeamMember]=true.
else
Revert.
end
/* Assigned transplant team members list is ready */
if (caller ==∈ assignedTransplantMembers_list) then
Emit an event announcing that the donor is medically
approved to donate
else
Revert.
end
/* Medical test approval is done */
if caller == ProcurementOrganizer then
Emit an event announcing that the donor is registered
else
Revert.
end

Algorithm 2 also illustrates the second phase, which is accepting and registering donors. The procurement organizer will assign transplant team members accountable for conducting medical examinations and tests. Furthermore, the procurement organizer must utilize the RegisteringNewDonor function to input the donor ID and the donated organ type. Additionally, third algorithm illustrates the matching process, which is managed by the MatchingProcess function. Prior to initiating the process, the organ matching coordinator should have access to the donor's blood type, as well as their weights, the type of organ donated, and their minimum and maximum ages. To ascertain a patient's eligibility for a donated organ, the algorithms must determine whether the patient meets the specified requirements.

Algorithm 3: Matching process

Input: Min_Age, Max_Age, Donor_BloodType,Donor_MinWeight, Donor_MaxWeight,_OrganType_
Min_Age is the minimum acceptable age that can be matched with the donor's age
Max_Age is the maximum acceptable age that can be matched with the donor's age
Donor_BloodType is the blood type of the donor
Donor_MinWeight is the minimum acceptable weight that can be matched with the donor's Weight
Donor_MaxWeight is the maximum acceptable weight that can be matched with the donor's Weight
OrganType is a particularized enumerate variable that represents various types of the needed organ.
if caller == OrganMatchingOrganizer then
for <i = 0 to < Patients.length> do
if Needed Organ Type[i] == _OrganType ∧
(Patients_age[i] > Min_Age) ∧
(Patients_age[i] < Max_Age) ∧
(Blood_type[i] == _BloodType) ∧
(Weight[i] > Donor_MinWeight)∧
(Weight[i] < Donor_MaxWeight) then
Matched.push(Patients[i])
end
New matched organ
end
Revert
end

A successful use of the AddingNewPatient method to add new patients to the waiting list is depicted in Figure 3.

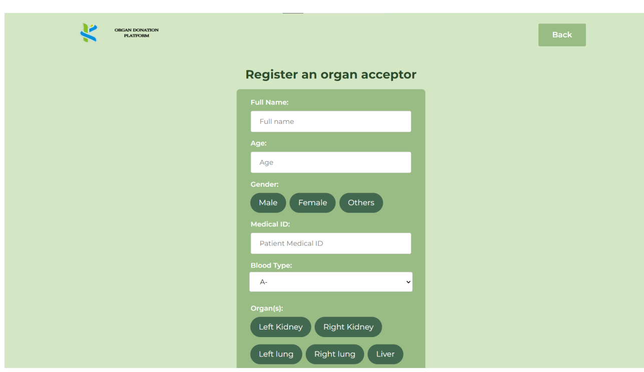

Figure 3: Adding new patient

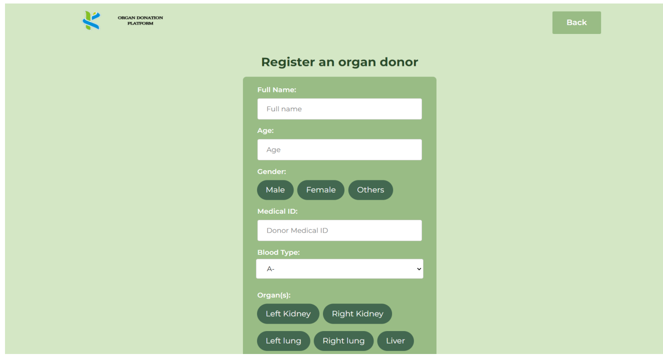

Figure 4: Adding new donor

The AddingNewDonor function, which adds new donors to the list, is successfully executed in Figure 4. Figure 5 and Figure 6 show a list of registered donors and patients respectively.

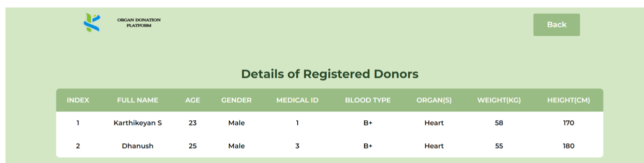

Figure 5: List of registered donors

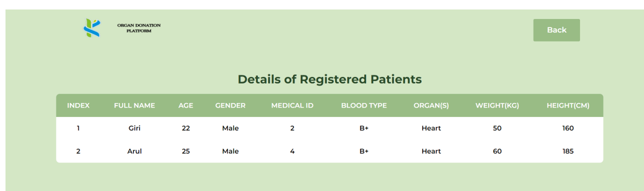

Figure 6: List of registered patients

In the matching process function, it was assessed if the organ matching coordinator could include the minimum and maximum ages, blood types, weights, and types of donated organs of a newly registered donor. This component of the smart contract is essential since it informs the matched patient about the available donor. Furthermore, Figure 7 shows a successful call of the matched patient that was saved in the array of matched when the patient and the ready donor were matched. Figure 8 tells a search of actors. Figure 9 and Figure 10 talk about the data stored in the Ethereum blockchain and transaction of the blockchain respectively.

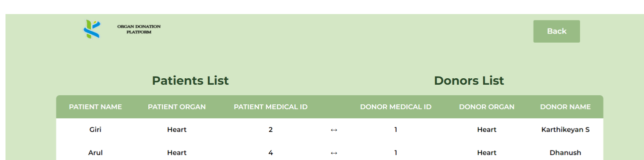

Figure 7: Matching process

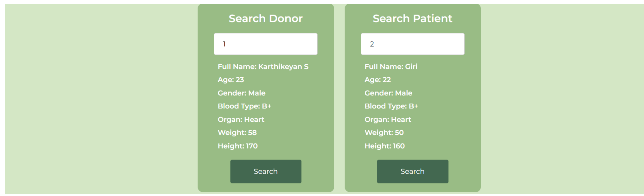

Figure 8: Searching donor and patient by Id

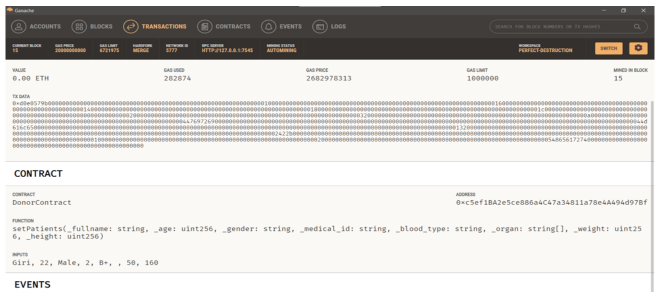

Figure 9: Data stored in Ethereum blockchain

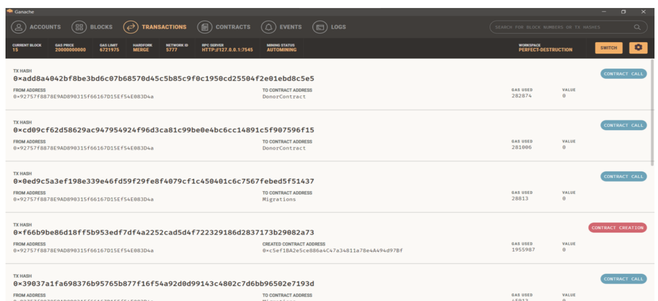

Figure 10: Transactions of the Ethereum blockchain

5 Results and Discussion

5.1 Comparison with the Existing Solutions

A comparison between the proposed approach and current blockchain-based alternatives are provided. Some key characteristics, including the blockchain platform being used, the mode of operation, the development of smart contracts, the capacity to trace transactions, real-time monitoring, implementation, and the creation of DApps, are utilized in the comparison.

5.2 Generalization

In the registration, match, removal, transportation, and transplantation stages of the donated organ transplantation process, blockchain technology can help with tracking and management. This is demonstrated by the suggested blockchain-based system. The created smart contracts, which depict the many stages of the management system for donated organ transplants, can be tailored to match other systems involving extremely sensitive materials and needing accountability, tracing, and tracking. For instance, delivery tasks are widely applicable in the healthcare sector as well as other fields and businesses. Similarly, blood donation operations, medical device donation, and even industry items can benefit from the concept of comparison and auto-matching between the registered patient and the donor.

If the application incorporates large-sized content, off-chain storage is required since the players and their interactions will differ. Furthermore, the established smart contract algorithms can be adjusted to accommodate any new system's requirements. Overall, this solution can be structured similarly to other applications; however, depending on the intended use case, some designations need to be addressed.

6 Conclusion

We present a novel approach to organ donation and transplantation management using a private Ethereum blockchain with the goals of decentralization, auditability, traceability, security, and reliability. It describes how to use smart contracts to automatically log events and guarantee the provenance of data. Three algorithms and the details of their implementation, testing, and validation are also presented. A comprehensive security analysis is carried out to protect smart contracts from frequent attacks and weaknesses. A comparative analysis with existing blockchain-based solutions is provided to highlight its advantages. The creation of an end-to-end DApp and the testing of smart contracts on an actual private Ethereum network are examples of future improvements. However, the paper acknowledges a potential confidentiality limitation compared to platforms like Quorum, where transactions are restricted to specific participants, unlike the proposed solution where transactions are visible to other authorized actors in the private blockchain.

References

[1] L. A. Dajim, S. A. Al-Farras, B. S. Al-Shahrani, A. A. Al-Zuraib and R. Merlin Mathew, "Organ donation decentralized application using blockchain technology", *Proc. 2nd Int. Conf. Comput. Appl. Inf. Secur. (ICCAIS)*, pp. 1-4, May 2019.

[2] A. Powell, A Transplant Makes History. Harvard Gazette, Mar.2019,[online] Available: https://news.harvard.edu/gazette/story/2011/09/a-transplant-makes-history/.

[3] *Organ Donation Facts and Info: Organ Transplants*, Apr. 2021, [online] Available: https://my.clevelandclinic.org/health/articles/11750-organ-donation-and-transplantation.

[4] *Facts and Myths About Transplant*, Mar. 2019, [online] Available: https://www.americantransplantfoundation.org/about-transplant/facts-and-myths/.

[5] *Organ Procurement and Transplantation Network*, Apr. 2021, [online] Available: https://optn.transplant.hrsa.gov/resources/ethics/ethical-principles-in-the-allocation-of-humanorgans/.

[6] *How Donation Works*, Jan. 2022, [online] Available: https://www.organdonor.gov/learn/process.

[7] *Organ Donation and Transplantation in Germany. Plastic Surgery Key*, Aug. 2017, [online] Available: https://plasticsurgerykey.com/organ-donation-and-transplantation-in-germany/.

[8] *Electronic Health Records Can Improve the Organ Donation Process*, Dec. 2021, [online] Available: https://hbr.org/2021/12/electronic-health-records-can-improve-the-organ-donation-process.

[9] U. Jain, "Using blockchain technology for the organ procurement and transplant network", 2020.

[10] *The Illegal Organ Trade Thrives in India-and it isn't Likely to End Soon*, Dec. 2021, [online] Available: https://www.livemint.com/Politics/pxj4YasmivrvAhanv6OOCJ/Why-organ-trafficking-thrives-in-India.html.

[11] D. P. Nair, Organ is Free Transplant Cost is Problem, 2016, [online] Available: https://timesofindia.indiatimes.com/life-style/ healthfitness/health-news/Organ-is-free-transplant-cost-isproblem/articleshow/54014378.cms.

[12] V. Puggioni, An Overview of the Blockchain Development Lifecycle. Cointelegraph, Feb. 2022, [online] Available: https://cointelegraph.com/explained/an-overview-of-the-blockchain-development-lifecycle.

[13] *History of Blockchain*, Apr. 2022, [online] Available: https://www.icaew.com/technical/technology/blockchain-and-cryptoassets/blockchain-articles/what-is-blockchain/history.

[14] M. Hölbl, M. Kompara, A. Kamišalić and L. N. Zlatolas, "A systematic review of the use of blockchain in healthcare", *Symmetry*, vol. 10, no. 10, pp. 470, Oct. 2018.

[15] L. A. Dajim, S. A. Al-Farras, B. S. Al-Shahrani, A. A. Al-Zuraib and R. Merlin Mathew, "Organ Donation Decentralized Application Using Blockchain Technology," *2019 2nd International Conference on Computer Applications & Information Security (ICCAIS)*, Riyadh, Saudi Arabia, 2019, pp. 1-4, doi: 10.1109/CAIS.2019.8769459.

[16] P. Ranjan, S. Srivastava, V. Gupta, S. Tapaswi and N. Kumar, "Decentralised and Distributed System for Organ/Tissue Donation and Transplantation," *2019 IEEE Conference on Information and Communication Technology*, Allahabad, India, 2019, pp. 1-6, doi: 10.1109/CICT48419.2019.9066225.

[17] N. Chaudhary, S. S. Manvi and N. Koul, "Organ Bank Based on Blockchain," *2022 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT)*, Bangalore, India, 2022, pp. 1-5, doi: 10.1109/CONECCT55679.2022.9865787.

[18] G. Ajay, A. Lokesh, D. Sravanasandhya, G. Kousalya, D. D. Teja and T. Daniya, "A Web DApp for Efficient Organ Donation Management System: Leveraging Centralized Wallet Architecture as Backend," *2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, Salem, India, 2023, pp. 666-672, doi: 10.1109/ICAAIC56838.2023.10141438.

[19] C. Harvey and J. R. Thompson, "Exploring advantages in the waiting list for organ donations," *2016 Winter Simulation Conference (WSC)*, Washington, DC, USA, 2016, pp. 2006-2017, doi: 10.1109/WSC.2016.7822245.

[20] C. A. C. Yahaya, A. Firdaus, Y. Y. Khen, C. Y. Yaakub and M. F. A. Razak, "An Organ Donation Management System (ODMS) based on Blockchain Technology for Tracking and Security

Purposes," *2021 International Conference on Software Engineering & Computer Systems and 4th International Conference on Computational Science and Information Management (ICSECS-ICOCSIM)*, Pekan, Malaysia, 2021, pp. 377-382, doi: 10.1109/ICSECS52883.2021.00075.

[21] D. Hawashin, R. Jayaraman, K. Salah, I. Yaqoob, M. C. E. Simsekler and S. Ellahham, "Blockchain-Based Management for Organ Donation and Transplantation," in IEEE Access, vol. 10, pp. 59013-59025, 2022, doi: 10.1109/ACCESS.2022.3180008.