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An Implementation of a Blockchain-Based Model for Provision of Incentives to Rare Group Blood Donors

Leah Chebet Bunei
Student
Kabarak University Nakuru, Kenya

Prof.Simon Maina Karume
Senior Lecturer
Kabarak University Nakuru, Kenya

Dr. Ruth Oginga
Lecturer
Kabarak University Nakuru, Kenya

Abstract: A critical necessity towards provision of universal healthcare by the Kenyan government is to ensure constant blood supply in the countries blood donor unit. Rare blood group donors always play a critical role in healthcare sector by provision of life saving support to patients with specific medical needs to live longer and with higher quality of life. However, the scarcity of these rare blood types namely; AB negative, B negative, A negative and O negative leads to a great challenge especially in emergency or high demand situations. Despite the crucial need for blood donations, donors may be less motivated to donate blood regularly due to lack of effective incentives. Traditional blood donation management systems are often not transparent, inadequate donor identification and delayed incentives to rare blood group donors. This demoralizes them from donating blood again particularly those individuals with rare blood types. To address these challenges, this study aimed to develop a blockchain based model prototype for provision of incentives to rare blood group donors that offered trust, transparency and security tailored to increase blood donation. Study involved creation of a solidity smart contract that was deployed and implemented through the use of React js and is available at https://grandmullah.github.io/donor. For the purpose of regulatory hurdles, data protection measures are used to safeguard donor information which includes encryption, access controls and also ensuring compliance with data privacy regulations. In conclusion, a blockchain based model for provision of incentives to rare blood group donors presents an approach to address the challenges encountered by the blood donation systems, particularly when it comes to rare blood types.

Keywords: Blockchain, Model, Smart Contract, Confidentiality, Donors

1. INTRODUCTION

Blood donation is essential in healthcare worldwide, yet many blood donor units face persistent challenges in maintaining adequate supplies, especially for rare blood types. Blood transfusion helps in supporting surgeries, emergencies, chronic illness treatments as well as benefiting patients that face life-threatening situations for example leukemia and hemophilia in order to live longer and with higher quality of life. World Health Organization emphasizes the need for safe blood and blood products, specifically for those individuals with the rare blood types that are critical yet often in short supply (World Health Organization, 2021).

Blood mainly comes from voluntary non-remunerable donors including students and patient's family members. The emergencies that require blood donation are always on the rise but lifesaving donors are not present to meet the needs of these emergencies. Blood has a great significance role in human life and delivers required substances like nutrients and oxygen to the cells (Sadri, et al., 2021). For medical treatment, blood availability is vital where the need for blood is growing up every year (Kumar & Dhanya, 2020).

Despite many awareness campaigns, it is still hard to keep enough blood reserves available at all times, which makes it even worse for rare blood groups. The rare blood types include AB negative (AB-) which is the rarest blood types found in less than 1% of the population, B negative (B-) is another relatively rare blood type which 2% of the population has, A negative (A-) present in about 6% of the population and O negative (O-) which is the universal donor type found in about 7% of the population. However, finding and encouraging donors with these rare blood types is difficult, especially when their blood is needed quickly. Therefore, it is important to have a reliable and motivated group of rare blood group donors to meet the demand (American Red Cross, 2023).

Ensuring the availability of blood is very important in saving human lives thus every drop of blood counts whereby in a country like Kenya, seven people need a blood transfusion in every ten minutes. The COVID-19 (coronavirus)

pandemic in the year 2020 worsened the situation where only sixteen percent of the one million blood units required were collected (World Bank, 2022).

Globally, the policies that govern blood donation are normally guided by a combination of international guidelines, national regulations as well as local health standards. These includes: world health organization which provides global guidelines and standards for safe blood donation practices (WHO, 2010). We also have American Association of Blood donor units (AABB) that is responsible in setting standards for the blood donor units and transfusion services in United State (AABB, 2021). Furthermore, there is United State Food and Drug Administration (FDA) used to regulate blood and blood products in order to establish quality standards and safety (FDA, 2020).

In addition, there is European Blood Alliance that is responsible in providing support as well as guidance for blood services across Europe (European Blood Alliance, 2020). Moreover, National Blood Transfusion Service (NBTS) where each country may have its own governing body that is responsible in setting specific policies regarding the blood donation, safety protocols and donor eligibility criteria (National Health Service Blood and Transplant, 2021).

However, policies and guidelines that govern rare blood donations in Kenya are Kenya National Blood Transfusion Service (KNBTS). This policy is responsible for coordinating blood donation and transfusion services as well as establishing policies for safe and effective blood collection, testing, processing, and distribution of blood to healthcare facilities (Kenya National Blood Transfusion Service, 2013). Kenya Health Act is another policy responsible for provision of a legal framework for health services that help to ensure blood safety and management (Republic of Kenya, 2017).

In addition, there is also the Kenya National Blood Policy 2019 which is a document used to outline strategies for blood collection that leads to increase donations of rare blood types (Ministry of Health, Kenya, 2019). Moreover, National Emergency Response Policy for Blood Transfusion is used to outline procedures that mobilize rare blood group donors during the emergencies situations (Kenya National Blood Transfusion Service, 2020).

However, in the year 1994, Kenya recognized benefit of coming up with a national blood service in line with World Health Organization (WHO) proposals and World Health Assembly (WHA) declarations recommendations with an aim of establishing a regional system of transfusion centers managed by central coordination. In 2001, Kenya's initial blood policy plan was put in place and opened their first Regional Blood Transfusion Center (RBTC) and national management office in Nairobi. Currently, Kenya Tissue and Transplant Authority (KTTA) were established in August 2022 under the Ministry of Health. KTTA mandate is to oversee, supervise and coordinate the collection and distribution of secure blood in Kenya (Kenya Tissue and Transplant Authority, 2023).

One way to encourage blood donation is by offering incentives or rewards. In countries like the United States and Australia, monetary payments are used to motivate donors. While this method has been effective in attracting some donors, it has also raised ethical concerns about treating blood donation like a commercial transaction (Murray et al., 2019). In Canada, blood donor units often provide gift cards or vouchers for local businesses to encourage donations (Harrison et al., 2018). In the United Kingdom, non-monetary incentives such as awards and public recognition are commonly used to acknowledge donors (Gonzalez et al., 2020).

Although traditional incentive methods have benefits, they also have problems. These include a lack of clear processes, chances of misuse, and difficulty keeping track of donations accurately. Managing donor information and rewards in one central place can also lead to privacy issues and delays, reducing the programs' effectiveness and trust. Furthermore, the current models used for blood donation and management include blood donor unit management system, blood donation management system, life blood, digital blood donation management platform, blood connect, red cross blood services, and Damu Sasa. However, these systems often lack important features such as security, decentralization, transparency, and trust, especially for donors with rare blood types.

Blockchain technology offers a promising solution to these problems. Blockchain is a secure, transparent, and decentralized system that can keep donation records safe and unchangeable. It protects donor privacy while allowing quick verification and tracking of blood donations (Li, et al., 2021).

Therefore, the development of a blockchain based model prototype for provision of incentives helps to secure records and allows donors to track their blood donation history, as well as building trust. Donors receive tokens for each blood donation that has to be redeemed for various incentives, including and not limited to subsidized medical care, preferential medical services, free medical check-ups and T-shirts. This helps to increase donor participation and improve the supply of rare blood types in the blood banks. To address regulatory challenges, the study implements data protection measures like encryption and access controls to secure donor information and ensure privacy compliance,

while also developing a non-monetary incentives model aligned with regulations.

1.2 STATEMENT OF THE PROBLEM

Rare blood group donors play a critical role in healthcare sector by provision of life saving support to patients with specific medical needs to live long and with higher quality of life. However, the scarcity of these rare blood types namely AB-, B-, A- and O- leads to a great challenge especially in emergency or high demand situations. Despite the crucial need for blood donations, donors may be less motivated to donate blood regularly due to lack of incentives and motivation.

The traditional blood donation management systems are often not transparent, secure trust worthy, and efficient. The existing system does not provide any form of motivation or incentives to blood donors. This discourages them from donating blood particularly those individuals with rare blood types. However, due to these challenges there was a need for transparent, secure, and decentralized solution that improved donor engagement. Therefore, a blockchain based model for provision of incentives to rare blood group donors offered significant potential that provided immutable records, enhanced traceability and ensured that donors received incentives based on their donation history and blood type demand. This assisted to foster a culture of appreciation and recognition for donors hence lead in contribution of better healthcare outcomes and saving lives.

1.3 OBJECTIVES OF THE STUDY

The general objective of the study is to develop a blockchain based model for provision of incentives to rare blood group donors that offers trust, transparency and security tailored to increase blood donation.

2. LITERATURE REVIEW

2.1 The Blockchain Technology

Blockchain is a decentralized public ledger that supports creation of permanent and unchangeable records of data. This ensures transparency and trust among stakeholders by providing real-time access to donor information and donation histories. Smart contracts which are executable on blockchain platforms automate the verification and distribution of incentives as well as enhancing operational efficiency (Guo, et al., 2021).

2.2 How Blockchain Works

The technology that has emerged nowadays is the blockchain which is defined as a list of records which are normally linked using the cryptography that helps to allow participants in industry to keep track of digital currency transactions without central recordkeeping. Blockchain is a decentralized public ledger on peer-to-peer networks which allows real-time tracking and verification of blood donations **as** well as ensuring that donor records are transparent and accurate (Li, et al., 2021).

2.3 Blockchain Smart Contracts

A Smart contract is a self-executing program with term of agreements among two or more parties being directly written into lines of code which run on a blockchain network. This contract permit transactions that are trusted and agreements to be carried out without the need of central trusted. The smart contracts provide transparency, security, cost effective by eliminating intermediaries and provision of automatic execution when a certain condition is met without the need of any manual intervention (Kosba A et al., 2016).

The blockchain smart contracts provide the health-centered system whereby the rare blood donor owns the records and decide who can access the information and cannot delete hence trust issues are solved. Interoperability can also be provided where blockchain act as a catalogue that list all the donors' records and history.

2.4 Benefits of the Blockchain

i) Enhanced security: Blockchain transactions use cryptographic techniques such as hashing in order to highly secure data. These transactions are always verified by numerous nodes through a mechanism of consensus for instance proof of work before they are added to the blockchain and once a block is added, it is difficult to make any changes without the consensus of the network. Furthermore, information is stored across the network of computers instead of a single server hence this makes it difficult for hackers to access the data.

ii) Greater transparency: Blockchain is a distributed ledger that offers transparency by ensuring that all transactions on a public blockchain are always visible to anybody who participates in the network. However, this visibility ensures that all transactions including the rare blood donations and incentive distributions are transparent without the need of an intermediary thus helps in building trust among donors.

iii) Increased efficiency tracking of incentives: Blockchain streamlines the tracking of incentives given to rare blood group donors and smart contracts assist in automating the distribution of rewards to donors after

meeting specific condition hence, this help to ensure timely and accurate delivery of incentives.

iv) Improved traceability: Blockchain allow the hospital blood donor unit that deals with blood donors in creation of audit trails for historical transaction of data and this help to prevent fraud.

v) Decentralization: The decentralized nature of blockchain helps to allow multiple stakeholders for instance blood bank and hospitals to access and share information without depending on a central authority.

vi) Reduction of cost: The use of blockchain helps to eliminate the need for any third parties or middlemen and put trust only the data on the blockchain.

3. METHODOLOGY

3.1 Requirements for Model Development and Implementation

To implement the blockchain based model for provision of incentive to rare blood group donors, this study used the Ethereum blockchain API. Ethereum is an open-source platform that allows developers to build decentralized applications. On Ethereum, each transaction uses a resource called "gas," which represents the computational effort required to process the transaction (Kurt et al., 2020).

a) Environment set up

When setting up the environment of the study the following tools were needed to be installed:

i) Solidity Version 0.8.20: Solidity is a programming language used to build smart contracts on blockchain networks like Ethereum. In this study, Solidity helps to create automatic rules that handle donor registration, verify blood donations, and give out rewards such as digital tokens when a blood donation is confirmed, the smart contract written in Solidity sends the reward directly to the donor's digital wallet without needing any manual work. This makes the process fast, fair, and secure. It also keeps a record of donations and can give extra rewards to donors with rare blood types or those who donate often. Because everything is recorded on the blockchain, the system is transparent and trustworthy.

ii) Hardhat: This is a development tool used to build and test smart contracts that automate the reward process. These smart contracts ensure that when a verified donor gives blood, they receive incentives such as tokens without the need of a middleman. Hardhat helps developers create and simulate this system in a safe environment before it's launched, making sure it works smoothly and securely. This approach supports a transparent and reliable way to motivate rare blood group donors.

iii) Node.js Version 22.18: This is used as the backend environment that runs the server-side part of the system. It helps manage donor information, process requests like registration or donation confirmation, and connect the application with blockchain networks such as Ethereum. Using tools such as Web3.js or Ethers.js, Node.js allows the system to talk to smart contracts for example, to send a token reward after a donation is confirmed. The updated version (22.18) includes better performance and stronger security making the system more reliable. Overall, Node.js plays an important role in ensuring smooth communication between the user interface and the blockchain, helping donors to receive their rewards efficiently and safely.

iv) Ethers.js Version 6: This is an important JavaScript tool that helps the application connect and work with the blockchain. It allows the system to communicate with smart contracts which are programs that control how rewards are given. For example, when a donor's blood donation is confirmed, Ethers.js can trigger a smart contract to automatically send tokens or rewards to the donor's digital wallet. This version of Ethers.js is faster, easier to use, and more secure. Furthermore, it helps with tasks such as connecting to the blockchain, reading information from it, and handling secure digital signatures. Generally, Ethers.js makes it simpler to use blockchain technology in the system hence this ensures donors get their rewards quickly and safely.

v) MetaMask: This is digital wallet that helps donors interact safely with the blockchain. It allows donors to store and manage their rewards such as tokens earned from donating blood. MetaMask connects the donor's web browser or application to the blockchain, making it easy for them to approve transactions, such as receiving their incentives. It also keeps their private information secure by allowing them to sign transactions safely. Moreover, MetaMask makes it simple and secure for donors to get, keep, and use their blockchain rewards in the incentive system.

vi) React.js: React.js is used to build the user interface of a blockchain based model that rewards rare blood group donors. It creates an easy-to-use and fast web application where donors and hospitals can register, verify donations, and claim rewards. React.js connects the app with digital wallets like MetaMask, allowing users to securely interact with the blockchain. It also updates information instantly, so donors can see their rewards right away. Furthermore, it shows both on-chain and off-chain data, React.js helps make

the donation and reward process simple, clear, and reliable for users.

vii) Visual Studio Code (VS. Code): This is a helpful tool that developers use to create the blockchain system that rewards rare blood donors. It is a code editor where programmers write and fix the smart contracts and the applications front-end parts. Visual Studio Code makes coding easier with features such as showing helpful hints, checking for mistakes, and running commands without leaving the editor. It also lets developers test and send smart contracts to the blockchain and work together by keeping track of changes in the code.

viii) NPM (Node Package Manager): This helps developers build the blockchain application that rewards rare blood group donors by managing all the software tools and libraries they need. It makes it easy to add, update, and use ready-made code pieces such as blockchain tools, user interface parts, and testing helpers. This saves time because developers do not have to write everything from scratch. In the donation reward system, NPM helps make sure the app works smoothly by connecting the blockchain, wallets, and user interface.

ix) GitHub: This is web-based platform used primarily for storing, managing, and collaborating on code. It uses Git, a version control system, to track changes in code over time, allowing developers to save different versions of their work and revisit previous updates if needed. This is especially useful when working on large projects or with teams, as it prevents the loss of important changes and supports organized development. GitHub enables multiple people to collaborate on the same project simultaneously by letting them contribute code, suggest improvements, or fix issues through features like pull requests. It hosts code files online in repositories, which can be either public or private, making them accessible from anywhere.

x) Bootstrap / Cascading Styles Sheet (CSS) Frameworks: This help to make the blockchain based model for provision of incentives to rare blood donors look good and work well on all devices such as phones and computers. They provide ready-made designs for buttons, forms, and layouts, making it easy for donors to register, check their donations, and claim rewards. This makes the application simple to use and faster to build. However, the responsive design ensures the application fits different screen sizes, so donors can access it anytime, anywhere**.**

The model was categorized into modules and organized according to the following achievable functions as stated below:

i) Smart Contract: This is a computer program written in Solidity that works on the Ethereum blockchain. It automatically gives digital rewards (called tokens) to donors with rare blood types and makes sure the reward rules are followed correctly. Solidity is a general-purpose programming language used to write Ethereum smart contracts. It defines contracts and methods to send and receive digital tokens and manage data on the blockchain.

ii) Ethereum Wallets: To effectively achieve the research objective, three different Ethereum wallets were created: for the rare blood donor, for the hospital blood donor unit record officer, and for the smart contract. These wallets keep track of the digital rewards and make sure all transactions are safe and clear.

iii) Decentralized Application (DApp): This is a simple application that connects users to the blockchain through the smart contract. DApp was developed to allow front-end users to interact with the blockchain through the smart contract (Front End → Smart Contract → Blockchain). The Hardhat development framework for Ethereum was used to build and manage the application.

b) Smart Contract Development

Smart contract development is essential for creating a blockchain system that automatically rewards rare blood group donors. These contracts are self-running programs that verify donations and issue digital rewards like tokens without needing manual help. When a hospital confirms a blood donation, the smart contract checks the donor's details and sends the reward directly to their wallet. This process is fast, secure, and trustworthy. However, developing smart contracts involves writing, testing, and deploying code to ensure the system is fair and reliable, encouraging rare blood donors to participate. The steps for creating a smart contract are as follows:

i) Define Requirements: Clearly outline what the smart contract should for example, register donors, verify blood donations, and distribute rewards based on blood type and donation confirmation.

ii) Choose the Blockchain Platform: Select a blockchain platform that supports smart contracts, like Ethereum, Binance Smart Chain, or Polygon.

iii) Write the Smart Contract Code: Use a programming language such as Solidity (for Ethereum) to write the smart contract. Code the rules for donor registration, donation verification, and automatic reward issuance.

iv) Test the Smart Contract: Thoroughly test the contract in a safe development environment such as Remix to catch errors and ensure all functions work correctly.

v) Deploy the Smart Contract: Deploy the tested contract to the chosen blockchain network so it can interact with real users and data.

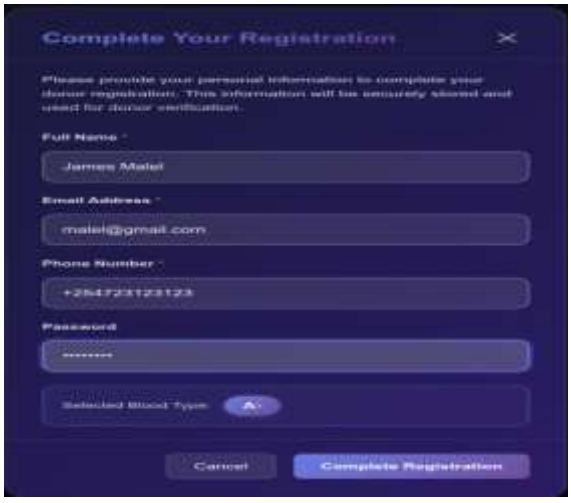
vi) Integrate with Front-End Application: Connect the smart contract with a user-friendly front-end decentralized application that was built using tools such as React.js and MetaMask) so donors and hospitals can interact with the system.

4.1 Development of the Donor Registration and Authentication

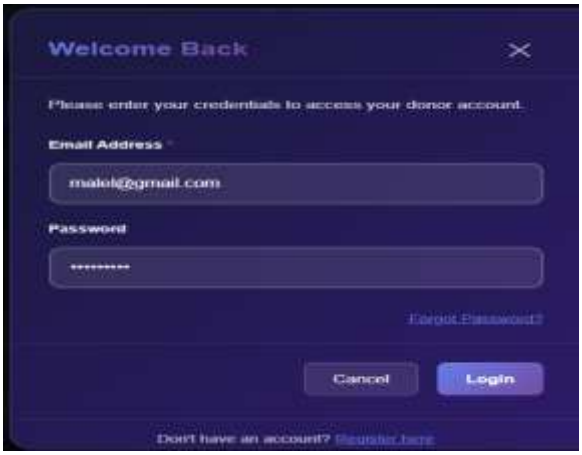
Donor registration is the initial step where individuals create an account in a model by providing basic details such as their full names, email address, phone number and a password. This information is securely stored by the system for future identification of the user. On the other hand, user authentication is the process of confirming the user's identity when they attempt to log in. The model checks the entered username and password against the stored data. If the information matches, the user is granted access.

i) Donor Registration Module

The registration process is the first step to access the model. During registration, users provide personal information such as their Full name, email address, phone number and a password. The figure 1 below shows a donor Registration Form Screenshot.



ii) Donor Login Module: The donor login is a safe and easy way for registered blood donors to sign in and use the system. This platform uses blockchain technology to keep records safe and reward donors with rare blood types. However, user login is crucial because it help the blood donor to log in securely to the model, check past blood donations, see any rewards or token earned and get alerts when their blood type is required. The rare blood donor logs in the model by entering their email address and password. The figure 2 below shows a donor login form.



4.2 Development of the Token Reward Module

The token reward module is a key component of the blockchain system that encourages and rewards people who donate rare blood types. It automatically creates, distributes, and tracks digital tokens when a verified donation is made. Donation of blood type AB- is awarded 250 tokens, B-200 tokens, A- is awarded 150 tokens, O- is awarded 230 tokens because they can be given to all other blood types. These tokens can be redeemed for benefits like subsidized medical care, preferential services, free medical checkups and T-shirt. Using blockchain ensures that all transactions are securely recorded, making the process transparent and preventing fraud. Smart contracts handle the rules automatically, such as checking donor eligibility and determining token amounts, which increases trust and efficiency.

4.3 Development of the Incentive Award Module

Incentive award is reward given to motivate or recognize blood donors. To encourage blood donation, many organizations offer thoughtful incentives such as free health screenings or blood tests, discounted medical checkups, and even vitamin packs or nutritional supplements to support donors' well-being. Donors might also receive small tokens

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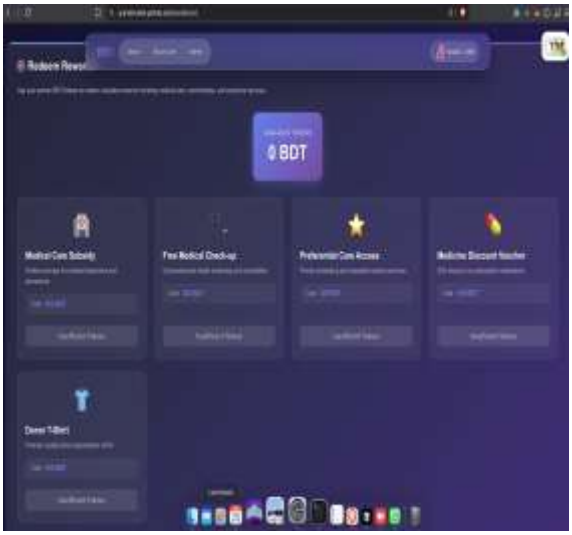
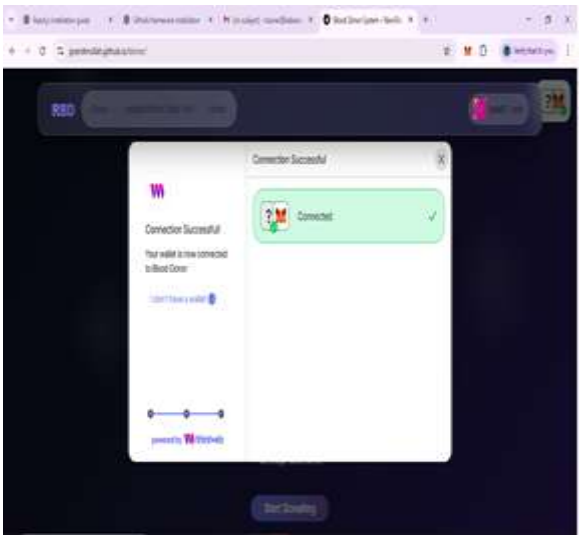
of appreciation for instance Free medical checkups subsidized medical care, preferential care access and donor T-Shirt as a simple way to say thank you for their life-saving contribution. The figure 3 below shows the incentives claims screenshot.



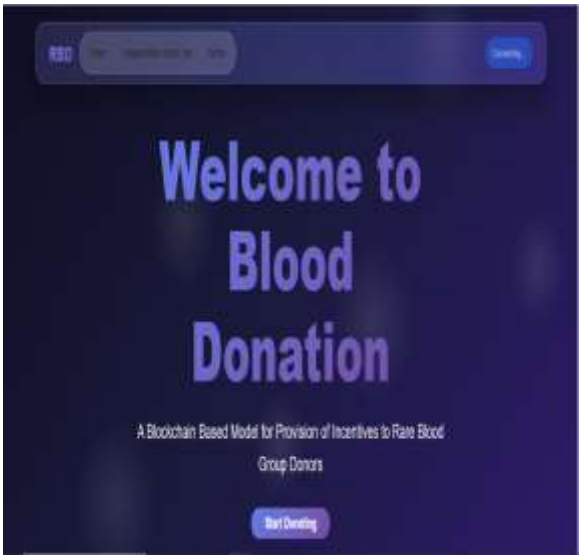
4.4 Deployment of Smart Contracts to Blockchain Network

Before launching a project on the Ethereum blockchain, developers usually test it on a test network, known as a "testnet." A testnet works like the real Ethereum network but uses fake Ether, so developers can test their smart contracts without using real money. This makes it safe and cost-free to check for errors and make improvements.

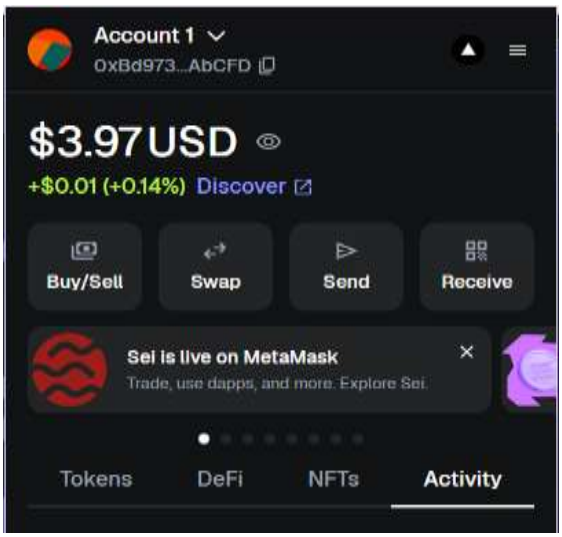
MetaMask, a browser-based wallet, was then used to send test Ether and tokens. MetaMask also allows switching between the real Ethereum networks. When the network is switched, MetaMask updates the wallet's balance and transaction history to match. Since Ethereum addresses and private keys are the same on both the main network and testnets, it is important to avoid sending real Ether to a testnet address. A connection is made to MetaMask wallet to enable the donor to interact with the solidity smart contract as shown in figure 4 below**.**



The home page is lorded for user to interact with the various parts of the system as shown in figure 5 below.



In order for the system to allow transactions, the MetaMask Wallet must have enough gas to facilitate network fees for the users as shown in 6 below.



5. RECOMMENDATIONS

The study recommends development of user-friendly interfaces to promote wider adoption and ensuring compliance with data privacy laws such as General Data Protection Regulation (GDPR) and Health Insurance Portability and Accountability Act (HIPAA). Furthermore, this study recommends enhancing the blockchain based model prototype by integrating it with **the** existing blood donation and management systems in order to improve donors' verification and blood inventory management. To enhance donor participation, the study suggests implementing flexible incentive schemes tailored to donor preferences as well as maintaining robust security through regular updates.

6. CONCLUSION

A blockchain based model for provision of incentives to rare blood group donors presents an approach to address the challenges encountered by the blood donation systems, particularly when it comes to rare blood types. The use of blockchain technology provides security and transparency during the distribution of incentives through smart contract, creation of immutable donation histories as well as the capability to maintain donor privacy through cryptographic techniques. Moreover, the decentralized nature of blockchain assists to foster higher level of trust among rare blood donors.

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