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Voucher tokenisation using blockchain and smart contracts to support people in need

In South Africa, many people are homeless or doing informal work for which they receive small amounts of cash from caring individuals. The world is moving towards cashless transactions, but devices are needed to support that move. Many people in need cannot afford such devices and usually receive cash, but fewer donors carry cash. Consequently, people in need receive less informal financial support. We propose a system that allows donors to give digital vouchers that can be redeemed at participating stores and institutions of care. This study aimed to investigate the use of blockchain technology in digital voucher management and to demonstrate the application of smart contracts to disintermediate the value transfer process specific to the donation process. A demonstrator was built to include a front end for the user to interact with and a back end containing the application logic, which was built on the Polygon blockchain, a second-layer solution for the Ethereum blockchain. The model included tokenising vouchers as non-fungible tokens, and the smart contracts governed their logic and the conditions to be met. The demonstrator was validated using smart contract and unit tests to evaluate the security and functionality. While the model was not implemented in reality, a fully functioning demonstrator was developed. The platform achieved the aim of disintermediating the voucher management process. A real-world implementation could help many in need to receive tokens for food, shelter and clothing from direct, individual donors.

Significance:

We developed an architecture for a digital voucher donation management system that enables individual donors to transfer cashless vouchers to recipients in need. The recipients can then exchange the vouchers for necessities such as shelter, food and clothing. Such a system will become essential in the near future as we move towards a cashless society. The proposed system is safe because it is based on blockchain technology.

Introduction

South Africa has a complicated history of racial inequality and is the world's most economically unequal country, according to the Gini coefficient. This coefficient is an index of economic inequality and ranges from 0 (perfect economic equality) to 1 (complete economic inequality). The value of the Gini coefficient for South Africa was 0.63 in 2023, which is the highest value in the world.¹ Furthermore, the top 10% of the South African population earn more than 65% of the national income. Various factors contribute to these figures, and financial exclusion is considered a key factor, according to the World Bank.² Financial inclusion (FI) is the state in which "all persons have timely and fair access to appropriate, fair, and affordable financial products and services", according to the South African Financial Sector Regulation Act.³ The World Bank⁴ asserts that this cannot be guaranteed in practice, particularly for lower- to middle-income countries. The significance stems from the fact that, as of 2018, research⁴ shows that more than one billion people around the world lack a formal means of proving their identity, of which about 81% reside in South Asia and Sub-Saharan Africa. In the poorest 20% of countries, 45% of people lack a national identity document. Formal or legal identity documentation in South Africa is either in the form of a green bar-coded identity book, identity card or valid South African passport issued by the Department of Home Affairs.⁵ In South Africa, individuals without formal identity documentation are severely disadvantaged and inhibited from participating economically and socially. They are likely to be excluded from access to basic services or opportunities such as opening a bank account, applying for a mobile service provider, using a money market, applying for formal employment or government housing and receiving various forms of social grants.⁶ Economic inequality and education levels are usually linked, and many people are denied an education due to poverty.^{7,8}

The South African Government has the developmental objective of closing the wealth and financial inclusion gap⁹, and the National Development Plan for 2030 presents a roadmap describing the process to relieve the poverty and inequality¹⁰ in the country. Citizens should, however, not leave it to their governments alone to improve people's lives. They can also help others as individuals. Claude Ake, a renowned Nigerian political philosopher, said, "It is the ordinary people who alone can make development sustainable, and development has not really occurred until it is sustainable. The people make development sustainable only insofar as its content becomes an integral part of their lives"¹¹. Community philanthropy by civil participation is one way for individuals to uplift their peers.

In South Africa, philanthropy is multifaceted: it ranges from structured, formal giving mechanisms, such as corporations, organisations or high-net-worth individuals to informal peer-to-peer forms of supporting the underserved.¹² Informal philanthropy is usually done by donating money or time directly to the underserved, and not via an organisation.¹³ In lieu of cash donations, the Western Cape government (2022) promotes the donation of food, clothing and household goods or vouchers. Informal donations are typically not premeditated acts of kindness. It is uncertain when or where a donor would get in contact with someone in need, and it is unlikely that a donor travels with donatable items at all times. As a result, the standard method of helping someone in need is to give money. This is only possible if the donor has cash on them. This is unlikely to remain the case in the future because South Africa's payment environment is gradually moving away from cash and towards digital methods.



According to the FinMark study¹⁴, 77% of people in South Africa used digital services for payments, with 71% of those payments going towards receiving income. In this study, we examined the country's digital payment landscape as well as the use of and access to financial services.

A cashless society using e-wallets, credit cards, mobile money and cardless application (app) payment systems is predicted by the growth trajectory in digital payment usage.¹⁵ According to the Better Than Cash Alliance¹⁶, these payment methods are becoming more widely accepted in communities and can reduce the disparity in financial exclusion. This hypothesis is supported by BankservAfrica¹⁷ which claims that innovative digital solutions for financial services targeted at the less fortunate can benefit societies. This also applies to donation platforms and charities that may use digital means to disperse their aid.

We propose a digital voucher management system to facilitate voucher donations to ensure that the recipient uses it for responsible purposes¹⁸ to empower the less fortunate and make 'responsible giving' more convenient. The conservative assumption is that the beneficiary does not own a mobile device and will be issued with a simple, cheap device such as a quick response (QR) code. For this reason, digital vouchers and card-based systems could be considered as a digital means for distributing donations, and to enable this, we discussed the potential of blockchain technology (BCT) as a mechanism for informal peer-to-peer charity donations in South Africa. We demonstrated the concept with a digital voucher donation management system (DVDMS) developed using engineering methods and available software products. The demonstrator showcased the practical implementation of BCT and its ability to enable digital donations through voucher tokens while ensuring security and accountability for all parties involved in a donation.

The concept of the DVDMS is presented now, while the design will be presented later. Caring institutions such as night shelters, retailers and individuals create digital vouchers for products on the DVDMS. These products could be a loaf of bread, a can of milk, a pack of nappies or a night at a shelter. Donors consider the digital vouchers on offer and buy one or more. When the donor wants to give a digital voucher to a beneficiary, the donor uses a mobile device to scan the QR code of the beneficiary, thus reserving the specific product for them. The beneficiary presents the QR code to the vendor in exchange for the product. No cash is involved, and the beneficiary does not need any expensive devices. The beneficiary, when registering on the DVDMS, receives a near-field communication (NFC) card and a QR code for identification. All transactions are secured and visible on a blockchain platform.

Voucher systems

Vouchers and voucher systems have a long history, having been used as money or as a means of redeeming goods and services in ancient civilisations.¹⁹ Vouchers have been used for numerous purposes in the modern era, such as exchanging goods between businesses, marketing for drawing in clients and distributing and redeeming government benefits. Vouchers may be used as gift certificates or as part of a loyalty programme, as a way to redeem a stay at a hotel or a meal at a restaurant or to redeem a ticket or pass for travel.²⁰ Vouchers serve to transfer value without giving up the tangible item up front, which makes them useful for charitable donations and situations where the donor might not have cash on hand and/or the beneficiary does not have a bank account. Additionally, vouchers can stimulate the local economy by supporting small businesses and promoting consumer spending.²¹

The introduction of digital vouchers is one of the many consequences of the increased use of digital technologies where the need for digital solutions to traditional methods arose. Digital vouchers provide a convenient and secure means of exchanging value and goods. In recent years, consumers have been adopting digital vouchers more and more as a method of payment instead of traditional cash or credit card options.²²

Decentralised donation voucher systems involve the use of digital vouchers that are distributed among a community of donors. These vouchers can then be redeemed for goods or services by recipients such as vulnerable

individuals or organisations. By using a decentralised platform, these donation systems can promote horizontal community philanthropy, which is based on the idea of collective action and shared responsibility for the well-being of the community. Next, we present a secure digital platform allowing the exchange of digital vouchers for individual charity.

Blockchain and vouchers

The blockchain concept was first introduced in a 2008 white paper by the pseudonymous individual or group known as 'Satoshi Nakamoto'.²³ BCT has recently gained attention as a solution for various industries. It is a decentralised and distributed digital ledger used to record transactions across a network of computers. It started as a secured transactional concept and is a distributed ledger technology (DLT) that allows multiple parties to access and update a shared database without needing a central authority.²⁴ Transactions recorded on a blockchain are grouped into blocks and linked in a chronological chain, creating an immutable record of all transactions on the network. Transactions are validated by consensus among the nodes.²⁵ Decentralisation is a type of network in which nodes are independent of a central point or master node, and rather share a distributed control among the other nodes on the network.²⁵ It makes blockchains more resilient to attacks and failures because there is no single point of failure in the network. BCT presents promising tools for various applications, including secure and transparent record-keeping, identity verification and decentralised financial systems. One well-known application of BCT is cryptocurrency, particularly Bitcoin, which utilises the technology as a decentralised record-keeping database for monetary transactions.²³

BCT offers smart contract functionality.²⁶ Smart contracts are digital contracts that hold their logic in code, which is automatically executed by a computer program, whereas a traditional contract is a legal agreement that is manually executed. Smart contracts can be used to create and manage vouchers, ensuring that the terms of the voucher are met before it can be redeemed. For example, a smart contract could be set up to allow a voucher to be redeemed only after a certain date, or only if certain conditions are met. Smart contracts can also be used to track the usage of vouchers, providing transparency and traceability for both the issuer and the holder. The smart contract can also include a unique identifier that verifies the authenticity of the voucher.²⁷⁻²⁹

Blockchain contracts enforce their terms without reliance on a third party and create tamper-proof records due to the cryptographic and immutable nature of BCT.³⁰ Along with these programmable contracts, BCT facilitates the creation of non-fungible tokens (NFTs) that resemble unique, indivisible and in-exchangeable (for other tokens) digital assets.³¹ On blockchain markets, smart contracts are often used to facilitate the buying and selling of NFTs. The funds are held by the smart contract, which functions as a digital escrow, until the buyer receives the NFT. This contributes to ensuring the security of the transaction and compliance with the terms of sale. NFTs and digital vouchers are similar in that they are both digital assets that can be bought, sold and traded. However, NFTs are unique digital assets that are verified on a blockchain, while digital vouchers are typically digital versions of physical vouchers that can be redeemed for goods or services. By using BCT, vouchers in the form of NFTs provide a new level of security and authenticity for both the issuer and the holder.

One of the biggest challenges with vouchers is ensuring their validity and preventing fraud.³¹ BCT can help solve this problem by providing a secure and transparent way to create and track vouchers. Blockchain-generated digital tokens can be redeemed like coupons or gift cards. The tokens can be fungible or non-fungible, and a variety of token formats can be created, including the non-fungible ERC-721 tokens on the Ethereum blockchain. These tokens can be programmed to have specific attributes, for example, expiration dates, and can be tracked on the blockchain to verify their validity, just like a traditional voucher.

BCT can also be used for vouchers by creating decentralised applications (dApps).²⁵ dApps are digital applications that run on a blockchain network, allowing for a decentralised and trustless platform. dApps can be used to create and manage vouchers, enabling users to redeem vouchers directly on the blockchain without needing a centralised

intermediary. It can facilitate the management of charitable donations (in this case, a voucher token) by creating a secure and transparent record of an asset's ownership and location, and the conditions of the individual voucher donations made in a system.

This research aims to explore three use cases in the form of (1) vouchers as tokens, governed by the (2) logic of smart contracts, all on (3) a decentralised platform such as a blockchain. By building the DVDMS on a blockchain, it effectively disintermediates the distribution of voucher donations, resulting in a more direct form of transferring vouchers from those who have the capacity to give, and those who are in need. The smart contracts act as self-executing programs that execute the creation, purchase transfer (from vendor to donor), donation transfer (donor to beneficiary) and redemption transfer (donor to vendor), based on preset conditions.

System functional requirements

We present the functional requirements we anticipated a DVDMS should have. Before we do that, we explain the workings of the system in simple terms. Three role players enable the system operations. These are the beneficiary (person receiving a donation), donor (an individual wishing to donate to a beneficiary via a token) and vendor (usually a business entity that provides items that are associated with tokens). The vendor digitalises their products by creating voucher tokens that represent the value of their sales items. The donor buys a token from the vendor via the DVDMS platform; for example, a box of rusks. The donor then hands the token to the beneficiary, who will trade the token at the vendor for the box of rusks. Our vision is that the tokens will represent at least food items, clothing and shelter. The functional requirements for such a concept are shown in Table 1.

These requirements were used to develop a demonstrator, which will be discussed later.

Assumptions made

Assumptions were made prior to the design of the system to determine boundaries. These were:

1. The vendor is the end user and initiates the flow of information. We assume they have access to the Internet and computers.

2. The beneficiary is conservatively defined as someone who is not likely to have a cellphone or formal documentation, but may have access to a device via others, as well as having the capacity to carry a QR code or NFC chip device with them.
3. The custodianship and digitalisation process (i.e. assigning serial numbers representative of the token ID to the physical asset) of the vendor's products is not included in the scope.
4. Vetting the vendors is important, and it will still be necessary to implement operational protocols if the system is deployed. However, the system will provide the platform for the managing and transferring of the voucher token, not the onboarding of the vendors.
5. The beneficiary onboarding is not included in the system scope; however, it will be necessary to provide an in-person registration process for the beneficiary to receive their QR code and NFC card.
6. The onboarding payment gateway between fiat currency and cryptocurrency is not included.

System specification

We describe the DVDMS specification in words, as follows:

1. The DVDMS is a digital voucher donation management process built as a web-based platform. It enables the purchase and donation of voucher tokens, exchangeable for physical assets such as food, clothing and shelter.
2. Three different groups of stakeholders will be interacting on the DVDMS platform, namely the vendors, beneficiaries and donors.
3. Vendors will use a 'token template' to create vouchers for their products. The DVDMS will mint the vouchers as tokens, allowing the traceability of their movements on the blockchain.
4. The DVDMS is interoperable and has a self-sovereign identity service – this will facilitate the secure registration process of each of the stakeholders in the system and assign role-based access rights.

Table 1: Functional requirements (FRs) of the digital voucher donation management system (DVDMS)

FR ID	Functional requirement	Description
FR1	Connect digital wallet	System must enable the user to connect their wallet to the DVDMS via prompts or notification
FR2	Registration	System must facilitate the vendor's registration process
FR3	Log-in	System must automatically recognise the address of the user once their wallet is connected
FR4	Access control for vendor registration	System must grant registered vendors access rights to create (mint and list) a voucher token
FR5	Voucher platform catalogue	System must display the available vouchers for sale to the public in the form of a voucher catalogue
FR6	Manage voucher controls	System must allow the registered vendor to populate the voucher template and delete a voucher token
FR7	Manage voucher sale	System must list the vouchers for sale once the voucher has been minted as a token
FR8	Mint a voucher as a token	System must mint the vouchers as tokens once the vendor has populated the token template with the required attributes
FR9	Purchase, transfer and store tokens	System must create a marketplace that allows the donors to purchase and transfer the tokens from the vendor
FR10	Provide transparency and traceability of the tokens	System must provide full transparency of the movement of the tokens as they change ownership
FR11	Scan QR code wallet addresses	System must have a built-in QR code scanner that reads the address belonging to the code
FR12	Validate voucher	System must be able to validate the voucher by querying the blockchain and determining its status
FR13	Redeem voucher monetary value	System must allow the vendor to redeem the monetary value of the funds once the voucher has been successfully redeemed
FR14	Escrow function to hold funds	System must include an escrow service that automatically executes the release of the funds once the vendor proves the voucher has been redeemed

5. The DVDMS integrates the use of a digital wallet called MetaMask that will allow the donors to purchase the vouchers with their digital currency.
6. Voucher donations and transactions will be transparent and visible to all users via a dashboard.
7. The DVDMS allows the donor to donate directly to the beneficiary without any intermediary involvement.
8. Emphasis is placed on the ability of beneficiaries to participate (i.e. redeem vouchers and sign transactions) without the need for expensive technology such as a mobile phone.

The stakeholders

The three stakeholders are briefly discussed. Their role and technology requirements are emphasised.

1. **Donor:** The donor will exchange fiat currency (in this case, the South African rand) for tokens representing digital vouchers and will directly donate to the beneficiary of their choosing. The donor must have a mobile device capable of taking photos and scanning a QR code. In addition, the donor needs to have a digital wallet installed; for example, MetaMask.
2. **Vendor:** The vendor is a participant registered on the system by a system administrator and is offering something for sale on the platform. The vendors create the digital vouchers based on their products or services, and they define the conditions and intrinsic value of the digital voucher as well as the process of redeeming the value of the digital voucher. The vendor is the owner of the physical asset associated with the voucher donation token and plays an essential role as the redeemed value of the token needs to be guaranteed. The vendor needs a mobile device which is also capable of taking photos and scanning a QR code and which has a digital wallet installed, for example, MetaMask. A QR code scanner can be used in place of a mobile device; however, this requires additional integration procedures. An NFC reader is required to allow registered beneficiaries to sign their transactions by tapping their cards.
3. **Beneficiary:** The beneficiary is registered on the system, and they redeem the voucher for either goods or a service. Their interaction with the DVDMS is via a QR code assigned to them at registration and representing their digital wallet address. This allows the beneficiary to view their wallet contents as well as redeem the intrinsic value of the voucher at a participating vendor. The beneficiary needs only a QR code and an NFC card. The QR code represents their public key on the blockchain, similar to the use of a 'username' for an account, while the NFC card holds the encrypted private key, representing the secret password.

The information flow design is presented next, based on the above system specification and stakeholder description.

Information flow design

The registration of a beneficiary is shown in Figure 1. It is assumed that the beneficiary does not have a mobile device, but the option is still provided for. The beneficiary will register at a public place such as a clinic, participating retailer or other caring institution such as a night shelter. The NFC card and QR codes are inexpensive and safe to carry and use.

An activity diagram was constructed to explain the information flow and activities of the DVDMS and is shown in Figure 2. As mentioned before, there are three stakeholders in the DVDMS: the vendor, donor and beneficiary. The vendor agrees to participate in the system and provides products such as food items or shelter. The donor chooses an item from a selected vendor to donate and purchases a digital voucher for that item. The donor hands the beneficiary a QR code for the digital voucher. The beneficiary can then claim the item from the vendor, and the digital voucher expires. All transactions are securely handled by the blockchain platform, and the expiry of the voucher token is based on the conditions set in the smart contracts.

The life cycle and state transition of a digital voucher or token as used in the DVDMS are shown in Figure 3. The digital voucher is created by the

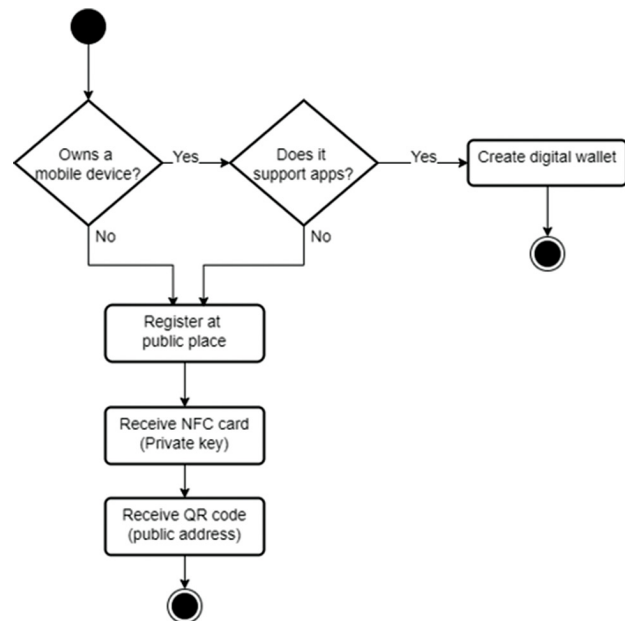


Figure 1: Beneficiary registration process.

vendor and the donor purchases it. An escrow function keeps the money paid safe while the digital voucher is transferred to the beneficiary. Once the digital voucher is claimed, it ceases to exist.

A prototype to demonstrate the concept

A prototype was developed to conceptually demonstrate the use case of BCT as the foundation for a digital voucher management system. The blockchain-based DVDMS is abstracted as a front-end and back-end web application that facilitates the creation, purchase and redemption of digital voucher tokens for physical assets. The prototype was built using the following available technologies and components; the numbers in the list below correspond to the numbered labels in Figure 4:

1. The web application, which is accessible via any web browser. This is the front-end user interface of the DVDMS.
2. The donor or vendor, who would need to have a digital wallet to hold their cryptocurrency to integrate into the DVDMS. The donor needs to ensure that they have cryptocurrency in their digital wallet, while the vendor needs to ensure that they can receive cryptocurrency.
3. Authentication – To use the DVDMS, the user will need to authenticate transactions as well as user access rights using their digital signature from their cryptocurrency wallet. This is a cryptographic signature that authenticates the user as a donor, rather than a vendor, allowing them to purchase a digital voucher token, but not create one on the platform. The user will use their private keys that are stored in their digital wallet to prove to the platform that they control the respective wallet that is trying to 'connect' to the platform.
4. The MetaMask wallet, which is a cryptocurrency wallet, is the link between the user and the blockchain. This digital wallet allows a user to connect to the platform and interact with it by holding cryptocurrency to transact.
5. A gateway is required between the DVDMS and the InterPlanetary File System (IPFS), to make the IPFS service HTTP accessible from a non-decentralised Internet browser. This allows the DVDMS to upload and store files without needing a decentralised browser. The Infura gateway is used to support write access to IPFS.
6. Infura provides the tools and infrastructure that allow developers to take their ready blockchain application from testing to (scaled) deployment. Included in the development suite is access to IPFS and Polygon networks.
7. IPFS is founded on the concepts of peer-to-peer networking and content addressing and is a modular suite of protocols for

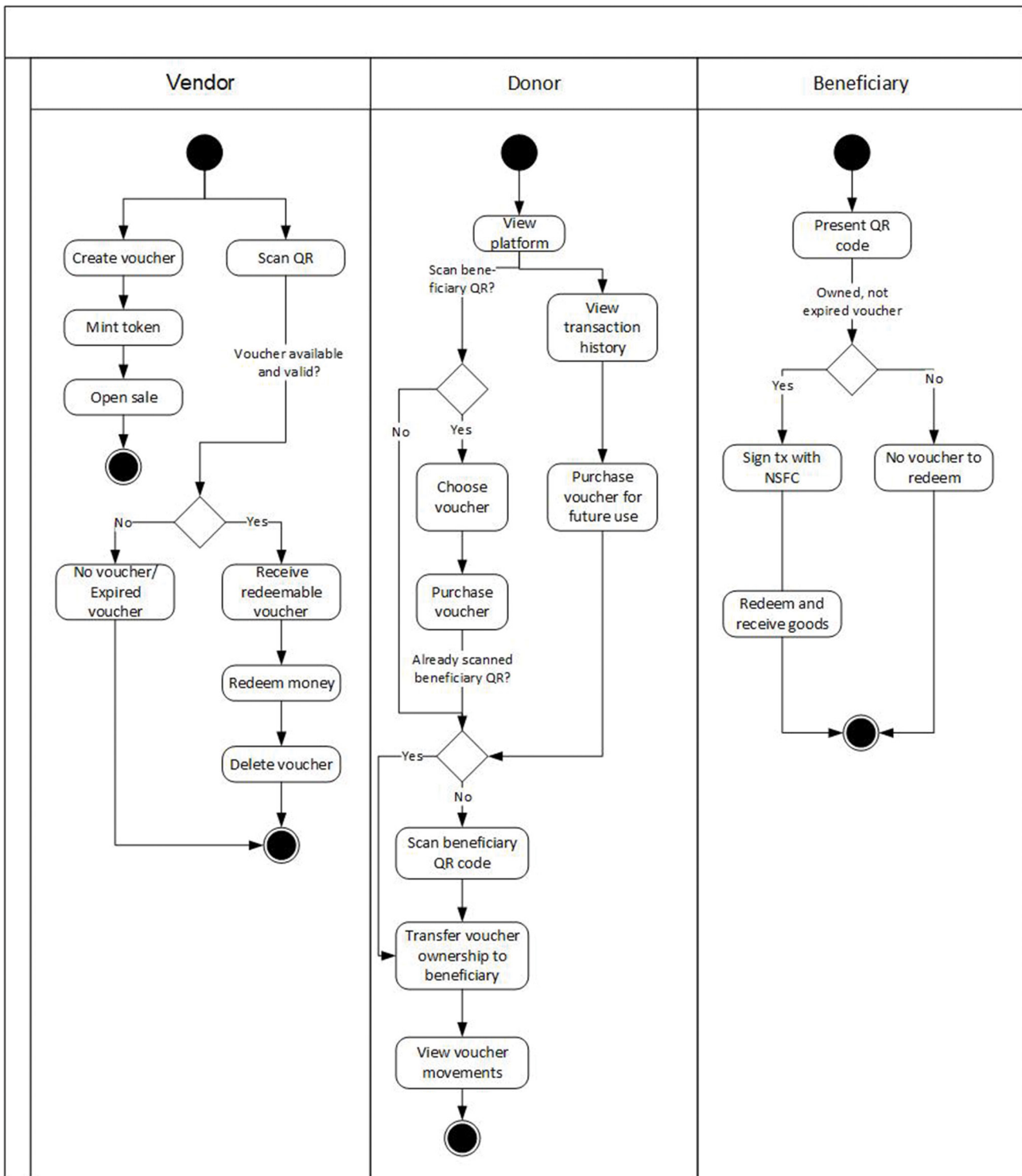


Figure 2: The digital voucher donation management system (DVDMS) activity diagram.

data organisation and transfer. This is used in a similar manner to a database; however, it is a decentralised storage service that stores data across multiple nodes on the network. The information associated with the digital voucher tokens is stored using this service, which also results in an entirely decentralised application.

8. The DVDMS host platform was built on the Polygon blockchain as it is a more affordable alternative to Ethereum. Polygon also allows for scaling of the network, and the resources for developers make it a more attractive blockchain to use for prototyping. Additional libraries, frameworks and tools are used to extend the capabilities of the Polygon blockchain. Hardhat is a development environment that allows for the debugging, testing and deployment of smart

contracts on a test blockchain. Ganache enables local testing of smart contracts. OpenZeppelin is an open-source library for smart contracts, allowing developers to build on top of a secure foundation of code based on community-vetted security standards.

9. PolygonScan provides a blockchain explorer, search, API and analytics platform for Polygon. This was used to track any updates, changes or transactions specifically associated with the DVDMS platform. It was used to demonstrate the transparency and traceability of transactions on the blockchain, smart contract interactions and any digital voucher token movements on the Polygon network. It was also used to verify transactions and monitor the flow of assets within the application securely.

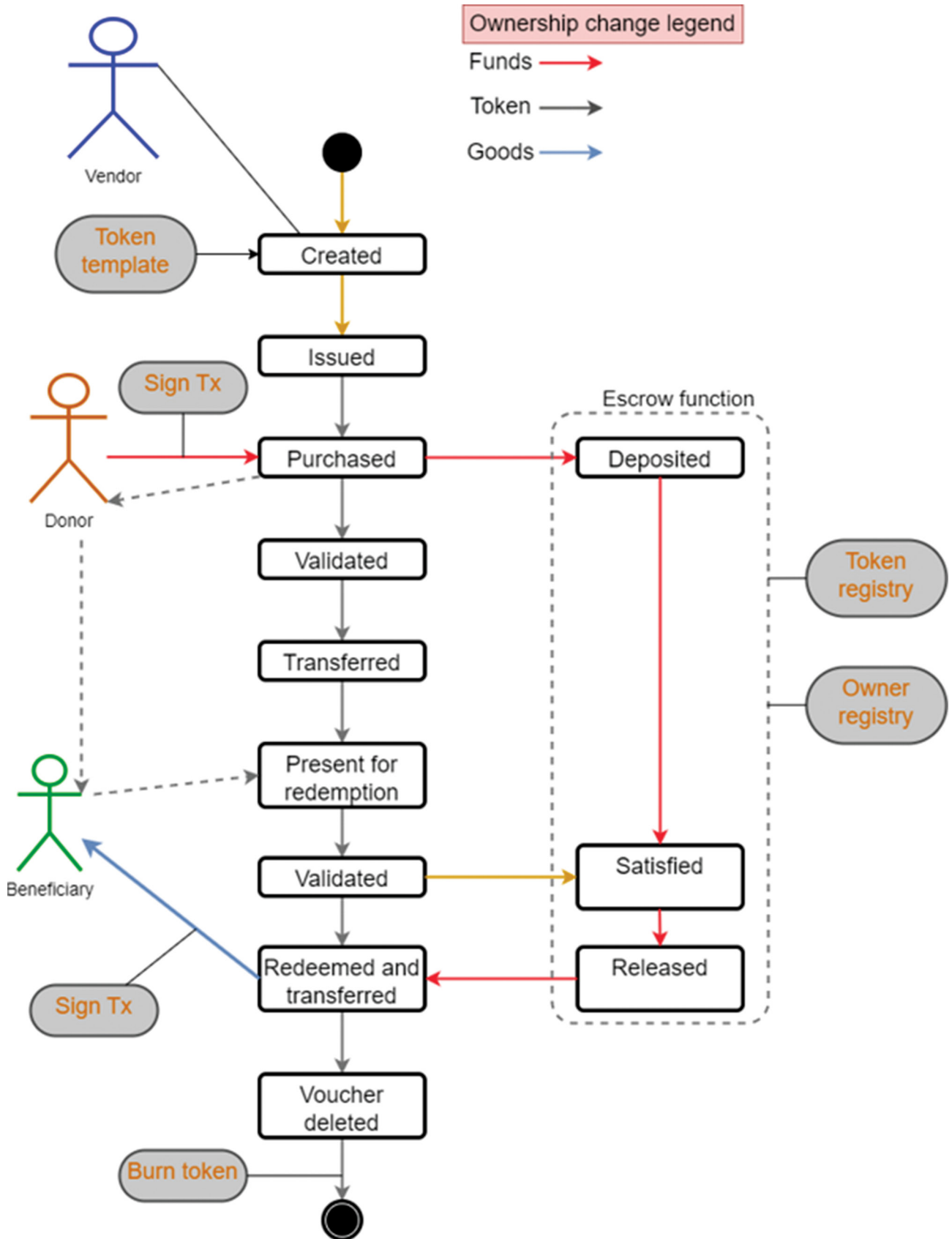


Figure 3: The life cycle and state transition of the voucher.

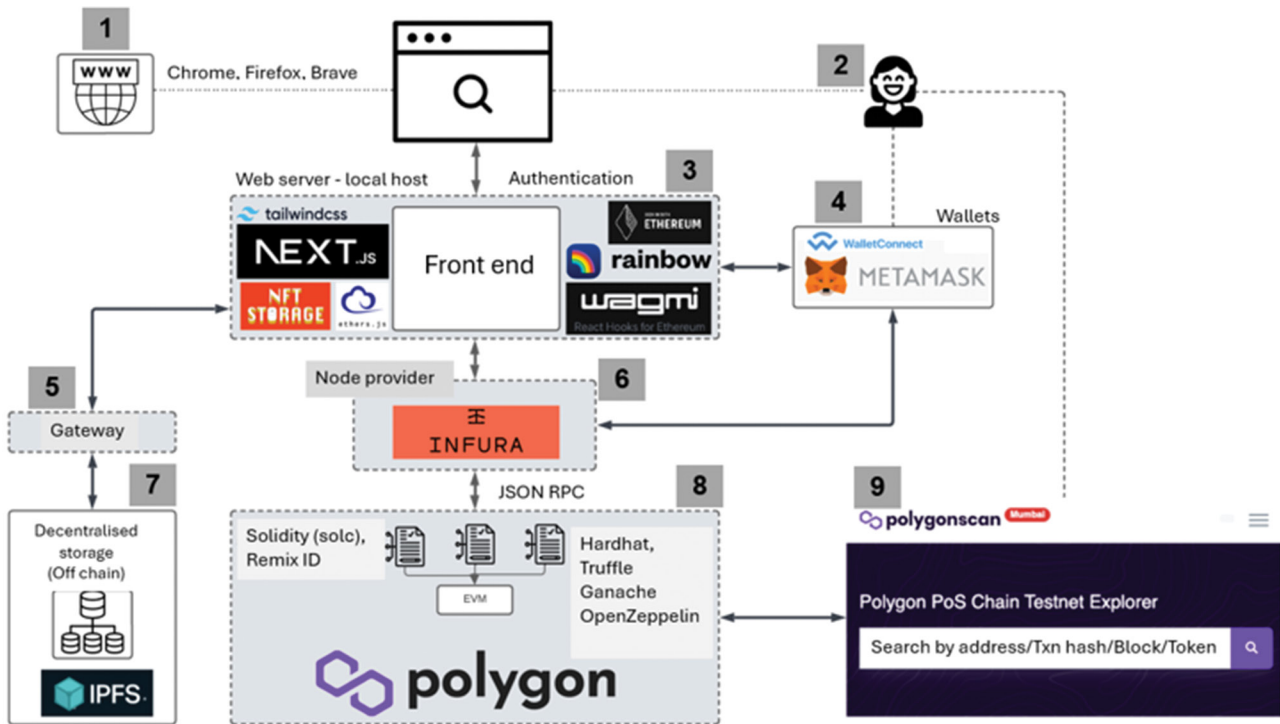


Figure 4: Digital voucher donation management system (DVDMS) software technology architecture.

Conclusion

We have proposed a system that will enable donors to give tokens to recipients with no cash involved. The donor, therefore, does not need to carry cash to support an underprivileged recipient, and the latter can safely redeem tokens from participating vendors. BCT has the potential to revolutionise the way digital vouchers are created and managed and was the cornerstone technology used to enable the proposed DVDMS. It enables the creation and tracking of digital vouchers on a safe platform that guarantees the vouchers' usefulness and validity. Furthermore, redeeming digital vouchers is automated using decentralised applications and smart contracts, improving efficiency and cost-effectiveness. As BCT develops, more companies can use it for financial instruments such as digital vouchers. Using BCT in a DVDMS has some limitations. The decentralised nature of BCT may pose regulatory challenges because it is unclear how existing regulations and laws apply to this new technology. Despite these limitations, the potential advantages of using BCT in a DVDMS make it an exciting area of research and development. A peer-to-peer DVDMS enabled by Blockchain could be a revolutionary way to manage charitable donations by providing transparency, security and efficiency to the donation process.

Data availability

There are no data pertaining to this article.

Declarations

This paper is based on the MEng thesis of T.H.³² We used Grammarly Premium to assist with language editing. To the best of our knowledge, we have no conflict of interest to declare.

Authors' contributions

T.H.: Conceptualisation, methodology, validation, writing – the initial draft. J.B.: Conceptualisation, writing – revisions, student supervision, project leadership. Both authors read and approved the final manuscript.

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