A blockchain-based object sharing system for local communities

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***Abstract*—This paper aims to show how blockchain technology can enhance the reuse of unused items by facilitating the lending of physical goods in local sharing economies. While this type of interaction between citizens is already established informally, we propose a model that helps to digitalize the process without crowding out interpersonal relationships within local communities. This is achieved by making a digital twin of each item via a totally decentralised lending management system where each loan takes place between two parties without any mediator. This lending system is available to communities through a web application we developed as a submodule of TOKENAPP [1], a specialised wallet app designed to provide civic communities with the necessary tools to encourage active civic participation within the community.**

Keywords: Tokenization, local economies, civic blockchain, Internet of values 2.0.

I. Introduction

The term "Internet of Values" describes a space where monetary value exchanges can take place between two users without any middleman. Since the advent of the first fully decentralised digital currency, Bitcoin [3], in 2008, the term "Internet of Values" has become much more prominent, and the exchange of values between parties has been revolutionised. People can send money to others without relying on third parties like banks. In 2013, Ethereum was conceived by Vitalik Buterin, which brought about further developments. While the primary function of Bitcoin is value transfer between parties, thanks to Ethereum, developers could start to deploy code onto the Ethereum blockchain through its most innovative and important feature, smart contracts. A smart contract is computer code that gets compiled and executed by the nodes of a blockchain. This code cannot be updated once deployed by the developers unless specific patterns are used. The most common programming language used to develop smart contracts is Solidity, which is very similar to object-oriented languages like Java.

With Ethereum, decentralised applications (DApps) have started to be developed. DApps are decentralised because the information included in them are not saved to a centralised server owned by a company but are rather contained in a smart contract on a blockchain. An explorer such as DappRadar can be used to get an overview of current existing DApps.

The most common uses for smart contracts are decentralised finance (DeFi) and art collections (with non-fungible tokens), but they are not limited to those domains. Tokens are comparable to coins, and are often referred to as 'cryptocurrencies' [18]. Tokens can fall into two categories: 'fungible', indicating interchangeability with another identical token, or 'non-fungible', signifying uniqueness and irreplaceability. Experimentations with blockchain technology are emerging beyond finance and global cryptocurrencies. They include applications in the domains of civic participation within local or urban communities such as commoning [5], and social and solidarity economies [22, 16] . However, empirical research on actual experiments and on their social implications for local communities are still at an early stage. This paper addresses this gap by describing experiments that leverage blockchain as a catalyst for digital social innovation and civic engagement within local communities, which are different to the global and speculative cryptocurrencies that are most commonly associated with blockchain. These experiments explore the potential of blockchain-based tools to orient monetary innovations towards achieving goals of public and collective interests, and encouraging citizen engagement through various tokenization mechanisms. In this paper, we describe a lending platform developed for local communities where users can put their physical items up for loan or send a borrowing request to other users. The main goal is to encourage the reuse of unused items and to facilitate the management of a decentralised booking system using blockchain technology.

The application is built on top of TOKENAPP , a wallet app designed and developed to support social and collaborative economies in local communities [1]. It contains different tools that local communities can use to build a more inclusive and sustainable economy. They can create their own tokens, start crowdfunding initiatives, give sharing rights for tools, or represent digital collectibles like tickets to events using non-fungible tokens [2]. According to the civic blockchain approach, tokens are not limited to monetary values [1]. They hold a broader significance and can represent any asset deemed relevant by the local community.

In this paper, we present a decentralised and innovative lending

[1]The name of the application has been anonymized in accordance with the submission rules

system called the *Library of Things*, built as a submodule of TOKENAPP . Each item on loan has a digital twin, a non-fungible token (NFT) that gets minted by the lender whenever a new item gets uploaded onto the platform. Borrowing something has an associated cost based on the number of days requested; each day adds 1 token to the total cost. The crypto token we have developed for the Library of Things is called PROJECT [2] (an Italian acronym meaning Organised Communities for the Exchange of Objects, and with reference to a project with the same acronym). We designed it to help and encourage community members to contribute to the system: every action which is considered good for the community generates new tokens as a reward. This helps new users to bootstrap their experience.

In the upcoming sections, we will commence by stating the problem we are trying to solve in this paper. This will be followed by an exploration of related works (see Section II-B). After that, we will introduce TOKENAPP (Section III-A) and present a comprehensive overview of the utilization of blockchain in local sharing economies (Section III-B). Following this, I will delve into of the Library of Things (Section III-C), focusing on the most important aspects of its architecture. We will then see the creation of new booking requests into the blockchain. This discussion will be complemented by an in-depth examination of the token economy. In the final section of this paper, the focus will be towards the evaluation of the system (Section V), and we will give insights into future developments of the platform (Section VII).

II. Background

A. Problem statement

The research aim described in this paper is to provide local communities with a tool for enabling citizens to manage the lending of unused items in a disintermediated way, as part of civic engagement actions. All of this is achieved using the capabilities of blockchain technology.

B. Related work

Other authors have proposed projects on enabling digital sharing economies by sharing physical items using digital twins on blockchain. García-Moreno et al. [12] proposed a proof of concept for a decentralised rental system based on smart contracts and Ethereum. Their work is about the economic impact of sharing cars, while we are more focused on the social impact that a sharing platform of unused items can have on a small community.

Fedosov et al. [10] developed JSI (Just Share It) for sharing items using smart contract technology. While their core idea is the same as ours, the technical implementations and contexts differ in various ways. We included custom-made ERC20 and ERC721 crypto tokens that can be used across different communities in TOKENAPP . Another difference is that in JSI, users can only make a new request for an item if the item is free at that moment, while in The Library of Things, users can request items for future dates. Huckle et al. [14] explored diverse scenarios for the application of blockchain in various Internet of Things (IoT) systems, with a specific emphasis on its relevance to the sharing economy.

Ranganathan et al. [19] developed a decentralised marketplace application, which may be worth considering for any potential future development that involves not only the lending but also purchase of items. Tiansong et al. [21] applied blockchain technology to the development of an item booking platform similar to Just Share It and the Library of Things. In that system, users are only able to borrow an item when it is currently available, there is no calendar to reserve items for future dates, and standard interfaces like ERC20 or ERC721 have not been implemented.

Numerous projects leveraging blockchain technology for managing items have explored applying it to traditional libraries, and some proposals have been made by Cabello et al. [6] and Tella et al. [20]. These models utilise blockchain to monitor and manage books within a library system or physical archive. We designed the Library of Things to be flexible, envisioning its adaptability to the different needs of different communities, without limiting uploads to books. Although not our primary focus, our platform stands ready to integrate with other projects. Exploring the integration of blockchain technology in civic contexts has revealed possible applications in various scenarios with diverse potential benefits and challenges, as highlighted in [1]. This pivotal insight has motivated our conceptualisation of the Library of Things, where the forefront of technology converges with civic applications.

III. A proposal for civic blockchain

A. The TOKENAPP wallet app

TOKENAPP is a blockchain-based wallet app with the main goal of providing users with tools to customise tokens representing material and immaterial assets that can be exchanged in local community economies. Its core function is to enable the fluid circulation and redistribution of such assets by representing them as tokens, and ensuring secure and direct transactions without intermediaries. Users can create their own ERC20 tokens to use in their own community, or create NFTs that act as coupons or tickets for events. Thanks to the web interface, users can view local economy initiatives, they can participate in these initiatives using instant payments and QR code deep-links, or they can propose new initiatives of their own. TOKENAPP focuses on local communities, and has social and informational, and not only economic, aspects. It is integrated with the CIVICAPP local civic social network, and is a working application that can be used for real-world experiments. You can find the web app by following this link: *anonymized*.

TOKENAPP introduces a range of financial tools such as coins, coupons, token exchanges, NFTs and crowdsales [2]. In our case study, we focus specifically on **coins** and **NFTs**. The app supports and enables different kinds of social and collaborative economies in local communities such as: reward

[2]The name of the project has been anonymized in accordance with the submission rules

schemes for civic actions, loyalty schemes for local economic activities, urban commons, complementary welfare systems, and local sharing economies. Unlike other proposals in the field of Blockchain for Social Good, TOKENAPP does not propose local community organisation based on a single type of token or single complementary currency. Citizens and stakeholders have the ability to create their own tokens to regulate their initiatives in their local area. This allows the creation of sub-communities within the area offering initiatives where participation is contingent on the possession of a particular coin or coupon. A citizen might want to acquire a particular coin through volunteering activities, but then might want to participate in a crowdfunding that requires a different type of coin as input. To support such scenarios, TOKENAPP offers the possibility of token exchange (the sale of coins or coupons). The object of the case study presented in this paper is local sharing economies.

B. Local sharing economies and blockchain

Before going further into our case study, we shall clarify our conception of local sharing (or collaborative) economies. With this term, we refer to digitally-enabled community-oriented sharing systems that take place at the local level and which are different to business-oriented sharing economies that rely on global commercial platforms ([8, 15, 17]). In what follows, we explore the potential benefits of integrating blockchain technology with such digital sharing platforms. Building upon the work of Bogner et al. [4], who demonstrated the feasibility of a sharing app built on Ethereum, our objective is to extend their approach by presenting a local sharing economy model centred around underutilised items. We achieve this by implementing a tokenization system into our platform. By tokenization, we mean the process of integrating cryptographic tokens to represent either physical goods or currencies. These tokens are community specific, so one community can choose to create its own type of token and provide a set of rules that apply to them.
Tokenization models serve as valuable tools for enabling mechanisms that are relevant for implementing sharing economies within local communities. Tokenization models can:

- **represent physical objects and assets digitally**, thus making them more liquid and fostering their circulation;
- **integrate gamification schemes**, thus stimulating citizen engagement. Jian Wang et al. [23] emphasise that integrating NFTs and cryptocurrencies significantly enhances gamification within a platform;
- **reward positive actions**: acknowledging positive actions accomplished by community members, and fostering collaboration to make the process trustworthy;

C. The Library of Things

Lending physical goods represents an important opportunity for small communities. It offers multiple benefits such as promoting the environmentally and economically sustainable practice of recycling old and unused items, and providing the borrower with cost savings when compared to purchasing new items from a shop. We also strive to improve social sustainability by strengthening social bonds. This is achieved by incorporating a physical aspect into lending interactions: both parties must meet in person at the beginning and end of the lending period.
The application described in this paper is called the *Library of Things*. The name refers to its main goal: all users manage their own library of items or "things" and they let other users borrow these items without the need for an intermediary "bookkeeper". An item is requested by a borrower by sending a booking request to the lender. Our goal is to ensure a smooth process for this kind of exchange in a community, and we have achieved this by introducing tokenization to the process. Tokenization of physical goods is the process of representing real-world, tangible items as digital tokens on a blockchain. In this context, a token serves as a digital twin of a physical asset. This makes it possible to digitally track and transfer possession of physical goods.
The Library of Things prioritises the following key aspects:

- **loan management**: we want the members of a community to be able to manage their lending and borrowing easily;
- **digital twin**: each item is uniquely represented by a non-fungible token (NFT) owned by the lender: the digital counterpart ensures effective tracking. The concept of digital twin has been explored in other articles e.g. [13];
- **reward for positive actions**: community members receive rewards for accomplishing positive actions, which fosters collaboration and makes the process more trustworthy;
- **the importance of physicality**: we recognise the potential for depersonalisation caused by digital solutions in small communities; our goal is to use digital platforms to enhance, rather than diminish, personal encounters among community members in urban spaces.

The Library of Things was developed as a submodule of TOKENAPP .

When users join the Library of Things website for the first time, they are asked to accept the rules of the platform. This will result in enough tokens being minted to their wallets that they can start making booking requests. We have developed a custom ERC20 token for our case study. The first time the user uploads an item, its digital twin gets minted in a personal collection created only for The Library of Things. A personal collection is created the first time the user uploads an item. Then, for each subsequent item, new digital twins are minted inside the existing collection.
We want to reward users for every action that contributes to personal relationships and collaboration within the local community. Each reward involves the minting of an amount of tokens inside the wallet of the user. We have planned the following rewards:

- **membership reward**: ten tokens are minted when community rules are accepted for the first time;

- **community reward**: two tokens are minted when a user uploads an item onto the platform;
- **trust reward**: one token is minted when the loan period is finished;
- **care reward**: two tokens are minted when a borrowed item is handed back in good condition to its owner;

Each loan has four possible states: pending, accepted, started, ended. Pending means that the lender has received the request but still needs to accept it. Started means that the lender has initiated the lending period and has physically given the item to the borrower. Ended means that the item has been returned to its original owner.

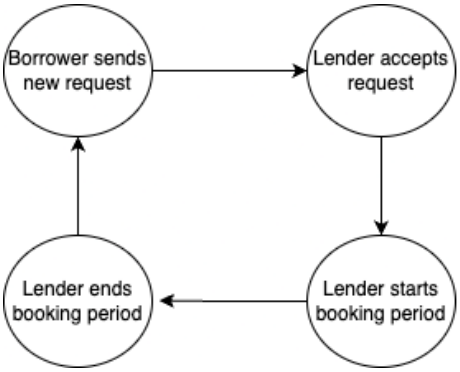

Figure 1: The full cycle of a loan

You can see from the image above (Figure 1) the full cycle of a loan, starting from the borrower's request. The borrower sends a new request for an item, the lender then handles the rest of the cycle by accepting the request, and then starting and ending the lending period.

When the lender ends the loan, (s)he states whether or not the item was damaged by selecting an option from a dropdown menu and may also leave an optional comment.
The price of each loan is calculated as follows: one token for every day the item is requested plus a deposit. For our first experimentation, we set the deposit to zero. When a user makes a new request, the tokens requested for the loan are sent to the main Library of Things smart contract. The tokens are sent to the owner of the item at the end of the lending period, at which point the owner can state whether or not the item was broken. and the deposit tokens are transferred to the borrower or lender accordingly. We know that this solution gives more power to the lender than the borrower, but we need to keep in mind that we're dealing with small communities, so there is no need to be too strict, and possible disputes can be resolved in person. The user experience was designed such that technical knowledge about blockchain or cryptocurrencies is not required.

IV. System Implementation

In this section, we go deeper into the architecture of our system. We start with an overview of the overall architecture and then we focus on each subsystem, providing a detailed explanation of their roles and how they are connected to the rest of the system.

A. Architecture overview

We start with a bottom-up view of the architecture. We have developed five smart contracts: Calendar.sol, ItemMarketplace.sol, HashRegistry.sol, TokenTemplate.sol, and NftTemplate.sol. ItemMarketplace.sol contains Library of Things items, Calendar.sol contains booking requests, HashRegistry.sol contains the hashes used for each request, TokenTemplate.sol is an implementation of the ERC20 standard that we used for the tokens, and NftTemplate.sol stores the NFT of each item and is an implementation of the ERC721 standard. It's hard for the client to efficiently handle complicated queries that involve reading events from smart contracts. Therefore, we have opted for a more scalable solution that implements a NodeJS microservice. Its main goal is to listen out for events emitted from the smart contracts and save them inside a MongoDB database. All the clients query this database through an API built using another NodeJS microservice that uses Express. This kind of middleware between the clients and the database is called "metadata-dapp". The process of saving events inside a database is an established practice in the industry. OpenSea has also adopted this model [9], and their APIs and clients query a database with all the information they need.

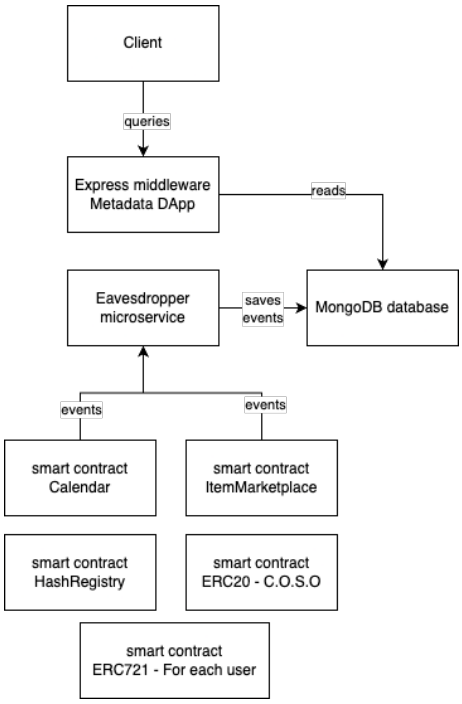

Figure 2: System architecture

B. Smart Contracts

Now we shall delve into the most important smart contracts. We will first look at ItemMarketplace. This smart contract is responsible for saving information about the items that are currently present in the Library of Things. The smart contract has a set of functions that make it possible to:

- upload new items;

- transfer an NFT between users;
- add or remove categories (to group together similar items). Each item is grouped in a category;
- issue a reward when a user joins the app for the first time;
- remove items;

ItemMarketplace also receives tokens when a new booking request is sent by a user. To save and access the information of an item, we use a mapping, with a counter as key:

Listing 1: Item mapping

```
mapping(uint256 => ItemMarketplaceLib.Item);
```

Once an item is registered, the digital twin is transferred from the user to the ItemMarketplace smart contract, and each time a loan begins, the item NFT is transferred from the smart contract to the user who has requested the item. Then, at the end of the lending period, it is transferred back to the smart contract.

The second most important smart contract is Calendar.sol. It is responsibile for handling booking requests. This smart contract has a set of functions that manipulate the state of each loan, specifically:

- created
- cancelled
- accepted
- ended

The last smart contract discussed in this section is HashRegistry.sol. It is responsible for saving and checking the hashes used when a new booking request is sent to the Calendar contract. Only the Calendar smart contract can register a new hash in HashRegistry.

C. The booking system

In this section, we focus on the core feature of the application: how we made the booking system work. For each item, there must be a calendar that shows the user which days the item is available and unavailable. This is not an easy task because saving and maintaining a whole calendar in a smart contract is expensive. We solved this problem with the following steps:

- the client queries the metadata-dapp microservice to find out if an item is available in a specific time period (Figure 4)
- each time an item is requested, the start and end dates are emitted using an event from the Calendar smart contract (Figure 4)
- the Eavesdropper microservice saves these dates in the MongoDB database (Figure 4)

But following these steps is not enough because it doesn't address the problem of multiple requests for a specific item for the same period. As such, we have included an extra check to make sure that only valid requests can be saved to the Calendar smart contract. Each time a booking request is made, metadata-dapp checks if the dates requested by the client are available in the MongoDB database. If they are available, a message is signed using the private key of a specific Externally Owned Account (EOA) called the "notary". When a client calls on the smart contract to add a booking request, it must also send a signed message as a parameter. The HashRegistry checks if the message was signed by the notary, and if so, the request is deemed valid and those dates are available. We use the Elliptic Curve Digital Signature Algorithm (ECDSA) to check if the message has been signed by the notary (Listing 2).

Listing 2: Register signature

```
function registerSignature(
    bytes32 _hashToCheck,
    bytes memory _signature
) public onlyWhitelistedAddress {
    require(
        !hashRegistry[_hashToCheck],
        "Hash already used"
    );
    require(
        ECDSA.recover(_hashToCheck, _signature) == notary,
        "Signer does not match the notary"
    );
    hashRegistry[_hashToCheck] = true;
}
```

This function is the core of our booking system because it allows us to filter out requests that clash with other dates. We could have placed this function inside the Calendar smart contract, but we decided not to. This is because we wanted to have a single source of truth for the hashes used by the users.

D. Web App

We designed the client to be as user-friendly as possible, even for those who have no experience or knowledge of blockchain. Each user can upload an item to the Library

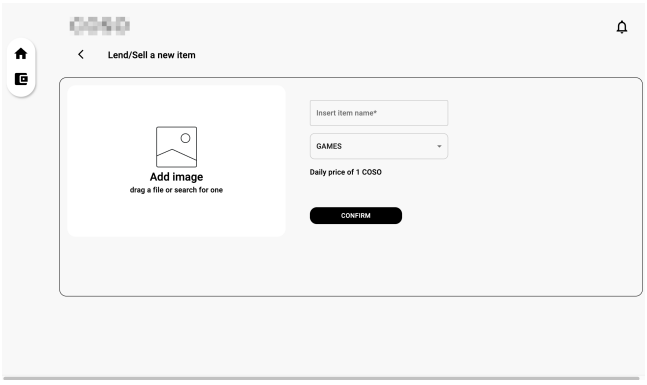

Figure 3: Form to upload an item

of Things through an online form (Figure 3). The only information required are name, image, item category and the deposit amount. The first time a user creates an item, the

app checks whether (s)he already owns an NFT collection in which to store the new item. If not, a new one is created and then the NFT is minted into the collection. Note that for our experimentation, we have set the deposit amount to zero for every user. The user can request an item from the homepage by selecting the requested dates from the item calendar. We also decided to set the daily cost of each item to 1 token, but in future versions this can easily be changed. Once the item gets minted, it can be accessed from the user's profile where all his/her items are stored. A borrower that wishes

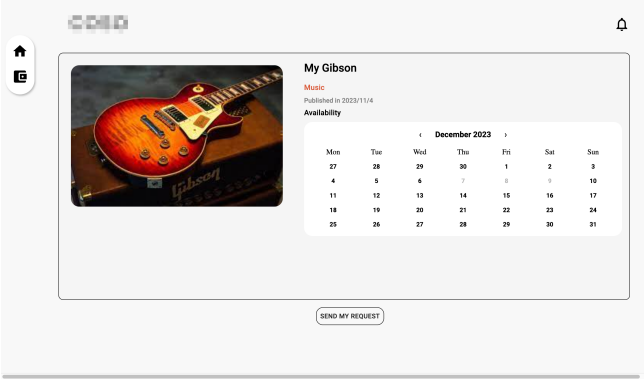

Figure 4: Form for uploading an item

to request an item can do that simply by visiting its page and selecting the dates he wants. Once the "Send request" button is clicked, a new request is sent to the owner of the item, and the required tokens are sent from the borrower to the ItemMarketplace smart contract. After this, both borrower and lender can keep track of the status of the loan by visiting their profiles. The lender accepts, starts and ends the loan as in the screenshot below. The lender can also refuse the request received. Once a booking request is sent to a lender, its status can be handled by visiting the relevant section on the user's profile page.

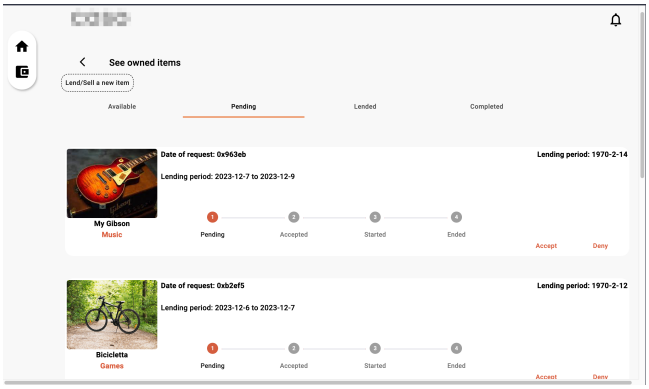

Figure 5: List of pending booking requests

V. System evaluation

The Library of Things was initially designed to meet the requirements of PROJECT , a project with the goal of strengthening community relationships and making it easier to borrow and lend unused items within a community. PROJECT (an Italian acronym meaning Organised Communities for the Exchange of Objects) participants took part in various phases of app development by providing input and feedback on issues from the design of the core token model to the design of the user interface. Their contribution was especially relevant during the testing phase of the alpha version of the Library of Things. We have tested the application several times with a small group of experts among community members. Each testing session followed a structured approach. Each tester was assigned specific tasks to be completed autonomously, and were asked to providing valuable insights as they navigated the application, sharing their thoughts aloud. This interactive process allowed us to observe and record problems with the user experience, pinpointing areas for improvement. After testers had successfully completed their task lists, we asked some specific questions on the overall user experience.

Following initial tests, we decided to standardise the cost of items to 1 token. This adjustment was crucial to prevent disparity, since users with more tokens tended to borrow higher-value items, which diverges from PROJECT 's fundamental ethos of creating a platform that is accessible and affordable to everyone. As the application attained the milestone of minimum viable product (MVP), essential feedback emerged concerning communication within the platform. Testers articulated a need for intra-platform communication, prompting us to start a comprehensive design process that included features like in-app messages while allowing more traditional methods by providing personal phone numbers or emails.

These iterative tests not only played a pivotal role in refining the platform's functionality but also served as a fundamental test on its accessibility. The outcomes were significant. Users, whether they were technically proficient or less familiar with such applications, navigated the platform seamlessly without requiring additional guidance from our UX designer.

VI. Security and evaluation of smart contracts

To better check the security of our smart contracts, we used Slither [11], a static analysis tool that when run on the code of a smart contract can show if it is vulnerable to a re-entrancy attack [7] or other common attacks like timestamp dependence, insecure arithmetic or denial of service. The result of the Slither analysis revealed only minor issues, with no critical bugs detected. The only issues identified were related to the naming conventions used for certain variables. For instance, in terms of timestamp dependence, our analysis examined potential scenarios where the smart contract's logic might be influenced by timestamps, making it susceptible to manipulation. An example of this could be a contract relying on timestamps for time-sensitive operations, such as unlocking certain functionalities after a specified period. Without proper safeguards, an attacker could manipulate timestamps, compromising the intended functionality.
Similarly, we thoroughly investigated potential insecure arithmetic practices within the codebase. An example could be wrong checks for arithmetic overflow or underflow, which

might lead to unintended consequences, such as the misallocation of funds or unexpected contract behavior.

VII. Future developments

Our roadmap foresees the following features. Some of them come from the initial brainstorming session and have been further enriched through iterative testing of the application. Embracing the potential of decentralised autonomous organisations (DAOs), we find intriguing developments where each community is represented by a DAO. Within this framework, community members gain agency via voting mechanisms, and can thus influence and shape platform updates. Such a democratic decision-making process would ensure dynamic and responsive evolution of the platform, fostering a sense of shared ownership and collaborative innovation.

One area that needs improvement is user communication. In our initial experimentation involving a small group of users, we facilitated communication by sharing users' email addresses once a request had been accepted. However, we recognise the need for improvement. In upcoming versions, we propose to develop a straightforward messaging platform within the wallet application. This would encourage increased interaction on the website, offering users an integrated communication experience.

Another planned enhancement is an interactive map showing the geographical positions of registered communities. This feature could make it easier for other members to join or explore communities in their surrounding area.

As regards the architecture and technologies adopted, we intend to change our current back end. We will no longer use any NodeJS middleware to retrieve user information. We will include in our tech stack *The Graph*[3], a powerful tool that allows us to make complex queries using only the events emitted by the smart contracts. This will facilitate scalability and the development of new features and the development cycle as a whole.

Another goal for the near future is to include a gamification system to make the user experience more fun. All these new milestones will be subject to testing cycles to ensure the high quality of the product we are developing.

VIII. Conclusion

We have developed the Library of Things, a platform that helps members of a community to find new uses for items they rarely or never use personally. Our application was initially designed in accordance with the requirements of PROJECT , a community-based initiative. Its core members participated in the testing phase to refine the overall user experience and find the next features to be developed for subsequent versions. We achieved our goal of developing a fully functional decentralised application that provides a simple and structured process for borrowing unused items in the community.

Each library item is represented by its digital twin, an NFT minted when a user registers an item onto the platform. After the item is uploaded, other users can send borrowing requests, selecting a start date and an end date. For each day the item is borrowed, the user pays 1 token. We have developed a custom ERC20 token called PROJECT The platform must be affordable for everyone; that's why each item has a standardised price of 1 token per day. Once a booking request is sent, the loan has a different status: pending, accepted, started, ended. Once the loan has ended, the NFT is transferred back to the lender. Whenever a user completes a good action in his community, (s)he is given a reward in tokens.

We have found other civic-minded projects similar to ours led by other scholars, but none of them offer the possibility of booking an item in the future like many mainstream platforms do. We use the commit-reveal strategy to handle the validation of new requests by users. This ensures that a new lending request is legitimate. We have organised multiple testing sessions in collaboration with PROJECT members, an initiative aimed at introducing blockchain technology to small communities to facilitate the process of reusing unused items. These sessions have been extremely useful for improving the user experience and testing whether the results obtained meet the original goals of the project. They have also highlighted the need for additional features and these will be designed and developed in subsequent releases.

Ultimately, we can confidently confirm that our research goals have been successfully achieved. Through meticulous testing sessions carried out in collaboration with members of the PROJECT community, we not only substantiated that there is genuine interest in our platform but also gained invaluable insights into its functionality and the user experience. The positive reception indicates that our optimism regarding the future development roadmap is well placed, and we anticipate the release of numerous enhanced versions in the next development cycles as we continue to refine and expand the capabilities of our platform.

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