Toward Decentralized Digital Asset Management on the Blockchain

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Abstract: The emergence of cryptocurrencies has significantly altered the financial landscape, introducing both opportunities and challenges, particularly within asset management. By harnessing the immutability and transparency of blockchain technology, our goal is to present a model that enables the decentralization of the traditional hedge fund industry by removing intermediaries. Our approach integrates smart contracts and pioneering standards like ERC-6551, offering a way for managers to hold and operate investors' assets securely. Furthermore, the model facilitates decentralized decision-making, enabling investors to participate in fund governance using voting mechanisms. This work outlines a concrete path toward decentralizing asset management, marking a significant step in reshaping traditional practices and fostering innovation in the financial sector.

1 INTRODUCTION

In the evolving landscape of finance, asset management has been a cornerstone, traditionally involving the stewardship of investments like stocks, bonds, and real estate. This field has seen considerable evolution with the advent of sophisticated instruments, diverse portfolios, and global investment opportunities. However, the most transformative change in recent years has come with the emergence of cryptocurrencies.

The birth of cryptocurrencies, with Bitcoin at the helm, has revolutionized the concept of value transfer, presenting a novel asset class that is not bound by traditional financial systems or geopolitical borders. The growth of this market has been exponential, reflecting a broader shift towards digital assets and compelling the development of a crypto asset management market. This burgeoning sector is swiftly expanding as investors seek to capitalize on the volatility and potential high returns of crypto assets.

The backbone of this transformation is blockchain technology, a decentralized ledger that meticulously records transactions across a network of computers (Yaga et al., 2018). Blockchain's inherent properties such as immutability, transparency, and security have positioned it as the fundamental infrastructure for cryptocurrencies (Ma and Huang, 2023) and for many other applications in the real world (Vyas et al., 2023b). The decentralization of blockchain technology not only enhances security but also democratizes financial transactions by removing the need for central intermediaries.

In traditional finance, intermediaries such as banks and custodians are essential for trust and the execution of transactions. Blockchain, however, ensures trust through its consensus mechanisms and cryptographic proofs, paving the way for secure peer-to-peer transactions without centralized control. The security in transactions, particularly in the realm of asset management, is paramount. Blockchain's architecture provides a level of security that is critically important for investors and asset managers alike, safeguarding against fraud and unauthorized access.

Despite these advancements, the majority of crypto transactions today occur on centralized exchanges. These platforms, while user-friendly, hold the same structural vulnerabilities as traditional financial systems, including the risk of hacks, fraud, and mismanagement. They operate as de facto custodians of assets, which contradicts the decentralized ethos of blockchain. The aspiration to decentralize this aspect of the cryptocurrency market has been gaining momentum. We intend to investigate this significant gap by proposing a blockchain-based approach that removes the custodian.

The blockchain technology can streamline many complex and labor-intensive processes in hedge fund operations, such as compliance checks and performance fee calculations, through smart contracts. Additionally, the immutability and transparency inher-

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ent in blockchain foster greater investor trust. It is estimated that blockchain could reduce financial services infrastructure costs up to $20 billion annually (Wyman et al., 2015).

The launch of the ERC-6551 standard marked a critical advancement in blockchain security and functionality, and was considered one of the most significant improvements in the tokenization ecosystem (Thornton, 2022). ERC-6551 introduces Token Bound Accounts (TBAs), creating a smart contract wallet for every NFT (Non-Fungible Token), making them more composable, dynamic, and interactive. These accounts provide an immutable record of all on-chain activities, thereby enhancing the reliability and utility of digital assets. This innovative standard opens new possibilities in blockchain applications, presenting an opportunity for the hedge fund industry to integrate advancements while adhering to strict security and compliance standards.

Our proposal leverages the ERC-6551 protocol, providing a decentralized model that empowers asset managers to securely hold and manage investors' assets on chains based on the Ethereum Virtual Machine (EVM). This innovation is poised to disrupt the current asset management paradigm, offering a decentralized alternative that ensures security, transparency, and control for both investors and managers, without the need for intermediaries. We also explore the opportunity of establishing a Decentralized Autonomous Organization (DAO), to facilitate decentralized decision-making by investors and promote broader community governance.

The paper is structured as follows. In the next section, we provide the background of our work. Section 3 presents our model for decentralizing asset management using blockchain. Section 4 delves into the initial results, elucidating the proof-of-concept that was developed. The final section concludes the paper, addressing broader implications and outlining the subsequent steps.

2 BACKGROUND

There is a substantial body of work related to utilizing blockchain to decentralize financial systems and industries. The whitepaper presented in (Madeira et al., 2023) discusses a blockchain-based platform, named DeLend, for managing real-world assets in credit, particularly for small and medium-sized enterprises (SMEs) in Brazil. This work employs Non-Fungible Tokens (NFTs) to represent funds and liquidity pools, creating opportunities for executing real operations with investors and borrowers. It is similar to our approach; however, our perspective differs as we focus on the decentralized management of digital assets rather than credit-related aspects.

Pablo et al. address the limitations of current Non-Fungible Token (NFT) platforms and introduce UniCon, a novel infrastructure for digital asset management (Pablo et al., 2021). UniCon aims to overcome shortcomings of NFT platforms by implementing a scalable infrastructure that is not tied to any specific blockchain, supports transactions in any digital currency, and incorporates verified digital identities to reduce fraud. The system is designed to be universal and scalable, enabling efficient management and transfer of digital assets. Using an EVM-compatible blockchain, our proposal integrates the ERC-6551 standard to allow asset managers to hold multiple tokens from investors.

ERCs stands for "Ethereum Request for Comments". ERCs are a set of technical standards used to create and manage tokens on the Ethereum blockchain. These standards provide guidelines for the development of smart contracts and dApps (decentralized applications) that can be applied to create, manage, and exchange tokens on the Ethereum network. ERCs define a set of rules that all Ethereum-based tokens must follow, ensuring consistency and interoperability within the ecosystem. In a way to provide a foundation for our proposal, we describe the main types of ERCs, including ERC-20, ERC-721, and ERC-6551.

ERC-20 is the most widely known and used ERC standard that defines a common interface for creating fungible tokens, allowing them to be seamlessly integrated with wallets, exchanges, and smart contracts by standardizing key functions such as transfers, approvals, and balance tracking. ERC-721 introduces the concept of Non-Fungible Tokens (NFTs), which are unique and cannot be interchanged on a one-for-one basis. Each ERC-721 token is distinct and can represent ownership of specific assets. ERC-721 laid the foundation for the NFT market, revolutionizing the way we think about digital ownership and spawning new forms of digital collectibles and art. ERC-6551 is a new standard for NFTs introducing Token Bound Accounts (TBAs), which relate a smart contract account for a given ERC-721 token, enhancing security and control. ERC-6551 offers dynamic and interactive experiences for NFT collectors and creators, improving fraud prevention, ownership control, and interoperability. Its applications extend to self-governing entities like DAOs, token distribution and secure supply chain solutions (Vyas et al., 2023a).

In the asset management industry, the application of ERC protocols brings three main benefits. The first

gain is the tokenization of assets, since NFTs enable the tokenization of real-world assets, simplifying the digital buying, selling, and trading of assets. This tokenization extends to a diverse range of assets, including real estate, art, and intangible assets like intellectual property. The second benefit is related to improved transparency and security, as the utilization of blockchain ensures that all transactions are transparent and immutable. It minimizes the risk of fraud, fostering increased trust among the parties involved in transactions. The third advantage is automated compliance and governance, since smart contracts, integral to ERC protocols, enable the automation of various compliance and governance tasks. This automation reduces reliance on intermediaries, streamlining processes and enhancing overall efficiency.

3 A BLOCKCHAIN-BASED MODEL FOR DECENTRALIZING ASSET MANAGEMENT

In this section, we outline our proposal, beginning with a review of the actors within a conventional market structure governed by centralized management. Subsequently, we elucidate the transition towards decentralization, highlighting independence from custodial entities and the consolidation of investor participation in decision-making processes.

3.1 Traditional Market

Asset management today involves a complex web of interactions between investment funds, custodians, and exchanges. Investment funds, often comprising diverse portfolios of digital assets, operate within a centralized structure, where fund managers wield significant control over decision-making processes. These managers devise strategies, allocate assets, and rebalance assets based on market conditions, investors' preferences, and the fund's overarching goals. However, the centralized nature of these operations introduces inherent vulnerabilities, such as single points of failure, compromised trust, and susceptibility to regulatory changes.

In the current landscape, custodians play a pivotal role by safeguarding the digital assets held by funds. These custodial entities serve as trusted intermediaries, responsible for secure storage, maintenance, and, at times, even execution of transactions on behalf of the funds (Davies, 2023). Additionally, exchanges act as the marketplace where assets are bought, sold, and traded. The interplay between funds, custodians, and exchanges lays the foundation for the asset management landscape, influencing the efficiency, security, and overall success of digital asset portfolios.

To provide context, the traditional market currently involves the following stakeholders: *Investor*, *Distributor*, *Exchange*, *Custodian* and *Fund*. The *Investor*, whether an individual or organization, allocates capital with the expectation of generating profit over time. On the other hand, the *Distributor* acts as an intermediary, marketing and selling financial products to investors. The *Exchange* serves as a crucial platform for buying and selling financial assets. Simultaneously, the *Custodian* is an entity that safeguards and manages financial assets. Ultimately, the *Fund* refers to a pooled investment vehicle managed professionally.

The flow of a traditional fund investment can be explained through the relations among the stakeholders as outlined below.

- *Investor & Fund:* Investors obtain a share in the fund by paying a management fee to the manager and a performance fee based on a percentage above the market benchmark. The fee structure aligns the managers' interests with the investment, as they earn fees for effectively operating the fund.
- *Distributor & Fund:* Acting as a crucial intermediary, the distributor bridges the gap between the fund and potential investors. Responsibilities involve the promotion and sale of the fund's financial products. Through collaborations and agreements, distributors contribute to expanding the fund's reach, increasing assets under management, and enhancing overall visibility and accessibility.
- *Exchange & Fund:* Exchanges serve as essential platforms where funds actively engage in trading activities. Here, funds can acquire or dispose of assets in line with their investment strategies. By providing a transparent environment, exchanges enable funds to execute trades based on real-time market conditions, contributing to the price discovery process and helping achieve investment objectives.
- *Custodian & Fund:* Custodians play a pivotal role in safeguarding the fund's assets, ensuring secure holdings resistant to theft or loss. Beyond asset safekeeping, custodians assist in transaction settlements and provide administrative services, ensuring a smooth operational flow and compliance with regulatory requirements.

The core idea of decentralized asset management is to eliminate reliance on custodial entities, as we explain as follow.

3.2 Towards Decentralization

The centralized control exerted by fund managers and the reliance on custodians introduce counter-party risks and potential conflicts of interest. Furthermore, the interaction between funds and exchanges can be hindered by inefficiencies, delays, and sometimes exorbitant transaction costs. Regulatory compliance, a critical aspect of the financial industry, adds an additional layer of complexity, with funds and custodians navigating through a maze of evolving guidelines.

In the context of the decentralized future, however, there lies a promising prospect for mitigating these challenges. Blockchain technology and decentralized finance (DeFi) protocols offer the potential to revolutionize the asset management industry by removing traditional players, causing a good disruption in the financial enviroment (Sarathy, 2023). By leveraging the power of smart contracts and blockchain, asset management can become more secure, efficient, and resistant to centralized risks. This shift towards decentralization not only addresses current challenges but also opens doors to new possibilities, fostering a more inclusive and resilient digital asset management.

Our proposed model can be seen in Figure 1. Here all stakeholders (presented in the traditional market) are kept, except the *Custodian*. The traditional *Distributor* is replaced by a component called *Whale Finance*, which is a system supported by blockchain to allow secure transactions. The *Exchange* is represented by an online platform focused on swap trading, for instance, Uniswap (Uniswap, 2023). Uniswap is a decentralized cryptocurrency exchange protocol that operates on the Ethereum blockchain. It enables users to swap various Ethereum-based tokens directly from their wallets without the need for a traditional order book or centralized intermediary (Sadykhov et al., 2023).

The relations shown in Figure 1 are detailed here. *Investor* pays performance and administration fees to *Distributor*, whereas he keeps earning profit of his investments. *Manager* receives fees due to the management of the fund. *Manager* in fact works through the *Whale Finance* to create the fund and operate it using swaps (i.e., the exchange of tokens). Swaps are now on-chain transactions using the available *Exchange*. As we can note, the *Custodian* is removed. Below, we detail how the incorporation of ERC-6551 allows it. We explain the fund creation, the investment flow, and the swap flow, which are implemented through three main Solidity smart contracts, namely: *WhaleFinance.sol*, *SafeAccount.sol*, and *QuotaToken.sol*.

3.3 Removing the Custodian

The *WhaleFinance.sol* contract is the core contract that allows the operationalization of decentralized asset management. This contract inherits from the ERC721 standard (the implementation of an NFT collection) implemented by Open Zeppelin (OpenZeppelin, 2023). So, the fund is represented by an NFT. Figure 2 shows the flow of fund creation. The *WhaleFinance.sol* creates (or mints) a fund with the following parameters:

- *Name:* The official title of the fund, used for recognition and branding.
- *Symbol:* A unique series of letters representing the fund in the stock market, used for quick identification.
- *Manager Address:* The designated account for managing the fund's financial transactions and maintaining records. It is indeed the manager's account, being represented in Figure 2 by the relation between NFT and *Manager*.
- *Tokens:* Digital assets within the fund that can represent shares or other assets, facilitating flexible transactions. One example is the token zUSD, a stablecoin of USD coin.
- *Administration Fee:* A charge levied to cover the fund's operational costs, maintaining its viability.
- *Performance Fee:* A fee charged based on the fund's performance, serving as an incentive to managers.
- *Open Investment Date:* The earliest time at which investments can be made into the fund, helping to manage the inflow of capital.
- *Close Investment Date:* The latest time at which the fund stops accepting new investments, assisting in portfolio stability.
- *Maturation Date:* The projected time for the fund to reach its investment goals, guiding investors on expected returns.

Our solution makes use of ERC-6551 (the standard for Token Bound Accounts, TBAs) to avoid dependence on a *Custodian* by establishing the logic that allows an NFT to own a smart contract account (known as TBA). Through this strategy, the fund can validate ownership by a designated manager (given an NFT) and execute transactions involving its assets registered in an account (given a TBA). The ERC-6551 standard defines two interfaces: *IERC6551Registry.sol* and

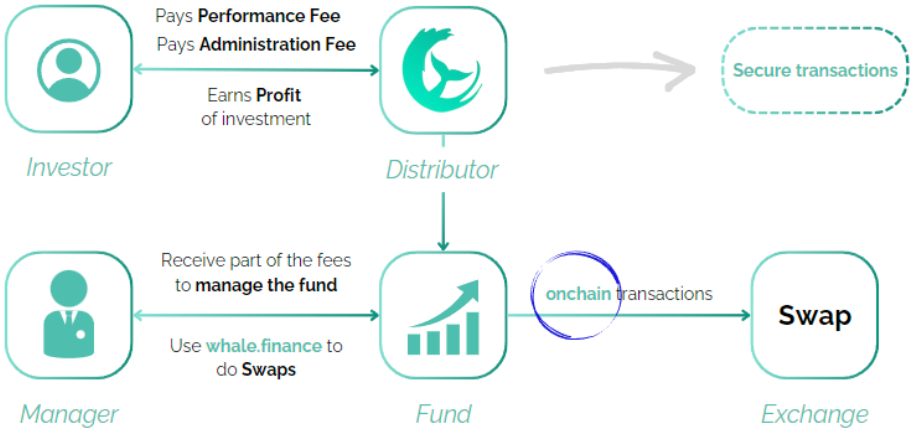

Figure 1: A Decentralized Asset Management Model supported by Blockchain.

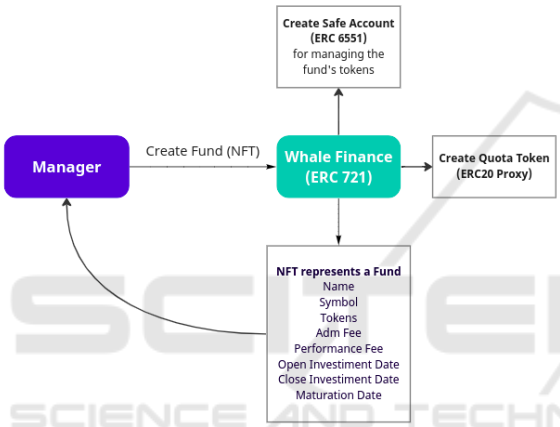

Figure 2: Fund creation flow.

IERC6551Account.sol. The registry is the contract used to create accounts. According to Figure 2, an account is linked to the fund address (here represented by the NFT created through *WhaleFinance.sol*) and to the account implementation (here represented by *SafeAccount.sol*). The *SafeAccount.sol* contract, in fact, inherits from the *IERC6551Account.sol* and implements additional features related to swap. The fund creation flow, in Figure 2, is also responsible for defining a token (using the standard ERC-20) used to create fund quotas, allowing later investors to acquire, hold, and trade fund quotas in a standardized and interoperable format.

The investment flow is represented in Figure 3. For the purpose of standardization, a trusted stablecoin can be chosen for investments. Here, wUSD is used to illustrate the scenario. The investor sends the assets to the fund through the *Whale Finance*. The assets that the fund owns are then deposited in the related *Safe Account*, and the manager is able to control them in a safe and limited way. After investing, the *Investor* receives tokens (known as *Quota Token*) of the fund. Here, for example, we define the quantity of *Quota Tokens* as the total invested minus the administration fee.

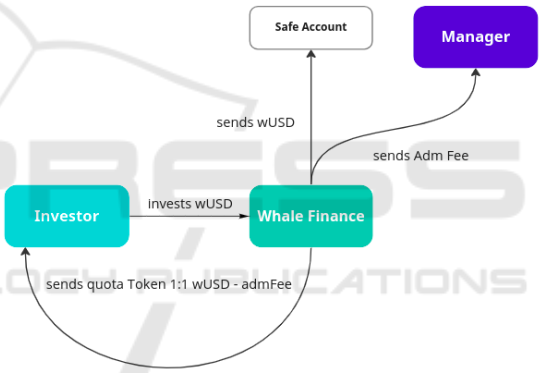

Figure 3: Investment flow.

Sending the assets to the *Safe Account*, the manager (who holds the fund) is able to make investments, in particular through a decentralized exchange. This investment is performed using a swap, where the manager swaps the stablecoin sent by the investor for other assets, such as *WETH, WBTC, LINK* or any fungible asset with a liquidity pool. In our proposal, the *SafeAccount.sol* implements the logic of swapping using the interface *IV2SwapRouter.sol* to interact with the decentralized exchange (DEX) Uniswap. The flow is shown in Figure 4. To implement that, we have forked Uniswap and deployed our version in an Ethereum testnet so that we can use it for testing.

3.4 Empowering Investors

When minting a fund, as indicated in Figure 2, another contract is created: the *QuotaToken.sol*. This

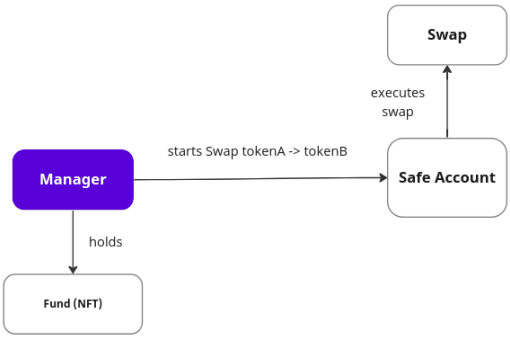

Figure 4: Indirect swap flow.

contract inherits from the ERC-20, the standard for fungible tokens deployment. The idea is that the investors will own these tokens both for redeeming possible yields after the fund is mature and voting on possible proposals for changes in the fund. The opportunity of voting is the foundation to implement a DAO (Decentralized Autonomous Organization), where decisions are made collectively by members based on the voting mechanisms without the interference of the central authority (in this case, the fund manager).

According to Figure 3, investors receive *Quota Tokens* upon making an investment. Consequently, individuals with higher investment amounts will possess more tokens, granting them increased influence in making future decisions related to the fund. This approach empowers investors by transforming them from passive observers of the manager's decisions to active contributors, enabling them to play a role in enhancing the overall fund performance.

Specifically regarding the contract development, *QuotaToken.sol* is implemented as ERC-20 token and *BeaconProxy*, following Open Zeppelin standards. Each fund has its own *Quota Token* that is initialized when the fund is created. The *QuotaToken.sol* is deployed to an address and each new quota uses this implementation to be created. The Beacon delegates the calls to the unique *QuotaToken.sol* implementation, so we can upgrade the implementation without the need to update every fund contract.

Voting is particularly important in case of investors desires to change the moment of closing investments (parameter *Close Investment Date* of the fund) to allow or prevent new contributions. Besides, investors may want to change the moment of investment redemption (parameter *Open Reedem Date* of the fund), for instance, if a manager is performing poorly in the fund, and investors want to redeem their investments earlier to avoid further losses, prompting the need to initiate a vote. Moreover, investors can vote to propose specific investment transactions (the swaps).

Given the voting about *Open Reedem Date* in *WhaleFinance.sol*, there are functions to consider aspects as the creation of the change proposal, the voting process, the change implementation, and the usage of *Quota Tokens* in voting. In the beginning, an investor creates a new proposal to change the redemption timestamp of a specific fund. The proposal becomes open to voting during a specified voting period. Investors can vote on the proposal considering their *Quota Tokens*. It is possible to check the quantity of votes received by a specific proposal, offering an overview of the total accumulated support for changing the fund's redemption timestamp. If the proposal is approved with a sufficient percentage of votes, the fund's redemption timestamp is updated. After the proposal is approved or after the voting deadline expires, investors can withdraw their *Quota Tokens* that were linked to that proposal.

4 A PROOF OF CONCEPT

A proof of concept was developed to validate our proposal, focused on following the best practices for the smart contracts application, according to the directives found in (Mustafa et al., 2023). To integrate smart contracts, an app was developed using Typescript.js (a language focused on project scalability), Tailwind.CSS (a framework to facilitate page design), and Vite.js (a build tool to better initialize the project on the web). From this stack, a way was conceived for users (including investors and managers) to have a good user experience.

A manager has the ability to create a fund, monitor its performance, and execute token swaps to manage the fund (as illustrated in Figure 5). Investors can access statistics (such as performance charts) of the available funds (refer to Figure 6), enabling them to choose funds to invest. In terms of the voting process, investors can initiate new proposals to modify the open redemption date and participate in voting for existing proposals.

Aiming to test the smart contract transactions, the creation of our proof of concept with Forge (ForgeStandardLibrary, 2023) allows the use of native solidity tests. The tests cover different functionalities of the *WhaleFinance.sol* smart contract, including fund creation, investment, proposal rejection, and proposal acceptance, as follows:

- *testCreateFund():* It tests the creation of a new fund, checking if the returned values are correct and if the fund owner matches the expected address.

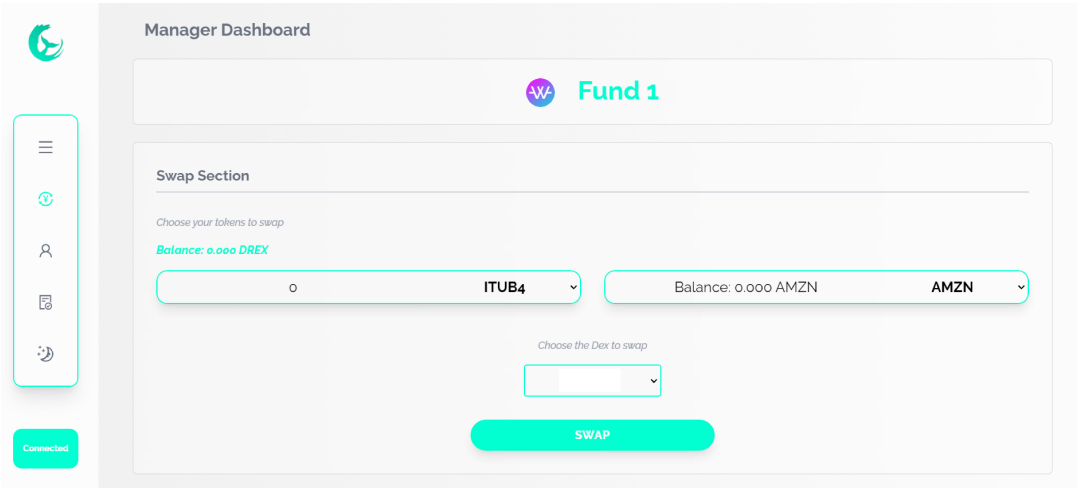

Figure 5: Manager dashboard.

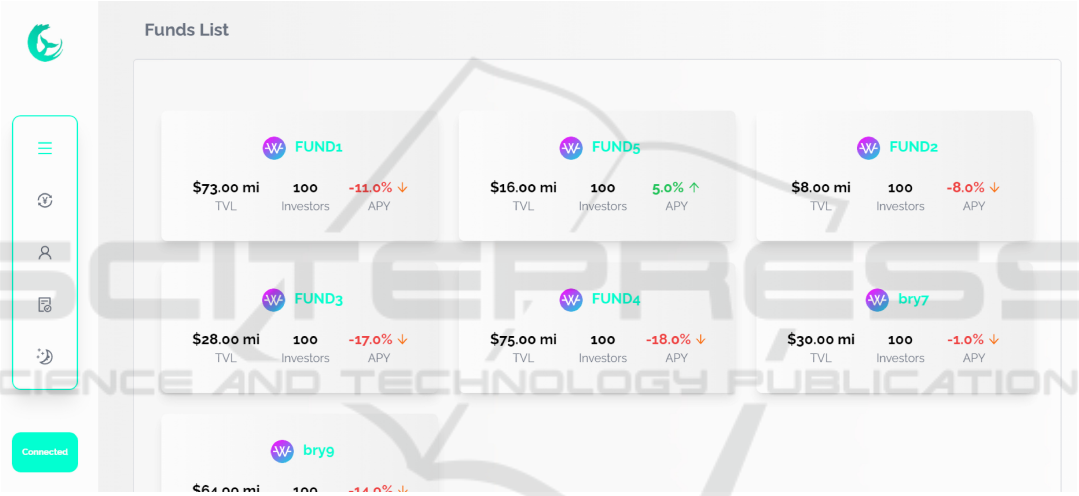

Figure 6: List of funds to invest.

- *testInvestiment():* It tests the investment process in a fund. It verifies whether an investor can invest a specific amount in a newly created fund. After the investment, it checks if the investor's quota token balance has been updated correctly.
- *testOpenRedeemProposalRejected():* It simulates a proposal for changing the open redeem timestamp being rejected. It tests whether the functionality of voting and rejecting a proposal for a timestamp change works properly.
- *testOpenRedeemProposalAccepted():* It simulates a proposal for changing the open redeem timestamp being accepted. It tests whether the functionality of voting and accepting a proposal for a timestamp change works properly.

All tests passed, as shown in Figure 7, confirming that the features behave as intended. These are

```
Running 4 tests for test/WhaleFinance.t.sol:WhaleFinanceTest
        testCreateFund() (gas: 675381)
        testInvestiment() (gas: 838071)
        testOpenRedeemProposalAccepted() (gas: 1126758)
        testOpenRedeemProposalRejected() (gas: 1074375)
Test result:    . 4 passed; 0 failed; finished in 5.52ms
```

Figure 7: Test results using Forge.

initial unit tests focused on validating isolated functionalities. However, more test scenarios must be defined and executed, including clear specifications of expected inputs and outputs. In addition, larger-scale evaluations that involve multiple users are necessary to assess the system's feasibility and performance.

Our proposal, named *Whale Finance*, has immense potential for expansion and integration. By incorporating advanced features, comprehensive analytics, and robust security protocols, the platform's capabilities can be significantly extended, enhancing both its functionality and overall appeal. The inte-

gration with well-established financial applications, cryptocurrency exchanges, and wallet services would not only extend the model's reach but also promote a more seamless and user-friendly experience. Furthermore, forming strategic partnerships with leading financial institutions and fintech firms can provide *Whale Finance* with broader market access, invaluable expertise, and enhanced credibility.

5 CONCLUSIONS

Our proposed blockchain-based model, the *Whale Finance*, aims to advance the asset management industry through the implementation of a decentralized paradigm using the ERC-6551 protocol. The main advantage is the ability to offer a more autonomous and cost-effective solution for asset management. By not relying on intermediaries, *Whale Finance* reduces operational costs and offers greater control to both investors and managers.

This approach stands out for its innovative use of blockchain technology, particularly in hedge funds, ensuring the efficiency, transparency, and security of financial transactions. The incorporation of smart contracts and the utilization of the Ethereum Virtual Machine (EVM) further streamline processes, ensuring compliance with regulatory standards while maintaining flexibility and ease of transactions.

By developing a proof of concept, we overcame numerous challenges, including technical complexities associated with blockchain implementation and integration with existing financial systems. However, we recognize that the real-world adoption of the proposed model may also face significant challenges, particularly regarding the widespread understanding and acceptance of blockchain technology within the traditional finance sector.

To demonstrate the proposal's efficacy in real-world scenarios, a thorough and systematic validation process is paramount. This process begins with rigorous market testing, accompanied by the collection of user feedback. The analysis of performance metrics, including user engagement, transaction volume, and security effectiveness, is essential over the testing period. These indicators will shed light on how well our proposal resonates with the market and its operational efficiency. Additionally, a comparative analysis with existing asset management solutions can illuminate our competitive edges.

For future work, the focus will be on enhancing the scalability of the system, increasing user adoption by simplifying the interface and user experience, and continuously updating the proposal to align with evolving blockchain technologies and financial regulations. Additionally, further research and development will be geared towards expanding the platform's capabilities to encompass a broader range of assets and services, thus broadening its applicability and impact in the global financial landscape.

REFERENCES

Davies, J. (2023). Enhanced scalability and privacy for blockchain data using merklized transactions in blockchain technologies. *Frontiers in Blockchain*.

ForgeStandardLibrary (2023). https://book.getfoundry.sh/reference/forge-std/.

Ma, W. and Huang, K. (2023). *Blockchain and Web3: Building the Cryptocurrency, Privacy, and Security Foundations of the Metaverse*. Wiley.

Madeira, G., Novaes, F., Cerqueira, A., Steler, F., and Carvalho, L. (2023). Cbdcs, open finance, and tokenization as tools to improve financial intermediation: Application to a smes' credit platform.

Mustafa, I., McGibney, A., and Rea, S. (2023). Smart contract life-cycle management: An engineering framework for the generation of robust & verifiable smart contracts (grv-sc) in financial blockchain. *Frontiers in Blockchain*.

OpenZeppelin (2023). https://github.com/OpenZeppelin.

Pablo, R., Pouwelse, J., and Vos, M. D. (2021). Unicon: Universal and scalable infrastructure for digital asset management.

Sadykhov, R., Goodell, G., Montigny, D. D., Schoernig, M., and Treleaven, P. (2023). Decentralized token economy theory (detect): Token pricing, stability and governance for token economies. *Frontiers in Blockchain*.

Sarathy, R. (2023). *Enterprise Strategy for Blockchain: Lessons in Disruption from Fintech, Supply Chains, and Consumer Industries*. The MIT Press.

Thornton, G. (2022). 2023 outlook for blockchain and digital assets in business. Grant Thornton.

Uniswap (2023). https://uniswap.org/.

Vyas, N., Beije, A., and Krishnamachari, B. (2023a). *Blockchain and the Supply Chain: Concepts, Strategies and Practical Applications*. Kogan Page.

Vyas, S., Shukla, V. K., Gupta, S., and Prasad, A. (2023b). *Blockchain Technology: Exploring Opportunities, Challenges, and Applications*. CRC Press.

Wyman, O., Group, A., and Innoventures, S. (2015). The fintech 2.0 paper: rebooting financial services.

Yaga, D., Mell, P., Roby, N., and Scarfone, K. (2018). Blockchain technology overview NISTIR 8202. https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf Accessed on 2024-01-02.