Blockchain Estate Registry in Ukraine

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Abstract. This paper outlines the early development of a Blockchain Estate Registry (BER) in Ukraine, designed as an innovative alternative to the existing land and immovable rights registries. Backed by the NGO Virtual Assets of Ukraine and parliament members of the Verkhovna Rada, the project centers on crafting a demo blockchain application tailored to meet the legal and regulatory demands of state-level titling and registry functions. The prototype, detailed in this paper, incorporates Polygon smart contracts and Internet Computer's decentralised storage, illustrating the practical application of blockchain in public services. Notably, the BER dismissed the concept of a permissioned blockchain, opting instead for a permissioned application on a public blockchain. In its future iterations, the BER aims to span across multiple blockchains using a cross-blockchain protocol for public registries, a concept introduced in academic papers by O. Konashevych. This model enables the state registry to retain control over legal title tokens, providing a mechanism to address various legal issues, such as disputes or erroneous transactions, while automating the registration process. This automation significantly diminishes the registrar's role to specific legal scenarios, where they intervene as a third party. Additionally, the shift from traditional notary-certified title deeds to automated, standardized smart contracts marks a move towards a completely paperless system. The paper concludes with a projection that the BER could enable up to 90% of real estate transactions to be conducted directly, bypassing traditional intermediaries like registrars and notaries, thus heralding a new era of efficiency and transparency in property transactions in Ukraine.

Keywords: Blockchain land registry, Permissioned smart contracts, Cross-blockchain protocol for public registries.

1 Introduction

The integration of blockchain technology into real estate transactions has seen increasing interest, as evidenced by various efforts in countries such as the Republic of Georgia, Sweden, the United Kingdom, and Afghanistan (pre-Taliban period). The efficacy and impact of these projects, however, have been under scrutiny due to their approach to blockchain implementation. In his PhD thesis, "Tokenization of Real Estate on Blockchain," O. Konashevych (2020) envisioned a novel land registry system

leveraging blockchain. This paper delineates the preliminary stages of actualizing this concept. It showcases a demo application, a collaborative effort by the NGO Virtual Assets of Ukraine and supported by members of the Verkhovna Rada of Ukraine (the supreme legislative body). Although not embodying the Blockchain Estate Registry (BER) in its original design, the app enables owners to maintain records of ownership as title tokens and conduct transactions with these tokens. The core smart contract of the BER executes several registry functions. This application aims to exhibit the benefits of real estate tokenisation to a broad audience, demonstrating how altering registry and titling processes can simplify and reduce bureaucracy in real estate transactions. This simplification could pave the way for the integration of blockchain innovations such as smart contracts, decentralised applications, decentralised autonomous organisations, and decentralised finance, which have historically struggled to infiltrate the real estate sector due to outdated regulations and underlying technologies. A significant impetus for this shift is the cybersecurity vulnerabilities of Ukraine's existing registry system. Transitioning to a blockchain-based system is vital not only to address the challenges of the ongoing war but also to embrace these innovations, which are not feasible with centralized technologies. The paper discusses a high-level concept and reviews academic literature on similar projects in other countries. It then outlines Ukraine's current registry system, presents the functionality and architecture of the developed BER app, the applied blockchain technologies, and the proposed smart contract design, concluding with an outline of future plans and conclusions.

2 Background and high-level concept

2.1 Projects in the world

Several attempts to harness blockchain technologies are worth mentioning mostly because of a lot of hype and misinformation found in the media about them.

Testbed Chromaway in Sweden
. The Chromaway testbed, in collaboration with the Swedish Land Registry, is often cited for using blockchain in land registry systems. However, according to their report [1]. this project is not ongoing, debunking the misconception that the "Swedish land registry uses blockchain." The project team developed a prototype application and showcased it in 2019. The project aimed to demonstrate an online application for stakeholders in real estate transactions with mortgages, including sellers, buyers, their agents, and banks. Its purpose was to facilitate data collection and interaction during various stages of a real estate transaction and mortgage, like offer postings and credit approvals, with all data visible in real-time to participants. However, the application itself added another layer of intermediation. Chormia ledger was used to post hashes of the user data in the app. Technologically, the Chromia platform was not a blockchain (as per rigorous academic criteria), but a permissioned (centralized) distributed ledger. Moreover, the state land registry never implemented blockchain, the role of the registry system was to provide information about land titles through their API. A positive aspect

was the introduction of digital signatures and electronic contracts, aligning with Europe's existing qualified digital signatures (QES) framework under the eIDAS regulation[1], where blockchain had no additional role.

Bitfury in Georgia Land Registry

. Bitfury's project in the Republic of Georgia represents a significant instance of blockchain technology application within a state land registry. Documented in various sources [2], [3], [4] and detailed on Bitfury's website[2], the project anchors (hashes) state registry records in a permissioned distributed ledger using the Exonum Distributed Ledger Technology (DLT) framework, with periodic anchoring (hashing) of snapshots of that ledger in the Bitcoin network. Although promoted as a protective measure for the state registry, this approach has been subject to academic and expert criticism [32]. The primary concern is that the hash sums in the ledger do not safeguard the actual data in the registry. The primary utility of hashing is to enable verification of record authenticity (the same comment applies to the Swedish project as well). They are incapable of preventing or rectifying damage from potential attacks, thus challenging the purported notion of registry data protection. Moreover, the project's dependence on a single or a few nodes of private permissioned ledger offers less robust protection than a public blockchain network, which benefits from a vast, independent network of nodes. This setup raises concerns about the centralization of hash sums, rendering them susceptible to alterations by system administrators or unauthorized access. Despite these criticisms, it remains the only blockchain project with a land registry that continues to operate.

Other projects

. The Digital Street project in the United Kingdom hosted a prototype application developed by Consensys. However, details are scarce as only limited information is available online [5–7]. Last updated in 2018, the project explored using tokens to represent property titles, with these tokens serving as duplicates of the rights records in the actual registry, termed as "twins." The project aimed to integrate these tokens into a distributed ledger for transaction purposes, but the legal implications and specific functions of these token records remain unclear due to the lack of available documentation.

Under the auspices of two UN organisations – the UN Human Settlements Programme and the Office of Information and Communication Technologies – an initiative was undertaken in Afghanistan to address the challenges of missing legal documents and disorganized registry records. However, the Taliban's ascension to power significantly impeded the ability to monitor the project's outcomes and progress. The initial stages of the initiative are detailed in academic literature [8], which outlines the project design: the use of a 'private chain' application within the LTO Network technology framework (where private chains are hashed on the LTO Network), deployed by land administration to record land tenure occupancy certificates. The project’s selection of blockchain technology sparked debate and scrutiny as no technical audit has been provided.

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1 https://www.eid.as/#article3

2 https://exonum.com/doc/version/latest/

2.2 Academic literature and Theoretical background

The project in Ukraine derives its concept from the PhD thesis (by publications), "Tokenization of Real Estate on Blockchain" by O. Konashevych (2020), specifically referencing two papers within this thesis [9, 10]. Unlike other research in the broader field of blockchain application in land registries, this is the sole theory positing the necessity of replacing an outdated, centralized registry with blockchain technology to reap genuine benefits. The majority of academic literature has focused primarily on integrating blockchain or DLT into existing centralized land registries.

The thesis paper [9] introduces a novel class of digital assets – 'title tokens' – which signify ownership and form the cornerstone of the Blockchain Estate Registry. Contrary to typical applications in various commercial attempts to tokenize real estate globally, where a token is a security asset (a legal interest in someone's property or their legal promise of something), here it represents an actual record of ownership of the token hodler. Consequently, a transaction involving such a title token equates to the conveyance of that title right, eliminating the need for any supplementary external register. The blockchain itself serves as the registry.

It is clarified that the term "estate" in the name is employed to highlight the method's applicability beyond immovable assets, extending to vehicles, vessels, aircraft, corporate rights, and intellectual property (such as patents and trade names). These rights, alongside real estate, are maintained in their respective state registries, which historically have been the sole reliable method of safeguarding legal rights and establishing a single source of truth regarding ownership. Blockchain usage potentially enhances the registry system and titling services, rather than eliminating governmental authorities as intermediaries, a common misconception among blockchain proponents.

The primary function of a land authority – maintaining the register infrastructure – becomes redundant with the advent of a public blockchain, which operates independently without an administrator. This self-organized and self-governed infrastructure contrasts starkly with traditional register technologies, where land title offices would be responsible for managing physical documents in secure archives or electronic databases.

The government's another role, however, remains crucial albeit significantly diminished. An authority is necessary to adjudicate legal issues, such as litigation, inheritance transfer, restitution, quiet title actions, and correcting registry errors. These responsibilities extend beyond the direct purview of land offices, encompassing a wider range of public bodies, including the judicial system. Nevertheless, the registry remains the final authority to enact changes in legal rights, a process that may vary across jurisdictions.

The paper [9] illustrates how the Blockchain Estate Registry (BER) aligns with both prevalent land systems: the European cadastral and Australian Torrens systems, which operate on a 'title by registration' basis, and the older English system (common in the U.S.), where land offices register title deeds. The BER, centered around title tokens, fits with the 'title by registration' system, while its unbreakable chain of blockchain transactions aligns with the American legal principle requiring an unbroken chain in the register to ensure a marketable record title.

With the registration function retained, the role of land authorities can still be substantially streamlined through automation. Currently, real estate deeds must be presented to land offices for registrars to make entries, whether to register the title deed or the title itself, depending on the system. The implementation of standard smart contracts, digital identities, and cross-checks through government databases – for civil capacity, marital status, etc. – would facilitate seamless peer-to-peer title transactions between individuals, obviating the need for a registrar in most cases. Registrars would only be essential in specific scenarios where title transfer occurs involuntarily, such as through litigation outcomes, crime restitution, nationalization, or in cases like inheritance or loss of private keys, and potential system issues (bugs, etc.).

2.3 Permissioned Ledger or Permissioned dApp?

The prevalent use of permissioned Distributed Ledger Technology (DLT) is often justified as the sole viable approach for public registry systems, owing to the necessity for land authorities to maintain control over the registry to exercise their powers in specific scenarios. However, this perspective overlooks two critical points. Firstly, permissionless blockchains are indeed viable for public registries. Secondly, the suitability of DLT as a solution itself is debatable.

The initiative in Ukraine rests on the following premises: A permissioned ledger, ostensibly a centralized system, remains centralized regardless of its designation. The attributes commonly associated with blockchain, such as data protection and immutability, are erroneously ascribed to permissioned DLTs. It is a misconception that every chain of blocks constitutes a blockchain[3] [11, 12]. A blockchain achieves immutability and resilience against significant infrastructural attacks — thereby safeguarding data — as the network scales. The Bitcoin network, with typically five to seven thousand nodes online, exemplifies the most secure digital storage system, boasting an unparalleled 100% uptime over 15 years. This robustness is attributable to its decentralised consensus mechanism, which is essentially a competitive mining of cryptocurrency by nodes. While Bitcoin enables the issuance of digital tokens[4], second-generation public systems like Ethereum offer enhanced functionality for programming digital assets using smart contracts, with a data protection level reasonably comparable to Bitcoin. In contrast, permissioned ledgers generally employ Byzantine Fault-Tolerant (BFT) consensus algorithms, where a two-thirds node majority can effectuate profound chain alterations without the significant computational resources required by Proof-of-Work consensus to modify older blocks.

Therefore, such DLTs lack the openness for universal participation, becoming vulnerable to a deluge of malicious nodes aiming to compromise data integrity. The

[3] We refer here to a method of creating timestamped data chains with hashes proposed by Haber and Stornetta in 'How to time-stamp a digital document' (1991) in the Journal of Cryptology, which is sometimes falsely called 'blockchain.' This method was not originally termed 'blockchain.' The term 'blockchain' appears with the invention of Bitcoin, which is more than just a method of building chains of blocks.

[4] For example, using Omni Layer Protocol, https://www.omnilayer.org/

practicality of a permissioned ledger lies in its inherent nature — to be permissioned, effectively forming a closed cartel where an administrator governs member admission and can halt service or alter the ledger.

The argument that based on various contingencies (e.g., loss of private keys, disputes, token theft, transaction errors) land authorities require the capability to modify the ledger is flawed. Contrary to this assertion, standard legal practice does not involve the deletion or alteration of records. The registrar chronologically logs all pertinent legal facts and titles; the most recent record indicates the current status. Alterations in relationships are not retroactively adjusted but are documented through supplementary agreements, akin to creating a new chronological entry in the database. Given that blockchain is a database ensuring immutable chronological data order, it emerges as not only a superior candidate for data protection but also as the ultimate technology for public registries. Its design inherently prevents backdating by any party, including potentially corrupt registrars.

Consequently, rather than adopting a permissioned ledger, the decision was made to utilize 'permissioned' smart contracts on a public, immutable ledger. 'Permissioned' here implies that the registrar retains the authority to allocate, halt, or burn and reissue tokens. This approach aligns with the ERC standards for security tokens [insert references]. It represents the only feasible method for legal smart contracts, as humanity has yet to discover a superior solution to legal complexities beyond involving an authoritative third party. This echoes the structure of public systems such as government, land agencies, and the justice system.

Thus, we arrive at a system where, unlike the permissioned ledger model, infrastructure and public functions are not conflated. Instead, we have a layered approach: the blockchain network layer provides the infrastructure, ensuring data immutability and hosting smart contract applications, devoid of governmental functions or legal powers. The second layer, consisting of BER (Blockchain-Enabled Registry) smart contracts, is where the government exercises its authority through appropriately designed smart contract functions.

The BER demo application has integrated several key functions from the numerous proposals discussed in the technical segment of this paper.

2.4 The Future Plan for a Multi-Chain System

It is widely acknowledged that blockchains are limited in their throughput capacity. The prevailing discourse often fixates on this limitation, overlooking a seemingly apparent solution: the employment of multiple blockchains in unison. The rationale behind utilizing a multi-chain system extends beyond simply augmenting the bandwidth of the Blockchain Ecosystem for Recordkeeping (BER). It encompasses a strategic move to foster competitive dynamics in blockchain technology, allowing end-users to select the blockchain that best meets their needs.

The thesis outlined in paper [10] delves into various facets of operating a BER service across numerous blockchains, facilitated by the proposed cross-blockchain protocol. The selection of blockchains within such a consortium must be judicious, limited to those chains deemed reliable at any given time. This restriction stems from the

understanding that immutability and security in blockchain technology are not inherent, but rather the byproducts of network growth and technological maturation. Consequently, only proven and time-tested technologies should be employed.
The cross-chain protocol fulfils a critical role in managing the registry, allowing for the inclusion and exclusion of ledgers, and facilitating the reallocation and migration of records. This includes provisions for scenarios where a blockchain is compromised. Moreover, the protocol addresses potential hardfork scenarios, enabling an explicit ledger selection to prevent asset duplication. It even accommodates the inclusion of a hardforked ledger while safeguarding against double spending. The protocol's capabilities extend to updating the system and, if necessary, halting it in a doomsday scenario, thereby ensuring comprehensive control over the registry without risking data loss or retrospective alterations.
Paper [10] further proposes conceptualizing this protocol as a 'jurisdictional filter'. Operating above the layer of blockchains, the protocol serves as a conduit through which authorities can execute transactions that alter legal rights. While such changes are immutable, the blockchain itself does not preclude the misuse of power or corruption. However, it ensures that such acts cannot remain concealed. In an extreme scenario of a 'digital dictatorship', a corrupt system can be dismantled by a new authority. All data, whether valid or otherwise, remains stored on the blockchain, subject to interpretation. The forthcoming implementation of a new BER will involve filtering out invalid data, though it will continue to be preserved on the blockchain due to its immutable nature. This approach forms a crucial part of the planned BER development for Ukraine.

2.5 Land Registry System in Ukraine

Ukraine possesses a cadastral system typical of Europe; however, its distinct characteristic lies in the separation of land rights and other immovable property rights into two different, albeit interconnected, registries. For instance, a land plot is recorded in the State Land Cadastre of Ukraine, whereas a building on this land is noted in the State Register of Real Property Rights, referencing the corresponding land cadastre number from the land registry. To attain legal validity, all land and real property transactions must undergo registration and notarial certification. This requirement extends to caveats, encumbrances, and third-party rights and interests, such as mortgages. Despite Ukraine adopting qualified electronic signature (QES) system akin to the European eIDAS, its application in real estate transactions is hindered by outdated registry and notary regulations.

2.6 Project Organization

In Ukraine, the Blockchain Electronic Registry (BER) project is spearheaded by the Civil Union "Virtual Assets of Ukraine" – a non-governmental, non-profit organization – in collaboration with the parliamentary group Blockchain4Ukraine of the Verkhovna Rada of Ukraine. Both entities have concurred on a roadmap commencing with the development of a demo application. Subsequent phases, as outlined in a memorandum, include the enactment of relevant legislation, followed by an open tender for a private

concession to operate the BER, and the development and commercial operation of BER. Notably, it is envisaged that BER will function concurrently as an alternative system, preserving user choice. Those opting for the new system can transfer their title records onto the blockchain (and vice versa). A cross-blockchain protocol, integrated with the two existing registers, will safeguard against double spending and ensure full consistency. Legally pertinent data (rights and encumbrances) and critical technical information (such as geographical coordinates of land plots) will be transferred on-chain, while other data will be hashed on-chain and stored off-chain. BER is slated to operate as a commercial service under governmental regulation and supervision.

3 Application design

The Blockchain Estate Registry (BER) is a demonstration application designed to showcase the potential of a blockchain-based real estate registry system. This demo app, although not fully functional land register, is critical in illustrating to Ukrainian policymakers and a broader audience how authorities can exercise control in the proposed design of the BER smart contract application. A key feature of BER is the state administrator's ability to allocate tokens, thereby executing court decisions in title disputes, inheritance transfer, fix mistakes and address other discussed issues.

This BER implementation leverages the use of two standard smart contracts, notably the register smart contract that allows creation of a title token (assets.sol) and a selling smart contract, referred to as a Peer-to-Peer selling platform (2PPlatform.sol). This framework allows sellers to list and transfer property titles and receive payments in Ether through an atomic transaction. This process signifies a substantial advancement in real estate transactions by making it paperless, eliminating the need for notaries due to the adoption of standard smart contracts and the application of Qualified Electronic Signatures (QES) for party identification.

Moreover, it removes the necessity for a traditional registrar, as the transfer recorded on the blockchain automatically updates the registry. Furthermore, the system facilitates remote, peer-to-peer electronic transactions between individuals, such as Alice and Bob, bypassing the need for commercial third-party intermediaries. System architecture is illustrated in Fig.1.

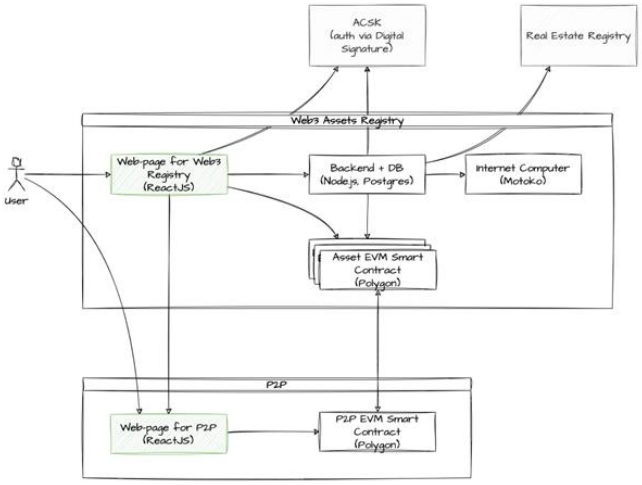

Fig. 1. Application architecture diagram

3.1 Technical Overview

Front-End[5] developed using React.js, integrated with Alchemy Web3, MetaMask, and IIT digital signature library.
Backend[6] constructed with Node.js. It employs Web3, HttpAgent, Dfinity/Identity, and IIT digital signature libraries.
Blockchain Technologies include Internet Computer's Motoko[7] to store data on-chain and make transparent while functionality is embodied in EVM compatible smart contracts[8] on the Polygon network with Solidity.
External Integration involves two systems. It is integrated with Certified Key Accreditation Centre for authorization using QES and Interacts with the State Register of Property Rights for real estate data.
This government registry agency was not involved in the project; however, the app utilizes their sandbox environment, which lacks some functionality necessary to record the transfer of the title token from the old registry system to BER. This functionality is planned to be developed once the project receives government approval and the regulatory framework is established.

3.2 Tokenization and Sale Process

User Registration: Users register on the Web3 registry platform with a QES. The system verifies their identity and creates an account on the Internet Computer.

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5 https://github.com/vybgss/assets-tokenization-frontend
6 https://github.com/vybgss/assets-tokenization-backend
7 https://github.com/vybgss/assets-tokenization-ic-contracts
8 https://github.com/vybgss/assets-tokenization-evm-contracts

Property Listing: Users view their property list fetched from the state registry. To obtain this data, the system queries the registry based on Person ID, which is recorded in the electronic signature, mentioned above. Now they can then select their property for tokenization.
Tokenisation: The user selects a property for tokenisation. A token smart contract is then created on the Polygon blockchain, and information about the newly created token is recorded on the Internet Computer blockchain. Subsequently, the seller chooses a decentralised platform they prefer to facilitate the sale. They sign the transaction on Polygon and switch to the chosen platform.
To illustrate the buying-selling process, we have developed a Peer-to-Peer (P2P) platform example. It is assumed that underlying smart contract of this platform must comply with official standards, earlier discussed as an approach to avoid notary participation.
On this platform, a user lists a tokenized property for sale and signs the transaction on Polygon. When another user is interested in buying this property, they first register on the Web3 registry platform. They then navigate to the P2P platform and can view the seller's listing for the property, including its description and price.
To finalize the purchase of the tokenized property, the buyer signs the corresponding transaction on Polygon. Simultaneously, the P2P platform's ability to manage the tokenized property is automatically revoked, transferring ownership rights to the buyer.

3.3 Smart Contract Analysis

Smart contract name: Assets.sol

Overview:

- Purpose: Tokenization of real estate assets.
- Platform: EVM-compatible blockchains.
- Version: Solidity ^0.8.14.

Key Components

- Structures
  - `Token`: Represents a real estate asset with properties like `owner`, `governmentRegistryId`, `name`, and `description`.
    - At this stage co-ownership can be realized through address abstraction (external smart contract) but without specifying shares.
- State Variables
  - • `_admin`: Deploying Address.
  - • `_state_admin`: Address that can change token ownership.
  - • `_withdrawAddress`: Address for erroneous payments on the contract.
  - `_tokens`: Mapping from token ID to `Token` struct, representing the assets.

        - At this stage the token is not divisible (no fractional ownership).
    - `_p2p_platforms, _selected_p2p_platform`: Related to P2P platform integration (user can transfer the token to an authorized P2P platform.
    - `_nextTokenId`: Counter for token IDs, indicating the contract is designed for a single asset. In the future, it is possible to implement a contract for a group of objects.
- Modifiers
    - `onlyAdmin, onlyP2P_selected, onlyStateAdmin_selected, onlyOwner`: Control function access based on roles.
- Constructor
    - Initializes the contract with asset details, tokenization, and P2P platform details.
- Main Functions
    - `withdraw`: Allows the admin to withdraw funds sent to the contract.
    - `AddP2pPplatform, AllowP2Pplatform, DenyP2Pplatform`: Manage P2P platforms for asset transfers.
    - `TransferTokenByP2pPlatform, AdministrativeTransfer`: Transfer asset ownership under certain conditions.

Analysis and Observations

- Single Asset Focus: The contract seems tailored for a single real estate asset.
- Role-Based Access Control: Various roles (admin, state admin) are defined for different actions, providing a layer of security and control.
- P2P Platform Integration: The contract integrates with P2P platforms for asset transfers.
- Withdraw Function: Allows the admin to withdraw ETH sent to the contract, a common safeguard against accidental fund transfers to the contract.
- Administrative Controls: AdministrativeTransfer allows a state admin to transfer ownership, implying a level of external control or compliance mechanism.

Potential Concerns and Recommendations

. • Security and Best Practices: Ensure comprehensive testing, including edge cases and potential security vulnerabilities (e.g., reentrancy, overflow/underflow).

• State Admin Role: The `AdministrativeTransfer` function implies significant power for the state admin. It is planned to introduce a more granular roles and collective decision making for specific situations.

• Upgradeability and Maintenance: upgradeability patterns will be introduced in subsequent versions.

Smart contract name: P2PPlatform.sol

Overview

- Purpose: P2PPlatform.sol manages the property sale process and records and tracks offers and transactions for property sales. It enables the transfer of property ownership upon successful transaction completion.
- Platform: EVM-compatible blockchains.
- Version: Solidity ^0.8.14.

Key Components

- Interfaces and Structs
  - `Asset`: An interface to an external Asset contract, specifically for calling `TransferTokenByP2pPlatform`.
  - `ControlledObject`: Contains details about an object controlled by the platform, including the owner, the date from which it's controlled, and its status.
  - `Deals`: Stores details about a deal, including the shopper (buyer), price, dates related to the deal, and status.
- State Variables
  - `_Administrator`: The administrator of the platform.
  - `_Control`: A control address will be defined in future versions.
  - `_controlledObjects`: Mapping of controlled objects.
  - `_deals`: Mapping of deals related to objects.
  - `_shoppers_deals`: Mapping to track deals associated with each shopper.
- Modifiers
  - `onlyAdmin`: Restricts function access to the administrator.
  - `onlyOwner`: Restricts function access to the owner of a controlled object.
  - `onlyShopper`: Restricts function access to the shopper in a deal.
- Constructor
  - Initializes the contract with admin and control addresses.
- Main Functions
  - `getObject`: Registers an object with its owner under the platform's control.
  - `setDeal`: Sets up a deal for a controlled object.
  - `acceptDeal`: Facilitates the completion of a deal, transfers payment, and invokes the transfer of the object's token to the new owner.
  - `myDeals`: Returns the list of deals associated with the caller.

Analysis and Observations

- Deal Flow

    - The platform allows an object's owner to set up a deal (`setDeal`) and a shopper (buyer) to accept it (`acceptDeal`).
    - `acceptDeal` transfers payment to the object's owner and calls the external Asset contract to transfer the tokenized asset.
- Payment and Transfer Mechanism
    - The payment for the deal is handled within `acceptDeal`, where the shopper sends the agreed price to the owner's address.
    - Upon successful payment, the token of the asset is transferred to the shopper via the Asset contract.
- Control and Administration
    - The contract grants considerable control to the administrator and the owner of the asset, aligning with typical P2P platform models.
    - The `_Control` variable's purpose is unclear and not utilized in the contract.
- Shopper Management
    - Shoppers' deals are tracked, and they have the ability to view their deals through `myDeals`.
    - The function `removeShopperObject` is used internally to manage the shopper's deals.
- Security and Best Practices
    - The use of modifiers for role-based access control is a good practice.
    - Ensuring transactions and status updates are atomic (e.g., in `acceptDeal`) is crucial for consistency.

Potential Concerns and Recommendations

• Error Handling and Validation: More comprehensive checks and error messages could enhance the contract's robustness.

• Gas Efficiency: Some optimizations could be considered, like reducing loop operations in `removeShopperObject`.

Overall discussion and Future Improvements

The code provided demonstrates a robust framework for property tokenization and transfer. However, there are areas for improvement:

Security Enhancements: Additional security measures, such as multi-factor authentication and improved encryption methods, could further secure transactions.

User Interface: Enhancements in user interface design can make the platform more accessible and user-friendly for a broader audience.

Integration with Other Payment Solutions: Currently limited to Ether, expanding to other digital payment solutions could increase accessibility.

Legal Compliance: To ensure regulatory compliance, the system should fully digitize and automate contract notarisation process which involves such steps as check in the state civil registry, check users clear will and understanding of the transaction, introduce financial monitoring and specific requirement to different types of deals.

Extend legal applicability: introduce more types of standard legal deals, such mortgages, leases, gifts, wills, types of legal relationships: co-ownership, fractional ownership, marital property and so on.

4 Conclusion

This paper has presented the pioneering efforts and developments of the Blockchain Estate Registry (BER) in Ukraine, a groundbreaking initiative integrating blockchain technology into real estate transactions and registry systems. Our analysis elucidates the project's inception, design, and implementation, as well as its potential implications for the future of land registries and real estate transactions in Ukraine and beyond.

Central to the BER project is its demonstration application, which effectively illustrates the viability of blockchain technology in transforming real estate transactions into a more streamlined, transparent, and secure process. The application's use of smart contracts and a permissioned application on a public blockchain offers a novel approach, distinct from the use of permissioned Distributed Ledger Technology (DLT) in public registries. This approach ensures data integrity and provides a framework for handling legal scenarios through automated registration processes, thereby reducing the registrar's role and paving the way for a predominantly paperless system.

The BER project's commitment to a multi-chain system is particularly noteworthy, highlighting its foresight in addressing the limitations of single blockchain systems and embracing a strategy that fosters competitive dynamics in blockchain technology. This approach not only augments the bandwidth of the Blockchain Ecosystem for Record-keeping but also grants end-users the flexibility to choose the blockchain that best suits their needs.

Furthermore, the BER initiative has made significant strides in addressing the cybersecurity vulnerabilities of Ukraine's existing registry system. By transitioning to a blockchain-based system, the project not only navigates the challenges posed by the ongoing war but also adopts innovations like smart contracts and decentralized applications, which were previously hindered by outdated regulations and technologies.

Looking ahead, the BER project is set to revolutionize the real estate sector in Ukraine by enabling up to 90% of real estate transactions to be conducted directly, bypassing traditional intermediaries. This shift heralds a new era of efficiency and transparency in property transactions, potentially serving as a blueprint for other nations seeking to modernize their land registry systems. The continued evolution and refinement of the BER will undoubtedly contribute significantly to the global discourse on the application of blockchain technology in public services, particularly in the realm of real estate transactions and land registries.

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