

ФЕДОРЕНКО ВЛАДИСЛАВ

Хмельницький національний університет

<https://orcid.org/0009-0001-6813-6065>e-mail: vladfeddorenko@gmail.com**ПАСІЧНИК ОЛЕКСАНДЕР**

Хмельницький національний університет

<https://orcid.org/0000-0002-8760-4688>e-mail: o.a.pasichnyk@gmail.com**СКРИПНИК ТЕТЯНА**

Хмельницький національний університет

<https://orcid.org/0000-0002-8531-5348>e-mail: tkskripnik1970@gmail.com**МАНЗЮК ЕДУАРД**

Хмельницький національний університет

<https://orcid.org/0000-0002-7310-2126>e-mail: eduard.em.km@gmail.com

МЕТОД ЗАБЕЗПЕЧЕННЯ ЦІЛІСНОСТІ ДАНИХ У СФЕРІ РЕЄСТРАЦІЇ НЕРУХОМОГО МАЙНА З ВИКОРИСТАННЯМ СМАРТ КОНТРАКТІВ

Забезпечення цілісності даних є досить актуальним у світі, яке набуває все більшого значення, і це не випадково. Реєстрація нерухомого майна є ключовим елементом функціонування суспільства, оскільки вона впливає на правові відносини, фінансовий стан громадян, а також має значущий вплив на економіку країни в цілому. Технологія блокчейн ґрунтується на створенні двох списків даних, де окремі елементи, відомі, як блоки, поєднуються в ланцюжок завдяки криптографії. Одна з ключових особливостей блокчейну – це його відкрите та децентралізоване зберігання даних. Це означає, що будь-який користувач може перевірити історію транзакцій або дані, збережені в блокчейні, без необхідності спирання на посередника. Такий прозорий доступ до інформації робить блокчейн особливо корисним для фінансових транзакцій, де важлива надійність та довіра.

Для багатьох людей блокчейн, в першу чергу, асоціюється із криптовалютами, такими як Біткоїн. Він використовується для забезпечення безпеки фінансових операцій і зберігання історії транзакцій. Проте, ця технологія застосовується не лише у фінансовому секторі. Блокчейн може бути використаний для обробки практично будь-яких даних, що мають велику цінність, включаючи ведення документації у медицині, створення систем управління постачанням, трансформацію голосів під час виборів та багато інших застосувань.

Блокчейн – це інноваційна технологія, що активно застосовується в різних галузях, таких як економіка, фінанси, медицина, правова сфера та інші. Проте використання блокчейну та смарт-контрактів в сфері нерухомості досі залишається недостатньо дослідженим. В цьому дослідженні розглядаються переваги та недоліки використання блокчейну та смарт-контрактів, і пропонується безпечна система для укладення угод, пов'язаних з орендою та продажем нерухомості, з використанням цих технологій. Блокчейн надає можливість створення безпечних та надійних записів про власність, транзакції та історію нерухомості. Кожен блок даних у ланцюжку блоків містить інформацію про конкретну нерухомість і всі транзакції, пов'язані з нею. Ця інформація підтверджується мережею користувачів і залишається незмінною, що гарантує історичну достовірність та надійність даних.

Ключові слова: Технологія блокчейн, смарт-контракт, цілісність даних

FEDORENKO VLADYSLAV

Khmelnyskyi National University

PASICHNYK OLEKSANDR

Khmelnyskyi National University

SKRYPNYK TETIANA

Khmelnyskyi National University

MANZIUK EDUARD

Khmelnyskyi National University

A METHOD OF ENSURING DATA INTEGRITY IN THE FIELD OF REAL ESTATE REGISTRATION USING SMART CONTRACTS

Ensuring data integrity is quite relevant in an increasingly important world, and this is no coincidence. Registration of real estate is a key element of the functioning of society, as it affects legal relations, the financial condition of citizens, and has a significant impact on the country's economy as a whole. Blockchain technology is based on the creation of two lists of data, where individual elements, known as blocks, are linked together in a chain using cryptography. One of the key features of the blockchain is its open and decentralized data storage. This means that any user can check the transaction history or data stored on the blockchain without having to rely on an intermediary. This transparent access to information make blockchain particularly useful for financial transactions, where reliability and trust are important.

For many people, blockchain is primarily associated with cryptocurrencies such as Bitcoin. It is used to secure financial transactions and store transaction history. However, this technology is not only used in the financial sector. Blockchain can be used to process virtually any data of great value, including medical records, supply chain management systems, vote transformation during elections, and many other applications.

Blockchain is an innovative technology that is actively used in various, industries, such as economics, finance, medicine, legal and others. However, the use of blockchain and smart contracts in the real estate sector is still insufficiently researched. This study examines the

advantages and disadvantages of using blockchain and smart contracts, and propose a secure system for concluding real estate transactions using these technologies.

Blockchain provides, the ability to create secure and reliable records of property ownership, transaction, and history. Each data block in the blockchain contains information about a specific property and all transactions related to it. This information is confirmed by the user network and remains unchanged, which guarantees the historical accuracy and reliability of the data.

General statement of the problem and its connection with important scientific or practical tasks

Real estate registration requires reliable data integrity to prevent possible fraud and disputes between property owners. One of the promising solutions in this context is the use of smart contracts based on blockchain technology. However, there are a number of scientific and practical challenges related to data integrity methods:

- 1) guarantee of data integrity;
- 2) authentication;
- 3) dispute resolution;
- 4) legal aspect of privacy and security.

The main scientific and practical challenges are related to the development and implementation of technical, legal, and organizational solutions that address these issues and ensure the safe and efficient registration of real estate using smart contracts. To succeed in this area, information technology experts and stakeholders must work together to develop a comprehensive approach to these issues.

Analysis of recent research and publications

Among the researchers who have studied the method for ensuring data integrity in real estate using smart contracts, I would like to highlight the following: Yuriy Musienko [1], Pierfrancesco de Paola [13], Articlebrata H [12], Kamalakanta Muduli [12], Sushanta Tripathi [12], Keke Guy [11], Lihuang Zhu [11], etc.

These researchers have studied the workings of the blockchain with the smart contract and its implementation in real estate or other areas and have made significant contributions to the field. They have researched and developed methods and tools to help ensure data reliability and security.

Identification of previously unresolved parts of the general problem to which the article is devoted

Given the large number of studies in the field of ensuring data integrity in property registration, we can identify some previously unresolved problems and prospects for further development of this topic.

One of the key problems with centralized registration systems is their vulnerability to manipulation and fraud. In other words, these systems can be subject to attacks or corruption, which can lead to inaccurate property information. The use of blockchain-based smart contract technology can create a decentralized system in which property data is stored safely and securely. The blockchain ensures the reliability of data and complicates any attempts to manipulate it, as the information is distributed across many network nodes.

Transparency and openness of processes is an important component of property registration. The use of decentralized blockchain-based registration systems can provide open access to verify, update, and store real estate information. Each record in the blockchain can be made available for verification and audit, which contributes to greater transparency and trust in the system.

For the successful development of decentralized property registration systems, it is important to develop international standards and principles to ensure interoperability between different systems.

All these aspects show the importance of further research and development of decentralized property registration systems based on blockchain and other advanced technologies. Such systems can play an important role in increasing the reliability, transparency, and accessibility of property information, thereby contributing to the development of modern societies and economies.

Formulating the objectives of the article

The purpose of this article is to review and analyze the method of ensuring data integrity in the field of real estate registration using smart contracts, as well as to gain an in-depth understanding of the capabilities and limitations of smart contracts in the context of real estate registration.

Basic information

Blockchain is an innovative decentralized data storage system that is actually an electronic journal of transactions, agreements, contracts, and various information that is built on sequential records. One of the main advantages of this technology is that the data is not centrally stored on one central server. Instead the information is distributed among hundreds or even thousands of computers that interact within a single global network. Each participant in this network has free access to the latest versions of the registry and can verify and monitor transactions and data. This technology opens up many opportunities for security, reliability, and enhanced capabilities in various industries, including finance, logistics, contract work, and many others.

Blockchain technology is based on the important principle of grouping all transactions into blocks using complex mathematical algorithms. These blocks are combined into a sequential chain and cryptographically linked to each other. The key element of each block is its hash, which is a unique digital signature based on information from the previous block.

New blocks are always added to the end of this chain, and once created, the block cannot be changed. This is important because it provides reliable protection against possible data forgery or falsification. Instead of changing existing blocks, information can only be added to new blocks. This characteristic makes blockchain technology particularly valuable for the real estate industry.

For example, in real estate, blockchain can be used to register important transactions, such as purchases, sales, or leases. This registry reliably protects data from any unauthorized changes and ensures its immediate availability on the network. Each transaction is subject to verification, which guarantees the reliability of operations and confidentiality of information. Thus, blockchain technology promotes a high level of trust in the payment and exchange of confidential information in the real estate sector.

To summarize, the main advantages of using blockchain technology are as follows:

1. In blockchain technology, openness and security are key aspects. Information about transactions, agreements, and smart contracts is available for public viewing, but the impossibility of changing or interfering with this data is guaranteed. Details about the participants in the process remain confidential, and each blockchain user has a unique key - a set of cryptographic records that not only ensure the reliability of the system but also protect information from potential hacker attacks. In the context of real estate, this advantage is particularly useful, as financial transactions between participants can be clearly identified without the need to disclose personal data.

2. Impossibility of forgery: Each block in the blockchain is immutable, which prevents any possibility of tampering or falsification of data.

3. Resistance to intrusions: By simultaneously updating the registry on all computers in the network, blockchain technology reliably protects data from possible intrusions and changes.

4. Guaranteed level of trust: The high level of trust in transactions and the exchange of confidential information makes blockchain technology popular for use in various industries, including real estate.

5. Decentralization - the equality and diversity of the system makes it almost impossible to hack or damage

6. Limitedness - an important feature of blockchain technology is that, in theory, its chain can be infinitely extended by adding any number of blocks. This means that the system can continuously develop and expand without being limited by the number of blocks. This capability creates endless prospects for the application of blockchain technology in various industries, providing a scalable and reliable infrastructure for recording and tracking transactions and data

Blocks in the chain have a standardized structure consisting of the following main components:

1. The address is a public key that is created based on the user's private key using a symmetric encryption algorithm;

2. Date and time - this information records the moment the block was created and allows you to determine when the operation was performed;

3. The block hash is calculated using a hashing algorithm and is based on the sum of the hashes of all transactions in the current block, as well as the hash of the previous block. This ensures data integrity and consistency in the block chain;

4. Information is a part of the block containing arbitrary data or messages. In the context of real estate transactions, this component may contain information about documents, amounts of money transferred in real estate purchase and sale or lease transactions;

5. Smart contracts are program code that automates certain processes in the blockchain network, making them more efficient and secure.

To ensure the reliability and security of property transactions, the use of smart contracts in blockchain technology is the best solution. Smart contracts are special protocols that are written in the form of program code and operate in a decentralized registry managed by a computer network. They usually define and verify contract terms.

Smart contracts allow for secure transactions without intermediaries that are open and irreversible. They contain all the necessary information about the terms of the contract and automatically fulfill those terms. This enables interested parties to exchange assets without the need for intermediaries and is a key factor in reducing the cost of property transactions.

Among the mandatory characteristics of smart contracts, key aspects stand out:

1. Use of electronic signature methods: Smart contracts are based on the use of public and private keys that belong to different parties to the transaction. These keys are used to sign and authenticate transactions.

2. Decentralized environment: Smart contracts are usually stored in a private and decentralized environment that guarantees security and independence from centralized systems.

3. Subject matter of the contract and tools for its execution: The smart contract itself includes a description of the subject matter of the agreement and the necessary tools for its execution, including settlement functions, oracle programs, and other components.

Vitalik Buterin, one of the most famous Ethereum developers, characterizes the platform as a "global computer." Thanks to the availability of an Internet connection, Ethereum is accessible to all users in the world, and they are free to use its computing capabilities. Despite the fact that the Ethereum network is a fairly young technology (it was launched in June 2015 and has undergone a series of large-scale protocol updates), it has quickly achieved great achievements.

Ethereum provides an ideal platform for systems that automate direct interaction between nodes or facilitate collaborative group behavior on a network. Some examples of such systems include applications that coordinate specialized markets or automate complex financial contracts. From a theoretical point of view, financial transactions of any complexity can be automated and executed reliably by code running on the Ethereum platform.

A blockchain network is a network of nodes, each of which has a deployed Ethereum client and connects to other nodes. This component is responsible for executing smart contracts and processing various transactions between users of the system. The blockchain and smart contracts interact in the following way: smart contracts are code snippets that are placed on the blockchain and perform certain operations when certain conditions are met. Once these operations are completed, they become permanent records in the blockchain network and cannot be changed.

In Figure 2, you can see a diagram of the components of the developed system designed to conduct secure real estate transactions. The system consists of four main parts: a blockchain network, a web client, a server side, and a relational database.

This infrastructure allows the system to reliably track and record all real estate transactions, ensuring data security and integrity. Using a web client, backend and relational database, the system provides users with an intuitive and user-friendly interface for accessing real estate information.

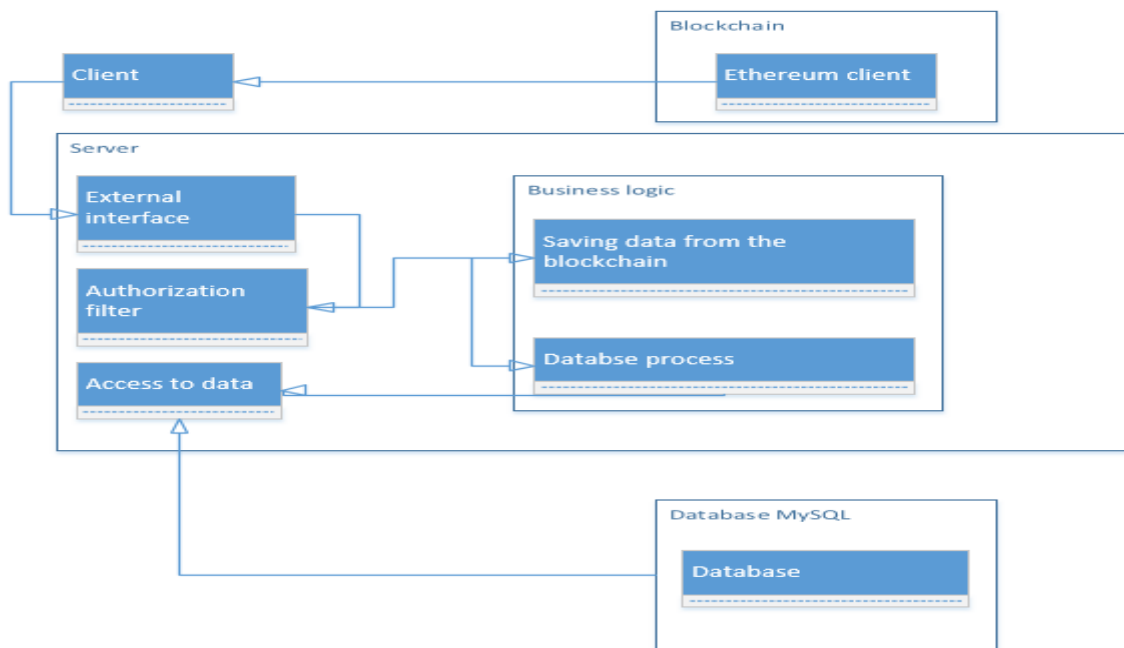


Figure 1. Diagram of system components for secure real estate transactions

The implementation of smart contracts is based on the use of the Solidity programming language, which is object-oriented and was specially designed to efficiently create smart contracts operating on the Ethereum platform. In addition, various library tools are used to speed up the application development process.

The data stored on the Ethereum blockchain is structured according to a relational and hierarchical scheme called the Merkle prefix tree. The leaves of this tree are located at the lower level and include the user's basic data. Each intermediate node is calculated by creating a hash of its two child nodes. The root node is the top of this tree and is formed on the basis of a pair of hashes of the nearest intermediate nodes in the hierarchical structure.

A web client is an interface that a user uses to interact with the system. The functionality of the web client depends on the role of the user, who can act as a tenant, landlord, seller, or buyer of real estate. All interactions between the client and the blockchain network are carried out using a set of Solidity libraries that allow you to perform various actions, such as transferring data from one account to another, reading and writing data from smart contracts, and creating smart contracts.

The Solidity implementation allows you to interact with Ethereum via HTTP using JSON RPC calls. This means that a web client can send requests to individual Ethereum nodes and read and write data on the blockchain. To connect to the network nodes, the main Solidity object acts as a kind of "bridge" between the client and the blockchain and transmits data to the provider where the blockchain network is deployed.

The software implementation of the web client application is based on the Solidity programming language.

To create the business logic of this system, we used the modern Solidity, which is designed for developing web applications. The business logic component is responsible for all aspects of data analysis and storage in the system.

It is important to note that storing data in the blockchain can be a time-consuming process due to the need to add new transactions to the block and confirm them. In order to improve the system's performance, all user data, real estate information, and user feedback are stored in a MySQL relational database. Only the main contractual

documents containing the terms of the contract, such as the price of the property, the payment term, and other necessary data and additional conditions, are stored in the blockchain.

A data access control system acts as an abstraction between web services and databases. In the context of our project, we used Solidity to design the database. This approach involves first defining entities and then creating a database schema based on those entities. In order to create an abstraction between the database and the client, we used the repository template. The repository mediates between the definition tier and the data distribution tier and provides a collection-like interface for accessing objects in the definition tier. This architectural feature helps to ensure efficient and secure exchange and storage of data in the system.

The system uses a software token-based authentication method to verify user identity. After successful authentication, users receive a special token that gives them access to specific resources and web services. This token serves as a token that confirms their identity and allows them to use the system.

Conclusion

Thus, in the real estate sector, the role of smart contracts and the Ethereum platform appears to be critical. In addition, another industry segment that may undergo significant changes due to blockchain technology is... Having analyzed all the risks inherent in the real estate sector and having previously considered blockchain technology, we conclude that smart contracts can significantly improve, simplify and make more accessible the processes of renting and buying real estate by storing all documents and data on the blockchain. An important aspect is that any information regarding transactions, payments or contractual agreements cannot be deleted from the blockchain, which significantly reduces the risk of abuse and fraud.

The main advantages of using smart contracts in real estate include:

1. Transparency: Each contract and all transactions are available for review by all interested parties.
2. Accuracy: The terms of the agreement are stored in detail in smart contracts, which allows for accurate automated calculations of the cost of housing or rent
3. Security: Smart contracts use the highest standards of cryptographic protection, ensuring the reliability of transactions.
4. Direct communication: There is no need to involve intermediaries for interaction between tenants and landlords or buyers and sellers of real estate; all processes take place directly between the parties.
5. Trust: Smart contracts increase the level of trust in the execution of transactions due to their transparency, autonomy, and security.
6. Electronic document management: Smart contracts, as program code, allow transactions to be made without the need for traditional paper documents.
7. Long-term data storage: All transactions carried out within the framework of agreements are recorded in the blockchain, which guarantees the safety of data throughout the existence of the network.

But it is important to note that blockchain is not a one-size-fits-all solution for all types of financial transactions. For example, smart contracts are not capable of automatically triggering each other or other contracts without the active participation of the user to initiate transactions.

The system developed and described above can be widely used in the field of financial transactions and data storage, as it realizes the benefits of using blockchain technology and smart contracts, provides a user-friendly interface, has high performance and the ability to store all the necessary information.

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