Real Estate Operations with Blockchain: Challenges and Implementations

Abstract—The Blockchain technology is a transformative innovation with significant potential across various industries, including finance, healthcare, supply chain management, and more. One area that could particularly benefit from blockchain's advantages is the real estate industry, which is known for its inefficient and opaque processes, leading to high transaction costs, fraud, and limited access to information. This paper seeks to provide insights into how blockchain technology can transform the real estate industry, improving efficiency, transparency, and trust while reducing transaction costs and fraud. We provide two online available open-source implementations of the solutions in C++ as well as with smart contracts in Solidity.

I. INTRODUCTION

A. Challenges in Real Estate Systems

The real estate industry is a crucial part of the global economy, with residential and commercial real estate representing a significant portion of wealth worldwide [1], [2]. Real estate transactions involve the transfer of property ownership, including buying, selling, renting, and leasing. The traditional process of real estate transactions is often slow, complex, and costly due to inefficiencies, multiple intermediaries, paperwork, and legal procedures. These inefficiencies not only hinder the overall transaction experience for both buyers and sellers but also limit the growth potential of the industry.

In the traditional process, a buyer typically engages a real estate agent to help find suitable properties and negotiate with the seller. Once a property is selected, the buyer makes an offer, which may be accepted, rejected, or countered by the seller. Once the parties agree on the terms of the transaction, a contract is drafted, and a deposit is made. The transaction then goes through a series of legal and financial processes, such as title search, appraisal, inspection, and financing, before finally closing the deal. The process also involves other intermediaries, such as escrow agents, who manage the transfer of funds, and mortgage brokers, who assist with financing.

The whole process can take weeks or even months to complete, depending on various factors such as the complexity of the transaction, the involvement of third parties (e.g., attorneys, appraisers, inspectors), and regulatory requirements of the jurisdiction [3]. Transaction costs can also be significant, including real estate agent commissions, legal fees, appraisal fees, and closing costs [4].

The process can also be complicated by a lack of standardization across jurisdictions, with different countries and states having their own regulations, documentation requirements, and procedures. Transparency is a critical factor in real estate transactions, yet the current process often makes it difficult for buyers and sellers to access accurate, up-to-date information about properties and transactions. There is also a high risk of fraud, especially in cases of identity theft, fake documents, and false representations.

Overall, the traditional process of real estate transactions is slow, costly, and opaque, making it ripe for disruption by new technologies such as blockchain.

B. Contributions and Paper Overview

This paper aims to explore the potential advantages of using blockchain technology to handle real estate operations. To do so, it examines the current state of the real estate industry, analyzes the market trends and factors influencing the adoption of blockchain, and discusses potential benefits and limitations of implementing blockchain technology in real estate. The paper has four main contributions:

- The paper provides an overview of blockchain technology and its key concepts, the current state of the real estate industry, and the potential benefits of using blockchain in real estate.
- Then, it also describes our initial attempt to implement a new blockchain from scratch using C++, and an advanced successful attempt using smart contracts to handle also complex real estate transactions.
- Last, it concludes with reflections on additional features and potential future applications for real estate.

Overall, this paper seeks to provide insights into how blockchain technology can transform the real estate industry, improving efficiency, transparency, and trust while reducing transaction costs and fraud. This research aims to contribute to ongoing discussions about blockchain technology's potential and encourage further exploration of its applications, not only in real estate but also in other industries.

II. MARKET ANALYSIS, CASE STUDIES AND RELATED WORK

A. The Real Estate Market

Market Overview. The global real estate market is a multi-trillion-dollar industry, with commercial and residential properties representing significant portions of wealth and investment worldwide. As technology continues to disrupt traditional industries, the real estate sector is no exception. Blockchain technology offers promising solutions to existing inefficiencies and challenges in the real estate market.

Market Segmentation. Effective market analysis requires the segmentation of the real estate market into different categories, each with its own opportunities and challenges.

- Residential real estate: single-family homes, multi-family homes, and condominiums
- Commercial real estate: offices, retail, industrial, and hospitality properties
- Real estate investment and financing: real estate investment trusts (REITs), mortgage-backed securities, and other financial instruments
- Real estate services: brokerage, property management, and valuation services

Each of these segments presents different opportunities and challenges for the adoption of blockchain technology.

Demand Drivers and Adoption Factors. The adoption of blockchain technology in real estate is driven by several factors:

- Increased transparency: Blockchain technology can provide a transparent and tamper-proof record of property ownership, transaction history, and other relevant information, which can improve trust and confidence.
- Improved efficiency: By eliminating intermediaries and automating various processes through smart contracts, blockchain can significantly reduce transaction times and costs, making the overall process more efficient.
- Enhanced security: Blockchain's decentralized and immutable nature can help prevent fraud and unauthorized alterations of property records.
- Streamlined cross-border transactions: Blockchain technology can simplify and accelerate cross-border transactions by removing intermediaries and reducing the need for currency conversion and other complexities.
- Tokenization of assets: Blockchain enables the tokenization of real estate assets, which can increase liquidity and open up new investment opportunities, such as fractional ownership and decentralized investment platforms.

Overall, the potential advantages of implementing blockchain technology in real estate operations are numerous and far-reaching. By improving transparency, reducing transaction times and costs, enhancing security, enabling tokenization, facilitating cross-border transactions, and integrating with IoT and other technologies, blockchain has the potential to transform the real estate industry and create a more efficient, accessible, and secure market for all stakeholders involved.

B. Existing Platforms

As we mentioned earlier, several companies have already implemented blockchain technology in their real estate operations, showcasing its practical applications and benefits.

Propy [5] is a global property marketplace that uses blockchain technology to facilitate cross-border real estate transactions. The platform leverages smart contracts to automate the property transfer process, ensuring secure and transparent transactions. In 2017, Propy facilitated the first-ever blockchain-based real estate transaction in the United States, involving the sale of an apartment in Ukraine. The case demonstrated the potential of blockchain to streamline international property transactions and eliminate the need for intermediaries, thereby reducing transaction times and costs.

Deedcoin [6] is a platform that enables real estate agents to be paid in cryptocurrency, reducing fees associated with traditional transactions by eliminating intermediaries.

RealT [7] is a platform that allows investors to purchase tokenized shares of real estate properties, enabling fractional ownership and creating a more accessible market for real estate investment. The platform utilizes blockchain technology to manage and track the ownership of these tokenized assets, offering increased transparency and security for investors. RealT showcases the potential of blockchain and tokenization to democratize real estate investment and create new opportunities for a wider range of investors.

Meridio [8] is a blockchain-based platform focused on the creation, management, and trading of tokenized shares of commercial real estate assets. By leveraging blockchain technology, Meridio aims to increase liquidity and transparency in the commercial real estate market, facilitating more efficient and accessible investment opportunities. The platform's success in tokenizing commercial properties highlights the potential for blockchain technology to revolutionize the way real estate assets are managed, traded, and invested.

C. Previous Academic Papers and Reports

Numerous academic papers and reports have been published on the topic of blockchain technology in real estate, exploring its potential impact, benefits, and challenges.

An early study by Avi Spielman [9] (in 2016) explores the potential of blockchain technology to transform the real estate industry by enhancing transparency, reducing fraud, and streamlining transactions. The author highlights the benefits of distributed ledger technology for maintaining secure property records and automating various processes through smart contracts. The paper provides a comprehensive overview of the potential applications of blockchain in real estate and serves as a foundation for further research in the field.

Next, Maurice Barbieri and Dominik Gassen [10] (in 2017) learn the potential of blockchain technology to revolutionize the land registry system by providing a secure, transparent, and tamper-proof database for land transactions. The authors discuss the benefits and challenges of using blockchain for land registration and highlight some of the ongoing initiatives and experiments in this area. The paper provides a useful overview of the potential impact of blockchain on land registration and is a valuable resource for anyone interested in the intersection of blockchain technology and real estate. Similarly, Benjamin Verheye [11] (in 2017) refers to the importance of publicity.

Karamitsos et al. [12] (in 2018) describe a use case in which a smart contract is used to automate the process of transferring property ownership. The paper discusses the benefits of using smart contracts in the real estate industry, including increased transparency, reduced transaction costs, and improved efficiency. The authors also discuss the technical aspects of designing and implementing a blockchain smart contract for real estate transactions. Another study by Rosa M. Garcia-Teruel [13] (in 2020) provides a detailed analysis of the legal implications of blockchain technology in real estate

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and highlights the need for regulatory frameworks to address these issues. The authors also provide recommendations for policymakers and legal professionals on how to navigate these legal challenges and take advantage of the opportunities presented by blockchain technology in the real estate sector.

Gupta et al. [14] (in 2020) describe how tokenization, which involves representing ownership of real estate assets using digital tokens on a blockchain, could increase the liquidity and accessibility of real estate investments. Next, Saari et al. [15] (in 2022) refer to cases such as land registries, and property management and discuss technical and legal issues.

III. Limitations and Challenges of Implementing Blockchain in Real Estate

While blockchain technology has the potential to revolutionize the real estate industry, it is essential to consider the limitations and challenges associated with its implementation. Here are some key challenges to consider:

Scalability. One significant limitation of blockchain technology is its scalability. As the number of transactions increases, the size of the blockchain grows, which can lead to slower transaction processing times and increased resource demands. This can be a challenge for the real estate industry, particularly when dealing with large volumes of data and transactions. However, ongoing research and development efforts are focused on addressing this issue, with solutions such as sharding and off-chain transactions.

Regulatory Concerns. Implementing blockchain technology in the real estate industry may face regulatory challenges, as existing laws and regulations may not adequately address the use of this new technology. For example, property registration and transfer processes are often governed by local and national laws that require specific documentation and procedures. Adapting these regulations for blockchain systems may require significant legal and policy changes.

Technology Adoption Barriers. The successful implementation of blockchain in real estate will require widespread adoption by industry stakeholders, including property owners, investors, brokers, and government authorities. However, many stakeholders may be hesitant to adopt this new technology due to a lack of understanding, concerns about security and privacy, or resistance to change.

Integration with Existing Systems. The real estate industry relies on various systems and databases to manage property records, transactions, and other essential processes. Integrating blockchain technology with these existing systems may prove challenging, particularly when legacy systems are not easily compatible with new technologies.

Privacy Concerns. While blockchain technology can provide enhanced transparency and security, it may also raise privacy concerns for some users. The public nature of some blockchain networks may expose sensitive information to a wider audience, potentially compromising the privacy of individuals and businesses involved in real estate transactions. Addressing these concerns may require the development of privacy-preserving technologies, such as zero-knowledge proofs or private blockchains, that can protect sensitive data while still providing the benefits of blockchain technology.

Environmental Impact. Energy consumption associated with some blockchain networks, particularly those utilizing proof-of-work consensus mechanisms, can be significant. This environmental impact may be a concern for stakeholders considering the implementation of blockchain technology in the real estate industry. However, alternative consensus mechanisms, such as proof-of-stake or delegated proof-of-stake, can significantly reduce energy consumption.

In summary, while blockchain technology holds significant potential for transforming the real estate industry, it is crucial to address the limitations and challenges related to scalability, regulatory concerns, technology adoption barriers, integration with existing systems, privacy concerns, and environmental impact. Overcoming these challenges will require continued research, development, and collaboration between technology providers, industry stakeholders, and regulators.

IV. Two Open-source Implementations

We implement two solutions for blockchain-based real-estate. We start with a simple but limited solution in C++ and continue with an advanced solution of higher functionality in Solidity. We make both solutions online available on GitHub.

A. A Baseline C++ Implementation - Limitations and Lessons

In our initial attempt, we aimed to create a real estate blockchain from scratch using C++. This open-source implementation is available as the following GitHub repository [16]. It includes the source code and detailed documentation (README.txt). Due to the complexities of implementing certain features and the potential advantages of smart contracts, we ultimately transitioned to building on an existing platform. Despite this shift, our C++ implementation offers several intriguing elements but also presents some limitations.

Our initial implementation includes several interesting features and consensus rules that govern the functioning of the blockchain. These features encompass mining using a Proof of Work mechanism, block structures that comprise an array of transactions and metadata, property ownership mechanisms that allow for the trading and splitting of shares, and property usage rules that manage tenants and rent fees. To facilitate user interaction with the blockchain, we developed an application (main.cpp) that acts as a client, full-node, and miner. This command-prompt-based application allows users to execute various blockchain commands and queries while adhering to the implemented protocol.

Key limitations of our C++ implementation include:

- A lack of encryption and signature for transactions, which leaves the system vulnerable to potential security breaches.
- The reliance on an imported Sha256 hash library, rather than a proprietary solution.
- The use of an "N-way Merkle Tree" for organizing transactions in each block, which might not be the most efficient method.

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- Absence of communication between nodes in the network, results in a single chain without fork conflicts, which limits the robustness of the system.

In conclusion, although our initial C++ implementation encountered several limitations, it provided valuable insights and served as a solid foundation for our project. By identifying the challenges and recognizing the potential advantages of smart contracts, we were better equipped to pivot our approach and leverage an existing platform for the subsequent phases of the project. Despite its shortcomings, this implementation serves as a testament to the complexities of building a real estate blockchain and highlights the importance of adaptability and innovation in the face of evolving technological landscapes. As we move forward, we aim to incorporate the lessons learned from this initial attempt to develop a more robust and efficient blockchain-based solution for real estate transactions.

B. An Advanced Solidity Implementation - Developing and Implementing Real Estate Smart Contracts on an Existing Blockchain Platform

Our advanced open-source implementation implements smart contracts with the Solidity programming language. It is built gradually and organized into two versions. This implementation is available as another GitHub repository, together with detailed documentation (README.md) [17].

Basic Asset Transactions. Our initial implementation of a real estate smart contract built on the Ethereum platform and utilizing the ERC-1155 token standard provides a functional foundation for facilitating the minting, buying, and selling of properties on the blockchain. The contract allows property owners to mint new properties upon payment of the required agency fees, and buyers can purchase properties using Ether. The integration of IPFS allows for easy access to property metadata for buyers.

Additionally, the contract keeps track of revenue generated by each property and allows property owners to withdraw their share, while also charging agency fees based on a set percentage. The smart contract includes functions such as initialization, minting new properties, buying properties, setting IPFS hashes for property metadata, withdrawing revenue shares for property owners, and withdrawing agency fees for the contract owner. These functions can be accessed via the intuitive Remix Ethereum IDE (**https://remix.ethereum.org/**).

In this version of the smart contract, users can initialize the contract with their desired agency fee percentage and mint properties by specifying a price. Buyers can purchase properties by calling the buyProperty function with the desired property ID and Ether amount. After buying a property, the buyer receives an NFT receipt containing metadata stored on IPFS. This initial version of the real estate smart contract provides a strong foundation for the creation of a full-fledged real estate blockchain system that can revolutionize the way real estate is traded and managed.

Expanding Functionality. In the second version of our real estate smart contract, we added advanced ownership and trading mechanisms, allowing for the buying and selling of shares of a property. This version builds upon the features of the initial version, including the ability for property owners to mint new properties by paying agency fees, buyers to purchase properties by paying the necessary amount in Ether, and the integration of IPFS for storing and accessing property metadata.

Additionally, the contract keeps track of the revenue generated by each property and allows owners to withdraw their share, while also charging agency fees as a percentage of the minting price. The main feature added to this version is the ability for buyers to purchase shares of a property by paying the required amount in Ether. This opens up new possibilities for ownership and investment, allowing multiple parties to own and invest in a single property. The contract also enables the selling of shares by property owners to other users.

To facilitate this new feature, we added three new functions to the contract: buyShares, buySharesFrom, and setShareOwnerSelling. The buyShares function allows a user to buy a specified amount of shares of a property by paying the required amount in Ether. The buySharesFrom function enables a user to buy shares from a seller by paying the required amount in Ether. Finally, the setShareOwnerSelling function allows a property owner to set the amount of shares they are willing to sell for a specified property.

In summary, the second version of our real estate smart contract builds upon the initial version by adding advanced ownership and trading mechanisms. This enables the buying and selling of shares of a property, providing new opportunities for ownership and investment. These new features are facilitated by the buyShares, buySharesFrom, and setShareOwnerSelling functions added to the contract.

Overall, this version provides a more comprehensive and flexible real estate blockchain system.

V. CONCLUSIONS AND FUTURE DIRECTIONS

First, we provided an overview of blockchain technology and smart contracts, and their potential application in real estate transactions. We highlighted the current inefficiencies of traditional real estate transactions and the potential market for blockchain-based solutions. Next, we outlined the potential advantages of using blockchain technology in real estate operations. To further examine the feasibility of this technology in real estate, we analyzed case studies and previous research. We also discussed the challenges and limitations of implementing blockchain technology in the industry. Then, we described the lessons learned during an initial development of the project in C++. We then provided an overview of the implementation of smart contracts for real estate transactions on an existing blockchain platform, including the basic asset transactions that were implemented and the expansion of functionality beyond these transactions. Overall, the development and implementation of smart contracts for real estate transactions on a blockchain platform has the potential to revolutionize the real estate industry. This technology has the potential to streamline and simplify real estate transactions, making them more efficient, transparent, and secure.

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