OneLand: A BLOCKCHAIN-BASED REAL ESTATE MANAGEMENT SYSTEM

By

TAKUDZWA MATIKI

(H190577R)

HIT400 Capstone project Submitted in Partial Fulfillment of the

Requirements of the degree of

Bachelor of Technology

In

Software Engineering

In the

School of Information Sciences and Technology

Harare Institute of Technology

Zimbabwe

Supervisor

Mr. M. Mutandavari

May 2023

HIT 400 /200 Project Documentation Marking Guide

ITEM	TOTAL MARK /%	ACQUIRED/% /%
PRESENTATION- Format-Times Roman 12 for ordinary text, Main headings Times Roman 14, spacing 1.5. Chapters and sub-chapters, tables and diagrams should be numbered. Document should be in report form. Range of document pages. Between 50 and 100.Work should be clear and neat	**5**	
Pre-Chapter Section Abstract, Preface, Acknowledgements, Dedication & Declaration	**5**	
Chapter One-Introduction Background, Problem Statement, Objectives – smart, clearly measurable from your system. Always start with a TO… Hypothesis, Justification, Proposed Tools Feasibility study: Technical, Economic & Operational Project plan –Time plan, Gantt chart	**10**	
Chapter Two-Literature Review Introduction, Related work & Conclusion	**10**	
Chapter Three –Analysis Information Gathering Tools, Description of system Data analysis –Using UML context diagrams, DFD of existing system Evaluation of Alternatives Systems, Functional Analysis of Proposed System-Functional and Non-functional Requirements, User Case Diagrams	**15**	
Chapter Four –Design Systems Diagrams –Using UML Context diagrams, DFD, Activity diagrams Architectural Design-hardware, networking Database Design –ER diagrams, Normalized Databases Program Design-Class diagrams, Sequence diagrams, Package diagrams, Pseudo code Interface Design-Screenshots of user interface	**20**	
Chapter Five-Implementation & Testing Pseudo code of major modules /Sample of real code can be written here Software Testing-Unit, Module, Integration, System, Database & Acceptance	**20**	
Chapter Six –Conclusions and Recommendations Results and summary, Recommendations & Future Works	**10**	
Bibliography –Proper numbering should be used Appendices –templates of data collection tools, user manual of the working system, sample code, research papers	**5**	
	100	**/100**

Certificate of Declaration

This is to certify that work entitled “OneLand: A Blockchain-Based Real Estate Management System “is *submitted in partial fulfillment of the requirements for the award of Bachelor of Technology (Hons) in Software Engineering, Harare Institute of Technology. It is further certified that no part of research has been submitted to any university for the award of any other degree.*

Mr. M. Mutandavari(supervisor)	Signature…….	Date…….
Miss L. Amos(mentor)	Signature…….	Date…….
Mr. W. Makondo(chairman)	Signature…….	Date…….

Abstract

The real estate industry has long been plagued by problems such as fraud, double sales, and lack of trust, leading to significant challenges for buyers and sellers. This abstract presents a proposal for a blockchain-based real estate management system that aims to address these issues and provide a secure, transparent, and efficient solution.

The proposed tools for developing the system include Solidity for writing smart contracts, Ganache for launching the Ethereum network, Truffle for testing and developing the blockchain network, JavaScript for the frontend, and MetaMask to create a blockchain browser. The resulting decentralized application (dApp) will run smart contracts, enable tokenization of land properties as NFTs, support decentralized data storage, and maintain immutability.

The decentralized nature of the system ensured the security and integrity of the stored data. The immutability of the blockchain prevented data tampering, reducing the occurrence of fraudulent activities. This robust security feature offered by the blockchain technology attracted developers and stakeholders, as it guaranteed the protection of records and prevented fictitious sellers from exploiting the system. By implementing this blockchain-based system, buyers and sellers can have increased confidence in the authenticity and accuracy of property ownership records, fostering a more transparent and trustworthy industry.

Keywords: blockchain, real estate management system, smart contracts, Ethereum network

Preface

This document provides an introduction to the concept and development of a blockchain-based real estate management system. It outlines the key objectives, challenges, and proposed solutions to revolutionize the real estate industry. The target audience for this document includes professionals in the real estate sector, potential buyers and sellers, and individuals interested in exploring the potential of blockchain technology.

Throughout this document, we explore the issues plaguing the real estate market, such as fraud, lack of trust, and inefficiencies. It presents a comprehensive overview of how a blockchain-based system can address these challenges by leveraging the immutability, transparency, and automation capabilities of blockchain technology. The aim of this document is to spark innovation and encourage stakeholders in the real estate industry to embrace this transformative solution.

Acknowledgements

I would like to express my deepest gratitude to God for His guidance, strength, and blessings throughout the journey. I would like to extend my heartfelt appreciation to Mr. Mutandavari, my supervisor, for his invaluable guidance, expertise, and continuous support. His insightful feedback and encouragement have been crucial in shaping the direction of this project.

I would also like to thank Mr. Makondo, the chairman of the software department, for his trust and belief in my abilities, Miss Amos, my mentor, for her unwavering support, guidance, and constructive feedback and the entire software department for their collaboration, insights, and encouragement. The collective effort and camaraderie within the department has created an environment conducive to growth and learning.

I would like to acknowledge my friends and colleagues for their support, motivation, and valuable input throughout this project. Their encouragement and belief in my abilities have been a driving force in overcoming challenges and achieving success.

Lastly, I am deeply grateful to my family for their unwavering love, understanding, and support. Their encouragement and belief in my abilities have been a constant source of inspiration.

Without the support and contributions of these individuals, this project would not have been possible. I am truly thankful for their presence in my life.

Dedication

This project is dedicated to the loving memory of my late father, Mr. Mike Matiki. Your unwavering belief in my potential and your constant encouragement continue to inspire me. Though you are no longer with us, your spirit lives on in my heart, and I am grateful for the values you instilled in me.

To my dear mother, Mrs. Patrisia Matiki, thank you for being my rock and my guiding light. Your unwavering support, sacrifices, and unconditional love have shaped me into the person I am today. Your unwavering belief in my abilities has fueled my determination to overcome challenges and reach for success.

To my beloved sisters, Praise and Precious, your presence in my life has brought immense joy and happiness. We have shared countless memories, laughter, and tears together, and I am grateful for the bond we share. This accomplishment is dedicated to our unbreakable sisterhood and the endless support and encouragement we provide to one another.

To my entire family, near and far, thank you for your unconditional love, encouragement, and belief in my dreams. Your presence in my life has given me the courage to pursue my passions. This achievement is dedicated to our family's unity, resilience, and the unbreakable bond we share.

To my dear friends, your presence in my life has been a source of inspiration and joy. Thank you for your unwavering support, encouragement, and for being there through thick and thin. This accomplishment is dedicated to our friendship, filled with laughter, shared experiences, and unwavering loyalty.

To all those who have played a significant role in my life, both past and present, thank you for your unwavering support and belief in me. Your presence has shaped me into the person I am today, and for that, I am forever grateful. This project is dedicated to each and every one of you.

"Even if I'm faced with demons, I will fight. Even if I'm faced with despair, I will not give up." - Tanjiro Kamado

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One- Introduction

1.1 BACKGROUND

Buying a house is an achievement meant to last for a lifetime and is considered to be the safest investment. For many years it has become the norm that when buying a house or a piece of land, you would be met with many problems. Instead of taking care of the problems, the real estate industry has accepted them as part of the industry. This has inconvenienced many clients who have been affected by these problems. In 2021, in Dzivarasekwa, two housing cooperatives took each other to court over the claim of the same land. Clients who had bought land from either cooperative had to put a pause on their development during the period when the issue was still in trial. When one party won, the other party had to tell its clients that they had to wait for them to acquire new land for them to be allocated their new stands. Some of the clients that belonged to the losing party did not accept this verdict and were adamant about staying to the point of threatening the winning party's clients. For many potential homeowners this served as a warning not to invest in a house because some thought that if the issue of double allocation could happen to housing cooperatives, what more to the ordinary citizen who at times might not have a legal team to back them up.

In 2020, iHarare published an article that pointed out some of the issues that have plagued the real estate industry. Many have fallen victim to real estate fraud in Zimbabwe. Fraudsters pry on home seekers and their tactics have become more organized and sophisticated that it can be hard to detect. Main culprits are agents, bogus real estate companies, and developers (iHarare, 2020). Some of the problems faced by people included having to pay a certain amount to be on the waiting list. This occurred when agents would tell clients that for them to be eligible for the stand. The deposit would ensure your spot when new land becomes available but when the land does not come and you decide to withdraw, a clause hidden in the agreement of sale is produced and a percentage of your money is taken. Another problem the issue of double sales. This when the same piece of land is sold to many different clients by the same agents. When the client comes to claim the land, they will find out that there are many other parties claiming that same property. The issue of identity theft is also affecting the industry. Fraudsters would identify land not being developed and the they acquire a copy of the title deeds and details of the owner. They then use these documents to initiate a sale with a new customer but when the rightful owner come the customer discovers that they have been duped.

These problems cause people to lose interest in investing in the real estate market and this negatively affects the market. The use of paper-based storages means there are more occurrences of redundant data, data theft and data loss. One thing that prompted the creation of this project is the question: How can I ensure that the property I am about to buy is legal and will not cause me trouble in the future? The project aims to eliminate all the problems currently being experienced in the industry by conducting transactions on a private blockchain. The use of blockchain using smart contracts removes the use of third party, speeds up verification and greatly reduces chances of fraud.

1.2 Problems Statement

The real estate industry faces several challenges related to the authenticity and security of property ownership records, which can lead to fraud and disputes. Issues such as incorrect land descriptions, double sales, unauthorized transfers, and the involvement of fake agents have led to a lack of trust between buyers, sellers, and intermediaries in the industry. As a result, there is a need for a secure and transparent system that can ensure the integrity of property ownership records and streamline real estate transactions.

A blockchain-based real estate management system can address these challenges by providing a tamper-proof and decentralized ledger that records all property transactions and ensures the immutability and transparency of property ownership records. The use of smart contracts can automate key aspects of real estate transactions, such as property transfers and payments, reducing the risk of errors and fraud. This system can also eliminate the need for intermediaries such as agents and cooperatives, further reducing costs and increasing efficiency.

By implementing a blockchain-based real estate management system, buyers and sellers can have increased confidence in the authenticity and accuracy of property ownership records, leading to a more transparent and trustworthy industry.

1.3 Objectives

- To facilitate the buying and selling of land assets
- To create a distributed ledger that enhances the security and transparency of real estate transactions
- To streamline real estate transactions and reduce the need for intermediaries such as housing cooperatives and agents
- To create an unmodifiable history of all the transactions that have been performed on a land asset.
- To enable the minting of currently owned land assets
- To reduce costs associated with manual tasks and human involvement, automating processes using smart contracts and blockchain

1.4 Hypothesis

Implementing a blockchain-based real estate management system will lead to improved security, transparency, efficiency, and trust within the real estate industry. This hypothesis is based on the assumption that the utilization of blockchain technology will address the current challenges faced by the industry, such as fraud, disputes, and the need for intermediaries. The hypothesis further posits that the integration of smart contracts and decentralized ledger technology will streamline real estate transactions, reduce costs, and provide a tamper-proof and immutable record of property ownership.

The hypothesis predicts that by eliminating the reliance on third-party intermediaries and introducing a decentralized and transparent system, the blockchain-based real estate management system will enhance the security and authenticity of property ownership records. It is expected that the utilization of smart contracts will automate key aspects of real estate transactions, leading to increased efficiency and reduced risk of errors or fraudulent activities.

Furthermore, the hypothesis anticipates that the implementation of the blockchain-based system will foster trust and confidence among buyers, sellers, and other stakeholders in the real estate industry. By providing a reliable and verifiable source of information, the system aims to eliminate double sales, unauthorized transfers, and other fraudulent practices, thereby creating a more trustworthy and efficient marketplace.

1.5 Justification

The security offered by blockchain technology makes it impossible for developers not to invest in it as it guarantees that the records are not to be tempered with. This also helps create a history of the property to be sold to prevent fictious sellers from gaming the system. The project also guaranteed that fraud and forgery are curbed and buyers can be safe from these problems.

1.6 Proposed Tools

The proposed solution is a decentralized application(dApp). The proposed system will be able to:

- run smart contracts
- tokenization of land properties to produce NFTs.
- Support a decentralized data storage
- Be immutable

The solution will be created using Solidity to write the smart contracts, Ganache to launch the Ethereum network, Truffle for testing and developing the blockchain network, JavaScript for the fronted of the application and MetaMask to create a blockchain browser.

1.7 Feasibility study

1.7.1 Technical

This study showed that the developer had the necessary technical skills needed for the completion of the project. The developer was familiar with the technology which included Solidity, Truffle and JavaScript. The tools needed to build the project were also considered along with alternative technologies which may be used to create the system. The approach to be used included the writing of the smart contracts for the blockchain network followed by the development of the frontend of the application.

1.7.2 Economic

Table 1. 1 Economic Feasibility Study

Component	Cost
Laptop	$700
WIFI	$100
External Mouse	$5
Total	**$805**

After compilation of the list of requirements needed for the completion of the project, it was determined to be economically feasible. This is because the project required a laptop to run on which was already available and the creation of the Ethereum network was handled by Ganache which was free to use.

1.7.3 Operational

The study was conducted and it showed that the solution will be able to solve the problems associated with the real estate industry. The solution will be an immutable ledger to prevent the tempering of records to avoid fraud. The solution is needed urgently as the problem being solved occurs daily to different people around the world.

1.8 Project plan

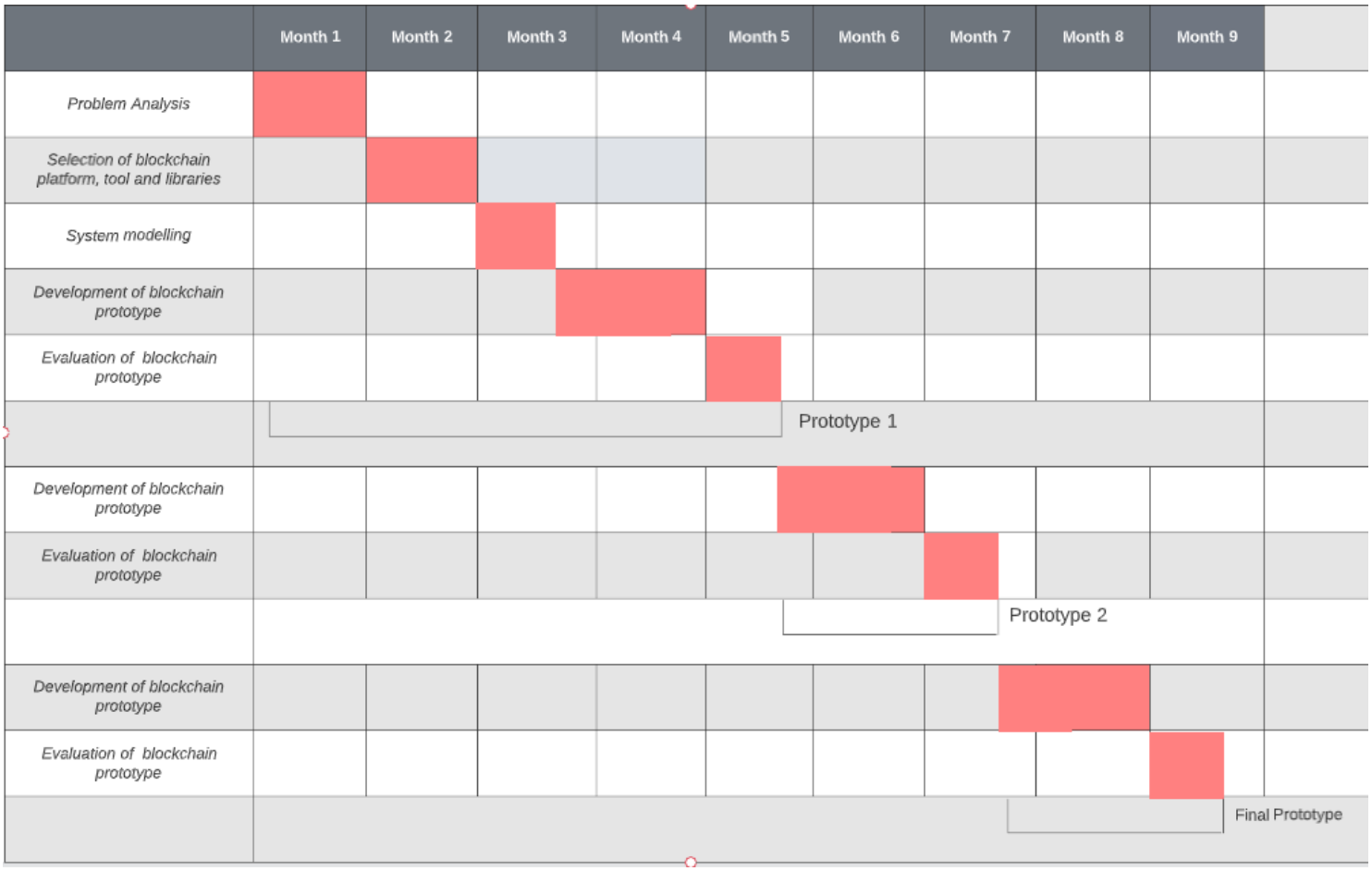
1.8.1 Time plan

Table 1. 2 Time Plan

Activity	Tentative Date
Problem analysis	**23/06/2022**
Selection of blockchain platform, tool and libraries	**20/07/2022**
System modelling	**19/08/2022**
Blockchain prototype development	**30/08/2022**
Evaluation of blockchain prototype	**01/10/2022**

1.8.2 Gantt chart

Figure 1. 1 Gantt Chat



Chapter Two – Literature Review

2.1 Introduction

Real estate management is a complex process that involves various transactions, record-keeping, and stakeholder interactions. Traditional systems often face challenges related to security, transparency, and efficiency. In recent years, blockchain technology has emerged as a potential solution to address these issues. This literature review aims to explore the application of blockchain in real estate management systems, highlighting its benefits in terms of security, transparency, and efficiency.

2.1.1 Blockchain Technology Basics

Blockchain is a distributed ledger technology that facilitates secure and transparent recording and verification of transactions across a network of participants [1]. It operates on the principles of decentralization, immutability, and consensus. Transactions recorded on the blockchain are resistant to alteration, providing a high level of data integrity [2]. The decentralized nature of blockchain eliminates the need for intermediaries, reducing costs and enhancing efficiency.

2.1.2 Blockchain in Real Estate Management

Blockchain technology, initially associated with cryptocurrency, has expanded its applications beyond financial sectors. Ølnes and Jansen have stated that blockchain has found relevance in various industries such as education, healthcare, city planning, and e-government [3]. This literature review focuses on the utilization of blockchain in the real estate sector, highlighting its potential to provide a secure, transparent, and immutable environment for managing property transactions.

In their research Ahmad, Alqarni, Almazroi, and Alam alluded that the adoption of blockchain technology in the real estate industry offers numerous advantages[4]. Blockchain provides a secure and transparent environment for recording property transactions, ensuring that records are tamper-proof and verifiable. This eliminates the need for intermediaries, such as brokers and lawyers, streamlining the transaction process and reducing costs mentioned by Gräther, Kolvenbach, Ruland, Schütte, Torres[5]. Moreover, blockchain enables the implementation of smart contracts, self-executing agreements that automate various aspects of real estate transactions, including property transfers and payment processing([8]-[12]). Smart contracts enhance efficiency, eliminate errors, and foster trust among parties.

One significant benefit of blockchain in real estate management is the establishment of a single, immutable source of truth for property records([13]-[15]). This eliminates

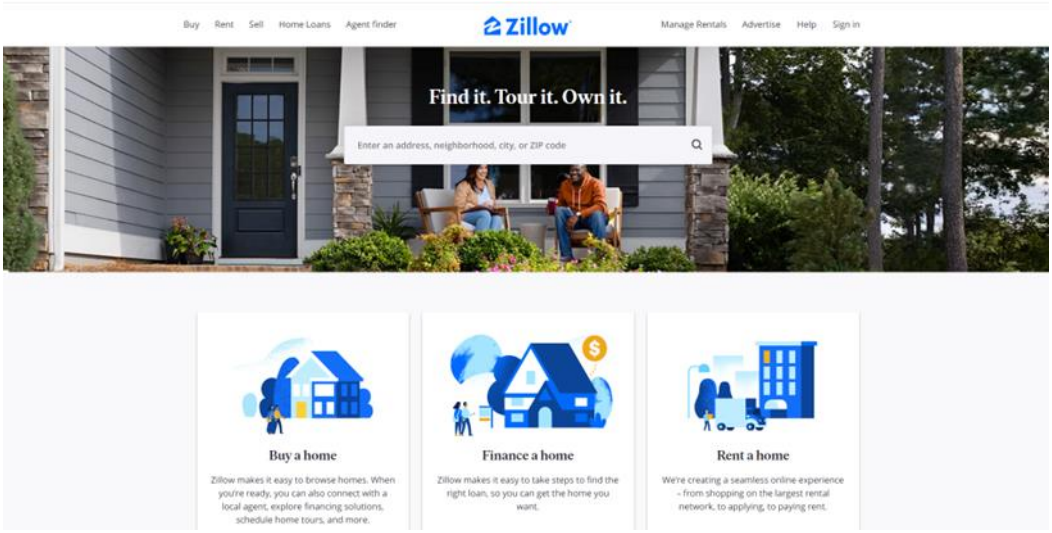
discrepancies and disputes arising from fragmented or inconsistent data sources. Additionally, blockchain enables the tokenization of real estate assets, representing ownership rights through digital tokens. This opens up new opportunities for fractional ownership, liquidity, and investment in the real estate market [16].

Furthermore, Cocco, Singh further allude that blockchain enables the adoption of smart contracts, optimizing contract formulation and negotiation [18]. Through a consensus service, transaction ordering and immutability mechanisms are ensured, while a membership service enhances auditability and accountability in trustless environments. Automating contract execution becomes possible, creating a more efficient and secure real estate ecosystem. This potential adoption of blockchain-based solutions can empower smart city developers, allowing for decentralized asset ownership, trading, and exchange without reliance on central servers [19].

2.2 Related Systems

2.2.1 Zillow

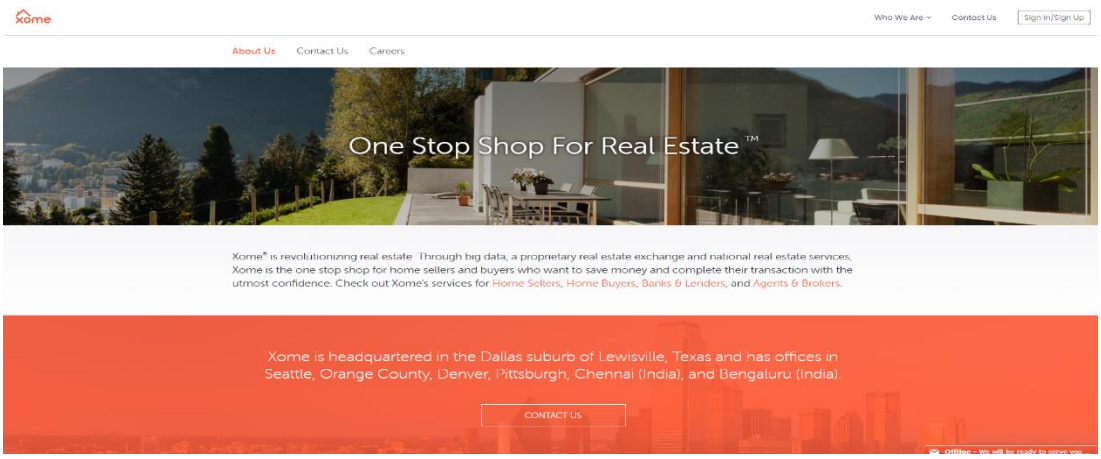
Figure 2. 1 Zillow Real Estate System



Zillow offers the option to list apartments for sale, rent, or lease as well as virtually tour properties and contact agents. Properties on Zillow also can be viewed through video tours and photographs. Users even can receive update notifications about selected properties from the app.

2.2.2 Xome

Figure 2. 2 Xome Real Estate System



Xome® is revolutionizing real estate. Through big data, a proprietary real estate exchange and national real estate services, Xome is the one stop shop for home sellers and buyers who want to save money and complete their transaction with the utmost confidence. It offers Xome's services for Home Sellers, Home Buyers, Banks & Lenders, and Agents & Brokers.

2.3 Conclusion

Existing real estate platforms such as Zillow and Xome provide users with listing options, virtual property tours, and contact with agents. However, these systems store data in centralized locations, making them vulnerable to security breaches. They often require third-party facilitators to ensure transactional trust, resulting in additional costs for users.

The integration of blockchain technology in real estate management systems holds great potential for enhancing security, transparency, and efficiency. By providing secure and transparent record-keeping, blockchain mitigates fraud and manipulation risks. It improves the overall transparency of the real estate market, fostering trust and confidence among stakeholders. Furthermore, blockchain streamlines processes, reduces administrative burdens, and accelerates transaction settlements.

While the benefits of blockchain in real estate management are promising, several challenges need to be addressed, including scalability, interoperability, and data privacy. Additionally, legal and regulatory frameworks must be developed to accommodate the unique characteristics of blockchain-based systems

Chapter Three –Analysis

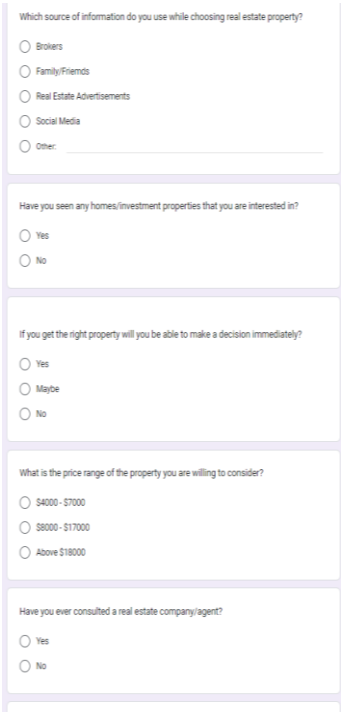
3.1 Information Gathering Tools

The gathering of requirements was done through two major methods, interviews and questionnaires. User stories were also used to get the attitude of customers towards the system and the views of the real estate agents without making them feel pressured to answer.

3.1.1 Questionnaires

These were chosen because they are a fast method of collecting data. They allow people to answer questions anonymously which allows people to feel more open and answer truthfully.

Figure 3. 1 Example of Questionnaire Sheet



3.1.2 Interviews

Interviews were chosen because they allow an in-depth prob of answers from the interviewee. The reaction and body language of the interviewee can be taken into consideration.

Figure 3. 2 Example of Interview Sheet

1. Why are you selling your home?
2. Are you completely committed to selling the home?
3. How many people are involved in the sales decision?
4. How long has the home been on the market?
5. What was the previous selling price?
6. What is included in the sale of the home?

3.2 Description of the system

The current system exhibits weaknesses due to its complex multi-party structure and the frequent movement of data between these entities. It involves four main entities: buyers, sellers, real estate agents, and the council.

3.2.1 Buyers

Buyers are individuals seeking to purchase properties and typically interact with real estate agents. They direct their questions and inquiries to the agents and have limited interaction with the sellers.

3.2.2 Sellers

Sellers are property owners aiming to sell their current properties. They often hire intermediaries to facilitate the sales process on a commission basis.

3.2.3 Real Estate Agents

Real estate agents serve as intermediaries in the real estate industry. They act as the primary channel for data flow and are responsible for assigning properties to buyers and listing properties for sellers.

3.2.4 Council

The council, a governmental entity, oversees the entire system. It allocates land to real estate cooperatives and expects progress in the development of the allocated land.

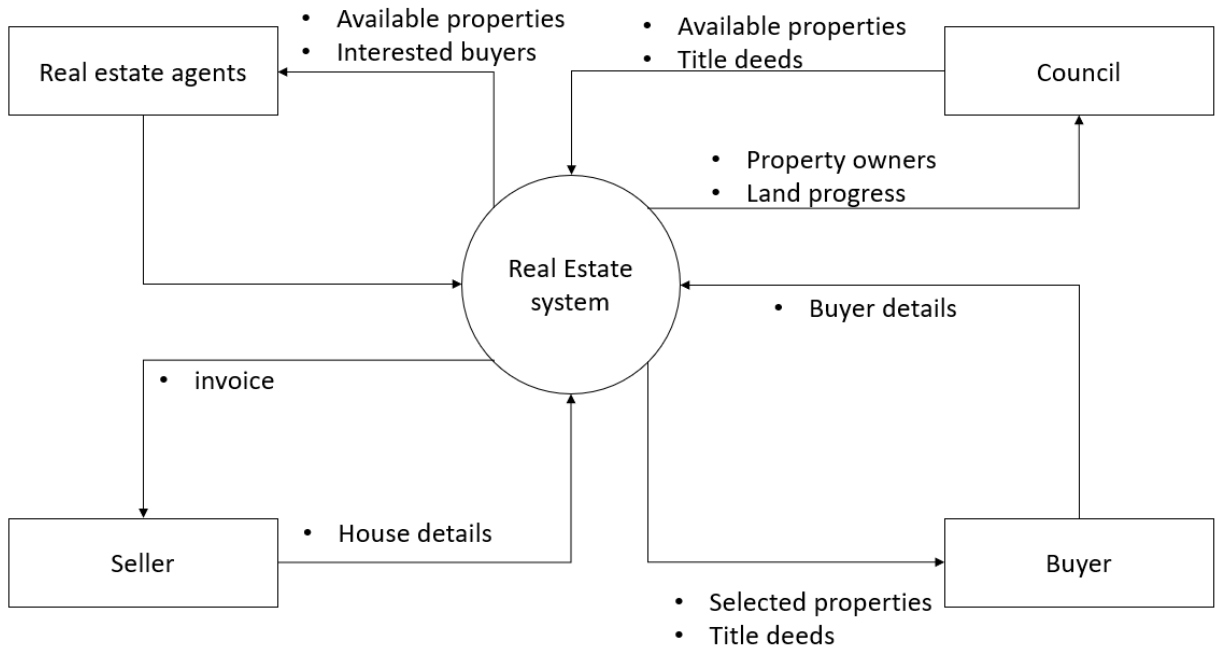
3.2.5 Current Property Purchase Process

In the current process, when a buyer intends to purchase a property, they must approach the real estate agents and pay the necessary fees for their services. They then rely on the agents to inform them about available properties that match their requirements. A payment plan is initiated with an upfront deposit to secure the property. The agents are responsible for allocating stands (plots of land) to all involved parties. Once a certain payment threshold is reached, the agents can show the buyers the specific location of their allocated stand. Each agent manages their own clients, often relying on physical ledgers for communication, which can lead to instances of double allocation of properties.

3.3 Data Analysis

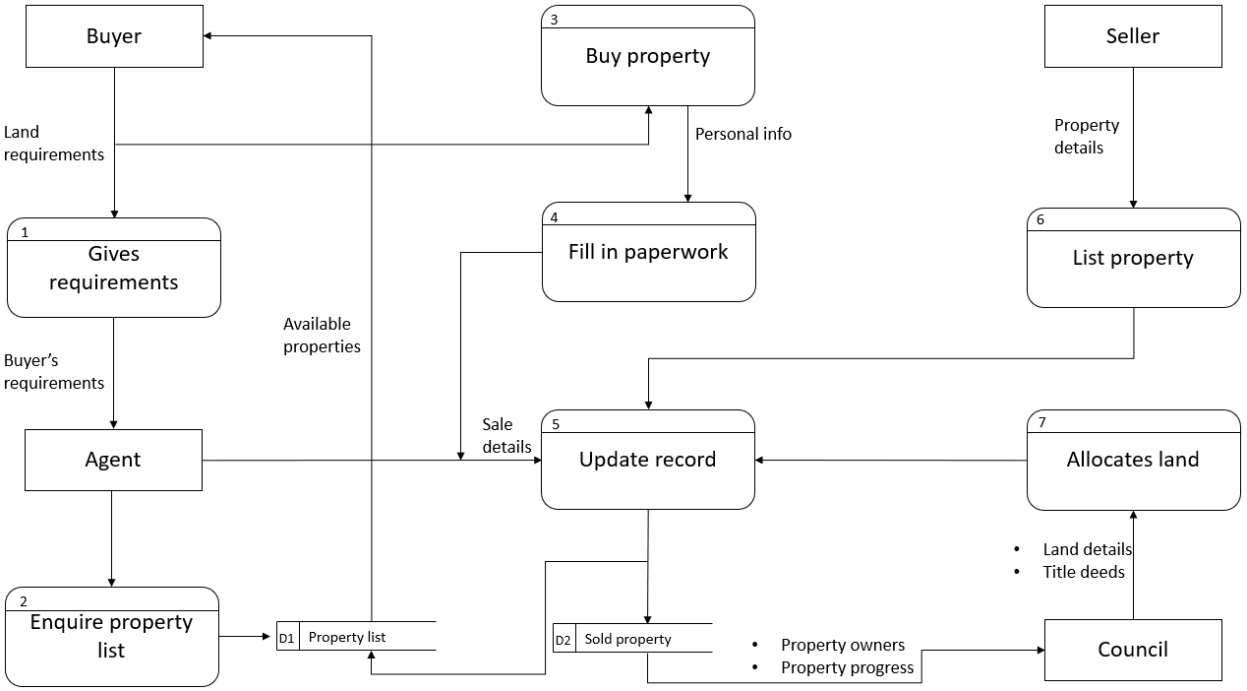
3.3.1 Context Diagrams

Figure 3. 3 Context Diagram of Existing System



3.3.2 DFD of Existing System

Figure 3. 4 Level 1 DFD of Existing System



3.4 Problems of the Existing System

- The current system does not have a secure way of storing data
- The current system is expensive to the customers due to many parties involved
- There is no way to guarantee the integrity of the data stored
- The current system is prone to inconsistency data

3.5 Evaluation of Alternatives Systems

3.5.1 Online Real Estate Marketplaces

Online marketplaces provide a platform where buyers and sellers can directly connect and conduct property transactions. These platforms offer a wide range of property listings, allowing buyers to search for properties based on their specific requirements. Online marketplaces often include features such as virtual property tours, detailed property information, and secure payment gateways, enabling buyers to make informed decisions and complete transactions online. By eliminating the need for physical intermediaries and paperwork, online real estate marketplaces streamline the buying process and provide a convenient and efficient experience for both buyers and sellers.

3.5.2 Digital Land Registries

Digital land registries aim to digitize and centralize land ownership records, making them easily accessible and verifiable. These systems technologies, such as centralized databases, to store land ownership information, including titles, boundaries, and historical transactions. Digital land registries reduce the reliance on physical documents and streamline the process of verifying property ownership, minimizing the risk of disputes and fraudulent activities.

3.6 Functional Analysis of Proposed System

3.6.1 Functional Requirements

1. User Account Management
    - The system should allow users to create accounts.
    - The system should allow users to log in.
2. Property Listing
    - The system should enable sellers to list their properties on the market.
    - The system should provide a user-friendly interface for sellers to input property details, including images, descriptions, and pricing.
3. Property Search and Viewing
    - The system should allow buyers to search and view available properties.
    - The system should provide search filters and sorting options to facilitate efficient property browsing.
    - The system should display property details, including images, descriptions, and historical information.

4. Transaction Management

    - The system should enable buyers to request transactions on properties of interest.
    - The system should facilitate communication between buyers and sellers for negotiation purposes.
    - The system should notify sellers about transaction requests and provide options to accept or reject them.

3.6.2 Non-functional Requirements

1. Data Consistency

    - The system should ensure consistent and reliable data storage and retrieval through the use of blockchain technology.
    - The system should maintain an immutable and transparent transaction history for properties.

2. Security

    - The system should ensure a high level of security due to the immutability nature of blockchain.
    - The system should implement robust authentication and authorization mechanisms to protect user accounts and transactions.
    - The system should employ encryption techniques to secure sensitive data, such as personal information and transaction details.

3. Scalability

    - The system should be capable of accommodating a large number of users and nodes simultaneously.
    - The system should scale efficiently to handle increased user and property data without compromising performance.

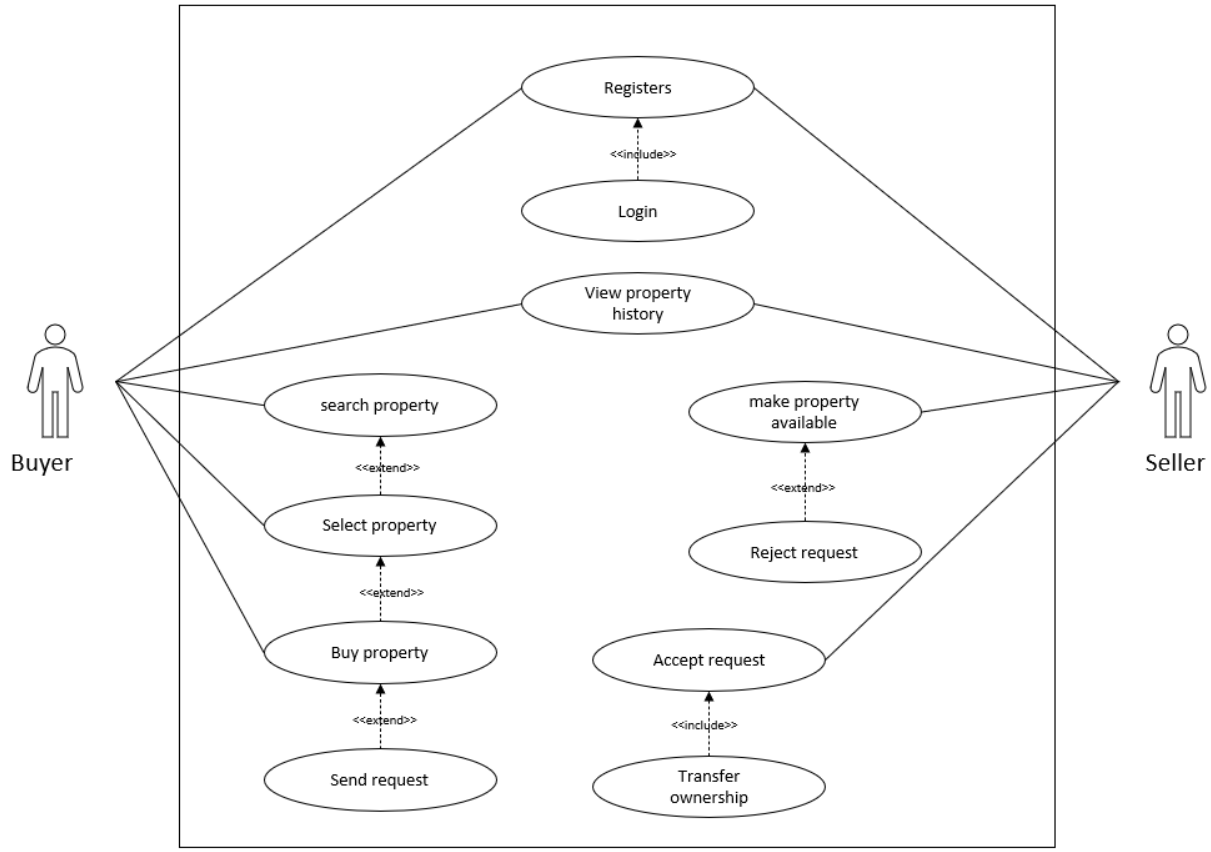
4. Responsiveness

    - The system should provide real-time response and feedback during property transactions, ensuring a smooth and efficient user experience.

- The system should minimize latency and delays in processing transactions and displaying property information.

3.7 User Case Diagram of proposed system

Figure 3. 5 Use Case Diagram proposed system

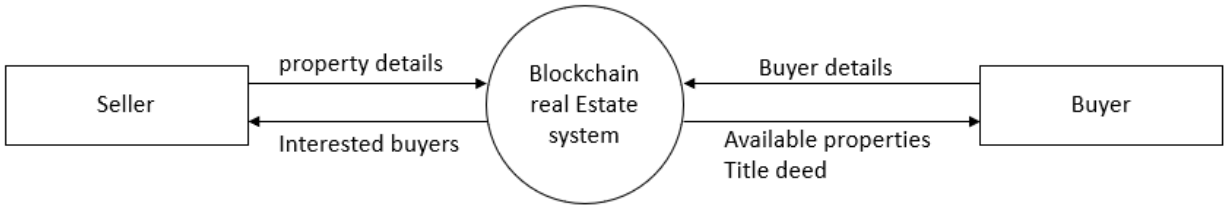


Chapter Four –Design

4.1 Systems Diagrams

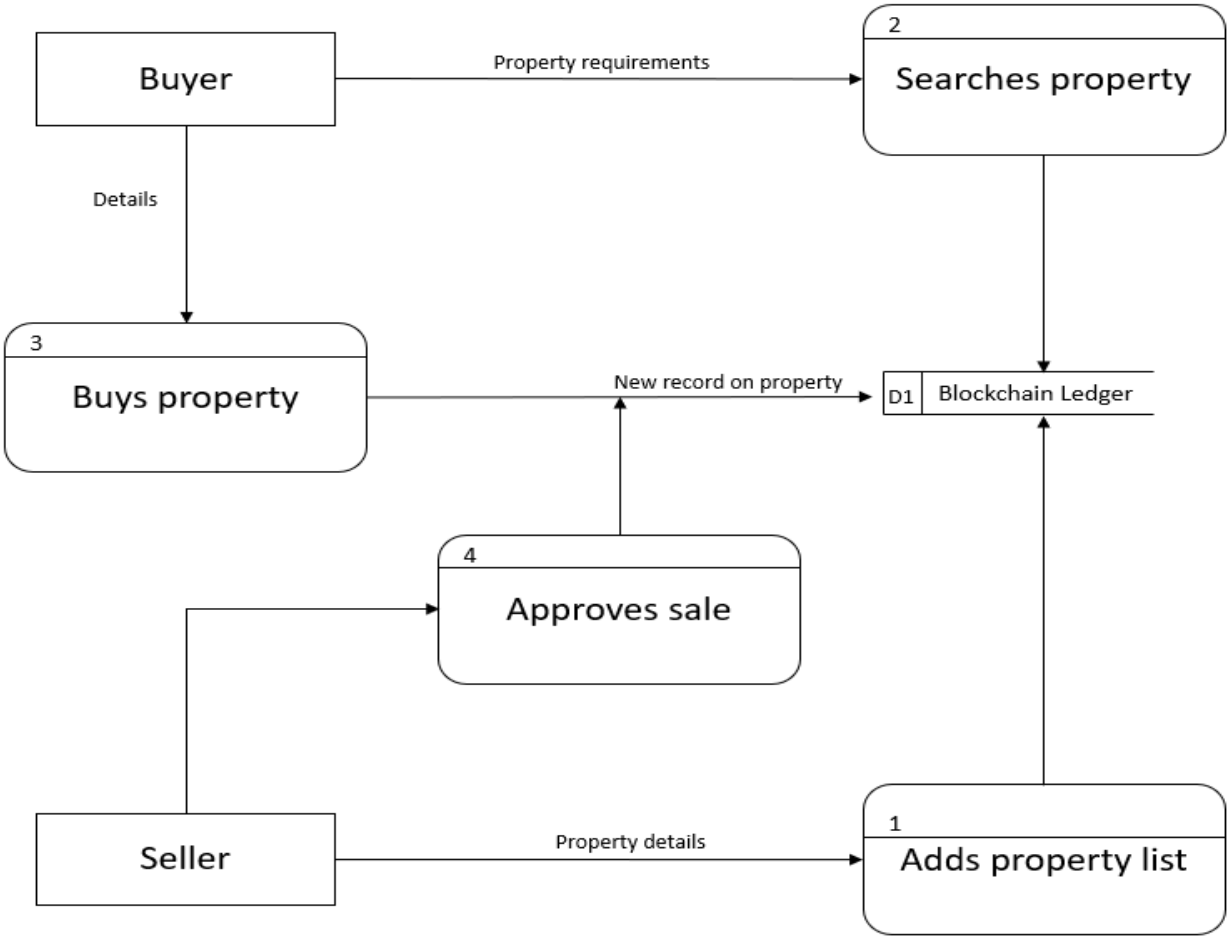
4.1.1 UML Context diagrams

Figure 4. 1 Context Diagram of New System



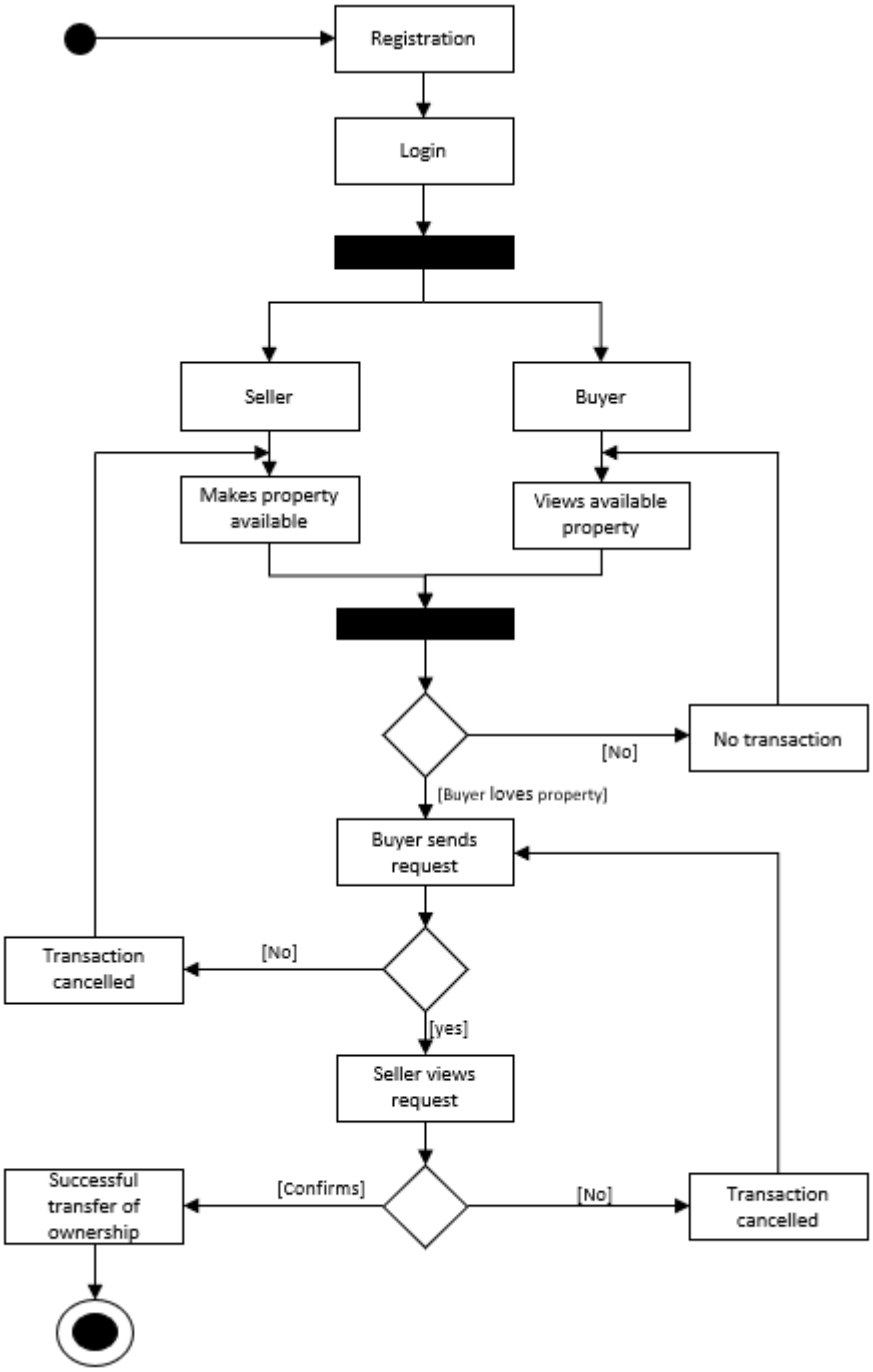
4.1.2 DFD

Figure 4. 2 Level 1 DFD of New System



4.1.3 Activity diagram

Figure 4. 3 Activity Diagram of New System



4.2 Architectural Design

The advantages of a blockchain-based real estate management system are security, immutability, and transparency. A decentralized architecture can be used to construct the system, with each node maintaining a copy of the blockchain and taking part in the consensus process to verify transactions.

4.2.1 Hardware Design

The following hardware elements may be needed to support the blockchain-based real estate management system:

Nodes

The nodes can be any computer, laptop, server, or mobile device that has an internet connection. These nodes have the ability to run a blockchain node software client that participates in the consensus algorithm and keeps a copy of the blockchain.

Storage

To store the blockchain's data, the blockchain-based real estate management system needs a sizable amount of storage capacity. Depending on the anticipated volume of transactions, the system may require storage devices such as hard drives or solid-state drives.

Network

The nodes' communication must be supported by the network infrastructure. Switches, routers, and high-speed internet connections can be needed for the system.

4.2.2 Networking Design

The blockchain-based real estate management system can employ the following networking design:

Peer-to-peer network

The blockchain network is able to be modeled as a peer-to-peer network, in which all nodes are able to communicate with one another directly and without the need for a centralized entity.

Load balancing

The system can employ load balancing strategies to manage a large number of transactions. To prevent overwhelming one node, load balancers can disperse incoming traffic to many nodes.

Network security

It is a requirement for the blockchain-based real estate management system in order to avoid hacking and illegal access. To safeguard the system, methods like intrusion detection systems, firewalls, and encryption network

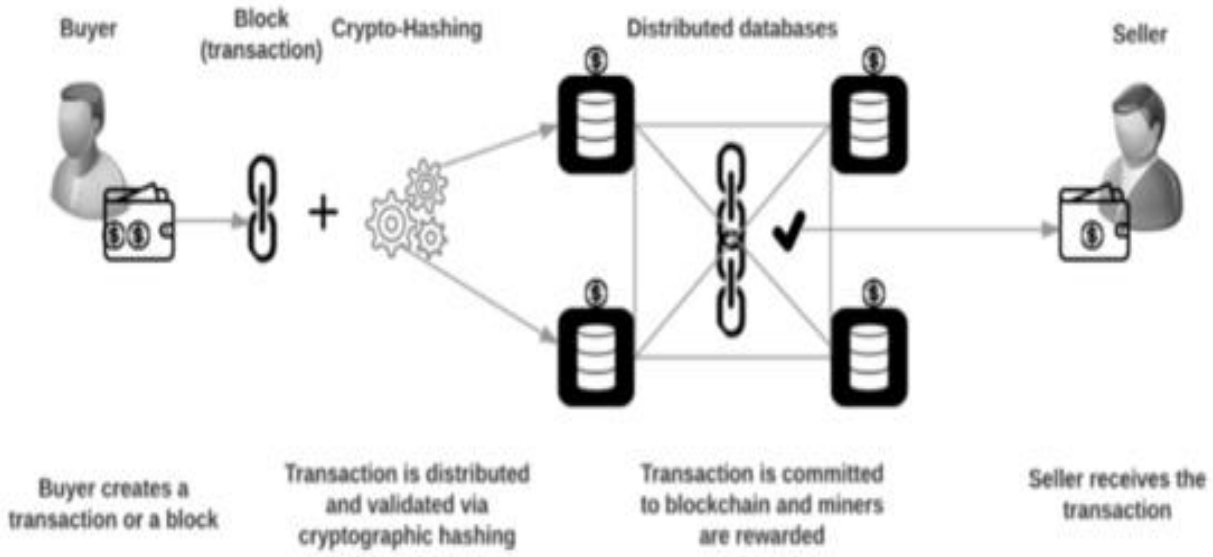
Redundancy

The system may be built with redundancy to provide high availability. To ensure that the system continues to function even in the event that some nodes fail, many nodes can keep a copy of the blockchain.

Hosting in the cloud

Cloud hosting services offer a scalable infrastructure that can accommodate a range of transaction volumes and can be utilized to host the nodes.

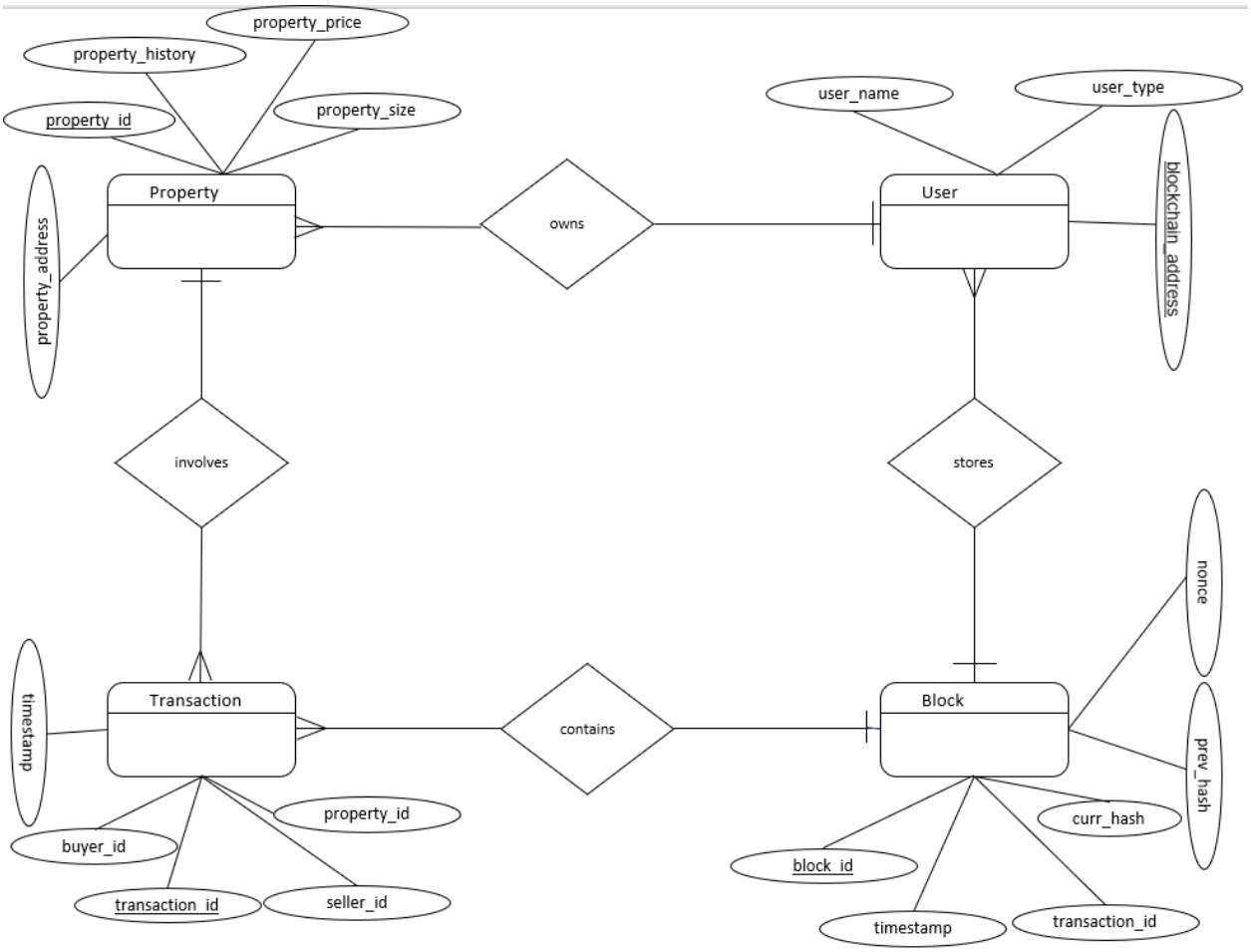
Figure 4. 4 Architectural Design Diagram



4.3 Database Design

4.3.1 ER Diagram

Figure 4. 5 ER Diagram



4.4 Normalized Databases

Property Table

Table 4. 1 Property table

PropertyID	Location	Price	Size
PK			

Owner Table

Table 4. 2 Owner Table

OwnerID	Name	Email	Phone Number
PK			

Property Owner Table

Table 4. 3 Property Owner Table

PropertyID	OwnerID
FK	FK

Transaction Table

Table 4. 4 Transaction Table

TransactionID	PropertyID	BuyerID	SellerID	Timestamp	Price
PK	FK	FK	FK		

Block Table

Table 4. 5 Block Table

BlockID	PreviousBlockID	Timestamp
PK	FK	

Transaction Block Table

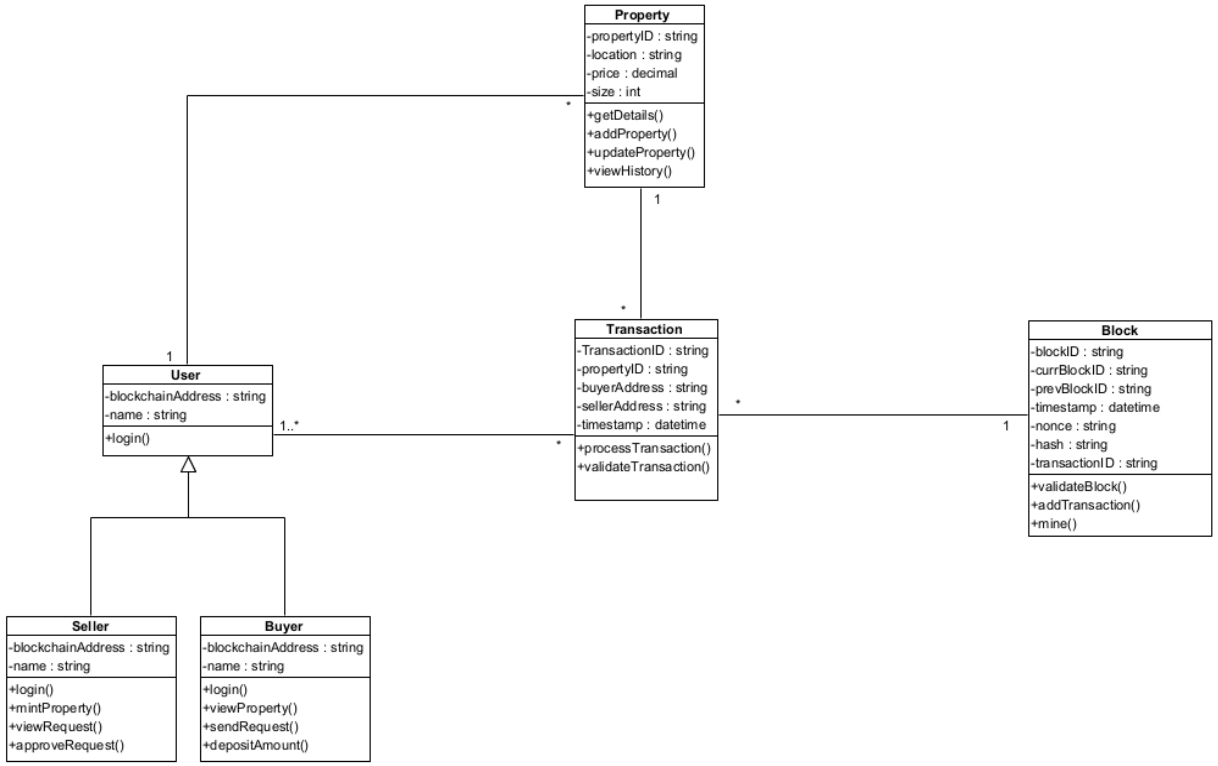
Table 4. 6 Transaction Block Table

TransactionID	BlockID
FK	FK

4.5 Program Design

4.5.1 Class diagrams

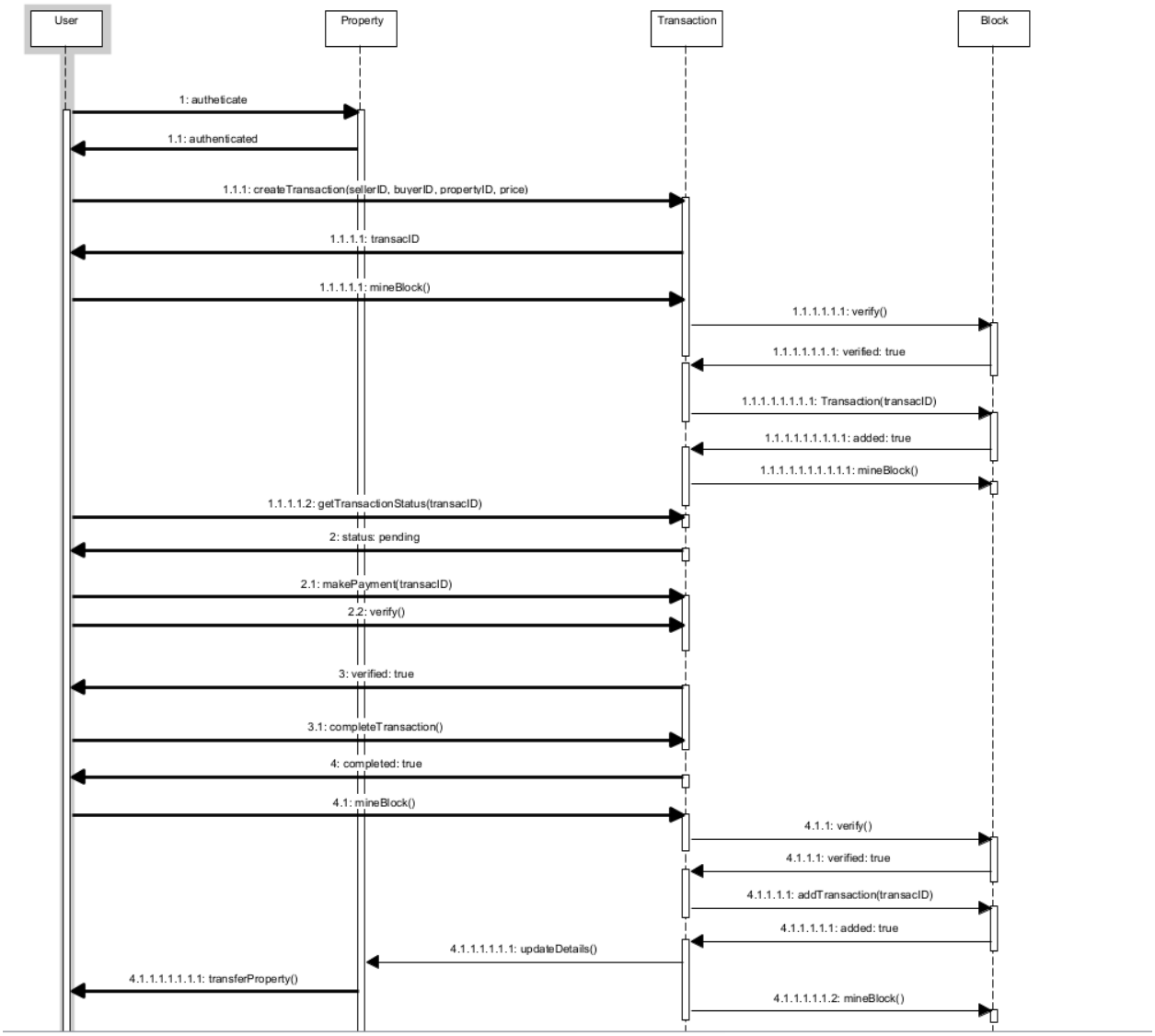
Figure 4. 6 Class Diagram



4.5.2 Sequence diagrams

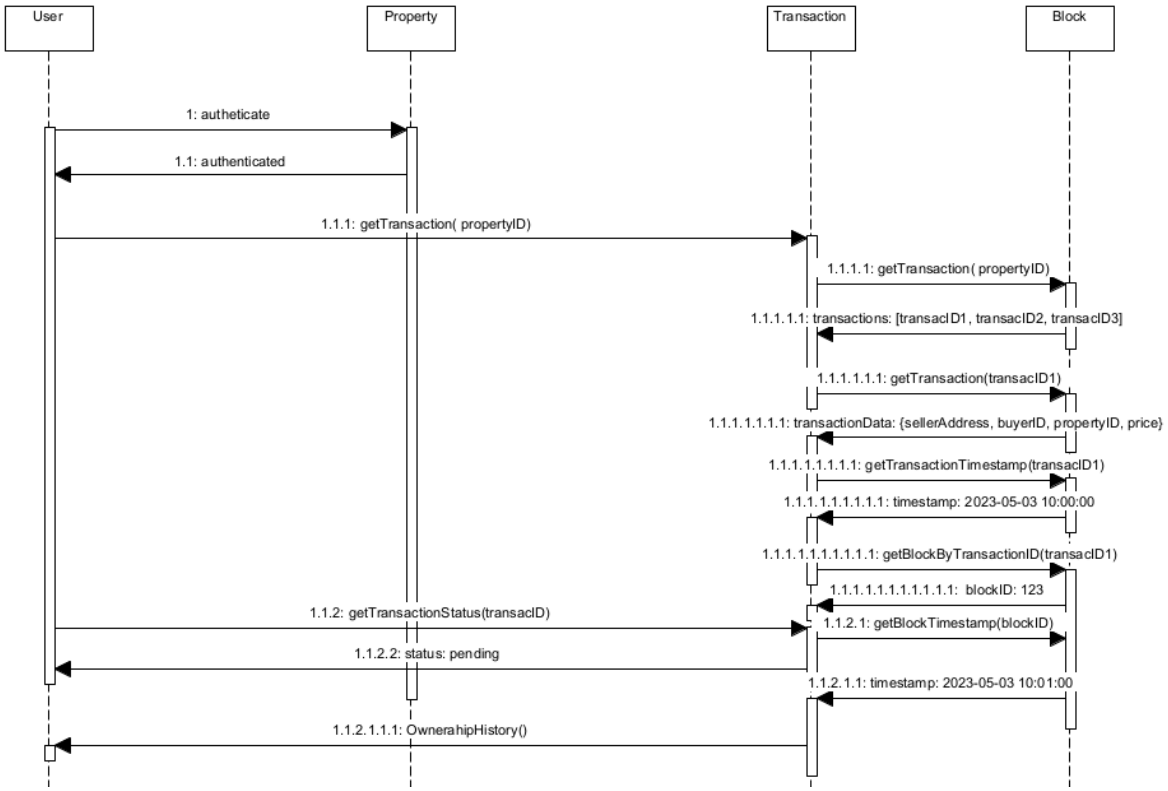
4.5.2.1 Sequence Diagram for buying Property

Figure 4. 7 Sequence Diagram for buying Property



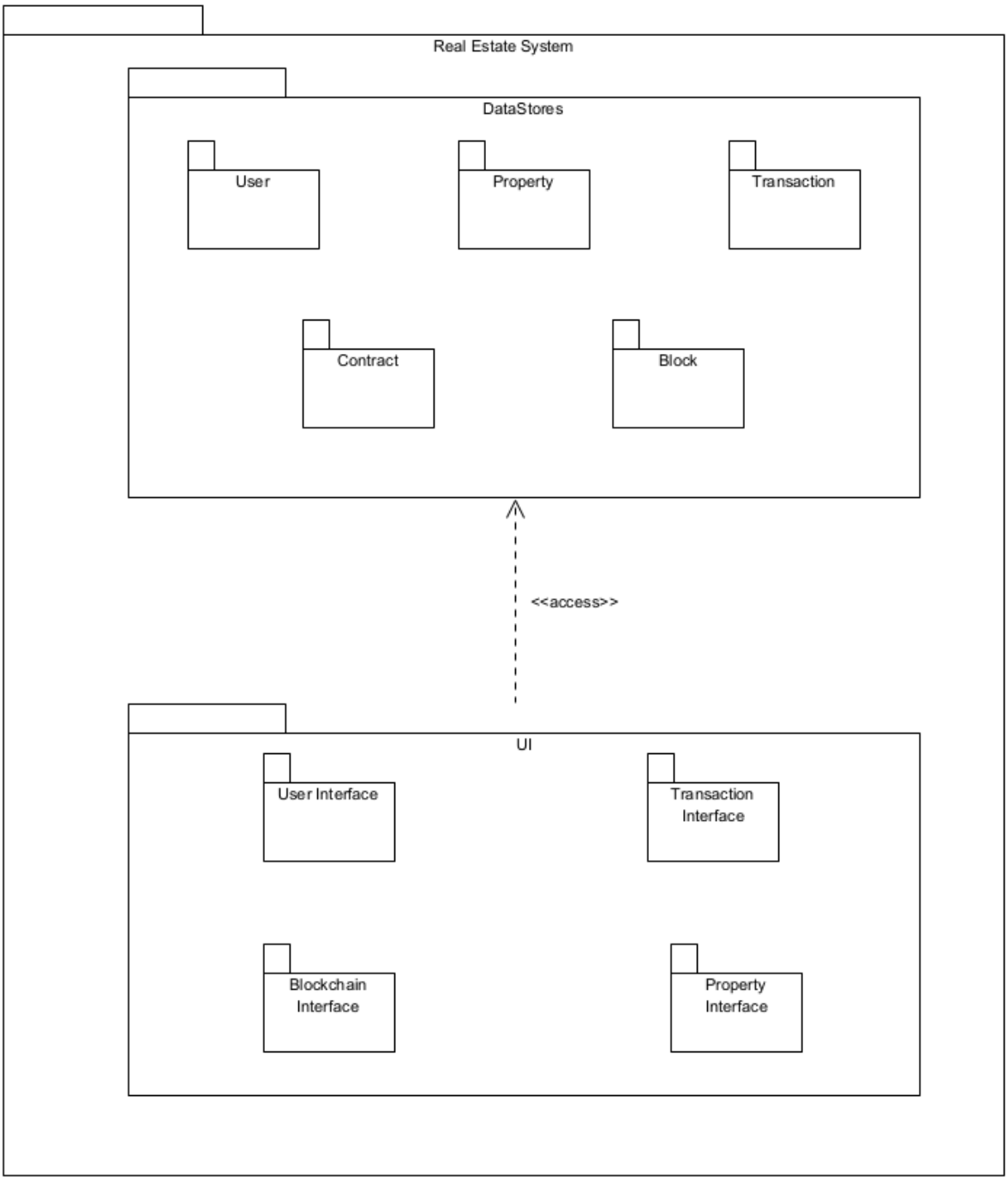
4.5.2.2 Sequence Diagram for viewing ownership history

Figure 4. 8 Sequence Diagram for viewing ownership history



4.5.3 Package diagrams

Figure 4. 9 Package diagrams



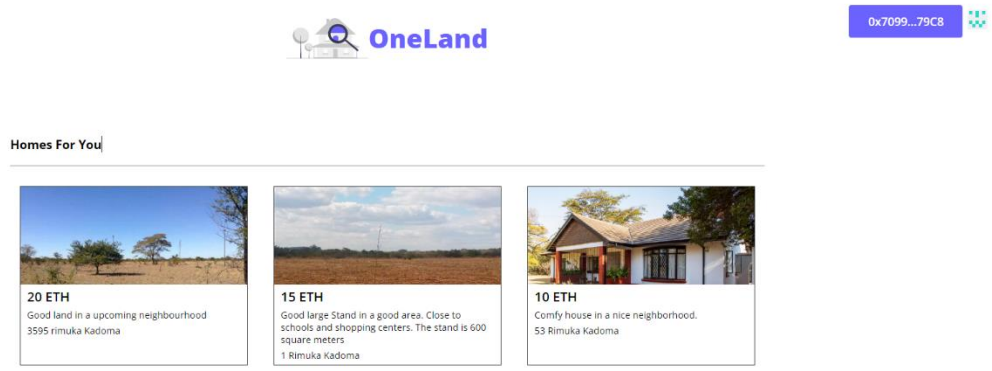
4.5.4 Pseudo code

1. Create a new property:
    a) User enters property details
    b) System creates a new Property object
    c) System adds the Property object to the Blockchain
2. View a property:
    a) User selects a property from the list of properties
    b) System retrieves the Property object from the Blockchain
    c) System displays the property details on the user interface
3. Make an offer on a property:
    a. User enters the offer details
    b. System creates a new Transaction object
    c. System adds the Transaction object to the Blockchain
4. Accept or reject an offer on a property:
    a. Owner selects an offer from the list of offers on a property
    b. System retrieves the Transaction object from the Blockchain
    c. System updates the Transaction object to reflect the acceptance or rejection
    d. System adds the updated Transaction object to the Blockchain
5. View transaction history:
    a. User selects a property from the list of properties
    b. System retrieves all Transaction objects related to the property from the Blockchain
    c. System displays the transaction history on the user interface
6. User login:
    a. User enters login details
    b. System access MetaMask for authentication
    c. System grants or denies access based on the User object's credentials

4.6 Interface Design-Screenshots of user interface

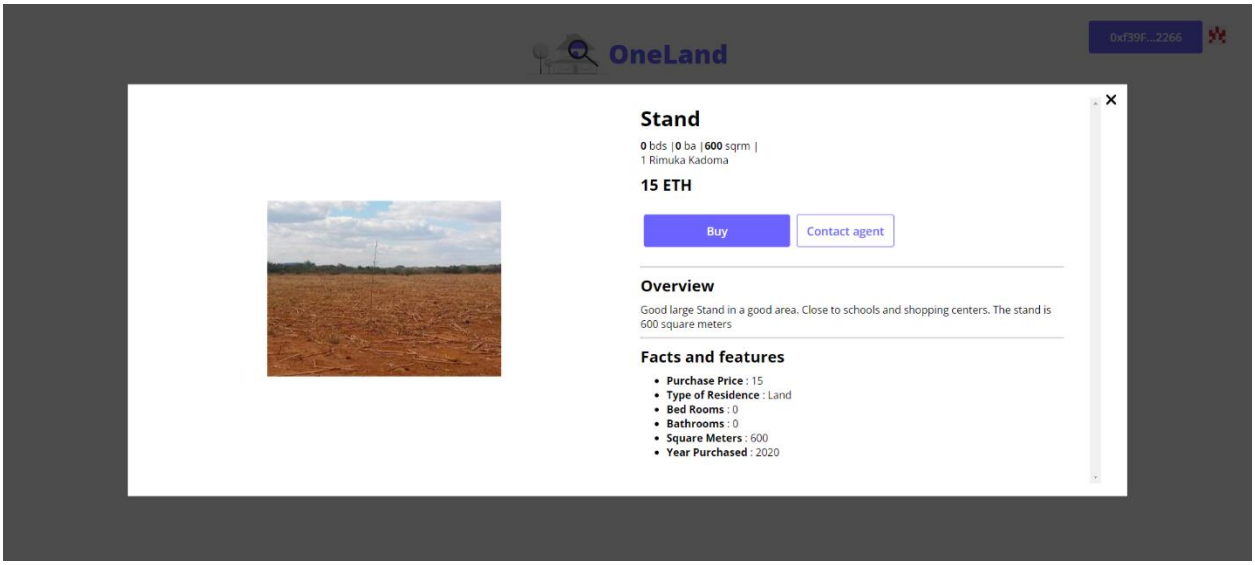
Landing Page

Figure 4. 10 Landing Tab



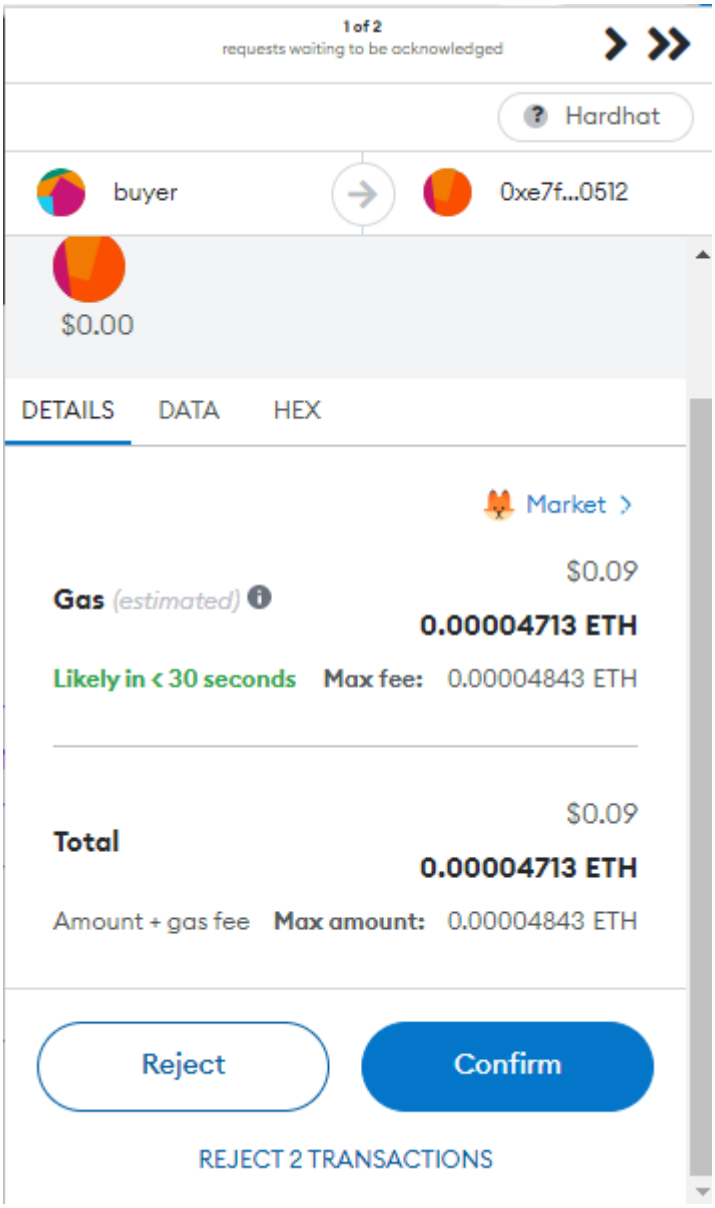
4.6.1 Stand Selection

Figure 4. 11 Stand Selection



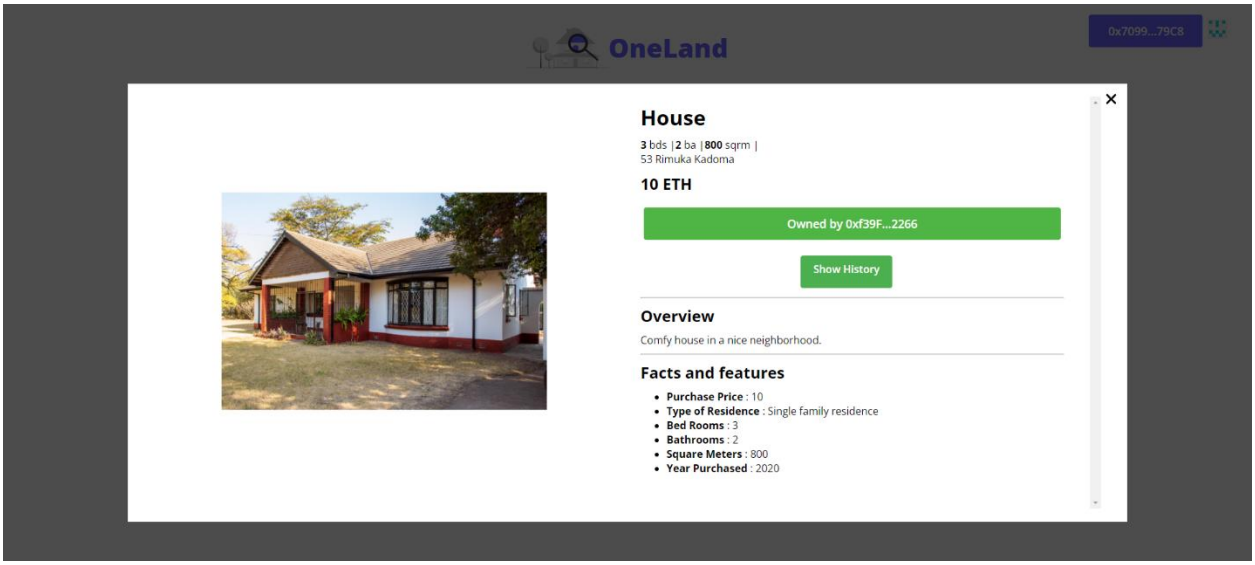
4.6.2 Payment Confirmation

Figure 4. 12 Payment Confirmation



4.6.3 Property Transfer Successful

Figure 4. 13 Property Transfer Successful



4.6.4 Show History

Figure 4. 14 Show History

Chapter Five-Implementation & Testing

5.1 Pseudo code of major modules

5.1.1 Sample code for Escrow smart contract

```
//SPDX-License-Identifier: Unlicense
pragma solidity ^0.8.0;

interface IERC721 {
    function transferFrom(
        address _from,
        address _to,
        uint256 _id
    ) external;
    function ownerOf(uint256 _id) external view returns (address);
}

contract Escrow {
    address public nftAddress;
    address payable public seller;
    address public inspector;
    address public lender;



    modifier onlyBuyer(uint256 _nftID) {
        require(msg.sender == buyer[_nftID], "Only buyer can call this method");
        _;
    }

    modifier onlySeller() {
        require(msg.sender == seller, "Only seller can call this method");
        _;
    }
    mapping(uint256 => bool) public isListed;
    mapping(uint256 => uint256) public purchasePrice;
    mapping(uint256 => uint256) public escrowAmount;
    mapping(uint256 => address) public buyer;
    mapping(uint256 => bool) public inspectionPassed;
    mapping(uint256 => mapping(address => bool)) public approval;
    mapping(uint256 => address[]) public ownershipHistory;
```

```
constructor(
    address _nftAddress,
    address payable _seller,
    address _inspector,
    address _lender
) {
    nftAddress = _nftAddress;
    seller = _seller;
    buyer = _buyer;
}

function list(
    uint256 _nftID,
    address _buyer,
    uint256 _purchasePrice,
    uint256 _escrowAmount
) public payable onlySeller {
    // Transfer NFT from seller to this contract
    IERC721(nftAddress).transferFrom(msg.sender, address(this), _nftID);

    isListed[_nftID] = true;
    purchasePrice[_nftID] = _purchasePrice;
    escrowAmount[_nftID] = _escrowAmount;
    buyer[_nftID] = _buyer;
    ownershipHistory[_nftID].push(msg.sender);

}

// Put Under Contract (only buyer - payable escrow)
function depositEarnest(uint256 _nftID) public payable onlyBuyer(_nftID) {
    require(msg.value >= escrowAmount[_nftID]);
}

// Approve Sale
function approveSale(uint256 _nftID) public {
    approval[_nftID][msg.sender] = true;
}
```

```
    // Finalize Sale
    function finalizeSale(uint256 _nftID) public {
        require(inspectionPassed[_nftID]);
        require(approval[_nftID][buyer[_nftID]]);
        require(approval[_nftID][seller]);
        require(approval[_nftID][lender]);
        require(address(this).balance >= purchasePrice[_nftID]);

        isListed[_nftID] = false;

        (bool success, ) = payable(seller).call{value: address(this).balance}(
            ""
        );
        require(success);
        IERC721(nftAddress).transferFrom(address(this), buyer[_nftID], _nftID);
        ownershipHistory[_nftID].push(buyer[_nftID]);
    }

    // Cancel Sale (handle earnest deposit)
    // -> if inspection status is not approved, then refund, otherwise send to seller
    function cancelSale(uint256 _nftID) public {
        if (inspectionPassed[_nftID] == false) {
            payable(buyer[_nftID]).transfer(address(this).balance);
        } else {
            payable(seller).transfer(address(this).balance);
        }
    }

    function getOwnershipHistory(uint256 _nftID) public view returns (address[] memory) {
        return ownershipHistory[_nftID];
    }

    receive() external payable {}

    function getBalance() public view returns (uint256) {
        return address(this).balance;
    }
}
```

5.1.2 Sample Code for Getting Ownership History

```
import React, { useState, useEffect } from 'react';
import { ethers } from 'ethers';

const OwnershipHistory = ({ contract, nftID }) => {
  const [history, setHistory] = useState([]);

  useEffect(() => {
    const fetchOwnershipHistory = async () => {
      try {
        const ownershipHistory = await contract.getOwnershipHistory(nftID);
        setHistory(ownershipHistory);
      } catch (error) {
        console.error('Error fetching ownership history:', error);
      }
    };

    if (contract && nftID) {
      fetchOwnershipHistory();
    }
  }, [contract, nftID]);

  return (
    <div>
      <h3>Ownership History</h3>
      <ul>
        {history.map((address, index) => (
          <li key={index}>{address}</li>
        ))}
      </ul>
    </div>
  );
};

export default OwnershipHistory;
```

5.2 Software Testing

5.2.1 Unit

Table 5. 1 Unit Tests

Test Case	Expected Result	Status
TestCreateAccount	User account is successfully created.	Success
TestLogin	User is able to login and access the system.	Success
TestPropertyListing	Property is successfully listed on the platform.	Success
TestPropertySearch	Relevant properties matching the search criteria are displayed.	Success
TestTransactionRequest	Transaction request is successfully sent.	Success
TestTransactionApproval	Transaction request is approved by the appropriate parties.	Success
TestTransactionCompletion	Property ownership is transferred to the buyer, and payment is processed.	Success

5.2.2 Module

5.2.2.1 Module: User Management

Table 5. 2 User Management Module Tests

Test Case	Description	Expected Result	Status
TestCreateUser	Test the functionality to create a new user.	User is successfully created in the system.	Success
TestLoginUser	Test the functionality to login with user credentials.	User is able to login and access their account.	Success
TestUpdateUserProfile	Test the functionality to update user profile information.	User profile information is successfully updated.	Success

5.2.2.2 Module: Property Management

Table 5. 3 Property Management Module Tests

Test Case	Description	Expected Result	Status
TestCreateProperty	Test the functionality to create a new property listing.	Property is successfully listed in the system.	Success
TestSearchProperties	Test the functionality to search for properties based on criteria.	Relevant properties matching the search criteria are displayed.	Success
TestUpdateProperty	Test the functionality to update property details.	Property information is successfully updated.	Success
TestTrasferProperty	Test the functionality to transfer a property listing.	Property listing is successfully transferred from seller to buyer.	Success

5.2.2.3 Module: Transaction Management

Table 5. 4 Transaction Management Module Tests

Test Case	Description	Expected Result	Status
TestInitiateTransaction	Test the functionality to initiate a transaction for a property.	Transaction request is successfully sent.	Success
TestApproveTransaction	Test the functionality to approve a transaction request.	Transaction request is approved by the appropriate parties.	Success
TestCompleteTransaction	Test the functionality to complete a transaction.	Property ownership is transferred, and payment is processed.	Success
TestCancelTransaction	Test the functionality to cancel a transaction.	Transaction is successfully canceled.	Success

5.2.3 Integration

5.2.3.1 Integration Test: User Registration and Property Listing

Table 5. 5 User Registration and Property Listing Integration Tests

Test Case Objective	Description	Expected Result	Status
Verify that a user can successfully register in the system, and upon registration, they can list a property without any issues.	Test the integration between the user registration process and the property listing functionality to ensure a seamless user experience.	User successfully registers and lists a property in the system.	Success
Verify that a user can login to the system using valid credentials and successfully view the listed property details, including property images, descriptions, and pricing.	Test the integration between user login functionality and the ability to view listed properties, ensuring smooth navigation and access control.	User is able to login and view the listed property.	Success
Verify that when a user updates their profile information, such as contact details or preferences, the changes reflect accurately in the system. Similarly, when a property's details are updated, such as price or availability, the changes are promptly reflected.	Test the integration between user profile update functionality and property update functionality, validating the synchronization of user and property data.	User successfully updates their profile and property details.	Success

5.2.3.2 Integration Test: Transaction Flow

Table 5. 6 Transaction Flow Integration Tests

Test Case	Description	Expected Result	Status
Verify that when a user initiates a transaction request, such as making an offer to buy a property, the request is properly communicated to the relevant parties, and upon approval, the transaction progresses to the next stage.	Test the integration between initiating a transaction and the approval process, ensuring smooth communication and validation between involved parties.	Transaction request is initiated and approved by the parties involved.	Success
Verify that when a transaction reaches its completion stage, the property ownership is transferred to the buyer, and the payment is processed securely and accurately.	Test the integration to complete a transaction in the system, including the transfer of property ownership and processing of payments.	Property ownership is transferred, and payment is processed successfully.	Success
Verify that a transaction can be successfully canceled, resulting in the property being relisted, and any associated payments or documents are appropriately handled.	Test the integration to cancel a transaction in the system, ensuring that the necessary actions are taken and the system is updated accordingly.	Transaction is successfully canceled and the property is relisted.	Success

5.2.3.3 Integration Test: Blockchain Network

Table 5. 7 Blockchain Network Integration Tests

Objective	Test Case Description	Expected Outcome	Result
Verify that when a property is listed or updated in the property module, the corresponding data is accurately stored in the blockchain module, maintaining data consistency.	Test the integration between the property module and the blockchain module to ensure seamless communication and data synchronization.	Property is listed successfully and data is updated.	Success
Verify that when a transaction is initiated, processed, or completed in the transaction module, the relevant details are securely recorded in the blockchain module, ensuring transparency and integrity.	Test the integration between the transaction module and the blockchain module to validate the flow of transaction data and its immutability.	Transaction is successfully completed and transactions details are stored on the blockchain	Success
Verify that when a user registers, updates their profile, or performs any user-related actions in the user module, the corresponding data is accurately stored in the blockchain module, maintaining user identity and data integrity.	Test the integration between the user module and the blockchain module, ensuring secure user registration and management of user-related data.	User details are successfully stored on the blockchain	Success

5.2.4 System

5.2.4.1 Black Box Testing:

- Test 1: Verify that users can create accounts and successfully log in.
- Test 2: Ensure that buyers can view available properties and request transactions.
- Test 3: Validate that sellers can list their properties and approve/reject transaction requests.
- Test 4: Confirm that property history can be accessed and viewed by authorized users.
- Test 5: Test the integration between the property module and the blockchain module.
- Test 6: Test the integration between the transaction module and the blockchain module.
- Test 7: Test the integration between the user module and the blockchain module.

5.2.4.2 White Box Testing:

- Test 8: Verify the correctness of the smart contracts and their interaction with the blockchain network.
- Test 9: Validate the data storage and retrieval mechanisms within the blockchain-based system.
- Test 10: Test the internal algorithms and processes for property allocation and transaction management.

5.2.4.3 Functional Testing:

- Test 11: Ensure that all functional requirements related to user account management are met.
- Test 12: Validate the proper functioning of property listing, viewing, and transaction processes.
- Test 13: Test the accuracy and reliability of property history tracking and auditing mechanisms.

- Test 14: Verify the integration and interoperability of different system modules.

5.2.4.4 Non-functional Testing:

- Test 15: Measure the system's performance in handling a large number of users and transactions simultaneously.
- Test 16: Validate the system's security measures, including encryption, access control, and data privacy.
- Test 17: Verify the system's fault tolerance and resilience to ensure data integrity and availability.
- Test 18: Evaluate the system's usability and user experience to ensure it is intuitive and efficient.

Table 5. 8 System Tests

Domain	Expected Result	Actual Result
Black Box Testing	The system should be able to receive user input and provide the intended outcome.	As expected
White Box Testing	The system's internal components and logic should function correctly.	As expected
Functional Testing	The system components should work as planned and generate the required results. Every functional requirement must be satisfied.	As expected
Non-functional Testing	Non-functional requirements have all been satisfied. The system is safe and effective.	As expected

5.2.5 Database

Table 5. 9 Database Tests

Test Case ID	Test Case Objective	Expected Result	Actual Result
DBT-001	Test the connection to the database	Successful connection to the database	Success
DBT-002	Test the creation of user accounts table	User accounts table is successfully created	Success
DBT-003	Test the insertion of user account data into the user accounts table	User account data is inserted into the user accounts table	Success
DBT-004	Test the retrieval of user account data from the user accounts table	User account data is successfully retrieved	Success
DBT-005	Test the updating of user account data in the user accounts table	User account data is updated in the user accounts table	Success
DBT-006	Test the deletion of user account data from the user accounts table	User account data is successfully deleted	Success
DBT-007	Test the creation of property table	Property table is successfully created	Success
DBT-008	Test the insertion of property data into the property table	Property data is inserted into the property table	Success
DBT-009	Test the retrieval of property data from the property table	Property data is successfully retrieved	Success
DBT-010	Test the updating of property data in the property table	Property data is updated in the property table	Success

5.2.6 Acceptance

Table 5. 10 Acceptance Tests

Objective	Test	Comment	Result
To facilitate the buying and selling of land assets	Test the functionality of property listing and search	Verify that users can list their properties for sale and buyers can search for available properties.	Pass
To create a distributed ledger that enhances the security and transparency of real estate transactions	Test the blockchain integration and data immutability	Ensure that the system successfully integrates with a blockchain network and that the recorded data remains immutable.	Pass
To streamline real estate transactions and reduce the need for intermediaries	Test the transaction process without intermediaries	Verify that buyers and sellers can directly interact and complete transactions without the involvement of intermediaries.	Pass
To create an unmodifiable history of all the transactions on a land asset	Test the transaction history retrieval	Validate that the system can retrieve the complete transaction history of a land asset and that it cannot be modified.	Pass
To enable the minting of currently owned land assets	Test the minting functionality	Check that users can successfully mint their currently owned land assets on the blockchain.	Pass
To reduce costs associated with manual tasks and human involvement	Test the automation of processes using smart contracts	Ensure that processes such as payment verification, contract execution, and property transfer are automated through smart contracts, reducing the need for manual intervention.	Pass

Chapter Six –Conclusions and Recommendations

6.1 Results and summary

In summary, the implementation of a real estate management system using blockchain technology provides a secure and efficient way of managing real estate assets. The system provides transparency and immutability to the transactions, which promotes trust among the stakeholders involved in the real estate industry. The blockchain technology eliminates the need for intermediaries such as brokers and lawyers, reducing the cost of transactions and speeding up the process of buying and selling real estate properties.

The implementation of the real estate management system using blockchain technology resulted in a more streamlined and efficient process. The smart contracts implemented on the blockchain provide automation, reducing the need for manual intervention, which saves time and resources. The use of a decentralized ledger ensures that all the transactions are recorded in a tamper-proof manner, which promotes transparency and eliminates the possibility of fraudulent activities

6.2 Recommendations & Future Works

6.2.1 Recommendations

To improve the real estate management system using blockchain technology, the following recommendations are suggested:

1. Integration with existing systems: The real estate management system should be integrated with existing systems such as property listing websites and property management software. This integration will allow for more efficient and effective management of real estate properties.
2. User-friendly interface: The real estate management system should have a user-friendly interface that is easy to navigate. This will ensure that users can easily access and use the system, promoting its adoption.
3. Scalability: The system should be scalable to accommodate an increasing number of transactions as the real estate industry grows.
4. Education and training: Education and training should be provided to stakeholders to promote the adoption and use of the real estate management system.

6.2.2 Future Works

The real estate industry is constantly evolving, and there is a need to keep up with the latest trends and technologies to remain competitive. Future works on the real estate management system using blockchain technology include:

1. Integration with AI and IoT: The integration of artificial intelligence (AI) and the internet of things (IoT) will enhance the capabilities of the real estate management system. The integration will allow for the automation of property management tasks and the collection of real-time data.
2. Blockchain interoperability: The interoperability of blockchain networks will allow for the exchange of information and assets between different blockchain networks, promoting the growth and adoption of the real estate management system.
3. Tokenization of real estate assets: The tokenization of real estate assets will allow for the fractional ownership of properties, promoting accessibility and affordability.
4. Integration with DeFi: The integration of decentralized finance (DeFi) will provide more financial opportunities and flexibility to the stakeholders in the real estate industry.

In conclusion, the implementation of a real estate management system using blockchain technology provides a secure and efficient way of managing real estate assets. The system provides transparency and immutability to the transactions, which promotes trust among the stakeholders involved in the real estate industry. The system can be improved by integrating it with existing systems, providing a user-friendly interface, ensuring scalability, and providing education and training to stakeholders. The future works on the real estate management system include the integration with AI and IoT, blockchain interoperability, tokenization of real estate assets, and integration with DeFi.

Bibliography

7.1 References

1. Thota, S., 2019. Blockchain for Real Estate Industry. *The Journal of Social Sciences Research*, (52), pp.53-56.

2. Paulavicˇius, R.; Grigaitis, S.; Igumenov, A.; Filatovas, E. *A decade of blockchain: Review of the current status, challenges, and future directions. Informatica* ***2019****, 30,* 729–748.

3. S. Ølnes and A. Jansen, *"Blockchain technology as support infrastructure in e-government," in Lecture Notes in Computer Science*, vol. 10428. Cham: Springer, 2017.

4. Ahmad, I., A. Alqarni, M., Ali Almazroi, A. and Alam, L., 2021. *Real Estate Management via a Decentralized Blockchain Platform.* Computers, Materials & Continua, 66(2), pp.1813-1822

5. W. Gräther, S. Kolvenbach, R. Ruland, J. Schütte, C. Torres et al., *"Blockchain for education: lifelong learning passport," in Proc. 1st ERCIM Blockchain Workshop 2018,* Amsterdam, Netherlands: European Society for Socially Embedded Technologies, pp. 1–8, 2018

6. FIBREE. *Global Industry Report "Blockchain Real Estate";* FIBREE: Vienna, Austria, 2020.

7. Belotti, M.; Božic´, N.; Pujolle, G.; Secci, S. *A vademecum on blockchain technologies: When, which, and how*. IEEE Commun. Surv. Tutor. **2019**, 21, 3796–3838.

8. Singh, S.K.; Sharma, P.K.; Pan, Y.; Park, J.H. *BIIoVT: Blockchain-based secure storage architecture for intelligent internet of vehicular things*. IEEE Consum. Electron. Mag. **2021**.

9. Graglia, J.M.; Mellon, C. *Blockchain and property in 2018: At the end of the beginning.* Innov. Technol. Gov. Glob. **2018**, 12, 90–116.

10. Cha, J.; Singh, S.K.; Pan, Y.; Park, J.H. *Blockchain-based cyber threat intelligence system architecture for sustainable computing. Sustainability* ***2020****, 12,* 6401.

11. Veuger, J. *Dutch blockchain, real estate and land registration.* J. Prop. Plan. Environ. Law **2020**, 12, 93–108.

12. Li, J.; Greenwood, D.; Kassem, M. *Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. Autom. Constr.* ***2019****, 102*, 288–307.

13. Davies, E.; Kirby, N.; Bond, J.; Grogan, T.; Moore, A.; Roche, N.; Rose, A.; Tasca, P.; Vadgama, N. *Towards a Distributed Ledger of Residential Title Deeds in the UK*; University College London: London, UK, 2020.

14. Androulaki, E.; Barger, A.; Bortnikov, V.; Cachin, C.; Christidis, K.; De Caro, A.; Enyeart, D.; Ferris, C.; Laventman, G.; Manevich, Y. *Hyperledger fabric: A distributed operating system for permissioned blockchains. In Proceedings of the 13th EuroSys Conference*, Porto, Portugal, 23–26 April 2018; pp. 1–15.

15. Hyperledger. *Hyperledger Fabric*. Available online: https://hyperledger-fabric.readthedocs.io/en/release-2.0/whatis.html (accessed on 26 June 2020).

16. Cocco, S.; Singh, G. *Top 6 Technical Advantages of Hyperledger Fabric for Blockchain Networks*. Available online: https://developer.ibm.com/technologies/blockchain/articles/top-technical-advantages-of-hyperledger-fabric-for-blockchain- networks/ (accessed on 28 July 2020).

17. Nawari, N.O. *Blockchain technologies: Hyperledger fabric in BIM work processes. In Proceedings of the International Conference on Computing in Civil and Building Engineering*, Melbourne, VIC, Australia, 3–4 February 2020; pp. 813–823.

18. Lemieux, V.L. *Blockchain and distributed ledgers as trusted recordkeeping systems. In Proceedings of the Future Technologies Conference (FTC)*, Vancouver, BC, Canada, 29–30 November 2017.

19. Thakur, V.; Doja, M.; Dwivedi, Y.K.; Ahmad, T.; Khadanga, G. *Land records on blockchain for implementation of land titling in India*. Int. J. Inf. Manag. 2020, 52, 101940.

7.2 Appendices

7.2.1 Templates of Data Collection Tools

7.2.1.1 Questionnaire for Blockchain-Based Real Estate Management System

Age:.....

.....

Gender:.....

Occupation:.....

Location: :.....

1. What are your primary concerns or challenges when it comes to buying or selling real estate?

   .....
   .....
   .....
   .....

2. Have you ever encountered any issues related to the authenticity or security of property ownership records?

   - ○ Yes
   - ○ No

3. If yes, please provide details.

   .....
   .....
   .....
   .....

4. How important is it for you to have a transparent and trustworthy system for real estate transactions?

   .....
   .....
   .....
   .....
   .....

5. Are you aware of any instances of real estate fraud or double sales within your professional network or local real estate market?

   .....
   .....
   .....
   .....

6. How confident are you in the current methods used for verifying property ownership and conducting real estate transactions?

.....
.....
.....
.....

7. Would you prefer a system that eliminates the need for intermediaries (such as brokers or agents) in real estate transactions? Why or why not?

.....
.....
.....
.....

8. Are you familiar with blockchain technology?

   ○ Yes
   ○ No

9. If yes, please briefly describe your understanding of blockchain technology:

.....
.....
.....
.....

10. How would you feel about having a tamper-proof and decentralized ledger that securely stores property ownership records?

.....
.....
.....
.....

11. What are your expectations regarding the speed and efficiency of real estate transactions?

.....
.....
.....
.....

12. Are you open to using digital platforms or tools for managing and conducting real estate transactions?

.....
.....
.....
.....

13. What concerns, if any, do you have about adopting a blockchain-based real estate management system?

.....
.....

14. How important is it for you to have access to a detailed transaction history for a property, including previous sales, ownership transfers, and any encumbrances?

15. Do you believe that implementing blockchain technology in real estate management could help reduce fraud and improve overall trust in the industry? Why or why not?

16. Would you be willing to provide feedback and actively participate in the testing and development of a blockchain-based real estate management system?

17. Are there any specific features or functionalities you would like to see in a blockchain-based real estate management system?

18. How comfortable are you with using digital wallets or cryptocurrency for real estate transactions?

19. Is there anything else you would like to share or any additional questions or concerns you have regarding blockchain technology in real estate management?

7.2.1.2 Interview Questions for Blockchain-Based Real Estate Management System

Name:.....

Age:.....

Gender:.....

Occupation:.....

Location:.....

1. Can you briefly explain your experience and background in the real estate industry?
2. Are you familiar with blockchain technology and its potential applications in various industries, including real estate?
3. From your perspective, what are the biggest challenges or pain points in real estate management that you've encountered?
4. Have you heard about blockchain being used in real estate management before? If yes, what do you think are the potential benefits it can bring to the industry?
5. In your opinion, how can blockchain technology improve transparency and trust in real estate transactions and property management?
6. How do you think a blockchain-based real estate management system can enhance the security and integrity of property records and ownership information?
7. Do you believe blockchain technology can simplify and expedite processes like property transfers, lease agreements, or property valuations? Why or why not?
8. Considering the involvement of various stakeholders in real estate transactions, such as buyers, sellers, agents, and legal entities, how do you think a blockchain-based system can streamline communication and collaboration among them?

9. How important is data privacy and security in real estate management, and what measures do you think should be in place when implementing a blockchain-based system to address these concerns?
10. In your opinion, what would be the potential benefits for non-technical users or stakeholders in adopting a blockchain-based real estate management system?
11. What challenges or obstacles do you foresee in the adoption and implementation of a blockchain-based system in the real estate industry, particularly from a non-technical perspective?
12. How would you approach training and support for users who may not be familiar with blockchain technology when transitioning to a blockchain-based real estate management system?
13. What key metrics or indicators would you use to measure the success and effectiveness of a blockchain-based real estate management system?
14. Are there any specific features or functionalities you would expect from a blockchain-based system to make it user-friendly and accessible for non-technical users?
15. Is there anything else you would like to add or any recommendations you have regarding the development and implementation of a blockchain-based real estate management system for non-technical users?

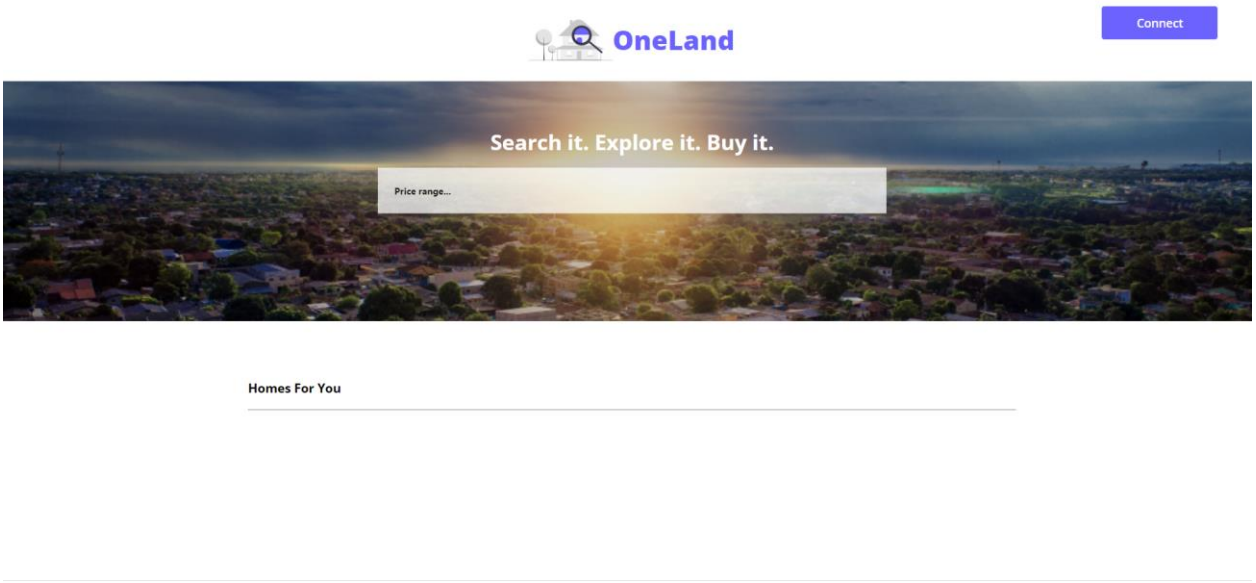
7.2.2 User Manual Of The Working System

7.2.2.1 Introduction

This user manual provides a step-by-step guide on how to use the blockchain-based real estate management system. The system provides users with the ability to manage and transfer real estate properties securely using blockchain technology. The system offers a user-friendly interface that makes it easy for users to navigate through the different features. The following interfaces are available:

7.2.2.2 Landing Page

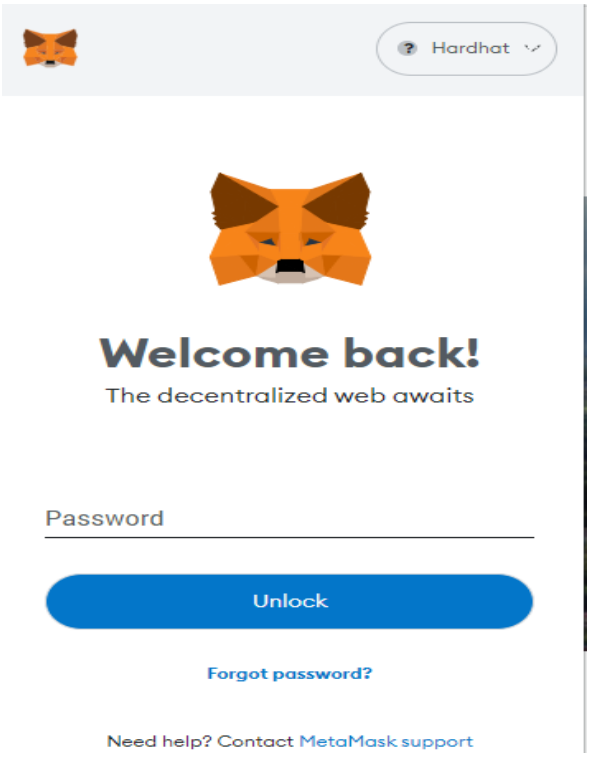
The landing page is the first page that users see when they access the system. The page provides users with a brief overview of the system's features and options to navigate to different parts of the system.



7.2.2.3 Login into MetaMask

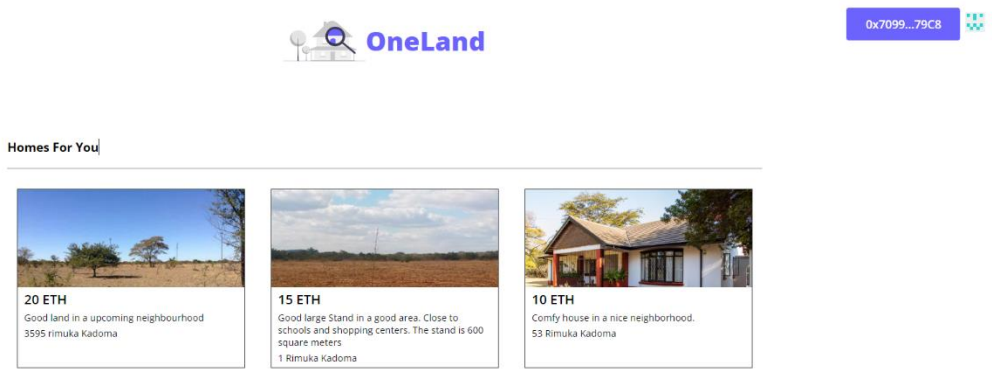
MetaMask is a browser extension that enables users to interact with blockchain networks. The blockchain-based real estate management system uses MetaMask to connect users to the Ethereum blockchain network. Here are the steps to log in:

- Click “Connect” to log into the MetaMask wallet
- Ensure that you have sufficient ETH balance in your MetaMask account to pay for transactions on the Ethereum network.
- Enter valid details and login



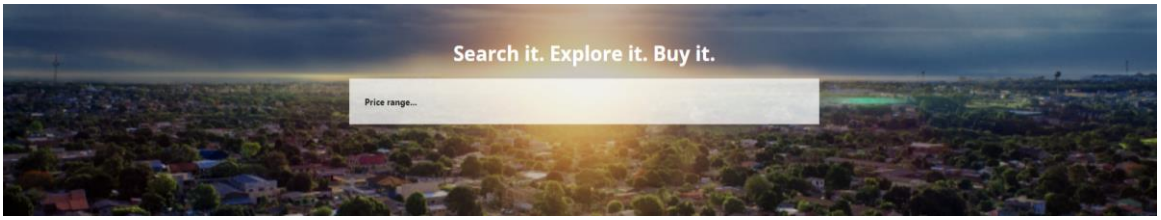
7.2.2.4 Home Page

Once logged in the list of properties available will be displayed



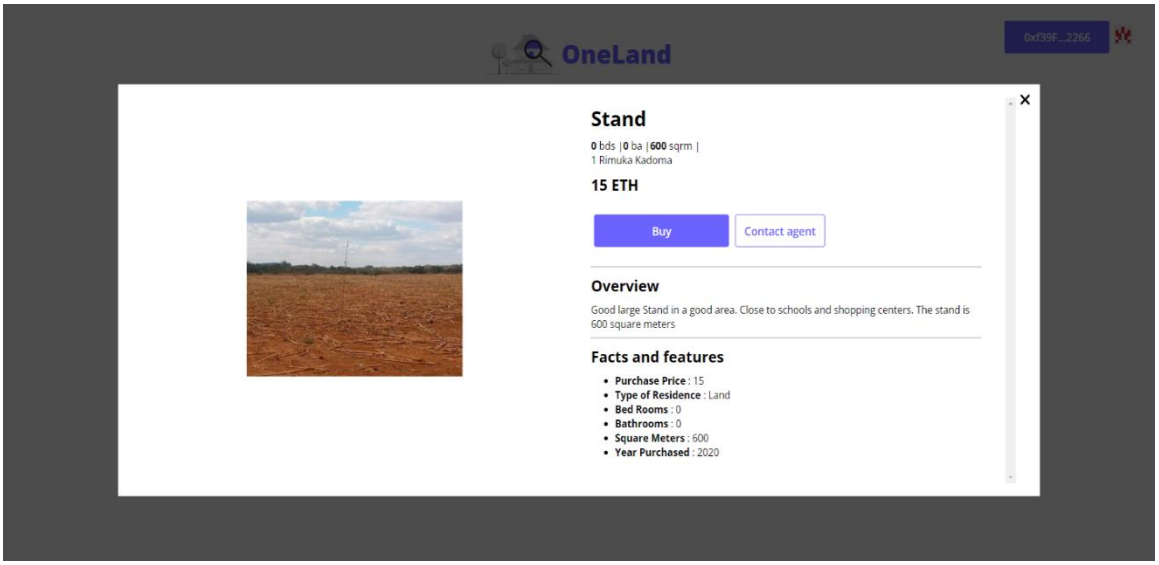
7.2.2.5 Search Feature

The search feature enables users to search for real estate properties listed on the system based on the price range.



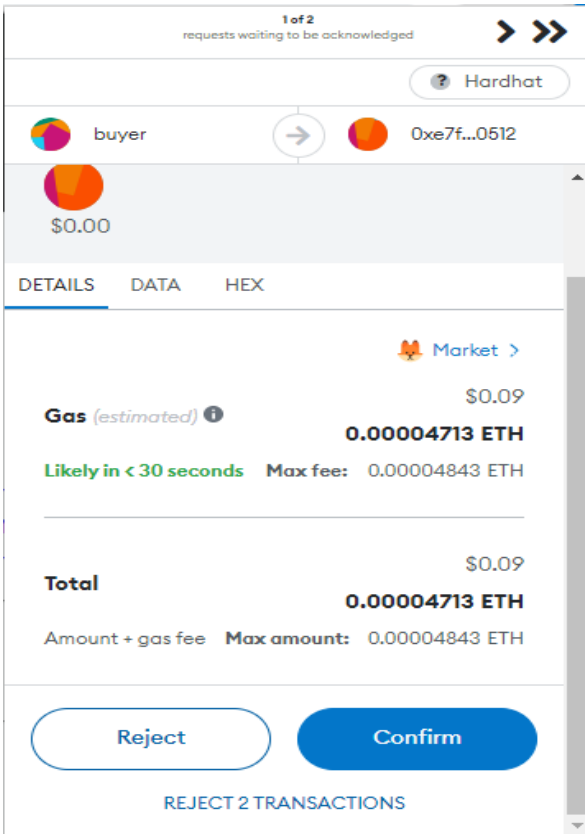
7.2.2.6 Stand Selection

The stand selection feature enables users to select the real estate property they want to purchase. Users navigate to the stand selection feature on the system, browse through the available real estate properties listed on the system. Click on the real estate property you want to purchase. Step 4: The system will display the details of the real estate property, including the price and payment options.



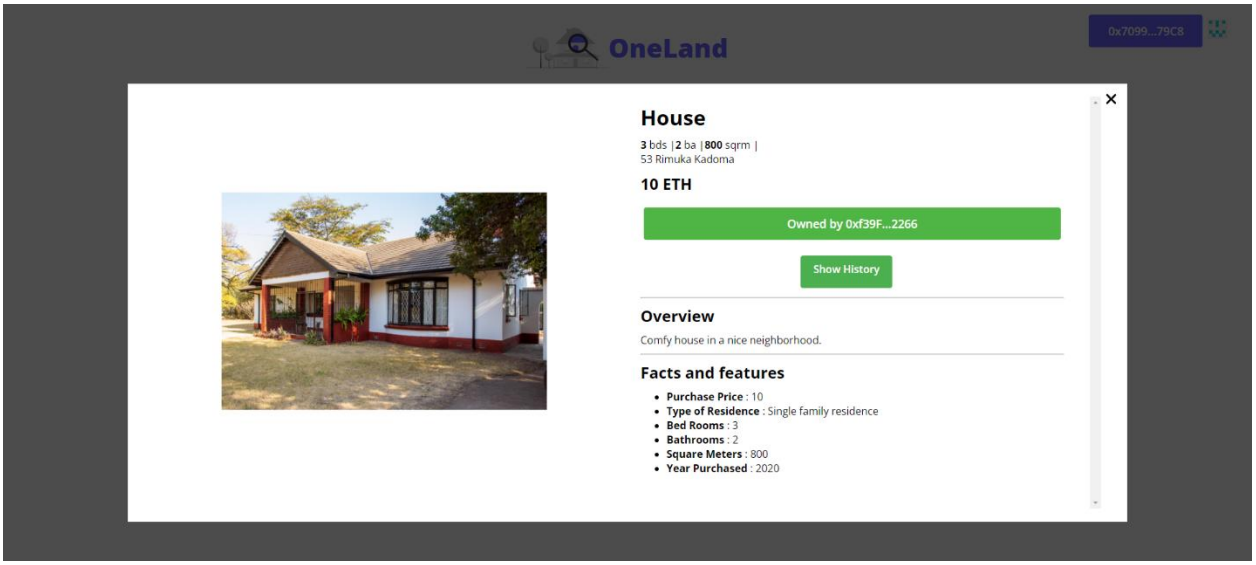
7.2.2.7 Payment Confirmation:

The payment confirmation feature enables users to confirm their payment for the real estate property they have selected.



7.2.2.8 Property Transfer Successful

After the seller confirms the final payment, the property is transferred to the buyer .



7.2.2.9 Show History

The show history feature enables users to view their transaction history on the system.

7.2.2.10 Conclusion

This user manual provides a guide on how to use the blockchain-based real estate management system. The system's features have been designed to make it easy for users to manage and transfer

7.2.3 Sample Code

7.2.3.1 Sample Code for Getting Ownership History

```
import React, { useState, useEffect } from 'react';
import { ethers } from 'ethers';

const OwnershipHistory = ({ contract, nftID }) => {
  const [history, setHistory] = useState([]);

  useEffect(() => {
    const fetchOwnershipHistory = async () => {
      try {
        const ownershipHistory = await contract.getOwnershipHistory(nftID);
        setHistory(ownershipHistory);
      } catch (error) {
        console.error('Error fetching ownership history:', error);
      }
    };

    if (contract && nftID) {
      fetchOwnershipHistory();
    }
  }, [contract, nftID]);

  return (
    <div>
      <h3>Ownership History</h3>
      <ul>
        {history.map((address, index) => (
          <li key={index}>{address}</li>
        ))}
      </ul>
    </div>
  );
};

export default OwnershipHistory;
```

7.2.3.2 Sample Code for The Navigation Panel

```
import { ethers } from 'ethers';
import logo from '../assets/logo.svg';
import Identicon from "identicon.js";

const Navigation = ({ account, setAccount }) => {
    const connectHandler = async () => {
        const accounts = await window.ethereum.request({ method: 'eth_requestAccounts' });
        const account = ethers.utils.getAddress(accounts[0])
        setAccount(account);
    }
```

```
  return (
    <nav>

      <div className='nav__brand' >
        <img src={logo} alt="Logo" />
        <a href=""><h1>OneLand</h1></a>
      </div>

      {account ? (
        <div>
          <button
            type="button"
            className='nav__connect'>{account.slice(0, 6) + '...' + account.slice(38, 42)}
          </button>
          <img
            className="identicon"
            width='30'
            height='30'
            src = {` ${new Identicon(account, 30).toString()}`}
            alt="
        />
      </div>
      ) : (
        <button
          type="button"
          className='nav__connect'
          onClick={connectHandler}
        >
          Connect
        </button>
      )}
    </nav>
  );
}

export default Navigation;
```

7.2.4 Research Papers

OneLand: A Blockchain-Based Real Estate Management System

Takudzwa Matiki ; Mainford Mutandavari

Department of Software Engineering, School of Information Sciences and Technology Harare Institute of Technology, Harare, Zimbabwe

takuematich@gmail.com; mmutandavari@hit.ac.zw

***Abstract*— The real estate industry has long been plagued by problems such as fraud, double sales, and lack of trust, leading to significant challenges for buyers and sellers. This abstract presents a proposal for a blockchain-based real estate management system that aims to address these issues and provide a secure, transparent, and efficient solution.**

The proposed tools for developing the system include Solidity for writing smart contracts, Ganache for launching the Ethereum network, Truffle for testing and developing the blockchain network, JavaScript for the frontend, and MetaMask to create a blockchain browser. The resulting decentralized application (dApp) will run smart contracts, enable tokenization of land properties as NFTs, support decentralized data storage, and maintain immutability.

The decentralized nature of the system ensured the security and integrity of the stored data. The immutability of the blockchain prevented data tampering, reducing the occurrence of fraudulent activities. This robust security feature offered by the blockchain technology attracted developers and stakeholders, as it guaranteed the protection of records and prevented fictitious sellers from exploiting the system. By implementing this blockchain-based system, buyers and sellers can have increased confidence in the authenticity and accuracy of property ownership records, fostering a more transparent and trustworthy industry.

Keywords: blockchain, real estate management system, smart contracts, Ethereum network.

I. INTRODUCTION

Real estate management is a complex process that involves various transactions, record-keeping, and stakeholder interactions. Traditional systems often face challenges related to security, transparency, and efficiency. In recent years, blockchain technology has emerged as a potential solution to address these issues. This literature review aims to explore the application of blockchain in real estate management systems, highlighting its benefits in terms of security, transparency, and efficiency.

Blockchain is a distributed ledger technology that facilitates secure and transparent recording and verification of transactions across a network of participants [1]. It operates on the principles of decentralization, immutability, and consensus. Transactions recorded on the blockchain are resistant to alteration, providing a high level of data integrity [2]. The decentralized nature of blockchain eliminates the need for intermediaries, reducing costs and enhancing efficiency.

Blockchain technology, initially associated with cryptocurrency, has expanded its applications beyond financial sectors. Blockchain has found relevance in various industries such as education, healthcare, city planning, and e-government [3]. This literature review focuses on the utilization of blockchain in the real estate sector, highlighting its potential to provide a secure, transparent, and immutable environment for managing property transactions.

The adoption of blockchain technology in the real estate industry offers numerous advantages[4]. Blockchain provides a secure and transparent environment for recording property transactions, ensuring that records are tamper-proof and verifiable. This eliminates the need for intermediaries, such as brokers and lawyers, streamlining the transaction process and reducing costs[5]. Moreover, blockchain enables the implementation of smart contracts, self-executing agreements that automate various aspects of real estate transactions, including property transfers and payment processing[8-12]. Smart contracts enhance efficiency, eliminate errors, and foster trust among parties.

One significant benefit of blockchain in real estate management is the establishment of a single, immutable source of truth for property records[13-15]. This eliminates discrepancies and disputes arising from fragmented or inconsistent data sources. Additionally, blockchain enables the tokenization of real estate assets, representing ownership rights through digital tokens. This opens up new opportunities for fractional ownership, liquidity, and investment in the real estate market [16].

Furthermore, blockchain enables the adoption of smart contracts, optimizing contract formulation and negotiation [18]. Through a consensus service, transaction ordering and immutability mechanisms are ensured, while a membership

service enhances auditability and accountability in trustless environments. Automating contract execution becomes possible, creating a more efficient and secure real estate ecosystem. This potential adoption of blockchain-based solutions can empower smart city developers, allowing for a decentralized asset ownership, trading, and exchange without reliance on a central server system [19].

II. PROBLEM STATEMENT

The real estate industry faces several challenges related to the authenticity and security of property ownership records, which can lead to fraud and disputes. Issues such as incorrect land descriptions, double sales, unauthorized transfers, and the involvement of fake agents have led to a lack of trust between buyers, sellers, and intermediaries in the industry. As a result, there is a need for a secure and transparent system that can ensure the integrity of property ownership records and streamline real estate transactions.

A blockchain-based real estate management system can address these challenges by providing a tamper-proof and decentralized ledger that records all property transactions and ensures the immutability and transparency of property ownership records. The use of smart contracts can automate key aspects of real estate transactions, such as property transfers and payments, reducing the risk of errors and fraud. This system can also eliminate the need for intermediaries such as agents and cooperatives, further reducing costs and increasing efficiency.

By implementing a blockchain-based real estate management system, buyers and sellers can have increased confidence in the authenticity and accuracy of property ownership records, leading to a more transparent and trustworthy industry.

III. RELATED WORK

Zillow

Fig. 1 Zillow Real Estate System

Zillow offers the option to list apartments for sale, rent, or lease as well as virtually tour properties and contact agents. Properties on Zillow also can be viewed through video tours and photographs. Users even can receive update notifications about selected properties from the app.

Xome

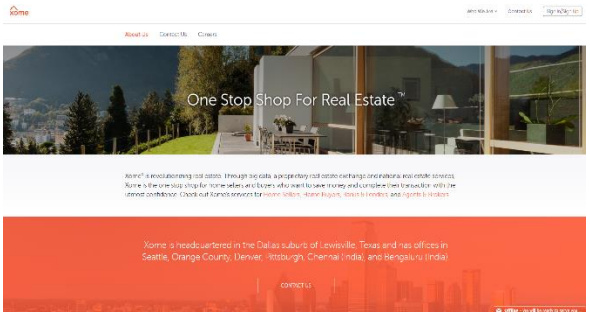


Fig. 2 Xome Real Estate System

Xome® is revolutionizing real estate. Through big data, a proprietary real estate exchange and national real estate services, Xome is the one stop shop for home sellers and buyers who want to save money and complete their transaction with the utmost confidence. It offers Xome's services for Home Sellers, Home Buyers, Banks & Lenders, and Agents & Brokers.

IV. SOLUTION

To address the challenges identified in the problem statement, a blockchain-based real estate management system was developed. The system aims to achieve the following objectives:

- To facilitate the buying and selling of land assets
- To create a distributed ledger that enhances the security and transparency of real estate transactions
- To streamline real estate transactions and reduce the need for intermediaries such as housing cooperatives and agents
- To create an unmodifiable history of all the transactions that have been performed on a land asset.
- To enable the minting of currently owned land assets
- To reduce costs associated with manual tasks and human involvement, automating processes using smart contracts and blockchain

A. Solution Architecture

The proposed blockchain-based real estate management system utilizes a decentralized architecture. The system architecture consists of the following components:

1. Blockchain network: The system utilizes a permissioned blockchain network where only authorized parties can access and participate in the network.
2. Smart contracts: Smart contracts are used to automate property transactions, ownership transfers, and property management tasks.
3. User interface: The system includes a user-friendly web interface for users to interact with the blockchain network.
4. Database: The system utilizes a centralized database for storing property data, such as

property records and ownership details.

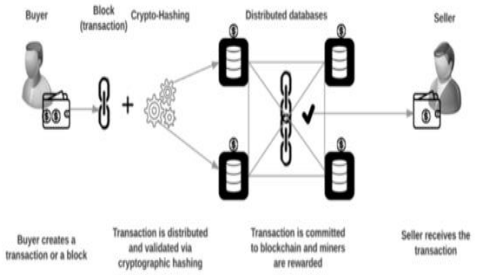


Fig. 3 Architecture of the New System

B. Coding Strategy

The development of the blockchain-based real estate management system followed a coding strategy that incorporated various tools and technologies. Rapid prototyping was employed to quickly iterate and validate the system's design and functionality. Smart contracts, which define the behavior of the system, were written in Solidity, a language specifically designed for Ethereum blockchain. To launch a local blockchain network for development and testing, Ganache, a personal Ethereum blockchain, was used. Truffle, a development framework, facilitated testing and development of the blockchain network, while JavaScript was used for front-end development to create a responsive and interactive user interface. MetaMask, a blockchain browser extension, allowed users to interact with the blockchain network through a web browser.

Version control was managed using Git, while continuous integration and deployment tools ensured efficient development processes. Security considerations, such as code audits and reviews, were implemented to ensure the integrity and robustness of the smart contracts. Documentation was maintained to facilitate collaboration and future maintenance of the system. By following this coding strategy, the development team successfully implemented the blockchain-based real estate management system, leveraging the benefits of rapid prototyping, Solidity, Ganache, Truffle, JavaScript, MetaMask, and other essential tools and practices.

V. RESULTS AND FUTURE WORKS

A. Results

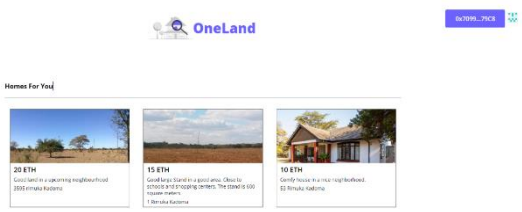


Fig. 3 The Landing Page of The System

The proposed system was tested to evaluate its performance and the extent to which it meets the stated objectives. The system was tested on a simulated network, and the results are summarized in Table I.

TABLE I
OBJECTIVE ACHIEVED

Objectives	Fully achieved	Partially achieved	Exceeded
Buying and selling of assets	✓		
Creation of distributed ledger	✓		
Show property ownership history	✓		
Minting of land assets	✓		
Removal of intermediaries in property transactions	✓		
Streamline real all transactions	✓		

B. Future Works

The real estate industry is constantly evolving, and there is a need to keep up with the latest trends and technologies to remain competitive. Future works on the real estate management system using blockchain technology include:

1. Integration with AI and IoT: The integration of artificial intelligence (AI) and the internet of things (IoT) will enhance the capabilities of the real estate management system. The integration will allow for the automation of property management tasks and the collection of real-time data.
2. Blockchain interoperability: The interoperability of blockchain networks will allow for the exchange of information and assets between different blockchain networks, promoting the growth and adoption of the real estate management system.
3. Tokenization of real estate assets: The tokenization of real estate assets will allow for the fractional ownership of properties, promoting accessibility and affordability.
4. Integration with DeFi: The integration of decentralized finance (DeFi) will provide more financial opportunities and flexibility to the stakeholders in the real estate industry

VI. CONCLUSION

In conclusion, the implementation of a real estate management system using blockchain technology provides a secure and efficient way of managing real estate assets. The system provides transparency and immutability to the transactions, which promotes trust among the stakeholders involved in the real estate industry. The system can be improved by integrating it with existing systems, providing a user-friendly interface, ensuring scalability, and providing

education and training to stakeholders. The future works on the real estate management system include the integration with AI and IoT, blockchain interoperability, tokenization of real estate assets, and integration with DeFi.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to God for His guidance, strength, and blessings throughout the journey. I would like to extend my heartfelt appreciation to Mr. Mutandavari, my supervisor, for his invaluable guidance, expertise, and continuous support. His insightful feedback and encouragement have been crucial in shaping the direction of this project.

I would also like to thank Mr. Makondo, the chairman of the software department, for his trust and belief in my abilities, Miss Amos, my mentor, for her unwavering support, guidance, and constructive feedback and the entire software department for their collaboration, insights, and encouragement. The collective effort and camaraderie within the department has created an environment conducive to growth and learning.

I would like to acknowledge my friends and colleagues for their support, motivation, and valuable input throughout this project. Their encouragement and belief in my abilities have been a driving force in overcoming challenges and achieving success.

Lastly, I am deeply grateful to my family for their unwavering love, understanding, and support. Their encouragement and belief in my abilities have been a constant source of inspiration.

Without the support and contributions of these individuals, this project would not have been possible. I am truly thankful for their presence in my life.

REFERENCES

[1] Thota, S., 2019. Blockchain for Real Estate Industry. *The Journal of Social Sciences Research*, (52), pp.53-56.

[2] Paulavicˇius, R.; Grigaitis, S.; Igumenov, A.; Filatovas, E. *A decade of blockchain: Review of the current status, challenges, and future directions*. Informatica 2019, 30, 729–748.

[3] S. Ølnes and A. Jansen, "*Blockchain technology as support infrastructure in e-government," in Lecture Notes in Computer Science*, vol. 10428. Cham: Springer, 2017.

[4] Ahmad, I., A. Alqarni, M., Ali Almazroi, A. and Alam, L., 2021. *Real Estate Management via a Decentralized Blockchain Platform*. Computers, Materials & Continua, 66(2), pp.1813-1822

[5] W. Gräther, S. Kolvenbach, R. Ruland, J. Schütte, C. Torres et al., *"Blockchain for education: lifelong learning passport," in Proc. 1st ERCIM Blockchain Workshop 2018*, Amsterdam, Netherlands: European Society for Socially Embedded Technologies, pp. 1–8, 2018

[6] *FIBREE. Global Industry Report "Blockchain Real Estate"; FIBREE*: Vienna, Austria, 2020.

[7] Belotti, M.; Božic´, N.; Pujolle, G.; Secci, S. *A vademecum on blockchain technologies: When, which, and how*. IEEE Commun. Surv. Tutor. 2019, 21, 3796–3838.

[8] Singh, S.K.; Sharma, P.K.; Pan, Y.; Park, J.H. BIIoVT: *Blockchain-based secure storage architecture for intelligent internet of vehicular things*. IEEE Consum. Electron. Mag. 2021.

[9] Graglia, J.M.; Mellon, C. *Blockchain and property in 2018: At the end of the beginning*. Innov. Technol. Gov. Glob. 2018, 12, 90–116.

[10] Cha, J.; Singh, S.K.; Pan, Y.; Park, J.H. *Blockchain-based cyber threat intelligence system architecture for sustainable computing*. Sustainability 2020, 12, 6401.

[11] Veuger, J. *Dutch blockchain, real estate and land registration*. J. Prop. Plan. Environ. Law 2020, 12, 93–108.

[12] Li, J.; Greenwood, D.; Kassem, M. *Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases*. Autom. Constr. 2019, 102, 288–307.

[13] Davies, E.; Kirby, N.; Bond, J.; Grogan, T.; Moore, A.; Roche, N.; Rose, A.; Tasca, P.; Vadgama, N. *Towards a Distributed Ledger of Residential Title Deeds in the UK*; University College London: London, UK, 2020.

[14] Androulaki, E.; Barger, A.; Bortnikov, V.; Cachin, C.; Christidis, K.; De Caro, A.; Enyeart, D.; Ferris, C.; Laventman, G.; Manevich, Y. *Hyperledger fabric: A distributed operating system for permissioned blockchains. In Proceedings of the 13th EuroSys Conference*, Porto, Portugal, 23–26 April 2018; pp. 1–15.

[15] Hyperledger. *Hyperledger Fabric*. Available online: https://hyperledger-fabric.readthedocs.io/en/release-2.0/whatis.html (accessed on 26 June 2020).

[16] Cocco, S.; Singh, G. *Top 6 Technical Advantages of Hyperledger Fabric for Blockchain Networks*. Available online: https://developer.ibm.com/technologies/blockchain/articles/top-technical-advantages-of-hyperledger-fabric-for-blockchain-networks/ (accessed on 28 July 2020).

[17] Nawari, N.O. *Blockchain technologies: Hyperledger fabric in BIM work processes. In Proceedings of the International Conference on Computing in Civil and Building Engineering*, Melbourne, VIC, Australia, 3–4 February 2020; pp. 813–823.

[18] Lemieux, V.L. *Blockchain and distributed ledgers as trusted recordkeeping systems. In Proceedings of the Future Technologies Conference (FTC)*, Vancouver, BC, Canada, 29–30 November 2017.

[19] Thakur, V.; Doja, M.; Dwivedi, Y.K.; Ahmad, T.; Khadanga, G. *Land records on blockchain for implementation of land titling in India.* Int. J. Inf. Manag. 2020, 52, 101940.