ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 14 (2024) No. 10, pp. 350-363
DOI:10.33168/JSMS.2024.1020

Revolutionizing Land Administration in Indonesia: An Exploration of Ethereum-Based Private Blockchain for Transparent and Efficient NFT Land Transactions

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Abstract. Land Administration is crucial for effective governance. However, in many developing countries, including Indonesia, traditional land administration systems often suffer from inefficiencies, corruption, and lack of transparency, leading to disputes and conflicting claims over land ownership. Blockchain technology has offered a promising solution to address the challenges by providing a decentralized, immutable, and transparent recording of land information. Provides encryption cryptography and descriptions to validate data. This research paper explores the implementation of an Ethereum-based private blockchain to build a land administration system DaPPS where users can sell and buy land certificates in Indonesia. A prototype land administration system was built with Ethereum and land certificates as NFT was built. This study focuses on adopting blockchain to help in the land registration system. Transaction performance testing is conducted, it shows between 6-15 seconds. While promising, more research is needed to address scalability and integration with legacy systems.

Keywords: Blockchain, Land administration, Ethereum, NFT, DaPPs

1. Introduction

Indonesia, as the largest country in terms of area, ranks 15th in the world with over 17,000 islands. It spans an area of 1,904,569 square kilometers. Despite its vastness, Indonesia faces significant land dispute risks due to its high population of over 250 million people within a relatively small land area. Land issues in Indonesia require attention from the government, as dozens of cases remain unresolved. Various problems such as the duplication of land certificates. One of the biggest challenges includes the availability of a land administration system with high reliability, transparency, coverage, levels of conflict, and accessibility to land rights. Additionally, land may be misused by individuals who are not the rightful owners, resulting in forgery of land documents. Some individuals seize the opportunity to engage in fraudulent activities, such as selling fake certificates and then disappearing. These actions fall under the categories of fraud or deception. Administrative issues arise from human errors such as inaccuracies of land records in manual data entry. Manual verification and approval can be processed very slowly, hindering the timely completion of land transactions. There are also instances of land administration being manipulated by irresponsible individuals, often associated with land mafias. This causes a lack of transparency making it difficult for the government to track land disputes. Statistical data from the Agrarian Reform Consortium (KPA) indicates that land problems and conflicts persist. The slow adoption of technology in traditional land administration hinders the implementation of efficient and secure databases, Geographic Information Systems (GIS), and other tools that can enhance accuracy and accessibility.

The land administration system in Indonesia has long been plagued by issues such as cumbersome bureaucracy, inefficient paper-based procedures, ambiguities in property ownership, and corruption that can thrive in manual systems. These challenges have not only hindered the effective utilization of land resources but have also led to disputes and contributed to social conflicts. Lack of public involvement leads to a lack of awareness and acceptance. Leaving vulnerable populations at a disadvantage as shown in Figure 1.

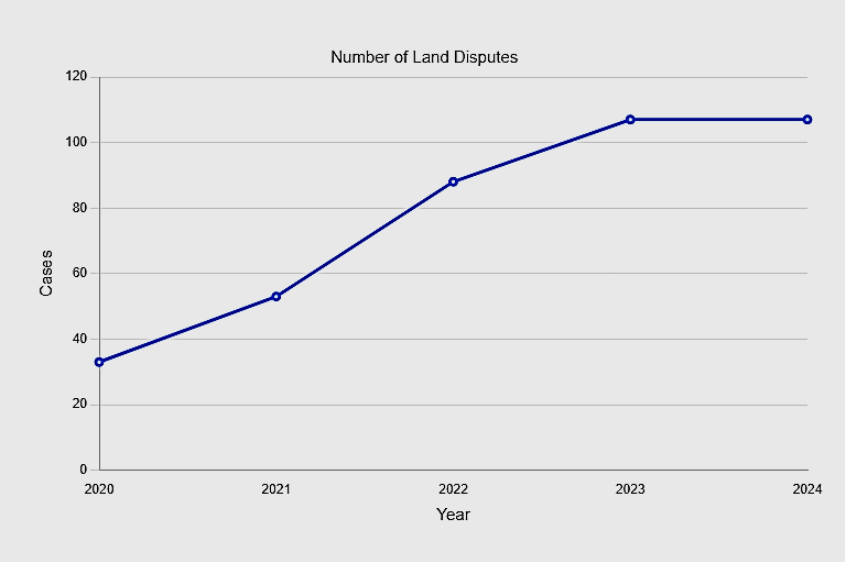

Fig. 1: Number of Land Disputes (tanahkita.id, 2024)

Over the past few years, the use of blockchain technology has emerged as a transformative and revolutionizing various sectors with its decentralized, secure, and transparent nature. Among the domains benefiting from this innovation, land administration stands out as a critical area that demands effective, efficient, and transparent solutions. Providing a solution to concerns about the functioning of centralized systems. The decentralization of the land data validation process through the blockchain network makes it difficult for unauthorized parties to manipulate changes to land data. Blockchain technology enables digital recording, easy distribution, and tamper-resistant storage of land information. This system does not have a centralized server and is not controlled by an individual or group but is

governed by the majority consensus of all blockchain users. Blockchain is a public ledger or distributed database where all digital transactions or other digital activities are verified by majority consensus, recorded, executed, and shared among participating parties, and cannot be deleted.

With blockchain technology, issues such as having two or more certificates for the same piece of land can be eliminated. The original owner can be identified, preventing the occurrence of certificate duplication, which could pose significant problems. Data will be transparent and stored on the blockchain. Blockchain can be considered a decentralized recording system or distributed ledger network. In this network, all participants have equal access to the same data, and activities such as buying and selling, certificate issuance, and land ownership records are shared.

The process of managing land certificates and other documents will become faster and more streamlined by using blockchain. Blockchain can be employed to create a secure land registry that can safely record and verify land ownership and transaction information, preventing fraud and disputes over land ownership. In countries like Indonesia, where land and property rights play an essential role in socio-economic development. Blockchain solutions and Non-Fungible Tokens (NFT), are the proposed approaches that will help the research to solve the challenges faced by people in Indonesia. In this study, a proposed marketplace prototype approach has been decided with the integration of blockchain technology which experts called, a decentralized land administration system with the help of an NFT minting system that runs on Ethereum Blockchain. With this new uprising technology, blockchain can check whether transactions are valid or not. The proposed system is not to take the heavy challenge of converting all land documents and converting them to NFT but to people seeking a solution. This study allows land administration users to use this system to do their buying and selling of land certificates in the form of metadata and NFT. With the help of blockchain technology features such as smart contracts and Non-Fungible Tokens (NFTs), the land transaction process, including ownership transfer and associated costs, can be automated. This can reduce the time involved in land transactions and address issues for those seeking solutions.

The goal of this research is to build a land system using blockchain technology. In this context, we will create a prototype using Ethereum to address land-related issues. This paper includes section 2 which describes the theoretical background, and section 3 explains the design and implementation. Section 4 explains the result and further discussions. Finally, Section 5 concludes this paper with some suggestions for future research.

2. Theoretical Background

2.1. Blockchain

Blockchain Technology is described as a collection of blocks that are connected and form a bridge like a chain. The blockchain structure consists of data structures described as nodes, where these nodes contain stored data. The goal is to store a set of data or a list of transactions and distribute them to the block on the blockchain network. The other name for blockchain is a database or a digital ledger where the data cannot be changed, always distributed, always available, secure, and serves as a storage place for data accessible to the public. Data is protected through cryptographic security methods to ensure its safety. By using cryptographic methods, blockchain's security technique where writing is done secretly with special characters, using letters and characters outside their original form. Cryptography allows someone to send a secret message to others by using a code system so that it cannot be understood by third parties or malicious individuals such as hackers. This is done to anticipate attacks or interruptions to the system. In other words, it involves filling the message with a specific algorithm, namely the SHA-256 (secure hash algorithm) hashing algorithm, which is used in blockchain. A Hashing algorithm is a process that transforms data into other data of a specific size. The input data becomes output data with a length of 256 bits or 64 characters, making the data valid and secure, not easily manipulated. There

are changes and differences in the original data between the input and output results.

In this case, blockchain can streamline this process by automating verification, validation, and ownership transfer. Smart Contracts, which are self-executing agreements on the blockchain, can facilitate automatic and error-free transactions, reducing administrative burdens and costs. Blockchain employs sophisticated cryptographic techniques and consensus mechanisms, making it highly secure. A land registry system with blockchain can assist in proving land ownership, addressing issues where traditional documents can be manipulated, lost, or inaccurately inputted. With blockchain, all ownership documents are recorded, making it difficult to manipulate or lose them. Each document uploaded to the blockchain is timestamped and digitally signed, ensuring its authenticity. This ensures transparency in the system. Many countries face issues with poorly documented land ownership or even conflicts over unclear land ownership. The solution with blockchain can be used to record land ownership transparently and securely. Every transaction or ownership transfer is recorded in a blockchain that can be accessed by all relevant parties.

Innovative businesses nowadays are using blockchain to aid in tracking, viewing records, and receiving payments. In an era like this, the importance of blockchain systems in business activities is crucial, and before long, the world will be using or interacting with blockchain on a broader scale. This opens up new opportunities for businesses like these.

2.2. NFT

Non-fungible tokens or NFTs is a concept of digital tokens that represent ownership or proof of authenticity of a digital content or unique item using blockchain technology, each NFTs have information that makes it distinct and irreplaceable. NFTs are built under smart contracts standards and blockchain which consist of rules and token standards (ERC-721) for creating, buying, selling, and transferring NFTs. Ownership and transaction history of NFTs are recorded on a blockchain, providing a transparent and secure way to verify authenticity and ownership. NFTs have gained popularity in the world of digital art and collectibles, giving new opportunities to monetize their work and connect with a global audience. NFT will benefit the land documents system, a new concept that can help verify ownership like in real estate.

2.3. Ethereum

Ethereum (ETH) is not just a cryptocurrency or digital currency. When it was first introduced in December 2013 by Vitalik Buterin and his colleagues, who were computer programmers and Bitcoin enthusiasts, Ethereum also represented an implementation of blockchain technology capable of building computational technology on the blockchain. Thanks to Ethereum, blockchain is not only about digital currency but also facilitates transactions between digital assets through programming languages. This is one of the driving forces behind and supports the NFT system. Ethereum was created because applications built with the Bitcoin blockchain protocol had issues with a very large transaction volume, making it slow. Bitcoin does not support large transactions in every application built using or based on Bitcoin. Due to this problem, Vitalik and his colleagues saw an opportunity for people to build decentralized applications easily and quickly. Ethereum can be developed to build blockchain technology-based applications such as Opensea, Metamask, and Uniswap, and many entrepreneurs use Ethereum as a tool to support this environment, known as dapps and defi.

Ethereum has a component called the Ethereum Virtual Machine that allows Ethereum to run using a scripting or programming language called Solidity to build decentralized applications, and Ethereum has a token called Ether or ETH, which can be used as a digital currency like other cryptocurrencies and can be used for transactions between users, collaborative processes like Bitcoin through mining. Storing transaction data on the Ethereum blockchain costs a gas fee for storing data on the Ethereum blockchain. Ethereum can be used more flexibly to develop blockchain-based applications that can be governed based on consensus.

Ethereum's Smart Contracts is the implementation of blockchain technology designed to determine contract agreements between multiple parties and is applied in the form of code as its logical system to interact with the blockchain. These contracts run on the Ethereum blockchain, and their execution is automated and enforced by the Ethereum network, eliminating the need for third parties. This is a solution to problems in blockchain technology. It enables communication between smart contracts and the blockchain. Smart Contracts work by following the code statements on the blockchain using the Solidity programming language specifically designed to build smart contract components. This action is executed when the specified conditions have been met and verified. The action can involve transaction data containing fund disbursement or transfer, and then the blockchain updates its block with the new transaction and its identity. These transactions cannot be changed by anyone, and only a few parties with permission can view the results.

Ethereum uses a consensus mechanism which is PoS or Proof-Of-Stake, a protocol that validates the transaction by rewarding an incentive for blockchain protocol traders. To stake some of the cryptocurrency as collateral which is locked in a deposit to help validate and verify transactions in a blockchain. This protocol aims to improve scalability, security, and sustainability.

2.4. DaPPS

A decentralized application or DaPPS is an open-source software program or application part of Web3 that runs on a peer-to-peer (P2P) blockchain network rather than on a single server/ computer. It is like other software applications that are supported on websites or mobile devices, but the difference is that DaPPS runs on a P2P network. DaPPS is built on a decentralized network supported by blockchain which is one of the examples of blockchain implementation. DaPPS can process data through distributed networks and execute transactions. There are a lot of platforms DaPPS can be built on, one of them is the Ethereum platform. In this paper, the authors build DaPPS using the Ethereum platform. Creating a decentralized app on a smart contract system requires combining several smart contracts and using third-party systems for the front end.

3. Design and Method

The system design phase comprises two parts: smart contract and user interface. This study uses another external web3 builder environment to help with the system. The other system development application tools that help in building the systems are Visual Studio Code (a code editor), Thirdweb (Ethereum development builder framework), and JavaScript (a programming language), and Metamask (a crypto smart wallet). This paper focuses on providing a secure land system where transactions can be placed.

Before building the prototype, the authors proposed a blockchain architecture which is an overview of the architecture as an Architecture Layer Diagram of the system that is built to determine which blockchain technology to use and their function as shown in Table 1 below.

Table 1: Blockchain Architecture

Blockchain Architecture	
Application Layer	Front-End, UI, Back-End & DaPPS
Contract Layer	Smart Contract (ERC721A and marketplace contract) using Thirdweb

Incentive Layer	Decentralized cryptocurrency wallet (Metamask)
Consensus Layer	Proof-of-Stake (PoS)
Network Layer	Peer-to-Peer (p2p)
Data Layer	Data blocks, Digital Signature, Time Stamp, Merkle Tree, Hash. Security of the data is using the above term

The traditional land system can involve conflicts in key aspects such as security and data integrity. Land data is typically stored in a centralized manner, and access is controlled by a specific authority. Consequently, this system may be vulnerable to fraud, lack of transparency, manipulation, and corruption. Based on the problems described in the previous section, the goal is to provide the development of a blockchain-based application system for buying and selling (land certificates) and displaying data. This decentralized application is referred to as the NFT Land Administration Marketplace. Through this application, land enthusiasts can increase and reduce data manipulation and other related issues. The authors proposed a system that can help in solving the problem of human error in land systems. This proposed approach was chosen over alternatives as we know that blockchain technology could be useful for undestroyable databases that hold almost all the data and transactions happening in real-time (Ali et al, 2021). Despite the growth of alternative blockchain networks, Ethereum is still a popular and trending platform to build on. Startup Businesses prefer the Ethereum platform because thousands of decentralized applications are running on Ethereum and tools (builder framework) connect to the Ethereum network, which makes it easy for businesses, reducing extra cost and timesaving. The easiness of Ethereum technology called Ethereum Virtual Machine (EVM) can make decentralized applications using their smart contracts program (Cointelegraph, 2023).

Using this proposed approach, data can be seen by the public so no manipulation can be made. All transactions can be seen by the public and people can track the records whereas in the existing system, land records cannot be tracked or seen by the public. This leads to more manipulation of data. This prototype offers automated agreement, which is built by the third-party tool, Thirdweb. The smart contract on the blockchain can be programmed automatically to do transactions, relevant regulations, and contractual agreements (Stefanović et al, 2018). Thirdweb is an example of Blockchain-as-a-service.

The contribution of this proposed system architecture is a new idea for the Indonesian government to integrate the latest system with this proposed system. In this paper, authors are using NFTs as the data or land certificates to be transacted. This will be a potential application of blockchain to help with land records. Ethereum network solves all the issues. With Ethereum consensus mechanism used here will help to verify all the transactions and records. Blockchain's P2P network can help individuals easily access their records with no intervention from a central server. The system will be tested according to performance. The data used are land certificates in the form of NFTs, so the traits or metadata are the description/details of the land certificates such as surface area, city, name of the land, etc.

Figure 2 shows how Land Documents can be changed into NFT and stored in blockchain. The proposed blockchain system should help with the problems in land administration using this proposed blockchain NFT marketplace.

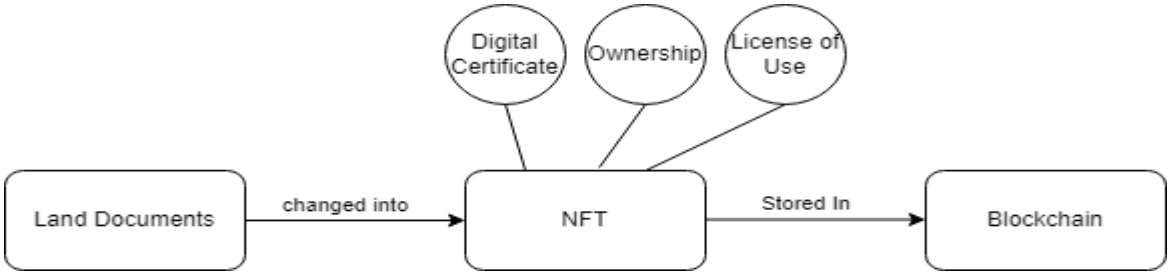

Fig. 2: How land documents change into NFT

3.1. Steps to Build Smart Contracts and UI

Smart contracts offer a secure and transparent method for executing agreements without the need for intermediaries. Ensuring automatic enforcement makes them valuable for complex or high-value transactions. Instead of creating their smart contracts, the author suggests using thirdweb.com, which enables easy development of web3 apps. Thirdweb also facilitates the creation and distribution of land certificates as NFT collections without coding, offering various smart contracts and SDKs for consumer firms building web3 products. The authors used two smart contracts: ERC721A NFT and marketplace. The first smart contract is used for the land certificates to change them into digital data, inside the metadata there are tokenID and descriptions about the NFT, each of them is unique and different. The second smart contract is used where users can buy and sell NFTs.

The steps involved in creating an application are as follows:

1. The author has an account on Thirdweb software to create a project containing API and Smart Contract SDK as a link between the application and the blockchain. The API from Thirdweb is imported using the command 'npm install @thirdweb-dev/SDK ethers@5' to the terminal used in the front-end file.
2. Smart contract data is entered into an object designed to create a transaction. The transaction must be signed to proceed using metamask. After that, the transaction process will be distributed to the blockchain.
3. To obtain the address of the smart contract created, the author can view the contract address on the Thirdweb dashboard and check transaction data for that block on Etherscan using the transaction hash generated from that transaction.

3.2. Flowchart of Selling and Buying Process

Figure 3 & 4 shows the purchasing and selling flowchart in this proposed system. The authors built a flowchart so that readers can easily understand what is going on for the front end and back end.

As shown in Figure 3, the flowchart of selling the land documents. Users can see the home page and must connect their metamask wallet, then automatically system can detect whether users already own a property or not, this will be discussed more in section 4. If the user owns the asset, users can start selling, setting the price accordingly and users must sign the metamask wallet transaction and pay a gas fee so that the system can post the user's asset in the marketplace and data will be stored in the blockchain. Once the asset is purchased by other users, the asset will transfer to the buyer and the seller will receive cryptocurrency equivalent according to the price setting. Every transaction will be recorded and stored in the blockchain.

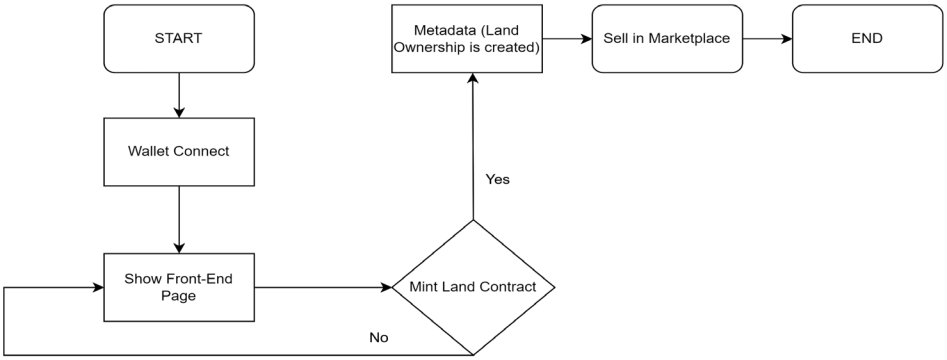

Fig. 3: Flow-Chart of Selling

The minting process is manageable for users, an easy way to start is to connect their wallet using Metamask to the website. Users can see the landing page or the front-end page. Users can go to the next step which is minting the land in the form of NFT and settling the minting with fees (to store the transaction on the blockchain). The minting process takes metadata inside the NFT. Minted NFTs are recorded on the blockchain.

The system will receive a request from the users to sell and buy the land NFT. The metadata required is processed for creating the NFT on the back end. Then NFT is transferred to the user's wallet. The minting process utilizes the library provided by Ethereum and thirdweb.

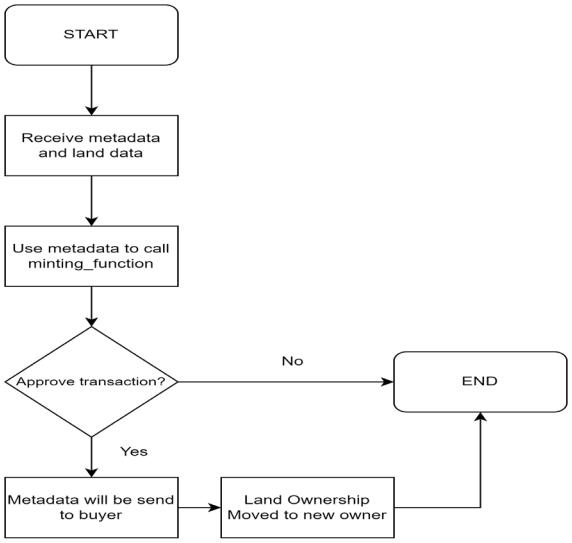

Fig. 4: Flow-Chart Minting (Purchasing) Back-End Blockchain

Figure 4 shows the flowchart or process of purchasing the asset using a metamask wallet and cryptocurrency. Users can look at the marketplace page and see what assets are available, once the users are interested then they can continue to purchase the asset using cryptocurrency and the user must approve the transaction so that the assets can be transferred to the new user.

4. Results and Discussion

In designing the land system application, the author carried out a system requirements analysis. This analysis was carried out by looking for needs that were by the problems obtained from conducting literature studies.

Thirdweb allows us to connect and build dapps with blockchain easily without hesitation. In this case, the authors used their service to connect and integrate with the front end. So, making it comfortable to build the system. Thirdweb does its back end with blockchain connected automatically. To connect and integrate with the blockchain, use this command "npm install @thirdweb-dev/SDK ethers@5" and execute the command to the terminal.

4.1. Smart Contract Algorithm

For this research, a smart contract has been created, specifically a smart contract for a marketplace, where buying and selling transactions will be recorded at the smart contract address for the marketplace. The address is "0xb0bc338f318670D3512d221249aa34aF7Ee9d9F4" with the help of Thirdweb services as shown in figure 5 below.

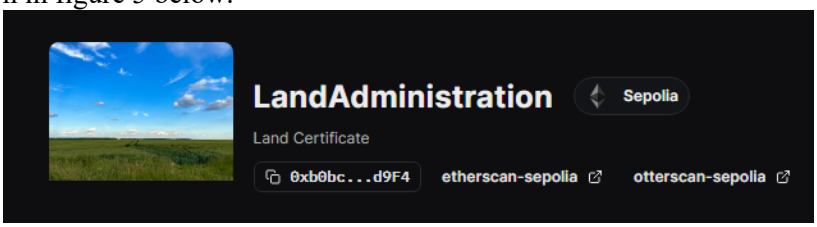

Fig. 5: Smart Contract Address Dashboard

4.2. DaPPS

These are the following prototypes used in land administration The explanations are as below:

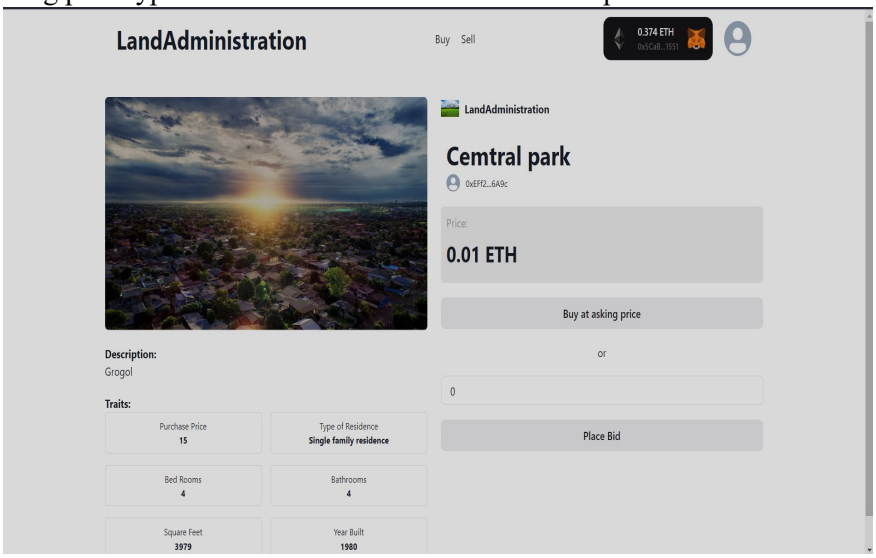

Fig. 6: Purchasing Page

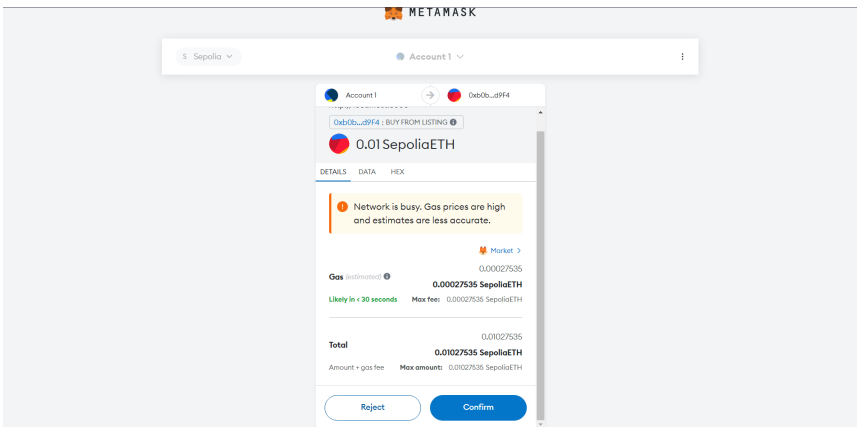

Fig. 7: Buying transaction approval

On the Buying Page shown in Figure 6, there are 2 buttons. The first button is "Buy at asking price" which is the purchasing of the land at the asking price which is shown in Figure 6. The second button functions as asking the price in buyers' price so the must price must be higher than the listed price. Other details such as the description of the property/land. Figure 7 shows the buying transaction approval page. The token used is the Ethereum testnet token (SepoliaETH). The price and the gas fee are just an example of how the buying process will be. The buyer can also view the assets in their profile.

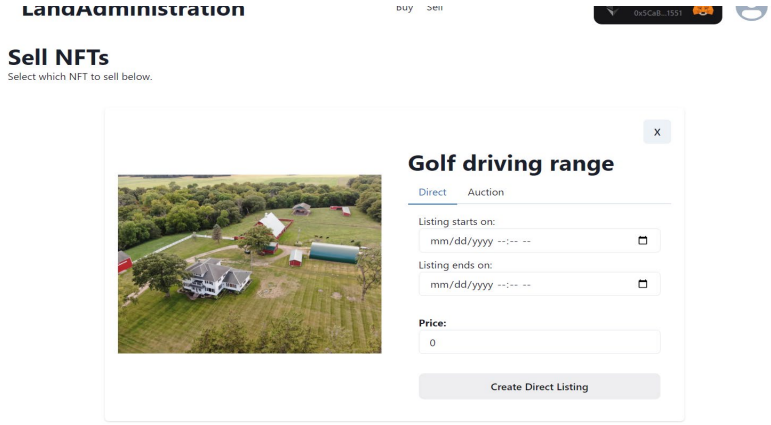

Fig. 8: Selling Page

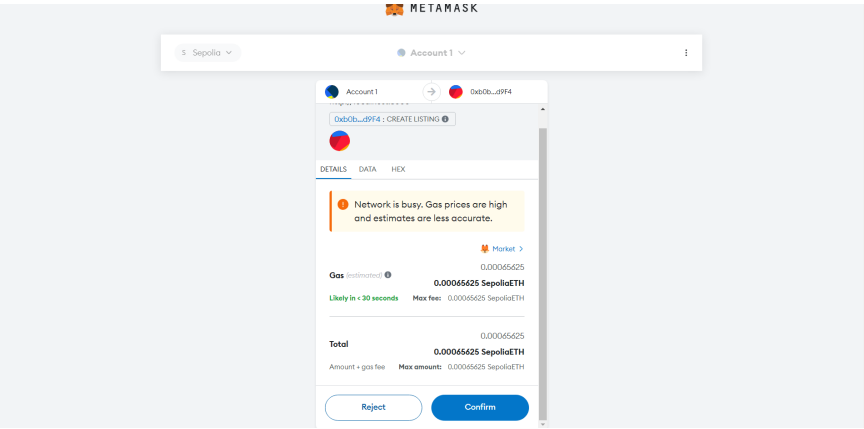

Fig. 9: Selling transaction approval

On the Selling Page shown in Figure 8, there is a button that can start selling the assets by using the "Direct" tab which lists the asset with the asked price. Other settings can also be edited, which as listing assets according to how many days to start and end their listing. After setting up the details, clicking the button will show transaction approval as shown in Figure 9. The gas fee of the transactions will be according to the nodes in the blockchain network.

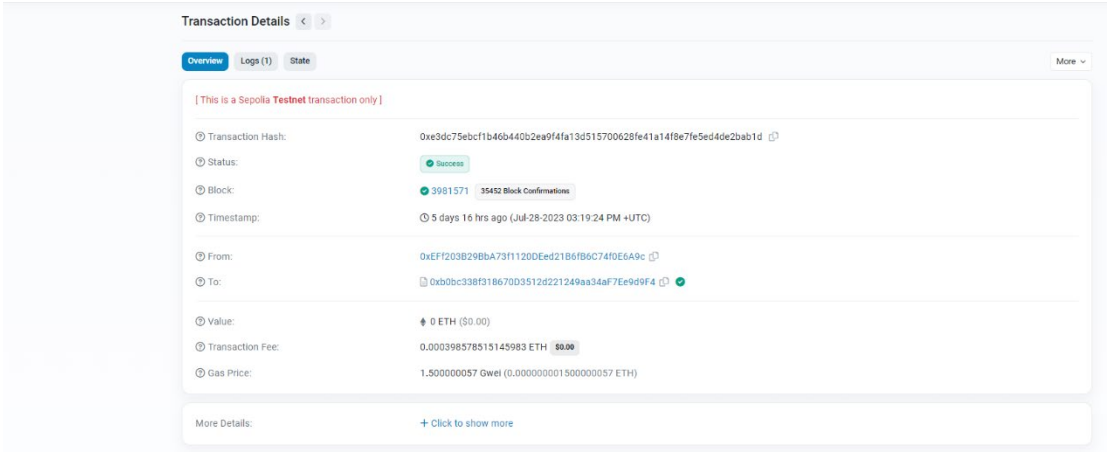

Fig. 10: Transaction on Etherscan

In Figure 10, the transaction is shown. Transaction hash provided in the previous stage, users can search for that transaction on Etherscan using the displayed hash. The data typically shown on Etherscan includes information about the transaction hash, status, block, timestamp, from, to, value, and transaction fee. The history of transactions can be seen by the public so transparency is true about blockchain.

4.3. Performance Testing

Performance testing is conducted, the author tests the time needed to do a transaction for each process which is the buying and selling process. The performance testing conducts 5 tests each for the selling and buying land certificates process and the time recorded to transact is in seconds. Each test is the NFT being transacted, showing the transfer of ownership to the other owner. For each transaction, the blockchain has a different transaction time for the following performance testing. The testing is using 2 metamask wallet addresses in the testnet environment. The results of the tests, shown in Table 2 below, indicate the time taken for transactions on the blockchain system. The unit of measurement used in this performance test is seconds. From all the system test results, it is observed that the blockchain exhibits varying transaction times. The table below shows the different times needed for each transaction.

Table 2: Minting time in seconds

Process of Selling Land Certificates (seconds)		**Process of Buying Land Certificates (seconds)**	
Test 1	9.64 s	Test 1	9.25 s
Test 2	7.40 s	Test 2	7.33 s
Test 3	15.05 s	Test 3	13.11 s
Test 4	7.54 s	Test 4	6.45 s
Test 5	9.04 s	Test 5	7.13 s

Table 2 above shows the testing performance time for the buying and selling process. The table shows the duration of time taken for buy and sell transactions. In the above table, it can be observed that the performance for conducting the process of selling/posting land certificates ranges from a minimum of 7.40 seconds to a maximum of 15.05 seconds. The total time taken is 48.67 seconds for five NFTs with the same metadata to be displayed in the proposed system, with an average of 9.734 seconds per NFT. In the same table, the time taken for the process of buying land certificates requires a minimum time of 6.45 seconds and a maximum time of 13.11 seconds. The total time taken is 43.27 seconds for five NFTs with the same metadata to be bought, with an average of 8.654 seconds per NFT.

Table 3: T-test Result

	Selling	*Buying*
Mean	9.734	8.654
Variance	9.75288	7.28608
Observations	5	5
Hypothesized Mean Difference	0	
df	8	
t Stat	0.5850422	
P(T<=t) two-tail	0.5746453	
t Critical two-tail	2.3060041	

The authors used a T-test and failed to reject the null hypothesis, shown in Table 3. The results are consistent and stable when conducting performance testing. Performance testing helps to validate results and verify the system is working as intended by performing tests repeatedly, ensuring that the results obtained are accurate.

Table 4: Simulation Concurrency Test

Number of Users	Average Minting Time (seconds)
1	7.50 s
3	8.08 s
5	7.48 s

The authors conduct a simulation concurrency test. The simulation test consists of 1, 3, and 5 simultaneous transactions, either buying or selling process. Table 4 presents the results of the test. The metadata set for this test is the land certificates. Results show no significant difference, it is consistent and stable. This test must occur to test the DaPPS to serve more users and the scalability of the blockchain.

4.4. Implications

The implication of building land administration systems using blockchain technology helps in some areas. It helps in all transactions which can be viewed and tracked so transparency allows better monitoring of activities. Blockchain data security uses strong encryption to protect sensitive data such as land certificates. Using smart contracts can automate the execution of agreements and transactions efficiently. Other than benefiting the land system, it also benefits the businesses.

For the implications of blockchain transaction systems, in terms of:

1. Transaction Speed: Transactions can be executed more quickly. All transactions can be viewed and tracked.
2. Data Security: Utilizes strong encryption technology to protect sensitive data such as land certificates.
3. Transparency: All parties participating in the system have access to the same data. This enhances transparency and allows for better monitoring of activities within the defense system.
4. Smart Contracts: These can be used to manage and automate the execution of agreements and transactions or efficiently process payments.
5. Implementing a System Using Blockchain as a Service (BaaS) for Businesses can be experienced by entrepreneurs which can benefit in many ways including time efficiency, security, and energy savings in transaction processes and cost. The advantage for businesses is simplifying the system's integration with blockchain, as there is no need to create and connect a blockchain from scratch; it is sufficient to use APIs through BaaS platforms such as Thirdweb, Alicloud, Moralis, and other BaaS platforms.

5. Conclusions

In conclusion, this paper demonstrates the potential for blockchain and NFTs to help address transparency and efficiency challenges in Indonesian land administration. The Ethereum-based prototype provides functionality for basic land transactions with reliable performance. However, the simplicity of this prototype also highlights key areas for further research such as integrations with existing systems and scalability. Testing used limited data, so expanding to larger datasets will indicate if performance impact emerges at scale. Additionally, expanded features like more advanced transaction logic and access control mechanisms provided by blockchain smart contracts should be explored. Addressing these areas can help realize more of blockchain's potential in transforming land administration systems. Future work can be integrated with IoT, regulations, satellite data with the land blockchain, and other features added like eKYC, integrated with newer versions of Ethereum 2.0 (Luno, 2022).

Acknowledgments

There are no acknowledgments.

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