

# Raven: NFT Based Land Records System using Blockchain

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**Abstract:** *The outdated land records system has several flaws, including a lack of openness and vulnerability to fraud and manipulation. Conflicts and ambiguity about property ownership result from this. The blockchain-based NFT (non-fungible token)-based land records system is being offered as a remedy to get around these limitations and increase the security of property records. Using blockchain technology, data may be stored in a decentralized, safe, and open manner. It uses cryptographic methods to ensure that it is impervious to tampering and safe against cyberattacks. This technology is used by the NFT-based land records system to maintain dispersed land records. In this system, each property has a unique identification number that is stored as a token on the blockchain. The ownership, transaction history, and other pertinent information related to the property are all provided via this token. The land records are readily available and secure thanks to the NFT-based technology. Additionally, it allows for an expedited transfer of ownership and reduces the time and costs associated with real estate transactions. It is easier to keep track of the ownership and transaction history of properties when the system is easily integrated with other government systems and stakeholders. The land records system's transparency and accountability are strengthened by the NFT-based technology. A more stable real estate market and more investment in the sector may result from this. Blockchain, decentralization, scalability, and land records are all index terms.*

**Keywords:** Blockchain , NFT , Smart Contract , Land Record , Decentralization , Security , Cryptocurrency, Multi-Point Permission.

## I. INTRODUCTION

Technology has advanced significantly in the quick-paced world of today, and its advancements have had an impact on practically every sector of the economy. The emergence of blockchain technology has completely transformed how we manage land records, and the real estate sector is not an exception to the NFT-based Land Record - Blockchain model. The outdated paper-based land record system has several drawbacks that make it a less reliable source for landowners and investors, including being time-consuming, error-prone, and susceptible to manipulation. Non-fungible tokens (NFTs)-based land records systems have been proposed as a solution to these problems. Unique digital assets known as NFTs may indicate ownership of any tangible or intangible object. On decentralised, secure, and tamper-proof blockchain networks, NFTs may be generated and transmitted. These characteristics of blockchain technology make it an ideal base for creating an NFT. Smart contracts, which are self-executing contracts with the specifics of the agreement between the buyer and the seller being directly encoded into lines of code, are used by the NFT-based land records system. By doing away with intermediaries, these smart contracts ensure that the ownership of the property is recorded and transferred in a secure and transparent manner. Smart contracts, which are self-executing contracts with the specifics of the agreement between the buyer and the seller being directly encoded into lines of code, are used by the NFT-based land records system. These "smart contracts" do away with the need for intermediaries like real estate agents or brokers by ensuring that the ownership of the property is recorded and transferred in a secure and transparent manner. Landowners may tokenize their property and create an NFT, which represents ownership of that property, using the NFT-based land records system. Because of the NFT's uniqueness, ownership may be transferred via blockchain technology in a secure and transparent manner, facilitating rapid, reliable, and effective transactions. Additionally, the NFT-based land records system guarantees that the property ownership information is easily

accessible and tamper-proof, enhancing the security and transparency of the land records. The NFT-based land records system could also aid in resolving the severe issue of land ownership disputes that exists in many countries. Conflict resolution may be made easier by the system's provision of a readily accessible, public, and secure record of land ownership.

NFT-based land records system may help resolve the significant issue of land ownership conflicts, which is a problem in many countries. Conflict resolution may be made easier by the system's potential to provide a transparent and secure record of land ownership that is easily accessed by the parties involved. Furthermore, fractional land ownership may be created using the NFT-based land records system. Multiple investors may hold a portion of the land via fractional ownership, and NFTs may be used to record the ownership details. Even if they lack the funds to buy the whole property, this arrangement may make it easier for people to invest in land. By making it easier for people to utilize land for a variety of purposes, including agricultural, residential construction, and commercial use, fractional ownership of property may also help to address the issue of land scarcity.

In conclusion, the NFT Based land records system is a novel concept with the potential to completely transform the real estate industry. The system provides a fast, easy, and trustworthy way to register and transfer ownership of real estate, doing away with the need for intermediaries and streamlining the transaction process. By encouraging fractional ownership of property and helping to resolve the issue of land ownership conflicts, the strategy may also make it easier for people to utilize land for a variety of uses. By using NFTs, the land records system may become more trustworthy for investors and landowners by improving its accessibility, transparency, and security.

## II. BACKGROUND

Nakamoto developed this method for his well-known cryptocurrency, or digital currency, known as bitcoin. The double spending problem with bitcoin was addressed by Nakamoto using blockchain technology, however soon this newTechnology was being used in a wide variety of different contexts. By recording transactions on the blocks, a blockchain is a network of interconnected blocks that is constantly growing. This platform employs a decentralized technique that allows for the dissemination of information and the shared ownership of each distributed piece of information, or piece of data as it is more often called. Blockchains, which are managed by peer-to-peer networks, store batches of hashed transactions that have been added to them for security. A blockchain offers several benefits including security, anonymity, and data integrity without interference from outside parties. It makes sense to keep patient medical records on it because of these qualities, since the advancement of technology in the healthcare sector has made patient medical data security a top concern. According to some academics, using blockchain technology in the healthcare industry is another possibility.

## III. RELATED WORKS

When Nakamoto created the blockchain technology, the main objective was to create a decentralized currency that could be used for financial transactions and was cryptographically safeguarded. Eventually, the concept of blockchain was being used in several other aspects of life, and the healthcare industry is one of them. Numerous academics have conducted research in this area; these studies focus on whether the idea of employing blockchain in the healthcare industry is practical. The advantages, risks, challenges, and drawbacks of using this technology are also highlighted. A few scholars also spoke about the challenges that would come with putting this into practice on a larger scale.

### 3.1 Architecture

Let us utilize the following **Figure 1**, which details the whole process of a transaction being transmitted by a user on the blockchain network, to understand the blockchain architecture. A new block is formed when a user sends a new transaction on the blockchain network. The blockchain uses blocks to store transactions, and these blocks are transmitted to all the network's associated nodes. Every node in the network receives a broadcast of the transaction contained inside a block. A copy of the whole blockchain is available to every node in the network, which helps with the verification process.

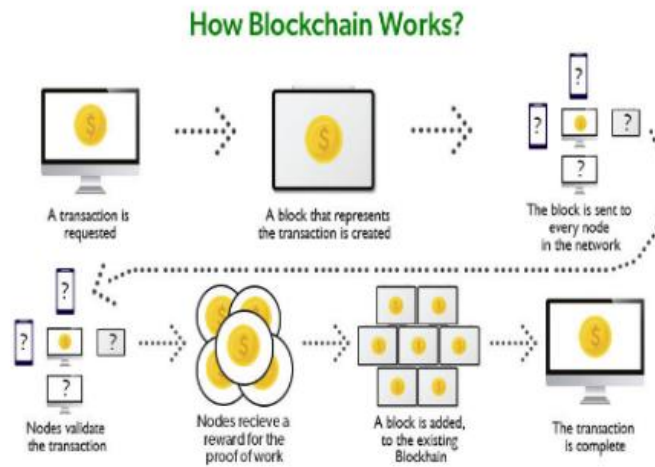


Figure 1: Blockchain Architecture

### 3.2 An Overview of Blockchain Architecture

The nodes reach an agreement where they choose which blocks are valid to be placed on the blockchain and which are not, and this completes the process of the block being put on the blockchain. The transaction is validated and it is confirmed that the sender is an authorized member of the network by the associated nodes using certain established mechanisms. When a node completes the validation successfully, it is paid with cryptocurrency. Mining is the term for this transaction validation procedure, and the miner is the node that is carrying it out. The block is added to the blockchain when validation is complete. The transaction is completed when the whole validation procedure has been completed. In the explanations that follow, several key features of blockchain technology may be understood.

### 3.3 Block

As previously said, blockchains are built by many blocks connected via a peer-to-peer network, creating a decentralized application. The hashes of the preceding blocks are included in the header of these blocks. Data, the hash of the previous block, and the hash of the current block are the three components that make up a block. Depending on the blockchain type, the data might be anything. The data consists of digital currencies, like how bitcoin works. These blocks include a hash that uses the SHA-256 cryptographic algorithm, which is used to uniquely identify each block in the chain.

### 3.4 Consensus Algorithm

Each block that is added to the chain must go by a set of consensus guidelines in order to be included. Blockchain technology makes use of consensus methods to do this. The Proof of Work (PoW) algorithm, which was adopted by Nakamoto in the bitcoin network, is the most popular consensus technique. Since there are many nodes or participants on a blockchain network, this algorithm's basic operation is that it must be computed whenever a participating node requests to post a transaction on the network. The nodes doing these calculations are known as miners, and the process is known as mining

#### 3.4.1 Key Features of Blockchain

##### 1) Decentralisation

With blockchain, information is spread out over the network as opposed to being centralized in one place. Additionally, this allows information control to be disseminated and managed by agreement reached via shared input from the network nodes. Data that was formerly centralized in one location is now controlled by several reliable organizations.

## 2) Data Transparency

To achieve data transparency in any system, relationships between organizations must be founded on trust. The information or record that is at danger must be protected and weatherproof. Any data that is stored on the blockchain is dispersed over the network and is not held at a single location or controlled by a single node. Data is now exchanged among several parties, making it transparent and free from outside interference.

## 3) Security and Privacy

Cryptographic techniques are used by blockchain technology to provide security to the nodes connected to its network. On the hashes that are stored on the blocks, it uses the SHA-256 cryptographic algorithm. Since they guarantee data integrity, SHA stands for Secure Hashing Algorithm, and these hashes provide the blockchain security. Strong one-way functions called cryptographic hashes provide checksums for digital data that cannot be used for data extraction. This makes blockchain a decentralized platform that is secure thanks to cryptographic techniques, making it a workable option for apps that need to preserve their users' privacy.

### 3.4.2 Challenges Faced By Block-- Chain Technology

#### 1) Scalability and Storage Capacity

Secrecy and scalability are the two fundamental issues with data storage on the blockchain. Since everyone who is present on the blockchain has access to the data, NFT based Land Record - Blockchain makes the data susceptible, which is not what a decentralized platform wants to happen. The patient's medical history, records, lab results, X-ray reports, MRI findings, and many more reports would be included in the data maintained on the blockchain. Since so much data would be preserved on the blockchain, this will significantly reduce its storage capacity.

#### 2) Lack of Social Skills

Very few people are aware of how blockchain technology works. This technology is still evolving and is still in its early phases. Furthermore, because hospitals and other healthcare organizations must completely convert their systems to blockchain, the transition from reliable EHR systems to blockchain technology may take some time.

#### 3) Lack of Universally Defined Standards

There is no set standard for this technology since it is still in its infancy and is constantly evolving. As a result, using this technology in the real estate sector would take additional time and effort. Because it would need approved standards from organizations that supervise the process of any technology becoming standardized. These consistent standards would make it easier to choose the kind, quantity, and format of data that may be stored on the blockchain. The established standards would also make it easier to implement this technology since they could be easily enforced in the workplace

## IV. PRELIMINARIES

1. The introduction to a suggested framework is described in this section officially.
2. It outlines the benefits of the software platform utilized to create this framework.
3. The most well-known and crucial for the implementation of this framework are Ethereum and IPFS, which are also covered in the section below.

### 4.1 Ethereum

Ethereum is a distributed blockchain network that makes use of the same blockchain technology as the well-known digital currency Bitcoin. The aim behind Ethereum was to develop a trustless smart contract platform that would be open-source and would also have the characteristic of programmable blockchain. Ethereum was initially released in the year 2015. The peer-to-peer network that gives this technology its dispersed nature is also shared. This platform also uses ethers, a proprietary cryptocurrency. This digital currency may be used to transfer funds between linked accounts on the Ethereum network. Additionally, Solidity, a programming language provided by Ethereum, allows programmers to create their own blockchains. It was created for Ethereum's primary feature, smart contracts

#### 4.2 Information Transaction

The way an external entity might communicate with Ethereum is via transactions. External users may use it to alter the state of a record or piece of data that is kept on the Ethereum blockchain network. The components of an Ethereum transaction are as follows:

1. From - the 20-byte address of the message's sender.
2. Likewise, the message recipient's address is 20 bytes long.
3. Value - the amount of money (wei) transferred from one party to another using NFT-based land records and blockchain
4. Gas - For each transaction on the Ethereum blockchain, the sender is required to pay a fee known as Gas in order to conduct the operation. Data is optional and contains the message being sent to the receiver. The petrol cap and petrol price are included in each transaction.
5. Gas Price: the price of gas that the transaction sender is willing to pay.
6. Maximum gas that might be paid for this transaction is the gas limit.

#### 4.3 Smart Contracts

On the blockchain, a smart contract is a piece of code that is used to carry out any operation. When users send in transactions, this piece of code is executed. They operate directly on the blockchain, protecting themselves from all types of tampering and changes. Solidity language is often used in smart contracts, which may be used to script any kind of blockchain action that a programmer wants to carry out. After performing the necessary processes, programmers may use the EVM bytecode, which will be discussed in the section below, to compile their work. And after putting them together, it may be launched and used on the Ethereum network. Solidity, a programming language provided by Ethereum, is encapsulated in JavaScript and Python to create code for smart contracts

#### 4.4 Ethereum Virtual Machine (EVM)

The programmable blockchain is one of the main features offered by the Ethereum platform. It offers its customers the chance to create custom Ethereum-compatible apps. Distributed applications, or Dapps, are the apps created using this technology. They include a variety of protocols bundled together to provide a platform for DApps. These DApps feature smart contracts with code that the user specifies to carry out certain functions of an application. The Ethereum Virtual Machine (EVM) is used to deploy and run that code. As a result, the smart contract-based programming that are developed are really being run on EVM

#### 4.5 The Interplanetary File System (IPFS)

The IPFS protocol uses peer-to-peer networks to store data. Because IPFS protects data from tampering, it offers secure data storage. Since any effort to modify the data recorded on IPFS could only be made by changing the identity, it uses cryptographic identification to prevent data tampering. Each data file stored on IPFS has a cryptographically calculated hash value. It is distinctive and is used to identify stored data files on the IPFS. The NFT based Land Record - Blockchain's critical and sensitive data may be safely stored via the IPFS protocol, which makes it an attractive option. To reduce the time-consuming computational processes on the blockchain, the generated cryptographic hash might be kept on the decentralized application. The peer-to-peer (P2P) network used by the IPFS protocol includes an IPFS object, a data structure that houses connections and data. Data is binary unstructured data, and the connection is an array. The IPFS protocol functions in the manner described below.

Duplicate files are not allowed on the IPFS network, and each node's content and index information are stored in cryptographic hash that is assigned to each file put there.

#### 4.6 NFT-Based Solution Proposed

We will go into more depth about our NFT-based solution in this section, including our system design architecture and system parts. In **Figure 2**, a high-level model of the proposed NFT-based system for managing land records and ownership is shown, along with the stakeholders that will be engaged and how they will interact with the smart contracts. Stakeholders may interact with the system's many parts, such as smart contracts, decentralised storage, and

other on-chain resources, using a decentralised application (DApp). The system's components are described in depth in the section below.

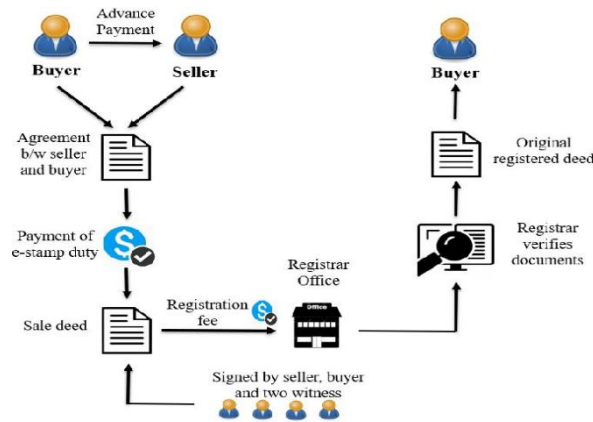


Figure 2: Smart Contract

A **REGISTRAR** is a public servant who approves each transaction a user makes inside a certain zone

### Interplanetary File System

IPFS is a peer-to-peer file-sharing platform for decentralized file content storage. Because storing media information connected to NFT on-chain has a significant cost, IPFS is an effective storage option in the context of NFT-based applications. In the suggested solution, the digital version of the physical device is stored using IPFS. The material kept on IPFS is accessible to all parties. Both the IPFS hash and the URI for the IPFS data are kept on the chain.

The decentralised off-chain storage is where the NFT's metadata, picture, and any other information pertaining to the actual medical device are kept

### 4.7 Blockchain Ethereum

A second-generation decentralised blockchain platform that enables the decentralised execution of user-defined processes and the running of code. It has its own currency, Ether, which miners aim to earn by solving challenges, much as with bitcoin. Externally owned accounts (EOA) and contract accounts (CA) are the two different categories of accounts in Ethereum. Transactions launched from EOAs are the source of all modifications to the Ethereum blockchain. The NFT unique identification number (ID) of a physical device in this system, together with all the transactions connected to it, are all stored on the Ethereum blockchain.

### 4.8 Smart Contracts

Self-executing programmed called "smart contracts" that operate on the Ethereum blockchain. Once deployed, they have a fixed address on the blockchain and cannot be changed. This enables an automated process that guarantees the execution of agreements once contractual requirements are met by involved parties without the need for an intermediate actor. The device verification and approval manager smart contract and the NFT smart contract are both implemented in this article. While the NFT-smart contract specifies functionality for minting ERC-721 tokens for validated medical devices, the device verification and approval smart contract manages all device verification and approval by regulatory body processes. Additionally, the NFT is locked until the new owner verifies receiving the medical device in order to verify that ownership of the NFT is transferred once it has been physically delivered to the new buyer. The new owner scans a QR code included on the delivered package to get this confirmation. A password is transferred on the chain as a result of the scan, unlocking the NFT and successfully transferring ownership

- **SELLER:** The landowner who initiates the land NFT transfer event, which can only be done with the registrar's permission
- **BUYER:** A person who purchases land from the seller.

## V. PROPOSED MODULE

### 5.1 Smart Contract

1. A smart contract for land registration using non-fungible tokens (NFTs) is a blockchain-based digital agreement that uses NFTs to represent land ownership. This smart contract offers a secure, open, and impenetrable way to track who owns what property and transfer land titles between parties. Each plot of land that is registered on the blockchain is given a distinct NFT by the smart contract in order to function.
2. The NFT offers details on the land, including its location, dimensions, and any pertinent legal documents. The NFT's ownership reveals who owns the land. The owner must execute the smart contract to transfer ownership of the NFT to themselves in order to record land ownership.
3. The smart contract will then document the ownership transfer on the blockchain, producing an unalterable and permanent record of the transaction. The NFT ownership may be passed to the new owner if the land is sold or transferred to a new owner, creating another permanent and immutable record of the transaction.
4. Additionally, the smart contract may be set up to impose certain restrictions or guidelines about the ownership and use of the property. For instance, the smart contract can specify that the property can only be utilized for agricultural purposes or that commercial development is not permitted.
5. Compared to traditional land registration processes, using NFTs offers several advantages. It eliminates the need for intermediaries like lawyers and notaries, cutting costs and increasing productivity. Additionally, it provides a more reliable and secure way to record property ownership, reducing the likelihood of fraud and legal issues.
6. In a nutshell, a blockchain-based digital contract that uses NFTs to represent land ownership is called an NFT-based land registration smart contract. It provides a secure, open, and unchangeable way to record property ownership and transfer land titles between parties.

### 5.2 NFT Market Place

1. Digital tokens known as NFTs represent ownership or authenticity of a special good or value, such as digital artwork, music, or virtual real estate. There is a lot of interest in using NFTs for land registration and developing NFT marketplaces for buying and selling virtual land as a result of their rising popularity.
2. The documentation of land ownership and transactions may be streamlined using NFT-based land registration, requiring less traditional paperwork and intermediaries. The use of NFTs enables the quick and easy recording of land ownership on a blockchain, producing a tamper-proof record of ownership that is accessible to all parties involved in the transaction.
3. A platform for purchasing and selling virtual real estate may also be provided via NFT marketplaces for virtual land, allowing investors and developers to buy and create virtual estates for a variety of purposes. These marketplaces may be developed to facilitate transactions across several virtual worlds, allowing users to buy and sell virtual assets on various platforms.

In general, land markets and NFT-based land registration can completely change how we think about real estate and ownership in the digital age. We should anticipate seeing more creative applications of blockchain and NFT technology in other industries as well as the real estate industry as these technologies develop.

### 5.3 NFT Splitting and Merge

1. The NFT technology, which creates an unchangeable and tamper-proof record of ownership, might alter the way that land is registered. NFTs are distinctive digital tokens that represent a specific asset and may be used to prove ownership of a certain home or piece of land. It may be possible to register land ownership using this technology, making it easier for individuals and governments to retain and transfer property rights.
2. The division and reunification of land parcels is one potential use of NFTs in land registration. It would be possible to divide a single piece of land into several NFTs, each of which would represent a different portion of the land, using NFTs. It would thus be possible to have more exact and adaptable land ownership, which would make it easier to sell, rent, or mortgage specific sections of real estate. NFT splitting could make it simpler for fractional ownership to arise, enabling more people to participate in real estate with less money.

3. On the other hand, NFT mergers would make it possible to combine several NFTs into a single asset. In situations where property ownership is fragmented, such as in heavily populated urban areas where many people may own little sections of a larger property, this may be desirable. These folks may create a single, larger property with more value and easier upkeep by uniting their NFTs.
4. However, there may be further issues with the use of NFTs in land registration. One issue is the cost and difficulty of implementing NFT-based solutions, which may be prohibitive for certain governments or individuals. Before NFTs are widely used for land registration, there can also be legal and regulatory difficulties that need to be resolved.
5. In general, NFT-based land registration may provide significant benefits in terms of effectiveness, transparency, and security. Despite the obstacles to be overcome, the potential
6. Governments, real estate firms, and individuals looking to invest in real estate are all interested in the NFT based Land Record - Blockchain benefits of this technology.

#### 5.4 Multipoint Permission

1. NFTs have gained popularity recently due of their ability to represent distinctive digital products reliably and securely, such as works of art or music. NFT could be used in the land registration process to designate ownership of a particular piece of land.
2. According to the concept of "multipoint permission," many parties must agree on a transaction before it can be completed. Multipoint Permission might be used in the context of NFT-based land registration to ensure that any changes to a piece of land's ownership are acknowledged by all relevant parties. This might include the current owner, potential buyers, and governmental organizations in charge of overseeing property ownership.
3. NFT-based land registration with Multipoint Permission could function as follows :An NFT that represents their ownership of a piece of land would be built by the current owner.

The location, size, and legal description of the property would all be included in this special NFT. Any potential bidders must have permission from the current owner before they can buy the NFT and take possession of the property. Multipoint Permission would be used in this situation, requiring the agreement of both the current owner and the potential buyer.

Governmental bodies in charge of governing land ownership would need to approve the transaction after the NFT had been transferred to the new owner. Any subsequent transactions involving the land would also need to be approved by all relevant parties through Multipoint Permission in order to ensure that the transfer of ownership is legally recognized and documented. This would ensure that the land's ownership remains clear and secure.

#### 5.5 NFT Profile

1. Digital assets that are one-of-a-kind and cannot be duplicated are known as non-fungible tokens (NFTs). They are created and managed with the use of blockchain technology, providing a secure and open method to confirm ownership and transfer of ownership.
2. Land registration is one scenario where NFTs could be used. Each parcel of land may have its ownership tracked and recorded on the blockchain by creating an NFT profile for it. This would make it possible to transfer and confirm land ownership in a way that is more secure and transparent.
3. Double ownership or challenged ownership would likewise be solved by NFT-based land registration. Even if the actual paperwork were misplaced or contested, it would be clear who the rightful owner of a piece of property is thanks to the blockchain's role as an immutable record of ownership.
4. Additionally, NFT-based land registration might perhaps speed up the purchase and sale of property. The process might be time-consuming and costly right now due to the various fees and taxes involved. The procedure might be shortened to save costs and boost efficiency by using NFTs.
5. There are, of course, additional issues with creating NFT-based land registration. For instance, there can be problems with the blockchain technology's scalability and security. There can also be issues with regulations and the law that need to be resolved.



- NFT-based land registration can revolutionize the way land ownership is verified and recorded despite these challenges. It might make land ownership management more transparent, safe, and effective, which would be advantageous to both individuals and society

## VI. EXPERIMENTAL ANALYSES

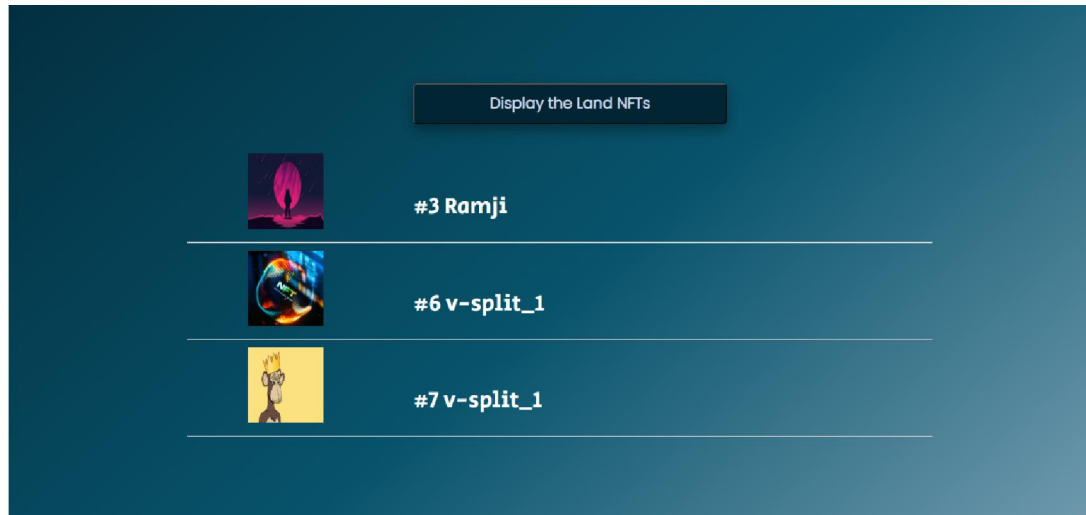


Figure 3: NFT Display

### 6.1 BLOCKCHAIN VS CENTRAL DATABASE

Central databases and blockchains are two different approaches to storing data, and each has its own advantages and disadvantages in terms of security. Central databases are controlled by a single entity, typically a company or organization, and the data is stored in a centralized location. Access to the data is typically controlled by usernames and passwords or other access controls, and the security of the database depends on the security measures put in place by the entity controlling it. Central databases are susceptible to hacking and other cyber-attacks, which can compromise the security of the data. In contrast, blockchains are decentralized and distributed ledgers that use cryptographic techniques to store data. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of records. The data in a blockchain is stored across a network of computers, and each node in the network has a copy of the entire blockchain. This means that there is no central point of control, and the data is more resilient to attacks. Blockchains also use consensus mechanisms, such as proof of work or proof of stake, to ensure the integrity of the data. Blockchains can allow for more transparent auditing of data security. Because the data is stored in a tamper-proof, decentralized ledger, it is possible to audit the entire history of the data and ensure that it has not been compromised.

## VII. CONCLUSION

In conclusion, the use of NFTs in land record systems has several advantages, including increased security and transparency. NFTs may ensure that land records are impenetrable and easily accessible by authorized individuals, reducing fraud and corruption. Additionally, the adoption of NFTs may reduce the time and money needed to manage property records, resulting in significant cost reductions. However, a variety of parties, including the public, businesses, and governmental organizations, must be included in the implementation of NFTs in land record systems. To ensure the safety and dependability of NFTs in land record systems, governments must set up the necessary legal and regulatory framework. To enable the use of NFTs in land record systems, private businesses must provide the necessary hardware and software. The benefits and limitations of employing NFTs in land record systems must be made known to the general public.

Additionally, there are several technological and legal barriers to the deployment of NFTs in land record systems. One of the issues that must be resolved is the interoperability across different blockchain networks. The legal recognition of NFTs in land record systems is an additional issue.

To guarantee the security and reliability of NFTs, governments must provide legal legitimacy and protection. In conclusion, the use of NFTs in land record systems offers a number of advantages, but their implementation requires collaboration among many stakeholders and more research to get beyond legal and technical hurdles. NFTs have the ability to alter land record systems and make them more productive and economical with the right collaboration and study.

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