# T-PASS: A Blockchain-based NFT Enabled Property Management and Exchange System

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*Abstract*—**Everybody is witnessing a tremendous rise in the tokenization of all types of assets, including stock, funds, debt, and intellectual property, as a result of the explosive growth of decentralized finance (DeFi). Blockchain technology enables users to convert physical or digital assets into Non-Fungible Tokens (NFTs) and trade using cryptocurrencies. Blockchain technology uses a Distributed Ledger Technology (DLT) system to enable immutable, traceable, and safe trading. NFT's use is currently restricted to fancy digital artwork, collectibles, games, etc., but its distinctive capabilities and platforms could be used for more real-world problems. This paper extends the DeFi applications with the real estate property assets as NFTs, examines the requirements of NFT-enabled property management and exchange system, and proposes a model for the same. We discuss the system design specifications and implementation approach extensively. The proposed model gives key components and direction for using NFTs in actual property management issues.**

*Index Terms*—**Blockchain, Smart Contracts, NFT, Ethereum, Property Exchange**

## I. INTRODUCTION

Blockchain and associated systems are taking the entire world of technology by storm. It was initially developed to solve the double-spending problem in cryptocurrencies like Bitcoin [1]. Since then, blockchain technology has been used not only in cryptocurrency but also in many diverse fields like finance, insurance, notary, supply chain, and digital asset management due to its unique characteristics such as decentralization, transparency, immutability, and auditability [2]. Blockchain allows anyone to build a decentralized application using smart contracts providing a trusted execution environment necessary for the application [3]. Blockchain works alongside existing Internet technology, incorporating core technologies such as a cryptographic consensus mechanism. Blockchain also provides security by using cryptographic methods (i.e., hash function, digital signatures, and other cryptographic techniques) to do transactions in a decentralized fashion [4].

Non-Fungible Tokens (NFTs), another trendy application of Blockchain technology, enable the system to create and store a digital blueprint or DNA of physical assets considered a proper digital form of the physical asset and Proof of Ownership of the specific asset [5]. The digital assets may include Digital DNA of Artworks, IPRs, Digital Arts, and similar assets [6]. This allows the possibility of transferring ownership of these assets over the Blockchain network for a specified value which could be paid through the currency supported by the Blockchain network holding the NFTs.

NFTs have become popular and widely accepted worldwide for Artwork and other assets. NFTs are widely accepted because of their unique features such as uniqueness, ownership, tradable, rarity, etc. This work utilizes this concept to create Real Estate Properties's digital blueprint. The property based-NFT will act as proof of complete or partial ownership of a piece of land, residential or commercial property.

This paper aims to develop a model for creating NFTs for Real Estate Property Assets on the Blockchain network, which provides Proof of Ownership to the actual owner of the property and develops a platform that can generate smart contracts over the blockchain network. Smart contracts facilitate the transfer of ownership of any assets in full or partial mode. This complete system emulates an NFT Based Property Exchange platform termed T-PASS (Tokenized Property and Asset Selling Services). T-PASS handles and manages the ownership, sale, lease, mortgage, and ownership transfer of real estate assets by blockchain-enabled NFTs. Each parcel (the smallest piece of the asset) is converted to an NFT, and the property or the asset is mapped to an NFT and stored on the blockchain. This allows an exchange that will function as a platform to buy/sell/lease the asset linked to these NFTs.

In Blockchain-enabled Real-Estate Property Management and Exchange Platform, all the stakeholders for any property will have the right level of access and control to the NFT created for every marketable or saleable parcel or unit of a property. The key stakeholders include the Property Developer, Current Owner, Proposed Owner, Banking Institutions, Leasing/Mortgage Agencies, Revenue Department, Local Authorities, Utility Companies, and Taxation Authorities.

The exchange will function as a marketplace where these assets would get listed, and any potential buyer can submit their bid for an asset. Once all the stakeholders approve or accept the bid, the transaction would get completed, provided the value consideration for the asset is available in an escrow account provided by the buyer or any reputed Banking Institution supporting the bid. In this paper, we propose a decentralized framework called "T-PASS" for NFT enabled property management and exchange system. We discuss the system's key requirements, design specifications, and implementation approach in detail.

The most significant benefit of the proposed solution would be the capability to handle the complex processes involved in Real Estate property transactions. Since this solution is based on Blockchain Technology and provides the facility

to get consent from all the stakeholders before committing the transaction, there will be a substantial amount of time to complete such a transaction today.

## II. RELATED WORK

Colored coins is a protocol built upon Bitcoin and have shown an initial path toward the NFTs. Despite being fungible, bitcoins can be labeled in such a way that they can be distinguished from one another. Colored coins allows users to represent various digital assets that may further be utilized to create and transfer the asset's ownership [7]. Due to the restrictions of the Bitcoin script, Colored Coins had limited utility. Nevertheless, Colored Coins paved the way for additional research and provided a foundation for NFTs.

Ethereum has several standards (ERC20, ERC721, ERC1155) for various tokens (Fungible, Non-Fungible, Semi-Fungible) to ensure that network interaction are successful. ERC20 is the most common standard that defines rules that allow a token to interact with Ethereum applications or other tokens [8]. However, the ERC20 standard does not provide how to create distinctive tokens. To achieve this, the ERC721 standard was developed. The ERC721 standard was purposely developed for creating NFTs on Ethereum blockchain [9]. Additionally, Ethereum has released one more standard, which is known as ERC1155. ERC1155 provides a common interface for token management contracts that handle various token kinds [10]. Any mix of fungible and non-fungible tokens or other configurations may be used in a single published contract of ERC1155. Many NFT marketplace has been developed for NFT creators, such as OpenSea, AtomicMarket, and many more. Each marketplace offers a wide range of NFTs, including digital art, books, trading cards, music albums, movies, virtual worlds, collectibles, etc.

Authors in [11] evaluated NFTs' creative thinking across many industries, closely examining their applicability and influence. Researchers have been looking for NFTs to solve more practical problems and extend the NFT marketplace. For instance, authors in [12] presented a scientific report discussing the requirements of presenting intellectual properties as NFTs. The authors in [13] have proposed a framework to represent intellectual property, i.e., patent as NFT.

Due to the pandemic in the last few years, artists and music creators are connecting people through digital platforms and generating more revenue. Such digitization makes it necessary to protect the creator's content through copyright. Therefore, the article [14] proposed a model for protecting the copyright of music industries after representing the music files as NFTs. Authors in [15] developed a framework where anyone can create an NFT corresponding to the desired artwork. The created NFT will automatically be added to one of the NFT marketplaces (OpenSea) through the wallet. Now the NFT is publicly available for the user of OpenSea to buy, or the owner can take it out for auction. The authors in [16] proposed a framework for NFT-based academic certificates enabling linking a legitimate NFT-based certificate and its owner.

Tokens and NFTs are more significant components of metaverse development, a brand-new digital and online world. The theoretical underpinnings of cryptocurrencies, tokens, NFTs, and the Metaverse were examined in [17], along with the potential for fundraising via token issues for various startups. To protect the authenticity of the items in the Metaverse, article [18] ties the idea of NFTs to the Metaverse as the finest digital asset. Article [19] first evaluates the literature on the development of tools for managing intellectual property using blockchain. Additionally, the authors have proposed a framework employing Blockchain technology to protect the Building Information Modelling (BIM) design's intellectual property. [20] presented a model for creating NFTs containing real estate information. The proposed model is implemented in a private blockchain rather than using Ethereum standards, resulting in a less transparent system. On the other side, we discuss in depth the system requirements and design specifications of NFT-enabled property management and exchange system in this paper while considering the Ethereum standards.

## III. SYSTEM REQUIREMENTS

All the requirements are listed here at an abstract level so that they can be expanded and implemented during the design phase. Detailed requirements of T-PASS include:

1) The system should be capable of converting any immovable property like real-state asset into the form of NFT (Non-Fungible Token) which have the capability to hold all the vital information associated with the property.
2) The system should be capable of creating smart contracts on the basis of NFC tokens.
3) The smart contract should have interface methods to transfer the NFT from the present owner to any prospective owner.
4) The smart contract created should have the option to add other stakeholders (other than the current owner and prospective owner) also as active participants in the contract.
5) The other stakeholders can be one or more from the set of Revenue Authority, Local Admin Body, Utility Companies, Banks/Fin Institutions, and Taxation Authorities.
6) There should be an option to set the privilege for each of the stakeholders other than the owners. The privilege can be of "Notification Only" or "Consent to Modify".
7) There should be one Escrow Account holder who will function as the custodian of the transaction. The transaction gets approved once the Escrow Account confirms that the buyer has sufficient verified buying power available which can be locked for the specific transaction. The exchange functions as the role of the escrow account.
8) When a new property is created or constructed, the builder/realtor should work with the exchange/system to mint or create the required NFTs in correspondence to the saleable units that are constructed or created.
9) All the other related stakeholder's interests and corresponding privileges should be protected while creating the NFT corresponding to any asset.
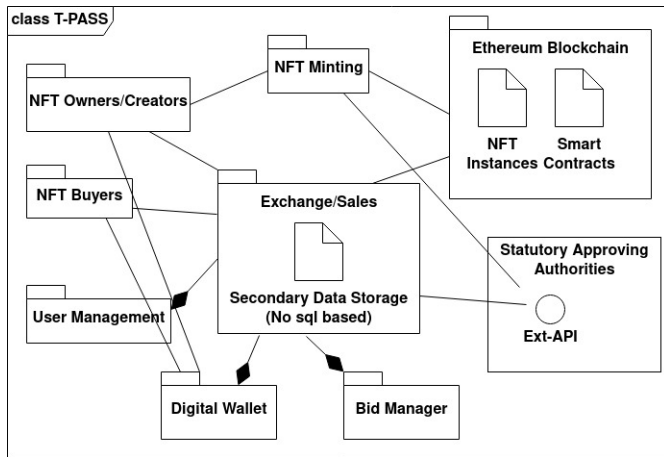
Fig. 1. Subsystem Level View of T-PASS System.

10) The exchange/system should provide the necessary interface for listing all the free-hold assets (NFTs) owned by either the original or subsequent owners.
11) There should be a front-end interface that facilitates the current owners to list their assets and prospective buyers to bid for any listed asset.
12) For other stakeholders, there should be secured APIs for closing the transaction depending on the privilege level and applicability of each stakeholder. All the relevant data should be part of the NFT Token under consideration.

## IV. DESIGN SPECIFICATIONS

We list all the key design objectives in accordance with the system requirements of the proposed system in Table I.

The system-level design in Fig. 1 depicts the interaction between multiple subsystems for each use case. It also provides a higher-level view of various subsystems that constitute the whole proposed T-PASS system.

### A. NFT Owners/Creators

This subsystem handles all the owners and creators of the Tokens representing the real estate property. A creator class is responsible for creating or minting a new token when a new property is created (Built by a Builder or Realtor). This token creation is activated when an existing property with the ownership documents in fiat form gets converted to an NFT. Another class of this subsystem corresponds to the set of NFT owners, which include the methods providing the services required by users with one or more Tokens under their belt.

### B. NFT Buyers

NFT Buyer class has complete services that implement the buy operation and keep the functionalities of the potential buyers of the properties. This includes verifying the credentials of the buyers as well.

### C. NFT Minting

The minting service subsystem implements all the functionalities related to minting or creating the valid Token as ERC721. The minting service creates the Tokens based on the

input attributes shared by the creator. In the current implementation, the Ethereum test network provided by Ganache is used as the platform to create and store the tokens.

### D. Exchange/Sales

Exchange provides the functionalities required for buying/selling services of the assets in the tokenized format. This subsystem performs as the central entity that connects/links all other subsystems. All the users are onboarded to the exchange, allowing them to list their properties subject to the necessary approvals from all the statutory agencies. The exchange also keeps a secondary database and historical data for audit and cross-verification purposes of all the NFTs listed in the exchange, even though all the NFTs are stored in the blockchain. The exchange classes implement the smart contract based on the successful bids placed in the system. We use truffle-based EVM (Ethereum Virtual Machine) and the associated development environment to create, update, and manage smart contracts that correspond to each transaction.

### E. Blockchain

This subsystem realizes the blockchain network holding all the NFTs and associated smart contracts. Ethereum blockchain developed its own high-level programming languages, which compile into bytecode that runs on the Ethereum Virtual Machine; its most popular being Solidity, which features a JavaScript-like syntax. Thus, we chose to develop the smart contract code for the prototype in Solidity. We relied on the development framework Truffle, which contains tools for the deployment of contracts and the testing library Mocha, and ganache-cli, which provides a local Ethereum blockchain for testing. In this work, we use a Ganache-based local Blockchain to execute the smart contracts and transfer the ownership of the properties in tokenized format.

### F. Statutory Approving Authorities

This subsystem realizes north-bound APIs required to get the transaction authorized by the external and statutory stakeholders. These authorities include revenue, land records, local bodies, taxation, banks, and financial institutions. Approval from these authorities is required right at the time of new NFT creation. Once an asset token is created, all the ownership-related attributes are validated with the corresponding authorities and are approved. If any lien/mortgage is with any financial institution, necessary approval is required to complete any transaction through the smart contract.

### G. User Management/Interface

This subsystem creates all the UI/UX design and implementation. This also handles user management, including creating new user accounts, assignment of user privileges, associate access control, etc.

TABLE I
T-PASS DESIGN OBJECTIVES

| SN | Design Objectives | Description | Evaluation |
|---|---|---|---|
| 1 | Digitization<br>• Digital storage of all data<br>• Digital exchange of all data | • The methods and processes used to convert all the property and associated documents to Digital (NFT).<br>• Providing secured market place for transfer of ownership of these assets. | These shall be validated for accuracy and effectiveness of the digitization as well as transactions at the exchange. |
| 2 | Primary and Secondary Market transactions<br>• Managing transactions<br>• Prices caps<br>• Charging transaction fees | • The design and implementation of the exchange shall have the capability to list all the approved new properties as well as any property that the current owner intent to sell.<br>• The system would set applicable prices caps to restrict speculation. | These shall be validated at the time of design through simulation automation. |
| 3 | Distribution of authority and independence<br>• Decentralization<br>• Trustfulness | • No centralized person can complete the transaction without the consent of stake holders. | Assessment of efficacy and validity through testing and descriptive evaluation. |
| 4 | Security<br>• Availability<br>• Integrity<br>• Privacy | • Security shall be one of the key considerations while implementing the design.<br>• A secure environment is characterized by the accessibility of resources (availability), the authenticity of the data (integrity), and the prevention of access to illegitimate users (privacy). | Consistency and reliability should be verified using simulation, testing, and description evaluation. |
| 5 | Validation<br>• Verifiability of ownership | • To increase trust in the integrity of the system with respect to: property ownership, transaction execution and control, notification and control that shall be enforced by the legal, revenue, and other authorities. | Functional testing and simulation to assess the reliability. |
| 6 | Transparency<br>• View of property ownership<br>• Access to transaction history<br>• Assess to the revenue and legal sanity of the property | • The property details, complete transaction history from the time of creation or minting | Analysis of accuracy and completeness through simulation and descriptive methods. |
| 7 | Automation<br>• No manual interaction required after setup<br>• The transaction shall be completed without any manual intervention except for the approvals from statutory authorities<br>• There shall be an option "open" to complete the statutory authentication in an automatic manner. | • The exchange system should not be required to perform any manual action after an initial set up.<br>• All the approval process shall be performed in an automatic manner.<br>• There can be exceptions with respect to the legal and statutory authentications, this could be done in a phased manner. | Functionality and reliability should be assessed through testing and simulation. |
| 8 | Cost Efficiency<br>• Efficient cost structure | • The fixed cost, per transaction cost and maintenance cost shall be optimum and economical to make the system acceptable to a wider population. | Assessment of efficiency through simulation. |

## H. Bid Manager

The Bid Manager process all the biddings that various users submit for the listed assets. This subsystem can create a bid for a different set of assets listed in the system. The budding system is capable of recording all the bids, including history data, validating the bid against various mandatory conditions specified, create a Dash-Board of the bid status at a given time.

## I. Digital Wallet Interface

The system provides the Digital Wallet interface to credit, debit, and hold the value consideration corresponding to the Bid or Buy request placed by any prospective buyer or bidder. The bidder has a sufficient balance in the wallet to place a successful bid. Upon successful completion and awarding of the bid, the asset is transferred to the buyer, and corresponding consideration is credited to the seller's account. Since this process is done through smart contracts, these records cannot be modified after that.

## V. DETAILED DESIGN AND IMPLEMENTATION APPROACH

This phase includes the creation of a detailed design of various subsystems and modules, identifying the right set of technologies, tools, development environment, integration platforms, test environment, etc. The implementation makes use of proven and industry-standard open-source platforms and software components. As discussed in the previous sections, the NFTs corresponding to the underlying assets are created based on ERC721, the open-source implementation by Open Zeppelin. The rationale behind this implementation is that it provides the most widely accepted implementation of ERC71-based tokens. As the execution environment is concerned, this work is created in the Truffle platform, and the complete testing is carried out on the personal blockchain provided by Ganache. This way, the intent is to prove the technology and the whole concept at no extra cost for SW licenses or the cost of Ether/Gas. As the Digital Wallet is concerned, a Metamask-based virtual digital wallet is used, and all the smart contracts
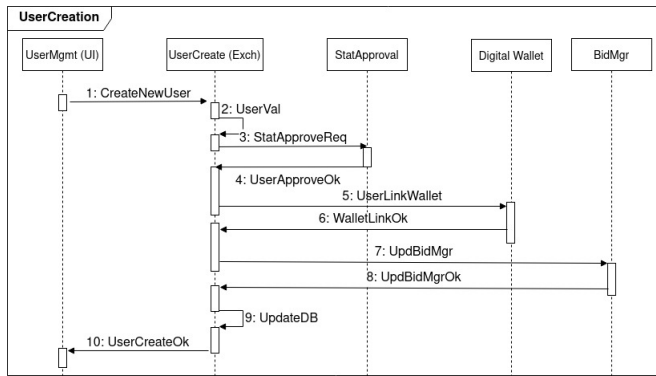
Fig. 2. Sequence Diagram User Creation

are created in solidity.

The above implementation guidelines are for the Blockchain and NFT-related implementations, but there are multiple other components that need to be implemented to realize the complete solution. These components include All the User Interface Modules and Subsystems. These are proposed to be developed using RectJS and redux. Back-End API Development and implementation. The Back-End API development is being proposed to be done in NodeJS Data Base Implementation. The initial thought process was to go with NoSql (MongoDB) for this implementation; however, the current implementation is to be done with PostgreSQL.

*A. User Creation*

This is the first key feature implementation that is carried out. Once the system is up and running, there can be a default configuration (based on the config file) active in the system. The Super User or Admin User is created by default. When someone wants to get connected with the system, on the default login page (for existing users), the user enters the UserID and password to get access and move forward. Since the master DB for the users is part of the Exchange subsystem, every *CreateNewUser()* requests the UserCreate object of the Exchange subsystem. The exchange does all the required validations for creating this particular user in the exchange or not. Once the user credentials and KYC are verified, the exchange checks for the statutory compliance check, generally done to ensure no legal compliance issues, are open with the specific user.

Once the verification of user data is completed, there will be communication between Digital Wallet and Bid Manager to update the information about the available users. This will enable the registration of each user with Bid Manager as well as the Digital Wallet. Subsequent to this, the UserDB is updated with the new User Profile. Post DB Update, the UserManagment UI gets a response stating that the new user profile is created, requesting the user to log in with new User Credentials submitted for User Creation.

*B. NFT Creation/Minting and Listing in Exchange*

This is the feature or the User Story, which has some of the key functionalities of the system. The NFT Creation, as
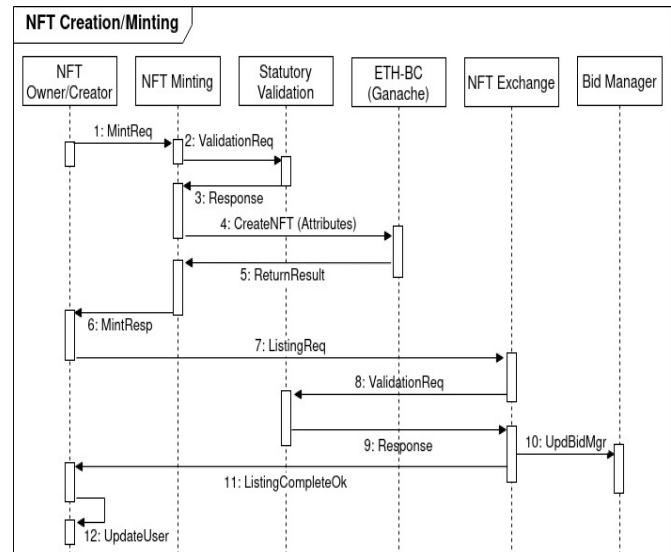


Fig. 3. Sequence Diagram of NFT Minting and Listing at Exchange

per ERC721, is done in this story. In addition to minting or creating, the NFT corresponds to the specific property. Since listing properties through NFT is a purely upcoming and new concept, the idea is to implement this method for the new properties that the real estate developers want to list and sell to the customers. The developer is the creator (Minter) of the NFT corresponding to each piece of saleable property that prefers to list and invite bids from prospective buyers.

Once the properties are ready for listing, the real-estate developer or the legal owner of the property logins into the User Management System and invokes the MintReq application. To invoke this service, the user provides all the attributes related to the property, which is verified with the Statutory Verification Agent. The verification is done with the Local Bodies, Revenue Department and Financial Institutions. Suppose the verification fails from any of the mandatory agencies. In that case, the NFT creation request is aborted, and a suitable error code is displayed to the user who requested the NFT creation.

Once the verification is successful, a new token is created (minted) and stored on Ganache's personal Ethereum blockchain instance. The NFT is created as per ERC721. Upon successful creation of the token, tokenID is returned to the user. The tokens are listed in the exchange to enable their tokens to be visible to the external world. The user sends a request to the exchange with tokenID and other details for listing it in the exchange. The exchange validates the request and the received data for all the mandatory fields and also for the approval flags from multiple Statutory Validation Agencies. Once the validation is through and the token cleared of all obligations, it is listed in the exchange indicating that the token and the property associated with that are freehold of the current owner and are available for sale to the successful bidder.
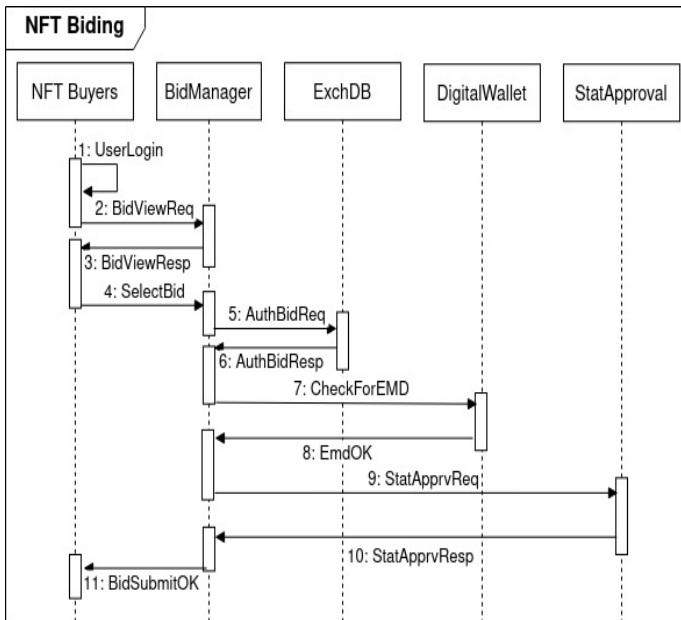
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Fig. 4. Sequence Diagram of Bidding Process

## C. Bidding for Assets (Properties)

Once the property listing is completed, authorized users can view the listed properties for bidding. The BidView screen has all the options to see all the open bids, recently closed ones, history of bids, multiple search options to see the bid history, and apply various filters that help the user to analyze previous bids of similar properties and compare the prices. Also, there are various Dash Boards with respect to the current/open bids.

Any authorized user can see the BidView page. The user can select the token/property which is of interest to bid. The user will enter all the required attributes as per the published form in the bid screen. As part of the authentication process, the exchange checks the user's privilege to submit a bid and the availability of a sufficient amount available in the Digital Wallet of the bidder. In case the bidder is pledging another property owned by the bidder as the EMD for the current bid, the authenticity of the pledged property is verified by the Statutory Authentication services. Once all the verification is successful and everything is in order, the bid is placed in the system, and the bid details are returned to the user. The bidders can modify the bid until the bid cut-off time. The bid is processed post the cut-off time specified at the time of bid opening.

## VI. CONCLUSION AND FUTURE WORK

Blockchain technology provides several key characteristics, such as decentralization, transparency, immutability, audibility, and others, that enable the creation of NFTs and allows users to sell or buy the NFTs through the exchange system. Researchers utilize the blockchain to solve practical issues through NFTs such as NFT-based patents. In this paper, we solved the general issues with property management, such as time-consuming process and resource wastage, increasing overhead, difficulty to control or access the data, managing contracts, managing payments, and communication breakdown. We developed a model for creating NFTs for Real Estate Property Assets on the Blockchain network, which provides Proof of Ownership to the real owner of the property. An exchange system is incorporated in the proposed model where assets can be listed and provided a platform to buy or sell the assets. Since NFTs are an integral part of the Metaverse, the proposed model can also be integrated with the Metaverse. We will try incorporating the proposed model with the Metaverse in future work.

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