A Minor Project Report

on

NFT Marketplace

Bachelor of Technology

IN

COMPUTER ENGINEERING

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Declaration

The work presented in the project entitled "NFT Marketplace" submitted to the Department of Computer Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University Aligarh, in partial fulfillment for the award of the degree of Bachelor of Technology in Computer Engineering, during the session 2022-23, is my original work. I have neither plagiarized nor submitted the same work for the award of any degree.

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Certificate

This is to certify that the Project Report entitled "NFT Marketplace", being submitted by "Mohd Mamoon and Ilma Shah", in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Engineering, during the session 2022-23, in the Department of Computer Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University Aligarh, is a record of candidate's own work carried out by him under my supervision and guidance.

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Abstract

The proposed work is a blockchain-based Non-Fungible Token (NFT) Marketplace that is developed for the provenance and authenticity of an artwork. Solidity programming language is used to implement smart contracts stored on the Ethereum blockchain which are executed automatically when predefined conditions are met. An Ethereum-based decentralized application is developed which allows a user to create his NFT by tokenizing his artwork on the blockchain and selling it on the marketplace.

In our implementation, we used OpenZeppelin's ERC721 Contracts which allows for the implementation of a standard API for NFTs within the smart contracts, booted up a development blockchain, created Ethereum smart contracts, wrote tests against them, and build a client-side website so that anyone can use the application.

Index Terms – Non-Fungible Tokens, Ethereum, Solidity, ERC721 Contracts

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CHAPTER 1
INTRODUCTION

1.1 Problem Statement

In 2016, the global trade of fake goods was worth around half a trillion dollars a year. A sum that is equivalent to 2.5% of global imports the art gallery Knoedler in New York was accused of selling forgeries for $80 million during a 15-year time period. Giuliana Ruffini, an art collector, was accused of selling artworks for around £179 million and the authenticity of particularly four artworks has been questioned by experts The quality of the forgeries has become so similar to the authentic artwork that the auction company Sotheby's has hired an in-house fraud-identifying expert. Furthermore, there are even experts that believe that 20% of art owned by public museums will be attributed to a different painter in 100 years [1].

According to the Economist, in general, art sold for more than €200,000 grows in value five times faster than cheaper paintings. Furthermore, the underlying value of American popular art grew nine times higher than S&P 500 between 2006-2016. As a result, art has attracted a lot of speculators and nearly 75% of art was purchased as an investment in 2016, which is an increase from 50% in 2012 [2].

According to Newman and Bloom, the value of art is defined by two key factors; the creative performance and the degree of physical contact with the original artist. The value of an artwork deteriorates if identified as a forgery and if the creative act is deemed unsatisfactory. As a consequence, the authentication of art is an important factor during valuation. This is usually exhibited in the documentation that accompanies the artwork which assures genuinity and the authorship of the artwork. The documentation is usually a signed certificate of authenticity. For more established works, getting the artwork appraised by experts can also strengthen the claim of authenticity. With antique artworks, there is rarely a signed certificate of authenticity.

Therefore, authentication strengthened by provenance is important.

1.2 Proposed Solution

Blockchains operate under the principle of "code is law". From the blockchain perspective, the creator of the token, to which an asset is attached, is initially the owner of the token. Anyone who buys that token owns the hash. In this way, they own the token. This shows that ownership of NFTs is transactional. It can be simple ownership of the NFT or additional ownership, which can be encoded in the underlying smart contract. Thanks to the blockchain, and distributed ledger technology, the sale, and movement of NFTs can be traced, verified, and recorded on an immutable ledger. This means that their creation, unique identifiers, and ownership are traceable and verifiable. Digital collectibles, artworks, and intellectual property are likewise protected, as each item can be traced to its origins. This means digital collectibles can be authenticated and verified, protecting both the creators and the owners from scams and fakes. NFTs provide proof of ownership of the asset, real or virtual, attached to the token which the token holder can use at his/her own discretion to provide an immutable and verifiable record of ownership that can be transferred at the owner's behest.

In different use cases, ownership can constitute different meanings. For example, a copy of a digital photo that was minted on a platform can be made available on a different platform while the ownership of the image remains with the NFT token holder. In the music industry, holding an NFT of an album can constitute ownership of that album, the proceeds from which will go to the NFT owner.

CHAPTER 2

BLOCKCHAIN TECHNOLOGY, NON-FUNGIBLE TOKENS, SMART CONTRACTS, AND GAS FEE

2.1 Blockchain Technology

Blockchain technology has been discussed as a possible solution to the identified difficulties regarding provenance and authentication. The reason is that blockchain provides a bonded registry of previous ownership. Although, the validity is dependent on the starting point of the blockchain registry.

Blockchain technology gained traction when Nakamoto published a paper laying the groundwork for Bitcoin. The technology is influenced by Haber and Stornetta's paper regarding the possibility of timestamping documents from 1991. Blockchain technology can be defined as a distributed ledger with the possibility of saving information in a secure and permanent manner. The information is usually about the receiver and sender and what is being sent between them. A blockchain consists of data packages that are chained together, called "Blocks". Each block has a certain amount of storage which is filled up with information concerning the transactions. Every block gets added onto the existing chain of blocks, in other words, the "Blockchain". The blockchain, therefore, represents the full ledger of the transaction history. For the blocks to "chain" together, each block contains a hash of the previous blocks and a timestamp addressing when the transaction took place. As a consequence of the hash, the chain of blocks becomes immutable and irreversible as long as the blocks are not invalidated by the other nodes/users on the blockchain network. The consensus algorithm proposed by Nakamoto (2008) entails that the majority of the nodes on the network accept the new block on the blockchain. Each node has a personal copy of the distributed ledger. The consensus is achieved when the ledger of the nodes corresponds to the newly proposed ledger on the blockchain. If the ledgers align, the block is added. As a result, no centralized power decides which blocks should be added to the existing chain.

2.2 Non-Fungible Tokens

An NFT is a special type of digital asset or token that can be proved to be unique and not interchangeable with another digital asset token (i.e., fungible). This is why it is referred to as a "non-fungible token". Typically, the record of the uniqueness of the NFT exists as a cryptographic record on a blockchain, or distributed ledger, and can readily be viewed by anyone. While that is not always the case, NFTs are not just digitized information about an asset – they are digital assets. This parallels the way that the blockchain constitutes the internet of value [3].

NFTs are created by certain frameworks or standards and deployed on-chain. At the moment, the most popular blockchain for NFTs is Ethereum, and the most standard is Ethereum's ERC-721, which determines certain characteristics for NFTs. In this way, NFTs can be managed, traded, and owned by the properties of the framework or protocol as those have been defined according to their issuance properties.

2.2.1 Characteristics of NFTs

(a) **Uniqueness:** With NFTs, it is possible to produce a limited number of tokens, with each being individually identifiable. A popular example is the 10 000 unique NFTs issued by CryptoPunks. Though in some cases having similar NFTs is plausible, as is the case with numbered series of an artist's digital work. A good way of thinking about this is the analogy of 1:1:X, or one, out of one, out of X.

(b) **Rarity:** Rarity in NFTs can come in many forms and can be either artificial, numerical, or historical.

(i). Artificial rarity refers to the uniqueness of the NFT as determined by its code, or the specifics of its issuance. To better understand this concept, we can again utilize the popular Cryptopunks. As

determined by their issuance, only 1.75% of the total Cryptopunks have a Medical Mask feature. Contrasting this with the 24.59% chance of having an Earring, we can denote that a punk with a Medical Mask will always be rarer than the one with the Earring if all else is equal.

(ii). Numerical rarity is closely tied to Artificial and as such, is relatively intuitive to understand. Consider the example of a popular artist releasing 100 digital copies of their latest music album as NFTs. Intuitively those 100 copies that come with the artist's "digital signature" and can be verifiably owned, will be more scarce and thus rare, than simply streaming the album off Spotify. It is useful to think of this as analogous to owning a physical album that is signed by the artists, and one that is not.

(iii). Finally, historical rarity refers to the historical significance of an NFT. This comes in many different forms. For example, part of the allure of Cryptopunks is that they were some of the first generative NFTs ever issued, thus they are special in that sense. Moreover, since blockchains record an immutable history of ownership, some NFTs might be historically significant, as they were owned by notable entities or individuals. This is analogous to how Stevie Ray Vaughan's Fender Telecaster, or Paul Newman's Rolex Daytona, are more special and shout after that any the same item, is not owned by them.

(c) **Ownership:** Proof of ownership of underlying assets, the potential of fractional ownership, and provenance tracking of assets are some characteristics that may be highly relevant in the context of NFTs backed by real-world tangible assets.

(d**) Immutability:** This is an inherent quality of all blockchain-based tokens. The tokens as well as the information embedded in the tokens are highly resistant to tampering, absent a compromise of the underlying blockchain protocol. This results in substantial trust and transparency.

(e) **Programmability:** This is considered by many an important differentiating factor separating NFTs from real-world assets. In addition to allowing artistic or business expression, NFTs can be programmed in any way that programmable software can – for example to ensure artists continue to receive residuals or moral rights throughout the lifetime of a work and not just the first sale. Moreover, experimental applications showcase how NFTs can be used as collateral for a plethora of Defi applications, similar to a mortgage.

2.2.2 NFT Use Cases

Some of the prominent use cases that have been explored thus far are as follows:

(a) **Digital Art:** NFT platforms provide an avenue for artists to showcase their work, in some cases directly to the public with new or no intermediaries and lower associated costs – connecting the artist directly to the public who thereby are compensated fairly by the smart contracts underlying the digital art galleries for not just the initial sale but also subsequent sales – thus making it easier to enforce moral rights that exist in some EU jurisdictions.

(b) **In-game assets:** With a market cap above 100 billion USD for the gaming industry, monetizing the collectibles is certainly attractive. Major gaming houses such as EA Sports, and Ubisoft have already started experimenting with tokens in their platform besides provenance tracking and transaction recording on the blockchain. NFTs, bring about an additional source of revenue for gamers who can buy/sell collectibles, in-game "skins" and other assets.

(c) **Content Ownership***:* Videos/audio content in the art and music space have recently been auctioned out by artists via NFTs to raise funds for new albums, and sell out old records, whereby the NFTs depict a fractional right of ownership of the content and any proceeds earned from the resale of underlying assets will be distributed proportionally to the NFT token holders

(d) **Tickets:** Tickets to events in the form of NFT serve as memorabilia to be part of a collection

(e) **Certificates:** NFTs are utilized for transparency, provenance tracking and to facilitate the authenticity and verification of records.

(f) **Metaverse:** NFTs are steadily emerging as the building block for the metaverse, a future state of the internet, made up of all-encompassing virtual spaces and assets that replicates or even iterate upon the physical world.

2.3 Gas Fees and Minting

When dealing with NFTs, it is important to understand the different costs associated with trading and creating NFTs. These costs are called "gas fees" and are used to pay the node operators who oversee registering the transactions on the blockchain. "Minting" is another type of gas fee which is done when creating the token associated with the digital or physical item on the specific blockchain. The gas fees for transactions and minting vary depending on the volume of transactions taking place on the blockchain. Since the blocks are added regularly, the higher the volume, the higher the price [4].

2.4 Smart Contracts

Another key attribute to understand is what the "token" is made of. The main code behind an NFT is encapsulated in what is called a "smart contract". Smart contracts are defined as scripts stored on the blockchain. When the scripts are triggered they perform a set of actions in a predefined manner if the conditions are met or a certain event happens. In the case of NFTs, there are a couple of "token standards" such as ERC-721 which require a certain amount of functions and events for the smart contract to be deemed a "Non-fungible token". The creator of an NFT smart contract can, for example, determine the scarcity of the NFT and if royalties are to be earned [5].

CHAPTER 3
LITERATURE SURVEY

Colored Coins are widely considered the precursor to today's NFTs. However, they are not NFTs in the currently popular sense of a token with a complex infrastructure that can support metatarsal objects, art, music, and more. Instead, Colored Coins are Bitcoins – or more likely small denominations of Bitcoin, made unique by the fact that every extant Bitcoin can be identified and have its history tracked based on ID information built into the operation of the protocol. These markings can be used to determine their purpose, for example, to represent real-world assets on the blockchain.
On 4 December 2012, a paper "Overview of Colored Coins," was released by cryptographer and President of the Israeli Bitcoin Association, Mr. Meni Rosenfeld. In this paper, a mechanism to take advantage of Bitcoin's "fungibility" by segregating a certain number of coins from the rest for special purposes, was explained. It was mentioned that adding "specialty" to coins by segregating them from the rest could help form niche applications within the Bitcoin blockchain [6].

in 2014 a peer-to-peer financial platform called Counterparty was created on top of the Bitcoin blockchain. Counterparty [7] was an economical and financial platform as well as a decentralized, open-source Internet protocol. Counterparty had a broad array of tools including wallets, an escrow agent functionality, and a clearing house. Additionally, it allowed for asset creation and had a decentralized exchange, as well as a native currency known as XCP. With this foundation, Counterparty became home to numerous projects and non-fungible assets, including a trading card game. At the same time, development had also begun on the then-dormant Ethereum ecosystem. Just three months after the launch of Ethereum's mainnet the Etheria project presented users with a virtual open world composed of hexagonal tiles that can each be bought, sold, and "built upon", as NFT.

The first project based on the ERC721 standard was CryptoKitties [8]; a blockchain-based virtual game that featured cartoon versions of cats and allowed players to "adopt", "raise", "breed" and virtually trade them. The project was launched by a Vancouver-based company called Axiom Zen. It was during the ETH Waterloo Hackathon that the game emerged to prominence.
Cryptokitties were significant to the NFT space for three primary reasons. First, they were one of the first projects to highlight gaming as a tangible use case for blockchain, legitimizing it in the eyes of many. Secondly, they underlined the significance of more flexible and expressive protocols, such as Ethereum. Their "raising" and "breeding" functions were also precursors to the widespread composability native to today's Defi applications. Finally, Cryptokitties also highlighted the limitations of blockchain and popularised the notion of the blockchain trilemma. The project was so popular, and responsible for such a high volume of transactions, that at times rendered the Ethereum blockchain unusable.

In [9] a secure platform for trading digital assets in the form of Non-Fungible tokens is proposed. It will enable the users to create new digital assets and trade them in exchange for Ethereum-based cryptocurrency. Along with this, the technical feasibility of a decentralized file system (using IPFS protocol) for storing digital assets more securely is explored. In this way, we attempt to address the issue of file storage.

Axie Infinity [10] is a digital pet community backed by the Ethereum chain and is Pokemon-inspired. Apart from the breeding pet system, the game includes a battle system along with its digital land. The pets and pieces of land are represented with the use of NFTs. In August 2021, the game achieved to have 1 million daily active players showcasing its popularity.

Aavegotchi [11] is a game with pixelated ghosts on the Ethereum blockchain. The ERC-721 standard is implemented for token generation. The game allows NFT staking and produces interest in tokens used in the AAVE protocol. In this way, the game blends Defi and NFTs.

Splinterlands [12] is a card gaming platform founded in 2018 that allows trading with the underlying blockchain technology. The game runs on the Hive blockchain and only stores actions on the

blockchain. Running a game on the blockchain may prove to be slow for the users. In July 2021, the game raised 3.6 million dollars via private token sales.

LiteBringer [13] is an idle RPG game that allows players to level up a character from various classes like a wizard or a warrior. The game uses the Litecoin blockchain for its implementation. The action in the game triggers gas fees as the players' actions, like creating a character or venturing into an adventure, are transactions that are included in the blockchain.

CHAPTER 4
SYSTEM IMPLEMENTATION

The implementation details of our application are discussed in the sections ahead.

4.1 Functional Dependencies

We have used the following tools and frameworks for building the website.

Front-End: HTML5, CSS, JavaScript (Testing smart contracts), and React Framework

Back-End: NodeJS, Solidity (Writing smart contracts), and Hardhat (Development Framework)

Tools: Infura IPFS, Ethers (Blockchain Interaction)

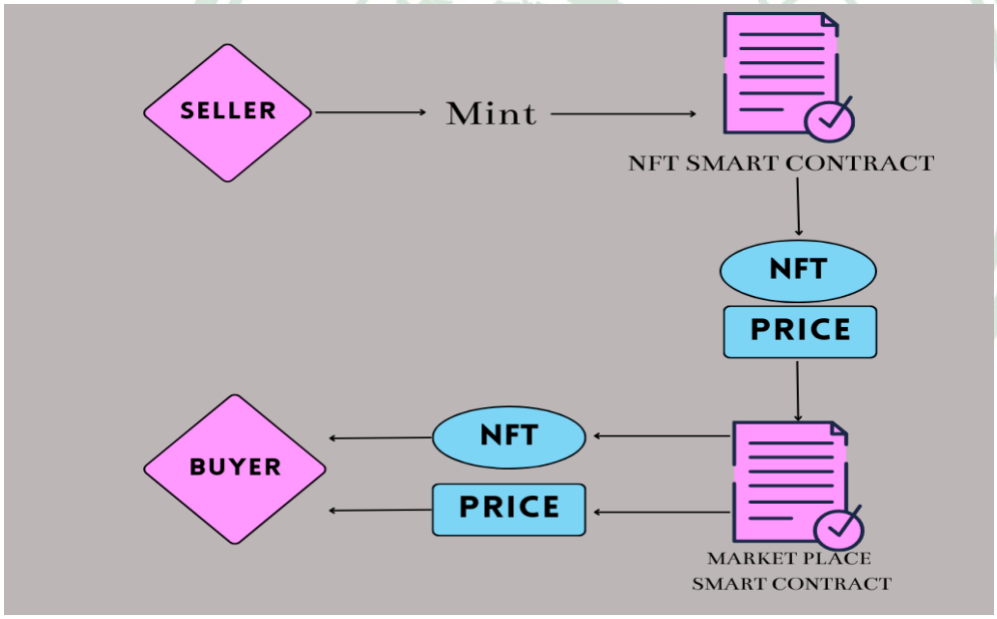
Libraries: OpenZeppelin Libraries: ERC721 Contracts (NFT tokenization), Reentrancy Guard; chai library (testing)

4.2 System Architecture

The decentralized application consists of two entities: seller and buyer.

The seller creates an NFT and sets the selling price for his artwork through NFT.sol.

The buyer then interacts with Marketplace smart contract and buys the NFT of his choice by paying the price set by the seller and a 1% marketplace fee.



4.3 System Design

Below are defined the essential files and components made for both the front-end and the back-end which are implemented for the system.

1. **NFT.sol**: The smart contract written in Solidity comprising of the mint function that allows the user to create his NFT. We used OpezZeppelin's ERC721 contract to represent the

ownership and non-fungibility of these tokens. It allows for the implementation of a standard API for NFTs within smart contracts. This standard provides basic functionality to track and transfer NFTs.

2. **Marketplace.sol:** This smart contract consisted of three functions namely,

   (a) **makeItem**: The seller sets the price of his NFT

   (b) **getTotalPrice:** The marketplace calculates the final price to be paid by the buyer including the price of the NFT and the 1% marketplace fee.

   (c) **purchaseItem:** The function that checks whether the buyer's account has enough balance to make the purchase and if the item he wants to buy is already sold.

   The nonReentrant function prevents a contract from calling itself.

3. **Deploy.js:** Our client-side app creates a JavaScript instance for our smart contracts. This is used to read and write data from our smart contract.

4. **nftmarketplace.test.js**: The testing of smart contracts is very important because once a contract has been deployed we cannot change its code. It is not like web development where we can fix bugs after the deployment of the application. The cost of bugs for smart contract developers is much higher.

   Therefore, writing robust tests for smart contracts is an integral part of blockchain development.

   In our implementation, we have used the 'chai' library for testing smart contracts. The test cases are as follows:

   Deployment

   (i). Should track the name and symbol of the NFT collection

   (ii). Should track feeAccount and feePercent of the marketplace

   Minting NFTs

   (iii). Should track each minted NFT

   Making marketplace items

   (iv). Should track newly created items, transfer NFT from the seller to the marketplace, and emit Offered event

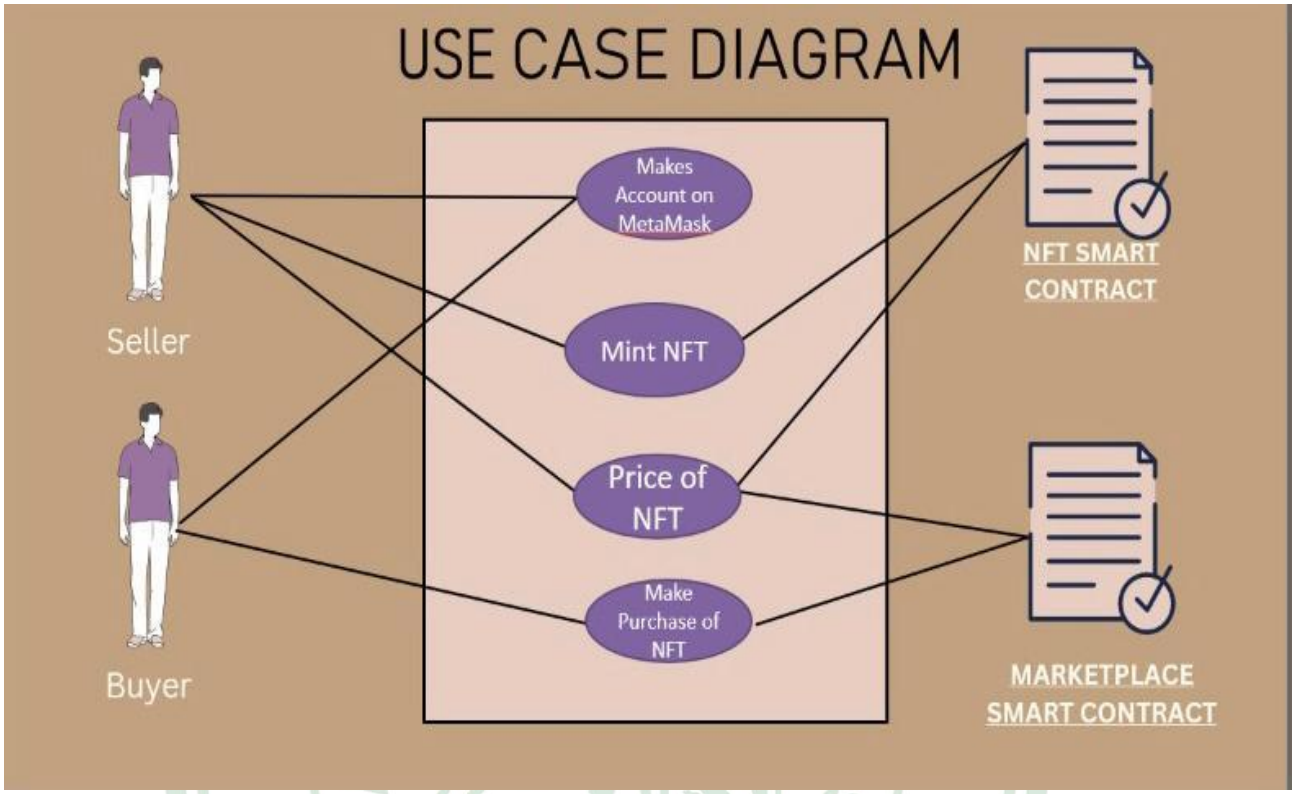
   (v). Should fail if the price is set to zero

   Purchasing marketplace items

   (vi). Should update item as sold, pay seller, transfer NFT to buyer, charge fees and emit a Bought event

5. **Front-End setup:** We used the ReactJS framework for creating the user interface of our application. We created a navigation panel with a logo of the marketplace and tabs which will lead the user to different pages.
   (a) Create: Allows the user to create his/her own NFT and list it on the marketplace.

(b) My Purchases: Displays the purchases made by the user on the marketplace.



Chapter 5
Conclusion

This section presents the potential advantages and disadvantages of applying NFTs to digital art.

5.1 Potential Advantages

5.1.1 Provenance

Since NFTs are founded on a blockchain-based ecosystem, similar potential advantages have also been proven. One of the main advantages of blockchain technology is the possibility of provenance through traceability. This is possible since every transaction is recorded on the distributed ledger and is said to be immutable. The possibility of verifying provenance through traceability has the possibility of eliminating third-party authorization methods, which otherwise are common in high-end physical art sales.
This implies that potential buyers or other stakeholders can view the transaction history of the art pieces from when it was minted on the blockchain platform.

5.1.2 Royalty Sharing

Artists, in general, cannot gain royalties after selling their artworks. In comparison, when applying an NFT to the artwork, there is a possibility of receiving predetermined royalties for each transaction made. For example, the artist can implement the possibility of receiving 10% in royalties for each transaction within the NFT's smart contract. Furthermore, a standardized protocol of royalties on the Ethereum blockchain also enables the royalty percentage to drop linearly over time. Implying the artist has lesser to gain in distant future transactions compared to near-future ones.

5.1.3 Expose Art to Larger Markets

Previously, only well-known artists could command large fees for commissioned work or gallery residencies. With the eruption of NFT marketplaces, less-known artists have gained the possibility to share their works with a larger audience. This has been done without marginalizing the provenance or scarcity of the art pieces. OpenSea, which is the largest NFT marketplace, had as of January 6th, 2022, over 2 million NFT collections and 80 million NFTs on its site reaching over 1.26 million active users.

5.1.4 Versatile Utilization

Some NFTs associated with art is not only used to uniquely identify the attached artwork. Certain NFT-art collections, such as the "Bored Ape Yacht Club" have further elaborated with the tokens. Giving the tokens additional utility as they double as membership cards for their exclusive community. This authorization is achieved by signing in with their Crypto wallet and verifying ownership of said art piece. Similar investments have been done with for example Adidas where NFT-holders are given access to exclusive physical and digital merchandise. Since the NFT-art boom of 2021, more use cases for NFT-applied digital property have arisen. Currently, it is possible to acquire land in digital universes called "Metaverse" with NFTs, own famous tweets, and videos of recorded sports highlights. The proven versatility of NFTs has enabled the possibility to monetize previously free digital assets. Giving creators a better chance of monetizing their works and fans getting access to authentic and exclusive content.

5.2 Potential Disadvantages

5.2.1 The False Belief of Provenance

Anonymization within blockchain technology is a key characteristic. Although applying NFTs to assets increase the transparency and traceability of who the current owner is, previous owners and the first

owner were. There is a risk of a false perception of provenance since the blockchain can only show provenance from the initial registration of the asset. Therefore, there is a risk of additional transactions having taken place before the minting. As a result, rigorous due diligence is still required with NFT-applied art in a similar way as traditional physical art. Due to the anonymity characteristic of blockchain, verifying the creator of the NFT, and the real-world creator is therefore required. Most NFT platforms have already implemented such verification processes. Nevertheless, not all NFTs are sold via platforms.

5.2.2 Storage

Since the amount of NFT transactions has increased during 2021, the cost (gas fees) of registering larger files to certain blockchain platforms such as Ethereum has risen. Consequently, many NFT art collections do not store the actual art piece together with the token on the blockchain, but rather register a smart contract that links to the actual art piece. This is known as "off-chain NFTs" and implies critical data such as the art piece is stored elsewhere from where the NFT is registered. There have been instances of NFTs with broken URL links. In other words, the token no longer links to the art piece it previously was associated with. Due to the immutability of the blockchain, there is no possibility of updating such URL links either.

5.2.3 Environmental Aspects

As previously mentioned, currently Ethereum is the status quo regarding supporting NFTs. Its current consensus method (Proof-of-Work) has therefore resulted in large energy consumption. Shaw, (2021) implies that the Beeple artwork sold for approximately $69 million produced 79kg of CO2 emissions. The equivalence is the combined annual energy consumption of 13 homes. The Ethereum community is aware of these discrepancies and vowed to switch the authentication method to (Proof-of-Stake) which is supposed to radically decrease the environmental impact of transactions done on the Ethereum blockchain platform. Nevertheless, critics are not content with the future promise of switching consensus methods. They indicate that the plan of switching to the Proof-of-Stake method has existed nearly as long as the Ethereum blockchain platform has been around. Indicating the switch is somewhat of a "running joke".

5.2.4 Not Blockchain Agnostic

Another problem is related to the long-term storage of NFT-applied digital art. The NFTplatforms can with ease disappear or become obsolete. Certain NFT marketplaces such as "Rarible.com" even state in their terms of services that they *"cannot guarantee continued operation or the integrity and persistence of data on IPFS"*. IPFS is a distributed protocol enabling peer-to-peer storage used by certain NFT marketplace platforms. Furthermore, NFT marketplaces such as "Rarible.com" do not offer the possibility of moving NFTs to other blockchains. Therefore, if the blockchain platform were to become obsolete, there is no way of moving the asset elsewhere. Certain less popular blockchain platforms with lower transaction fees have taken matters into their own hands and created so-called "cross-chain bridges" which enable users to move NFTs from popular blockchain platforms such as Ethereum to their own for a one-time fee.

2.2.5 Legal Aspects

NFTs have been described as an authorized way to determine the ownership of the artwork. Nevertheless, discussions regarding certain legal issues have been identified.

Firstly, contrary to what an NFTs consumer might assume, the original creator of the NFT retains exclusive rights to copy, modify and publicly display the art unless someone else is assigned these rights. Although, certain NFT art collections such as "Bored Ape Yacht Club" give the owner of each NFT full ownership and commercial rights of their NFT and underlying artwork. In most cases, the purchase of NFT will from a legal perspective, resemble a cryptographically signed receipt proving the ownership of a certain artwork but not the rights to commercial usage. Secondly, due to the anonymity factors of blockchain technology, enforcing contracts through ownership verification can be difficult. Furthermore, the legal enforceability of the smart contract is also questioned as they need to adapt to current legal contract frameworks across many jurisdictions. Lastly, due to the immutable

attribute of typical blockchains, there are certain risks regarding data protection laws, such as GDPR (General Data Protection Regulation) in the EU. The “right to be forgotten” is difficult to comply with as the potential user data stored on the blockchain is not possible to remove.

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