NFTs: Applications and Challenges

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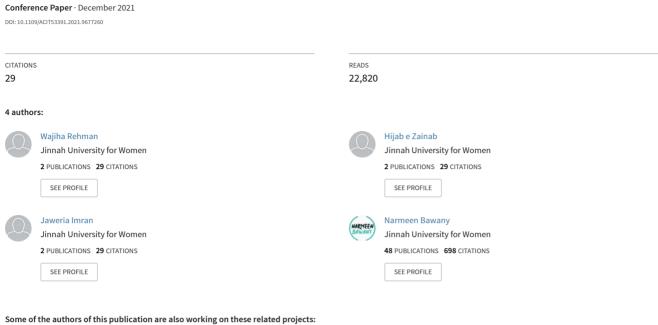
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NFTs: Applications and Challenges

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Abstract—Before the widespread application of blockchain-based technologies, the mechanisms in place for verifying ownership of digital assets and thus, means of securing them remained susceptible to tampering that translated into significant losses. Decades of research and advancements in blockchain led to the development of Non-Fungible Tokens (NFTs), which are tokens that represent digital assets and have proof of ownership embedded. The novel characteristic of each token being unique and distinctive from another has strengthened the security of assets and reinforced unique ownership. This cutting-edge technology continues to grow and capture the attention of the masses as more applications of NFTs are identified with time. This research aims to present a comprehensive overview of NFT and its underlying core technologies, namely blockchain and Ethereum. Further, numerous platforms for buying and selling NFTs are presented along with the applications of NFTs across various sectors including education, fashion, sports, and digital art. Moreover, the paper highlights the key challenges in adaptation of NFT technology from the perspective of security, privacy, environmental impact, ownership, governance, and property rights.

Keywords—Blockchain, NFTs, Ethereum, Tokenization, Digital Assets

I. INTRODUCTION

NFT, abbreviated for "non-fungible tokens", are digital assets that are representative of physical or digital creative work or intellectual property including music, digital art, games, gifs, video clips and more. "Nonfungible" in NFT means that each token is not exchangeable with another token, making each token a unique entity that represents a single specific object. These tokens consist of digital information in the form of media (music, video, image) the value of which can be calculated in terms of cryptocurrencies. The NFTs are part of the Ethereum blockchain in particular but differ from Ethereum coins which are fungible, that is, exchangeable with similar types of assets.

Rapid technological advancements and its growth are accompanied by increased security risks including those of authenticity. The uniqueness and non-fungibility of NFTs minimizes, if not completely eradicates, the problem of authenticity and counterfeits to a large extent by means of a digital signature of the owner incorporated in each token such that an asset is easily traceable to its owner. Furthermore, it also addresses the problem of the customers being deceived into buying counterfeit items e.g., tickets or artwork. Buyers can easily trace the items on sale to owners, thereby ensuring a legitimate purchase. Moreover, the introduction of NFTs is opening up new avenues for artistic businesses that previously found it challenging to establish online markets in an era of internet-based businesses due to the lack of exclusive ownership [1].

NFTs began gaining attraction of the masses with CryptoPunks in October 2017 but became more popular since the largest art sale in the history, made by Mike Winkelmann, a digital artist who sold his work for nearly USD 70 million. The sale directed a lot of attention towards NFTs, the growth of which has been on an upward trend since it has been getting a generous amount of attention from artists and art enthusiasts. Previously, NFTs were only known in a limited sphere of the blockchain community but currently have a market of their own, making up to USD 1.2 billion in sales as of July 2021[1].

Although, NFT is an emerging technology, but it has gained a lot of traction among researchers. Application of NFT is not limited to digital assets and various use cases have emerged more recently. The key contributions of this research are summarized below:

- We discuss the notable increase in deployment of NFTs since its inception
- We present the significant challenges posed by the NFT application in the current technological and legal atmosphere
- We explore the diverse applications of NFTs in various domains

The research paper is organized as follows: section 2 comprises an introductory overview of NFTs that entails the discussion of technologies that have been used to create NFTs as well as its history and current market state. Then, section 3 provides a brief look into the numerous use cases of NFTs in various domains. Section 4 presents the challenges pertinent to the implementation of NFTs. Lastly, the conclusion in section 5 summarizes the findings of the research and presents its future direction.

II. NON-FUNGIBLE TOKENS (NFT) - A PRIMER

This section gives a brief overview about the technologies being used around the concept of NFTs and the growth of NFT marketplaces.

A. Blockchain

A blockchain is essentially a distributed digital ledger of transactions [2] that encompasses the whole network of computers. It is dispersed, which means it does not require a central authority to function. Bitcoin was the first cryptocurrency to leverage blockchain technology; it was conceived in 2008 and deployed in 2009 [3]. Since then, this distributed ledger concept has attracted other initiatives from various industries; nonetheless, the financial industry is recognized as the key user. The reason seems to be that identifying the correct current owner of an asset is often not possible [4]. To verify and authenticate ownership, blockchain works in the following way: it is made up of data packages

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[1] https://nfews.crunchbase.com/news/nft-outlook-2021/

called "blocks", which are cryptographically interconnected to one another, and by adding each additional block, it creates a chain, which is a complete digital ledger. Distributed Ledger Technology (DLT) is a decentralized database that is administered by various people. Blockchain is a sort of distributed ledger technology [5] in which transactions are stored using an irreversible cryptographic signature known as a hash, and blocks can be authenticated by the network using cryptographic means. This concept ensures the blockchain's integrity all the way to the first block. As the hash values are unique, fraud can be detected because modifications to a block in the chain changes the hash value immediately. Because of the decentralized structure of blockchain, all transactions can be transparently viewed. The technology, on the other hand, is suitable for a wider range of applications and is being researched in a number of fields, including finance, public and social services, security and privacy, smart contracts, and IoT [3].

B. Ethereum

Ethereum is a community-run technology software platform that enables hundreds of decentralized apps to be built and deployed. Ethereum is based on blockchain technology. It is a blockchain with a built-in Turing-complete programming language. It has an abstract layer that allows anyone to define their own ownership, transaction formats, and state transition methods. This is accomplished through the use of smart contracts, which are a collection of cryptographic rules that are only performed if specific terms are satisfied [6]. In addition, such a platform serves as the foundation for a virtual currency known as Ether, which is a cryptocurrency asset used in the Ethereum blockchain. Ether is, in some ways, the gasoline for running Ethereum's distributed applications. It is possible to send money to other accounts or to machines that are doing a certain task using this currency. Ether may therefore be used to operate decentralized applications, create smart contracts, generate tokens, and make ordinary peer-to-peer payments. As a result, Ethereum is also known as "programmable currency" [7]. Ethereum consists of EOA and Contract. The EOA is controlled by a private key while Contract accounts are controlled through contract code. An account consists of four things: nonce, ether balance, contract code hash, and storage root [8]**.**

C. NFT Marketplace (Buying and selling NFTs)

Minting NFT is a process through which digital art becomes a part of the Ethereum Blockchain [9]. NFTs are tokens that are "minted" after they have been created, similar to how metal coins are minted and incorporated into circulation. The digital art is symbolized as an NFT, allowing it to be bought and sold on the market, as well as digitally tracked throughout the whole process [9][10].

The NFT market observed a sudden uprising in the second half of 2020 with an NFT art selling for USD 69 million. Furthermore, the total volume of NFT sales in 2020 was USD 2.5 billion while the total sales volume of NFTs in the first six months of 2021 surpassed USD 10.7 billion. This indicates a significant change in the growth of NFTs over a short period of time [11]. The 24-hour normal trading volume of the NFT market is USD 4 billion, while the 24-hour normal trading

volume of the entire cryptographic money market is USD 341 billion [12] .

Various online marketplaces can provide a platform for buying and selling NFTs but some of them are more sought-after than others as shown in Table I. However, not all marketplaces sell the same collectibles or works of art. As a result, the type of collectible is solely determined by the type of market. The majority of these marketplaces sell a diverse range of NFTs, but each platform operates differently[2].

TABLE I.   TOP NFT MARKETPLACES

Market	Traders	Volumes
OpenSea	46,067	$ 73.45m
Axie Infinity	40,429	$ 19.44m
CryptoPunks	12	$ 2.45m
AtomicMarket	7103	$ 1.03m
PancakeSwap	1342	$ 783.74k

* Statistics up to October 2021[3]

2021 has seen a significant increase in interest in NFTs, with NFT marketplaces like Nifty Gateway and OpenSea recording the highest trading volumes in the first quarter of 2021. The most expensive NFTs are listed in Table II.

TABLE II.   MOST EXPENSIVE NFTS

NFTs	Value
Everydays: the First 5000 Days	$69.3m
CryptoPunk #7523	$11.75m
CryptoPunk #3100	$7.67m
CryptoPunk #7804	$7.6m
Beeple's Crossroad	$6.6m

*Statistics up to October 2021[4]

III.   NFT APPLICATIONS

This section discusses the various applications of NFTs and how they are reshaping the future of digital assets. A summarized version of NFT application is given in Table III.

A. Digital Art

Digital art is the creative content that exists on the virtual or digital medium and consists of music, films, paintings, images and more. Like its counterpart i.e. physical art, it can be sold by artists and bought by art collectors and enthusiasts. However, it is also susceptible to being counterfeit or stolen. The use of NFTs in this regard attaches a unique hash with each piece of art that allows it to be differentiated. Artists or authors of original works can include their signature in the digital tokens, thereby reinforcing the authenticity of produced content. Although it is possible to make copies of the digital art, NFTs ensure that each copy belongs exclusively to the buyer such that it is not interchangeable with another copy [13], adding to the attraction of art for hobbyist art collectors and speculators.

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[2] https://news.bitcoin.com/nft-economy-grows-exponential-1m-in-non-fungible-token-sales-last-week/
[3] https://decrypt.co/80595/best-nft-marketplaces
[4] https://www.dexerto.com/tech/top-10-most-expensive-nfts-ever-sold

Tokenization of digital art by means of NFTs has enabled the artists to not only gain more profits from the sales of their work but also receive a royalty each time their artwork is transferred to a new owner. The concept of royalty was previously impractical, especially in case of physical art as it was difficult to keep track of its ownership but the incorporation of NFTs has enabled novel avenues for artists to be compensated for their craft [13]. The most notable record is that of Mike Winkelmann, better known as Beeple, who has made a digital art sale worth USD 69 million at Christie's, which is the highest sale made from art, historically.

B. Fashion

Luxury fashion brands are leveraging the properties of unique ownership, permanence and royalty acquisition enabled by the NFTs. Many fashion brands use their online presence to widen their reach but still remain economically inaccessible to the masses which sustains the demand for counterfeit and replicated articles. Businesses are losing large sums of money to counterfeit items of their brands, the effects of which can be prevented with the use of NFTs, if not eradicated completely.

The use of NFTs in fashion is still a relatively new concept but after pandemic, due to closure of physical stores for a year or so, the fashion industry is attempting to broaden their prospects by venturing into fashion tech. Companies have already begun embedding digital NFTs to physical articles to distinguish ownership and retain exclusivity[5].

Jacob & Co., a luxury goods brand, auctioned a digital watch which was sold to the highest bidder for USD 100,000. RTFKT, a virtual fashion brand, sold a jacket for a price of more than USD 125,000. High valuation of fashion-based NFTs indicate the presence of demand for virtual clothing articles. Since the fashion industry relies on the sales of physical goods, it is unlikely that NFTs will completely replace the same but it provides a lucrative opportunity for luxury fashion businesses to utilize it as an extension[6].

C. Licenses And Certifications

NFTs assigned to individual licenses and certifications can minimize the time and effort that companies have to expend on verifying critical documentation, thereby improving administrative operations. Moreover, the institutes issuing certificates and licenses can eliminate the workload of record-keeping with each document having a unique NFT that can be checked for authenticity[7]. The issuance of the licenses and certificates on the blockchain makes them resistant to tampering, which reduces the likelihood of encountering fraudulent documents.

An example of this use case of NFT is Zastrin, which is an education-based company that sells online programming courses. The company uses NFTs to purchase course licenses and issue course completion certificates[8].

D. Collectibles

Collectibles are a significant entrant among non-fungible token use cases. In fact, it was one of the very first ways that introduced and further normalized the idea of NFTs to the general public through Cryptokitties. These collectibles were introduced to the market in 2017 and were the reason behind the clogging up of Ethereum network as well [14].

They are one-of-a-kind digital kittens that users can procreate to create unique kittens [15]. Each crypto kitty has unique characteristics, such as fur pattern, eye color, etc. By clicking on a button, users can purchase two different cats, a sire, and a dame, for domestication [16].

The generated kitten has its own individuality as well as a genetic algorithm. The value of crypto kitties is determined by the scarcity of genetic profile. Furthermore, the number of times a sire is used to procreate other kittens is a key variable in predicting the significance of crypto kitties [17].

E. Boosting Gaming Potential

NFTs have gained a significant amount of attention from the gaming community and developers. They can provide ownership data for in-game objects, fuel in-game economic systems, and provide many other perks to facilitate the players [18]. Many standardized games let players buy different items and objects for inventory. However, if the purchased item is an NFT, the player could claim back the money by selling the item once they no longer need it. The player might even generate profit if the value of the said item increased over time [19].

This process is not just beneficial for the gamers but also benefit developers in multiple ways. Every time an NFT is sold in the marketplace, developers earn a royalty as well. This results in a more interdependently beneficial business framework in which both players and developers profit from the intermediate NFT market [20]. This also indicates that if the developers discontinue support for a game, the items accumulated by the gamers remain as their own property.

F. Domain Names

This is yet another way that NFTs are being used, perhaps in an unnoticeable way. Blockchain-based domain name services such as the Ethereum Name Service (ENS) and unstoppable domains have begun to receive the attention they deserve [21]. Users can change their address from a lengthy, complicated string of numbers to any desirable length resulting in a more welcoming and user-friendly process[22]. Furthermore, unstoppable domains are powered by the Crypto Name Service (CNS) which is developed on the Ethereum blockchain [22].

The process of creating a domain name generator is simple, but the struggle lies in the demand for these domains. Both ENS and unstoppable domains have been successful in their attempts at decentralized domains thus far.

G. Virtual World

For the virtual online world, blockchain presents an excellent decentralized environment [23]. In the real world, financial organizations have a variety of methods for evaluating assets. In order to get an appropriate assessment, it is generally required to hire an outside auditor or a rating agency, which is a costly procedure. As a result, many assets remain undervalued even outside market bounds, causing asset owners to lose trust[24]. However, in the virtual world, all types of digital activities are based on blockchain

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technology, so anyone who wants to buy assets in a virtual space does not have to worry about the authenticity of the assets because each change in ownership and money exchanged is completely recorded in an Ethereum smart contract [25], that also prevents a lack of trust. Furthermore, with their involvement in various Non-Fungible Token initiatives, content creators, artists, and personalities from a variety of industries have received a lot of attention [24]. There are a variety of platforms that reflect the virtual world, each with its own marketplace, such as Decentraland, which is one of the most popular virtual worlds and is also known as the metaverse [25][23]. A codified piece of metaverse can be purchased that converts to 16m-by-16m area of virtual land. Land can be freely traded and can be used as per desired.

Consider hosting a game that visitors may enter and play, or a shop that sells virtual or actual products. Perhaps a location where people can listen to a private concert or play at a casino using their hard-earned cryptocurrency. MANA is the virtual currency token that is being used to pay for goods and services in Decentraland [25]. Cryptovoxels [9], Somnium Space[10], MegaCryptoPolis[11], and Sandbox[12] are some of the most popular virtual worlds involving NFTs.

TABLE III.   SUMMARY OF APPLICATIONS

Categories	Applications
Digital Art	Cryptokitties
Fashion	Luxurious digital wearables
Licenses And Certifications	Course completion certificates Degrees Licenses
Collectibles	Trading cards Memes Tweets
Boosting Gaming Potential	In-game objects In-game lands Avatars
Domain Names	Candy.com Sushi.com
Virtual Worlds	Metaverse, Decentraland
Sports	Digital autographs Avatars, Stickers, Tickets Game Highlights.

H. Sports

The NFT concept seems to be a natural fit for the sports sector where it gained popularity and became a profitable venture in a short amount of time. Basketball, baseball, and boxing were among the sports that had the most expensive NFTs. The National Basketball Association (NBA) has launched a blockchain-based trading card system called NBA Top Shot, which enables basketball fans to buy, sell, and exchange officially licensed game highlights "moments" with their favorite players[13]. Furthermore, Golden State Warriors have released their own NFTs, making them the first US sports team to do so. People like NFTs because they are completely transparent. For example, NBA cards uses ranking system and the original owner have no idea of its whereabouts or the value of the card. Through NFTs, the value of these NBA cards can be digitally tracked[14]. Since NFT introduced a new way to

generate revenue, it is more beneficial for athletes and fans than traditional ways such as advertisement. It is also a novel approach to connect with fans and provide them with a one-of-a-kind experience. As more athletes and celebrities become involved in the NFT realm, the number of things that can be tokenized and sold as NFTs has grown. Digital Autograph Avatar, stickers, tickets, animation, and drawings are some of the items that can be tokenized [26].

IV. CHALLENGES

A. Intellectual Property Right

Intellectual property issues are the next significant entry in the list of NFT risks and obstacles. It is important to evaluate an individual's ownership rights to a certain NFT. It is critical to determine whether the seller genuinely possesses the NFT before making a purchase. There have been instances of someone photographing NFTs or minting reproductions of NFTs. As a result, when an NFT is purchased, the owner gets the rights to utilize it only but not the rights for intellectual property. The metadata of the underlying smart contract contains the terms and conditions for owning an NFT [27]. It is obvious that NFT applications may offer great revenue opportunities. They do, however, face numerous difficulties. NFTs are being endorsed by celebrities, and there is a massive market hype bubble surrounding them. The trading volume of NFTs surged more than once in just one year, indicating that they have great potential. The trade of NFTs, on the other hand, is not governed by any specific restrictions [28].

B. Cyber Security

The growth of the digital world, as well as the number of NFT transactions, has resulted in a significant increase in cyber security and fraud risk. Malicious actors can imitate well-known NFT artists and sell counterfeit NFTs in their names. Copyright theft, copying of popular NFTs or false airdrops, and NFT giveaways are some of the other major non-fungible token's threats and issues in terms of cybersecurity and fraud. One of the most recent examples of the NFT cybersecurity concern is the theft of NFTs from Nifty Gateway users by hackers[15]. The advancement of technology not only allows for greater efficiency in the trade of digital assets, but it also introduces unwelcome danger, notably in the area of cyber security.

C. Security and Privacy Issues

Security and privacy remain a critical challenge for every technological solution. The integrity and security of data is considered a priority in every system. The data, on the other hand, runs the danger of losing its linkage or being misappropriated by unauthorized parties. The privacy of NFTs is still being studied at this time [29]. The majority of NFT transactions depend on the Ethereum platform, which only provides pseudo-anonymity rather than complete anonymity. Users can hide their identities to some extent if the public is aware of the links between their true identities and associated addresses. Otherwise, all of the users' activity under the exposed address is visible [23].

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[9] https://www.cryptovoxels.com/

[10] https://somniumspace.com

[11] https://mcp3d.com

[12] https://www.sandbox.game/en/)

[13] https://www.techtimes.com/articles/263611/20210801/top-10-expensive-nfts-field-sports.htm

[14] https://www.forbes.com/sites/patrickmurray/2021/04/27/golden-state-warriors-launch-nft-collection-become-1st-sports-team-to-create-own-nfts/

[15] https://therecord.media/hackers-target-nft-craze-by-stealing-from-nifty-gateway-users/

D. Smart Contracts

Smart contract development and security are one of critical concerns in the NFT environment. Hackers recently targeted the famous Decentralized Finance (DeFi) protocol Poly Network, which provides cross-chain interoperability. The NFT theft, which resulted in a loss of nearly $600 million, puts a focus on serious flaws in smart contract security[16]. There are no clear security standards with industry-wide validation in the case of Solidity, which is one of the key causes that can lead to vulnerabilities in smart contracts. Smart contract transactions and code are both immutable, which implies that developers must assure the security of the code and each transaction. However, there are no defined standard procedures for designing smart contracts that developers should follow across projects [30]. Developers do not have the tools they need to make smart contracts easier to develop, test, verify, and audit, and, most importantly, they do not have the tools to collaborate[17].

E. Environmental Impact

The growth in the understanding of NFTs is influencing people to invest in the crypto technology but it has several evidence regarding its detrimental effects on the environment. Ethereum is recently estimated to use 44.94 terawatt-hours of electricity per year, which is nearly equivalent to the annual power consumption of countries such as Qatar and Hungary[18].

The total amount of electricity usage regarding the mining of bitcoins is easily comparable to the electricity usage of countries like Malaysia and Sweden[19]. According to a recent study [31], if blockchain-based technologies become as widely adopted as other new technologies, it could push the Earth's temperature 2 degrees Celsius above historical levels.

Crypto miners have already been held responsible for power shortages in Iran[20], and a recent study showed that the energy consumption from blockchain-based technology in China exceeds the Czech Republic's and Qatar's total annual greenhouse gas emissions[32].

V. DISCUSSION

NFTs present improved methods of enforcing authenticity and legitimacy of ownership of assets by linking unique information to a singular account on the blockchain. Consumers of NFTs are leveraging the advantages of NFTs to generate revenue by the sale of their original works with more convenience and security. However, the benefits of NFTs are accompanied by a number of challenges and risks. We discuss some of the ways that can be implemented to address the risks in certain use cases and overcome some of the problems that we have discussed above.

The privacy and security issues are one of the most prominent risk factors of the multiple use cases of NFTs. All transactions take place on the internet where information related to each transaction is vulnerable to unauthorized access and exploitation [33]. Emerging technologies such as zero-knowledge proofs (ZKP), are being developed that can address these issues in the future. ZKP is a cryptographic mechanism that allows you to prove to another party specific attributes without revealing them, such as proving the age of the subject without disclosing the actual age[21].

Blockchain-based technologies boast of substantial security and privacy, but certain offshoots of the technology are not completely immutable. The increased interest of users in cryptocurrency has led to the introduction of many platforms to facilitate the novel digital currency like web wallets. Although web wallets are based on the blockchain technology, they can be accessed by third parties when online, and some have vulnerabilities to phishing scams, malware, outdated security patches, and DDoS attacks, which cyber hackers can manipulate to their benefit. Therefore, it is also recommended that collectors and investors holding large amounts of NFTs use more than just a web wallet. Non-browser wallets like Binance or Coinbase with advanced security teams and 2FA, and hardware wallets like Trezor, which guarantees that the private keys never leave the device, are the best options for long-term safekeeping of your crypto and a more widespread use of such wallets can reduce the likelihood of the risk of security and hacking attacks[22].

Furthermore, to decrease the environmental impact of NFTs, developers can be encouraged to move towards more sustainable alternatives including SolarCoin and BitGreen rather than the Ethereum block chain[23].

VI. CONCLUSION

NFTs are built on blockchain technology, specifically Ethereum, thereby making it transparent, traceable, and secure. The novel characteristic of unique tokens enabled use cases that had not been demonstrated before such as the exclusive ownership of digital assets. The ownership of each asset is traceable which results in enhanced authenticity. The idea of having complete ownership of an authentic, purchased digital asset e.g., images, gifs, videos, music etc. intrigued art collectors and enthusiasts that led to a sudden growth in its market. NFTs are not only limited to digital assets but can also be applied to physical artistic works, allowing the exchange of physical assets similar to their digital counterparts. Numerous platforms facilitate the buying and selling of NFTs, comprising media of varied nature. Moreover, its use extended to many other domains namely education where NFTs are applied to licenses and certification, fashion where it is used to distinguish each article, sports where a new means of revenue generation through basketball card NFTs is devised and so on. The increasing widespread use of NFTs, however, comes with many challenges including lack of industry-wide security standards for smart contracts, uncertainty of intellectual property rights, fraud risks by

[16] https://101blockchains.com/nft-risks-and-challenges/
[17] https://101blockchains.com/smart-contract-best-practices
[18] https://digiconomist.net/ethereum-energy-consumption
[19] https://powercompare.co.uk/bitcoin
[20] https://apnews.com/article/iran-media-social-media-bitcoin-coronavirus-pandemic
[21] https://www.bbva.com/en/zero-knowledge-proof-how-to-maintain-privacy-in-a-data-based-world/
[22] https://www.blacknftart.co/blog/how-to-protect-your-nfts-from-phishing-and-theft
[23] https://www.leafscore.com/blog/the-9-most-sustainable-cryptocurrencies-for-2021/

means of artist impersonation, transparency that violates user security and privacy and drastic adverse environmental effects due to large amount of energy consumption. There exist viable solutions for many of these challenges like the use of zero-knowledge proofs (ZKP) for improved privacy, non-browser wallets for enhanced protection of the crypto assets and migration of blockchain development to more sustainable platforms such as SolarCoin and BitGreen. These solutions are yet to gain momentum among the wider blockchain community, so the challenges persist and remain yet to be addressed effectively in lieu of the massive potential of the NFTs, the marketplace for which is growing rapidly.

REFERENCES

[1]   A. Mani, "A Comprehensive Study of NFTs", International Journal for Research in Applied Science and Engineering Technology, vol. 9, no. 4, pp. 1656-1660, 2021. Available: 10.22214/ijraset.2021.34017.

[2]   D. Yaga, P. Mell, N. Roby and K. Scarfone, "Blockchain Technology Overview", arXiv: Cryptography and Security, 2018. Available: 10.6028/nist.ir.8202.

[3]   H. Wang, Z. Zheng, S. Xie, H. Dai and X. Chen, "Blockchain Challenges and Opportunities: A Survey", International Journal of Web and Grid Services, vol. 14, no. 4, p. 352, 2018. Available: 10.1504/ijwgs.2018.10016848.

[4]   M. Nofer, P. Gomber, O. Hinz and D. Schiereck, "Blockchain", Business & Information Systems Engineering, vol. 59, no. 3, pp. 183-187, 2017. Available: 10.1007/s12599-017-0467-3.

[5]   S. Ølnes, J. Ubacht and M. Janssen, "Blockchain in Government: Benefits and Implications of Distributed Ledger Technology for Information Sharing", Government Information Quarterly, vol. 34, no. 3, pp. 355-364, 2017. Available: 10.1016/j.giq.2017.09.007.

[6]   D. Vujičić, D. Jagodic and S. Ranđić, "Blockchain Technology, Bitcoin and Ethereum: A Brief Overview", 17th International Symposium Infoteh-Jahorina (INFOTEH), 2018. Available: 10.1109/infoteh.2018.8345547.

[7]   S. Ferretti and G. D'Angelo, "On the Ethereum Blockchain Structure: A Complex Networks Theory Perspective", Concurrency and Computation: Practice and Experience, vol. 32, no. 12, 2019. Available: 10.1002/cpe.5493.

[8]   V. Buterin, "Ethereum: Platform Review Opportunities and Challenges for Private and Consortium Blockchains."

[9]   L. Ante, "The non-fungible token (NFT) market and its relationship with Bitcoin and Ethereum", SSRN Electronic Journal, 2021. Available: 10.2139/ssrn.3861106.

[10]   Q. Wang, R. Li, Q. Wang, and S. Chen, "Non-Fungible Token (NFT): Overview, Evaluation, Opportunities and Challenges", 2021. Available: http://arxiv.org/abs/2105.07447

[11]   L. Ante, "Non-fungible token (NFT) Markets on the Ethereum Blockchain: Temporal Development, Cointegration and Interrelations", SSRN Electronic Journal, 2021. Available: 10.2139/ssrn.3904683.

[12]   A. Thilagaraj and J. Davis. "Non-Fungible Token (NFT) – The Game Changer in The Digital Art World", Ciencia Y Sociedad, vol. 51, pp. 190-194, 2021.

[13]   L. Kugler, "Non-fungible tokens and the future of art", Communications of the ACM, vol. 64, no. 9, pp. 19-20, 2021. Available: 10.1145/3474355.

[14]   Serada, Alesja. "Cryptomarkets Gamified: What Can We Learn by Playing CryptoKitties?" Proceedings of the 2020 DiGRA International Conference: Play Everywhere. DiGRA, 2020.

[15]   A. Fai, "Smart Collectibles: Unlocking the Value of Non-Fungible Tokens (NFTs)", 2021. Available: 10.36227/techrxiv.14762769.v1.

[16]   A. Serada, T. Sihvonen and J. Harviainen, "CryptoKitties and the New Ludic Economy: How Blockchain Introduces Value, Ownership, and Scarcity in Digital Gaming", Games and Culture, vol. 16, no. 4, pp. 457-480, 2020. Available: 10.1177/1555412019898305.

[17]   X. Cai, X. Zhao, B. Zhang and G. Feng, "Identifying Multiple Peer Influences on Smart Contract Adoption in Blockchain User Network", SSRN Electronic Journal, 2019. Available: 10.2139/ssrn.3387794.

[18]   A. Popescu, "Non-Fungible Tokens (NFT) - Innovation Beyond the Craze", in 5th International Conference on Innovation in Business, Economics and Marketing Research, 2021.

[19]   M. Goldberg, P. Kugler and F. Schär, "The Economics of Blockchain-Based Virtual Worlds: A Hedonic Regression Model for Virtual Land", SSRN Electronic Journal, 2021. Available: 10.2139/ssrn.3932189.

[20]   S. Bamakan, N. Nezhadsistani, O. Bodaghi and Q. Qu, "A Decentralized Framework for Patents and Intellectual Property as NFT in Blockchain Networks", 2021. Available: 10.21203/rs.3.rs-951089/v1.

[21]   E. Green, "The Next Internet Revolution the Unigrid Foundation."

[22]   N. Atanasova, "Non-Fungible Tokens Or: The Creation of a Social Contract in the Digital Agora", 2021. Available: https://www.academia.edu/49909705

[23]   S. Bolton and J. Cora, "Virtual Equivalents of Real Objects (VEROs): A Type of Non-Fungible Token (NFT) That Can Help Fund The 3D Digitization of Natural History Collections", Megataxa, vol. 6, no. 2, 2021. Available: 10.11646/megataxa.6.2.2.

[24]   D. Zagidullin and N. Pulyavina, "The prospects for the development of blockchain technology in the NFT format", Lizing (Leasing), no. 1, pp. 40-44, 2021. Available: 10.33920/vne-03-2107-06.

[25]   M. Dowling, "Fertile Land: Pricing non-fungible tokens", Finance Research Letters, p. 102096, 2021. Available: 10.1016/j.frl.2021.102096.

[26] U. Chohan, "Non-Fungible Tokens: Blockchains, Scarcity, and Value", SSRN Electronic Journal, 2021. Available: 10.2139/ssrn.3822743.

[27] D. Wood, "Ethereum: A Secure Decentralised Generalised Transaction Ledger", 2014.

[28] I. Okonkwo, "Valuation of Intellectual Property: Prospects for African Countries", SSRN Electronic Journal, 2019. Available: 10.2139/ssrn.3553288.

[29] D. Uribe, "Privacy Laws, Non-Fungible Tokens, and Genomics", The Journal of the British Blockchain Association, vol. 3, no. 2, pp. 1-10, 2020. Available: 10.31585/jbba-3-2-(5)2020.

[30] Chen, X. Xia, D. Lo, J. Grundy and X. Yang, "Maintaining Smart Contracts on Ethereum: Issues, Techniques, and Future Challenges", Arxiv.org, 2020. Available: https://arxiv.org/pdf/2007.00286.

[31] C. Mora et al., "Bitcoin emissions alone could push global warming above 2°C", Nature Climate Change, vol. 8, no. 11, pp. 931-933, 2018. Available: 10.1038/s41558-018-0321-8.

[32] S. Jiang et al., "Policy Assessments for the Carbon Emission Flows and Sustainability of Bitcoin Blockchain Operation in China", Nature Communications, vol. 12, no. 1, 2021. Available: 10.1038/s41467-021-22256-3.

[33] F. Regner, A. Schweizer and N. Urbach, "NFTs in Practice – Non-Fungible Tokens as Core Component of a Blockchain-based Event Ticketing Application", in 40th International Conference on Information Systems (ICIS 2019), Munich, 2019.