Non-Fungible Tokens: Might Learning About Them Be Necessary?

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***Abstract* - Non-fungible tokens (NFTs), as a variant of tokens making up the blockchain, are recently gaining attention with different opportunities for the real and virtual assets and with potential use cases in decentralized markets, arts, gaming and education. This paper gives an overview of the NFT concept and its uses and presents the results of the survey conducted in Croatia in 2021 with the goal of gaining insight into familiarity of respondents with the concepts of the blockchain and NFTs. The results of the survey, especially when compared to publicly available results of an international survey from 2020, indicate that educative efforts might be needed in Croatia towards increasing knowledge about NFTs taking into account their wide potential areas of application.**

Keywords - blockchain, smart contracts, non-fungible token (NFT), digital assets, NFT uses and challenges

I. INTRODUCTION

Although the blockchain technology is best known for its usage in cryptocurrency systems, its fundamental characteristic of being a distributed database with guaranteed fidelity and security of data records makes it applicable as a reliable way of storing data about different types of transactions (other than financial) as well.

The conventional definition of a blockchain is that it is a fully distributed and decentralized system in which all participants are required to follow specific rules for achieving data synchronization [1]. In general, a blockchain is a shared, trusted, public ledger of transactions, inspectable by everyone but which no single user controls. In particular, it is a distributed database that maintains a continuously growing list of transaction data records, cryptographically secured from being tampered with and revised [2].

Blockchains were initially designed and used for financial transactions, whereby the so-called "double spending issue" is resolved. Such applications are by convention referred to as Blockchain 1.0 [1], with the best known example being Bitcoin. Blockchain technology has, however, also showed the potential to be used for any kind of peer-to-peer value transaction on top of the Internet. The blockchain is essentially a kind of a distributed system which provides the computational capability for applications to run on multiple computation nodes [3].

With the emergence of Ethereum as the second generation blockchain (after Bitcoin), the concept of smart contracts was introduced to the blockchain world as a powerful feature of blockchain technology. A smart contract is computer code which automatically executes all or parts of an agreement between two parties and is stored on a blockchain-based platform [4]. More specifically, a smart contract is a collection of code and data that is deployed using cryptographically signed transactions on the blockchain network and executed by nodes in the blockchain network [5]. Blockchain systems with conditionality based on smart contracts are usually referred to as Blockchain 2.0, with Ethereum being a typical representative [1].

Along with smart contracts, decentralized applications (DApps) have started to emerge. Decentralized applications are applications that operate automatically without the top-down control by any company or individual. In Ethereum, the contract layer is decoupled from the blockchain layer, whereby the blockchain itself is used by smart contracts that trigger transactions automatically when certain pre-defined conditions are met. The mechanism of smart contracts enables easy development of applications for different application contexts and general purpose programs [3].

The second generation of blockchains has therefore extended the purpose of blockchains beyond purely transferring cryptocurrencies. Ethereum, for example, with its Turing-complete programming language (Solidity) offers a generally programmable platform which can be used as infrastructure for a variety of decentralized applications [6].

One of the fundamental concepts of blockchain technology is the concept of tokens. In general terms, a token is a representation of an asset. Within the blockchain technology context, tokenization is the process of converting something of value into a digital token usable in a blockchain application. Assets tokenized on the blockchain can represent tangible assets like e.g., gold, real estate or art, or intangible assets such as e.g., voting rights or ownership (Table I) [7].

TABLE I. EXAMPLES OF TOKENS (ADAPTED FROM [2])

Asset represented by tokens:	Tokens used as:
▪ Currency ▪ Insurance policy ▪ Event ticket ▪ Future download of a song ▪ Hours of solar energy ▪ Promises for a products in crowdfunds	▪ Ownership token ▪ Software license ▪ Voucher ▪ Stock certificate ▪ Membership / subscription ▪ Financial instrument ▪ A voting system

In the blockchain context, tokens can on a general level be differentiated as [6] (Figure 1):

- native (built-in) tokens – tokens that are inherent to a blockchain and are needed for any blockchain operation as well as for maintaining the blockchain itself (sometimes also called protocol tokens);
- application tokens – tokens that are used by applications on top of the blockchain.

Native and application tokens are usually easily interchangeable and have an important role in governing the blockchain platforms. Their characteristic of being interchangeable or convertible is in the blockchain context called fungibility, i.e., these tokens are fungible.

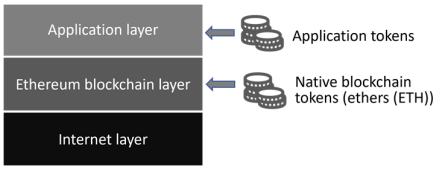

Figure 1.The Ethereum technology stack (adapted from [2] and [6])

As opposed to fungible tokens, the concept of non-fungible tokens (NFTs) has recently emerged in the blockchain world and attracted interest in both the industrial and the scientific communities, as a unique way of attributing ownership to a digital asset.

The remainder of this paper will focus on non-fungible tokens, their current usage and potential as well as related challenges. The paper will also present the results of a survey conducted in Croatia in 2021 which indicates that the concept of non-fungible tokens has not been widely adapted given their rising usage potential.

II. The Concept Of Non-Fungible Tokens

A. What is a non-fungible token?

The main idea behind the concept of a non-fungible token (NFT) is that it is indivisible and unique. A non-fungible token stores a complex digital value directly attributable to an entity [8].

Non-fungible tokens (NFTs) can therefore be used to represent ownership of unique items. They enable tokenizing artefacts or assets such as art, collectibles or even real estate (Figure 2). These tokens have only one official owner at a time and are secured by (in most cases) the Ethereum blockchain.

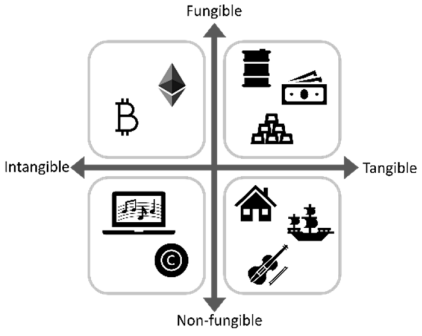

Figure 2. Examples of fungible and non-fungible tangible and intangible assets

As opposed to the concept of "fungibility", which is a property of an asset or a commodity that can be exchanged with other assets or commodities of the same type and value (e.g., money, "generic" gold bars), "non-fungibility" refers to assets or commodities that have unique characteristics and are not interchangeable (e.g., real estate, a gold bar with a unique artistic engraving).

B. A short history of non-fungible tokens

The term "non-fungible token" was, following a community consensus, officially coined in the Ethereum Standard ERC-721 published in January, 2018 to represent a "diverse universe of assets" including physical property, virtual collectibles, and negative value assets such as loans or responsibilities [9].

However, the first non-fungible token was actually created back in 2014 as an art experiment at a hackathon. It represented a video clip by digital artist Kevin McKoy and required a Bitcoin-based blockchain to be sold. This non-fungible token, called "Quantum", has most recently been sold for 1.47 MUSD at a Sotheby's auction in 2021 [10].

A significant amount of development and experimenting with non-fungible tokens occurred in the period 2014-2016 on the Bitcoin-based platforms, but they have really taken off with the Ethereum platform going live in 2015 and the majority appearing after 2017. Some of the most well-known projects with non-fungible tokens include CryptoPunks [11] (a collection of 10,000 unique digital characters stored on the Ethereum blockchain), CryptoKitties [12] (a blockchain game on Ethereum in which players can purchase, collect, breed and sell virtual cats), Decentraland [13] (a 3D virtual world browser-based platform) and others.

Interest in non-fungible tokens has significantly increased in 2021 with other blockchains (such as Cardano, Solana, Tezos, etc.) starting to introduce their own non-fungible tokens, especially with increased interest in the metaverse field. The future will show whether and how these trends will continue.

C. Standards behind non-fungible tokens

As standards generally describe the underlying principles for a technology to function seamlessly, non-fungible token standards in particular describe how to build non-fungible tokens upon a particular blockchain protocol. As Ethereum was the first blockchain to introduce non-fungible tokens, and as Ethereum still remains the most widely used platform for non-fungible tokens, the prevailing standards behind non-fungible tokens are ERC standards, where ERC stands for "Ethereum Request for Comments".

ERC-20 is one of the most significant standards for smart contracts on the Ethereum blockchain for fungible token implementations. ERC-20. With the emergence of non-fungible tokens, standard ERC-721 was introduced in 2018 and describes basic functionalities such as transferring tokens from one account to another, getting the current token balance of an account, getting the owner of a specific token and the total supply of the token available on the network, as well as some other functionalities [14].

Standard ERC-1155, published in 2018, is a multi-token standard for smart contracts that can include any combination of fungible tokens, non-fungible tokens or other configurations (e.g., semi-fungible tokens) [14].

With the rise of other blockchain platforms supporting non-fungible tokens, other standards may be expected in the future, but up to October 2021, the only other non-Ethereum NFT standard is TRC-721 published by the open-source blockchain TRON [9].

III. Uses Of Non-Fungible Tokens: Current and Emerging

The total value of NFTs issued on the Ethereum blockchain by the end of October 2021 was estimated at 14.3 billion USD, up from 340 million USD in 2020, with some analysts expecting the value to double in 2022 and to reach 80 billion USD in 2025 [15].

The biggest NFT sales so far have been of digital artworks (such as an artwork by digital artist Beeple sold at the auction house Christie's for 69.3 million USD), making NFTs for artwork the biggest mainstream use of NFTs today [16]. The appeal of NFTs to artists may arise from the fact that NFTs are easier, faster and more democratic than the traditional art world model. By minting an NFT for a piece of artwork, artists can set their own price and define royalties and rules for selling the artwork encoded in a smart contract, thereby also avoiding high commissions by galleries [16].

Galleries, museums, libraries and archives have also recently begun selling NFTs for works from their collections The British Museum, for example, has entered the NFT market by partnering with a French start-up platform LaCollection and launching two NFT auctions: for more than 200 works of the famous Japanese artist Katsushika Hokusai in late 2021 and for works of the English artist J.M.W. Turner, ongoing at the time of submitting this paper [17]. The famous Viennese Belvedere has on February 14, 2022 launched an NFT sale of 10,000 digital pieces of Gustav Klimt's masterpiece "The Kiss", with 3.2 million EUR in sales reached already at the morning of the launch [18].

Musical artists have also begun entering the NFT arena, and NFTs have the potential of being transformative for the future of music, as songs, albums, music, lyrics, and soundbites can all be protected by NFTs [19]. NFTs can enable a fairer compensation to musicians for their work by letting them control ownership rights and distribution of their work without the involvement of third party platforms.

Apart from digital artwork, NFTs are used for protection and trading of other types of digital collectibles such as e.g., virtual real estate, trading (or collectible) cards, diamonds, domain names, etc. [20].

Projects with NFTs for physical or tangible assets are, based on publicly available information sources, are in very early stages and it remains to be seen how and if those will take off. An example is a recent NFT auction of five paired digital and physical items by the luxury carmaker Lamborghini [21]. Another example is a project within the wine industry, including a platform for selling fine wine as an NFT (called WIWA) in partnership with wine producers, distributors, and merchants worldwide. The goal of the platform is to simplify wine trading process by utilizing blockchain technology and NFTs, thus creating a more transparent, efficient wine ecosystem that encourages trade but protects provenance [22].

Another use case for NFTs that started to emerge in real life is event ticketing. When buying tickets for events, such as cultural, entertainment or sports events in the traditional ticketing market, consumers must rely on a third party with the risk of buying a counterfeit or fraudulent ticket. An NFT-based tickets issued by the blockchain, on the other hand, represents a unique asset, whereby the smart contract provides a transparent ticket trading platform both for the event organizer and the consumer [20].

The already flourishing gaming industry may experience a further boost with the usage of NFTs. Users can create their own or purchase rare digital items in games, selling them for profits. This can attract a lot of investors to join the games, making NFTs more prominent. Furthermore, NFTs enable ownership of items in games thereby providing an economic aspect in games to the benefit of both developers and players [20].

Although still in their early stages, augmented reality applications are being embraced by many industries. Augmented reality as a technology superimposes digital elements upon the real (physical world) and it could highly benefit from NFTs for securing the property rights of included digital elements, i.e., NFTs could add the missing intellectual property and privacy layers needed to create a complete augmented reality application [8].

A potential use of NFTs to fund research might arise the interest of universities and other research institutions following a notable initiative of this kind by University of California, Berkley. It has, namely, in June 2021 raised about 50,000 USD in an auction for an NFT based on the Nobel Prize-winning research behind cancer immunotherapy. The proceeds of the auction are aimed at funding early-stage research with a potential broad impact on the society [23]. Another example of a university entering the NFT arena is the University of Miami which has been auctioning NFTs for a number of memorabilia of its football team ("The Miami Hurricanes") [24].

When it comes to using NFTs in the education sector, the Duke University Pratt School of Engineering has provided students who have completed a sequence of courses on the fundamentals of blockchain technology certificates of completion through NFTs [25]. Duke University is one of the first institutions to provide educational credentials as NFTs, and it remains to be seen whether this trend will continue in the nearest future.

Another example of NFTs used in education is the example of Preply, a global language e-learning platform, which has experimented by rewarding their best language tutors with NFTs representing digital artwork [26].

NFTs have also found their use in COVID-19 digital certificates, specifically in the Republic of San Marino where those certificates contain two QR codes. One QR code aligns with the European Union requirements, while the other QR code is linked with an NFT thereby

guaranteeing its digital authenticity and enabling its verification [27].

The examples presented in this chapter are by no means exhaustive but have been selected to illustrate the variety of potential NFT uses.

IV. Challenges With Non-Fungible Tokens

As with any new technology, a number of challenges related to the development and usage of applications need to be addressed and subsequently overcome. This chapter lists some of the most prominent challenges with NFT applications and platforms [9], [20].

A. Slow confirmation

Current NFT applications are tightly coupled with their underlying blockchains and therefore suffer from their slow performance, which makes the confirmation of non-fungible tokens also quite slow. This is mainly due to the underlying blockchain mining protocols used for the Proof-of Work (PoW) consensus mechanism. The current trend is that most of PoW mechanisms are migrating to faster and cheaper mining protocols to overcome this challenge [28].

B. Energy consumption

Perhaps the most notorious challenge with blockchain applications arises from their huge energy consumption, especially in the light of the increasing awareness of the worldwide climate crisis. Current energy expenditures with the PoW mechanism are too high and unstainable (as claimed by Ethereum in [29]). NFT transactions are even more energy consuming because of complex operations with contracts requiring significant computational resources and storage.

Attempts at tackling this challenge are largely focused on the transition from the PoW to the Proof of Stake (PoS) blockchain consensus mechanism. However, the transition to the PoS mechanism, while maintaining the essential principles of security and integrity, is not trivial ([29]) and requires significant efforts and investments. The future will show how this challenge will impact the trends in blockchain usage in general.

C. Security issues

A system or application using non-fungible tokens combines the technology of blockchains, storage and web applications. Each of these components are subject to security challenges thus making the whole system vulnerable. A comprehensive approach towards security issues therefore needs to be implemented which must address the following security threats [20]: spoofing (impersonating another entity, thus violating authenticity), tampering (malicious manipulation of data thus violating integrity), repudiation (not being able to prove that a transaction took place, thus violating non-repudiability), information disclosure (exposing information to non-authorized users, thus violating confidentiality), Denial of Service (attacks to the system aimed at making it inoperable, thus violating availability) and elevation of privilege (gaining permissions beyond those initially granted, thus violating authorization).

D. Problems with broken links

NFT systems and applications rely on the Ethereum blockchain to determine the ownership of digital assets. Although this ownership record cannot be altered, it merely stores a link to the actual asset. The asset itself is still hosted on a conventional URL where its creator originally posted it. This URL, just like any other URL on the internet, can over time rot or decay (i.e., cease to point to the original target because of the target becoming permanently available or relocating to a new address). This will mean that a link to a digital asset could point to a dead webpage.

Some of the NFT platforms are attempting to address this issue by deploying the InterPlanetary File System (IPFS), which is a peer-to-peer (P2P) web-based file system and protocol helping to ensure that files are distributed across many hosts [9]. IPFS allows content to be accessed as long as anyone on its network hosts a copy. IPFS, however, does not fully resolve the NFT broken link threat as it can also suffer from broken links. Efforts will be needed in the future to further address this issue.

E. Interoperability

Currently existing NFT ecosystems are mostly isolated from each other due to their underlying blockchains. The majority of them are fortunately based on the Ethereum blockchain, thereby using similar data structures and following similar rules. However, with the rise of a variety of NFT applications on different blockchains, the interoperability of future NFT ecosystems will need to be taken into account from the technology and usability perspective.

F. Governance issues

As any new and nascent technology with applications in different domains, non-fungible tokens face the challenge of being properly regulated with the corresponding markets in different legal systems. The services with digital assets, which include cryptocurrency exchanges as well as NFT systems, will need to be regulated by innovation-friendly suitable regulations. Initiatives are already underway in several countries, such as the Baltic countries, France and Malta ([20], [30]), but many other countries issues are being resolved by existing laws and regulations thereby imposing complex and sometimes contradictory terms. Furthermore, issues related to intellectual property (IP) of digital assets represented by non-fungible tokens need to be taken into account from the taxation perspective [20].

V. Results Of A Survey On Familiarity With and Usage of Non-Fungible Tokens

With the rise of popularity of non-fungible tokens, an international survey [31] was conducted in 2020 by Crypto.com, the company operating a large cryptocurrency exchange platform of the same name. The survey included 29,674 respondents, mostly from Europe, North America and Asia (a total of 83%), wherein 10% of respondents were female and 88% male, as many as 61% were born after 1980, and 52% had a university degree or higher. As indicated in Figure 3, 47% of respondents have heard of NFTs and of those who have heard of NFTs, more than half have never used NFTs while only 24% use NFTs on a regular basis of every few months or more often.

Furthermore, of those who have heard of NFTs, 24% claim to have a good or expert understanding of NFTs, while 63% claim to have basic understanding. The survey also revealed that 49% of respondents invested in NFTs expecting financial gain, while 45% did so because of their interest in technology

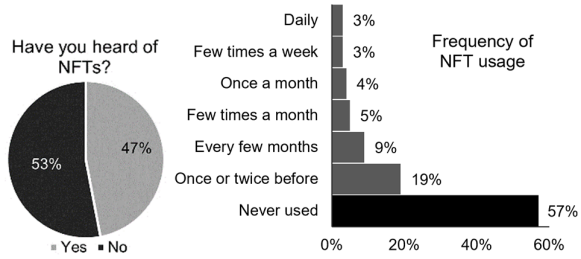

Figure 3. Respondents having heard of NFTs and NFT usage frequency (adapted from [31])

The actual types of used NFTs according to the Crypto.com survey are illustrated in Figure 4.

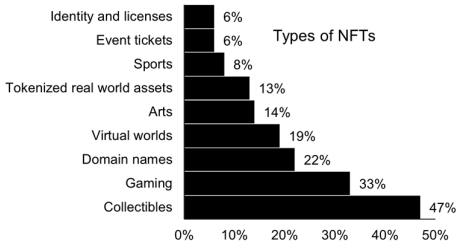

Figure 4. Types of used NFTs (adapted from [31])

A similar survey of a much smaller scale was conducted in May, 2021 as a part of a final thesis by one of the coauthors of this paper at the Zagreb School of Economics and Management [32]. The survey included 371 respondents from Croatia, wherein 17% were female and 83% male, 76% were born after 1980, and 35% had a university degree or higher.

As indicated in Figure 5, only 15% of respondents know what an NFT is and of those who do know what an NFT is, 44% have never used NFTs while only 2% them frequently.

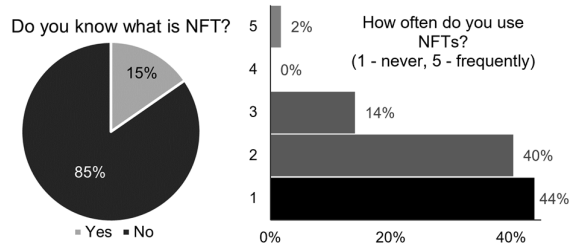

Figure 5. Respondents knowing what an NFT is and NFT usage frequency (adapted from [32])

The comparison between the results of the international survey [31] and the study in Croatia [32] when it comes to the frequency of usage of NFTs might be slightly misleading when taking into account only respondents who actually know what NFTs are. However, if the frequency of usage is observed on the total number of respondents, a total of 80% of respondents of the survey from [31] have never used NFTs, while as many as 92% respondents of the Croatian survey from [32] have never used NFTs.

The actual types of NFTs used or would be used by respondents according to the Croatian survey are illustrated in Figure 6.

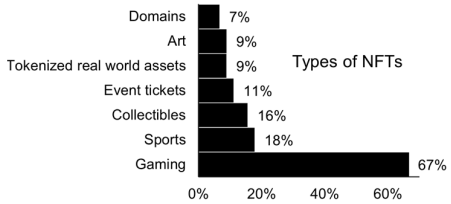

Figure 6. Types of NFTs used or would be used (adapted from [32])

Despite the recent rise in popularity of NFT applications in different areas, both surveys mentioned in this chapter indicate that a significant proportion of respondents is not familiar with the NFT concept, whereby this is especially pronounced in the survey conducted in Croatia. These results may surely be attributable to the fact that NFTs are indeed quite a new concept whose adoption, provided that the applications indeed do take off, will take time as with any new technological concept.

VI. CONCLUSION

Despite challenges requiring attention and skepticism that may be perceived around non-fungible tokens (NFTs), NFTs are currently having a moment, but their long-term value and future are still unclear. Arguments are ongoing whether NFTs are just a hype or fad, but history has shown the need to be careful about dismissing current hypes, as the importance of technological innovations often becomes clearer once the hype dies down (e.g., the dotcom bubble or the initial cryptocurrency enthusiasm) [33].

The potential of NFTs in the future can lie in their ability to completely change the rules of ownership in the digital world, as transactions of changing ownership of something have usually depended on layers of intermediaries for establishing trust in the transactions. With blockchains, recorded transactions are reliable because the information cannot be changed, and smart contracts can be used to automatically ensure that assets change ownership with involved parties respecting their agreements. The connected digital world needs to solve the problem of digital proof of ownership in all sectors, and NFTs might be one of the means for that [33].

Given the potential of NFTs in the future, as well as their already existing uses and applications, even taking into account their future which at the moment may seem unclear, the results of both surveys mentioned in this paper indicate that the level of knowledge about NFTs can hardly be considered as sufficient, especially as indicated by the survey conducted in Croatia. Educative efforts might therefore be needed both in formal education, but also in lifelong learning endeavors, to increase awareness and familiarity with the concept of NFTs, Wide areas of potential uses of NFTs with the rise of decentralized applications as well as many other developments of decentralized economies that might happen will have an impact on people's everyday lives. Such developments may be expected with the increasing portion of digital natives in

general populations, in the business and academic communities.

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