Blockchain Beyond Cryptocurrency: Non-Fungible Tokens

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Abstract

Blockchain technology is a disruptive innovation with the potential to replace existing business models that rely on centralized systems and third parties for trust. Even if there are a lot of application areas, blockchain used primarily for cryptocurrencies. Satoshi Nakamoto implemented the first blockchain application and invented the world's first digital currency which is named as Bitcoin in 2008. Fundamentally Bitcoin relies on cryptographic "proof of work" mechanism, digital signatures, and peer to peer distributed networking layer in order to provide a distributed ledger holding transactions. In 2014, a second generation of blockchains allow to program and execute them over distributed networks such as Ethereum project. The code to program any asset stored in blockchain's peer-to-peer network is called as "smart contract" and smart contracts gives a powerful tool to developers for decentralized applications. There are various types of tokens that anyone can built on top of Ethereum and by combining smart contracts and new tokens, this paved the way of possibility to build a wide range of decentralized projects. One of the disruptive blockchain based innovation impacting intellectual property is called non-fungible-tokens or NFTs firstly introuced in late 2017 on Ethereum network. This research contends that blockchain and non-fungible tokens (NFTs) which are cryptographically unique, scarce, non-replicable digital assets created through smart contracts and provably digital collectible assets. Our objective is to give NFT taxonomy, review NFT platforms and discuss technical challenges as well as recent advances in tackling the challenges. Moreover, this paper also aims to point out the future directions for NFT technology.

1 Introduction

Blockchain is a decentralized database and an emerging computing and development platform. It is a new paradigm that aims at empowering peers and "decentralized" network against the conventional "centralized" mechanism (Badreddin et al, 2018). Decentralization feature is at the hearth of blockchain technology. The decentralized nature of this new technology first of all makes cryptocurrencies theoretically immune to the old ways of government and banking control and also it eliminates the need for any 3rd party or mediation (Rosic, 2016). One of the key differences with blockchain and a traditional database is that databases have centralized architecture which can lead the single point of failure (spof), blockchains have distributed architecture can eliminate spofs. Even the concept of distributed computing has been around since 90s, Satoshi Nakamoto created bitcoin that accepted as the first form of blockchain tech maintained by anonymous consensus in 2008. There is a huge interest and rapid rise to prominence in corporate agendas as well as academia and media despite blockchain's short history. (DHL, 2018)

*Figure 1. A History of Blockchain Technology **Source:** DHL, 2018.*

Actually, history of cryptocurrencies starts before 2008. People may assume that cryptocurrencies had been discovered by Satoshi Nakamoto recently and gain much attention from public, cryptocurrencies had been argued for more than 3 decades. The first idea of it discussed by David Chaum's article, who is an American computer scientist and cryptographer, named "Blind signatures for untraceable payments" (Chaum, 1982). The concept of untraceable electronic payments and a secure digital cash system was presented for the first time in the history.

The basic idea was that users could withdraw a digital currency from a platform or a bank without being tracked by that platform or any 3rd party. Chaum founded DigiCash in 1990 to practice online payment system which ensures user's transaction anonymity. Even DigiCash did not succeed to achieve to introduce cryptocurrencies it has important contributions for future endeavors. By 1998, a computer scientist and cryptographer Nick Szabo began working on a decentralized digital contracts and digital currency called "bit gold." In 2008 the Bitcoin's white paper (technical guide) got published and finally found a way to implement the cryptocurrency by Bitcoin (Cuofano, 2021).
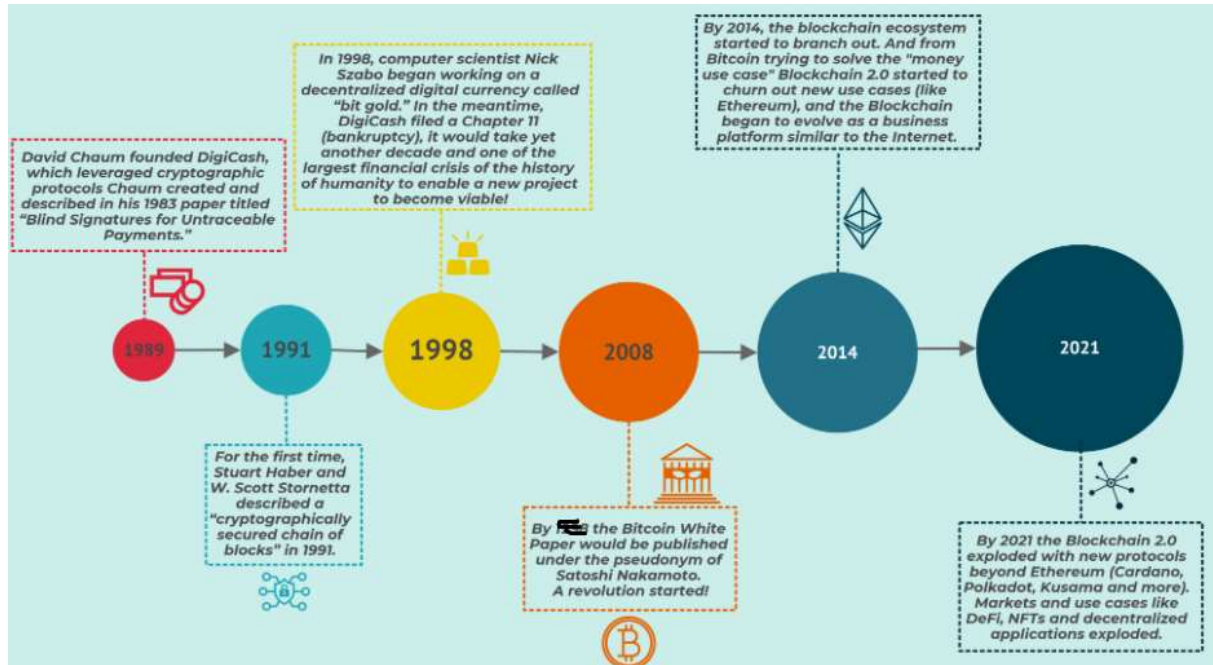

*Figure 2. Evolution of Cryptocurrencies **Source:** Cuofano, 2021.*

Blockchain is well known as the magic behind Bitcoin cryptocurrency, but also there are scores of other industries that are benefiting from this revolutionary technology. There are more than 10.000 crpytocurrencies according to coinmarketcap (Coinmarketcap, 2021). Blockchain revolution can broke down into three categories as shown in Table 1 (Swan, 2015).

Year	Blockchain Revolotion Explanation
Blockchain 1.0	Currency (digital payments, deployment of cryptocurrencies in application related to cash, i.e currency transfer, remittance)
Blockchain 2.0	Contracts (entire state of economic, market, financial applications)
Blockchain 3.0	Applications (beyond currency, finance and markets - especially for government, healthcare, science, literacy, art and culture industries)

*Table 1: Blockchain Revolution –as a summary **Source:** (Swan, 2015)*

The blockchain technology has developed beyond a global payments system and impacting other areas for example digital identities, supply chain management, healthcare, land registries through new decentralized applications. One of the critical blockchain based innovation which also impact intellectual properties are non fungible tokens (NFTs) which can be used to represent unique property. Despite the importance of the subject of the NFTs, there is few research about non-fungible tokens in literature, while there are many studies centered in Bitcoin or other cryptocurrencies. Our objective is to give information about cryptocurrencies and especially Ethereum because most NFTs are part of the Ethereum blockchain. And we will outline NFT taxonomy, review NFT platforms and discuss technical challenges as well as recent advances in tackling the challenge also point out the future directions in the NFT area.

2 Cryptocurrencies and Ethereum

Invention of blockchain technology has triggered a new wave of technological progress, transiting many industries, methods, processes and systems that used to be the norm. Transactions on a blockchain are processed by computers which works together on a public or private network and every transaction should be confirmed. All transactions sent on blockchain are processed in blocks. Each of the block is linked to the previous block and that makes it impossible to change and alter a transaction. Moreover, this is a transparent architecture because each computer called node in the network has a record of every single transaction that has confirmed. Records can be

added but can not be altered or deleted, they are immutable. Security guarantee for cryptocurrencies are provided by math and cryptography. Securely keeping and saving data in a way that is completely transparent and verifiable through a decentralized system has been key for the rise of cryptocurrency. Cryptocurrencies have gained much attention from the experts of financial and technical sectors and academic world recently. Cryptos are not ruled, managed or governed by central authorities. According to coinmarketcap web page, total market capitalization has surpassed 1 trillion dollar and as of June 29, 2021 and reached $1,418,409,684,091 (Coinmarketcap, 2021).

As Bitcoin becomes more popular, many individuals may think that Bitcoin is the only crypto in the market. All coins created after Bitcoin have a generic term and called as "Altcoins". In fact, the name "altcoin" that all are created after bitcoin actually means "alternative" to Bitcoin. Although there are thousands of cryptocurrencies in the cryptocurrency market, a few of them are popular and regarded as the major cryptocurrencies because their market capitalization is much higher than the others (Aghalibayli, 2019). Moving beyond the fundamental use case of Bitcoin, Ethereum has an incredible potential and is making its name on Decentralized Applications (dApps). Here is the list of most popular top 10 coins among 10698 cryptos are shown in below table:

Name	Symbol	Market Cap
Bitcoin	BTC	$654,030,330,565
Ethereum	ETH	$248,319,380,015
Tether	USDT	$62,475,376,607
Binance Coin	BNB	$45,515,842,324
Cardano	ADA	$42,857,089,064
Dogecoin	DOGE	$33,482,185,763
XRP	XRP	$30,492,490,538
USD Coin	USDC	$25,383,636,199
Polkadot	DOT	$15,517,991,561
Binance USD	BUSD	$10,501,715,901

Table 2. *Top 10 Cryptocurrencies by market cap* ***Source:*** *(Coinmarketcap, 2021)*

Although most of the altcoins are built upon the similar basic framework of Bitcoin, many claim to be better versions of Bitcoin. Ethereum is an important actor among cryptocurrencies because many new tokens and dApps are already being built upon the Ethereum blockchain. According to the total market cap, Ether, which is the symbol powering Ethereum network, is in the second trading currency after Bitcoin (XRP). There is a fixed, limited number of Bitcoins that can be created and exist which is 21 million. That number decided by the creator/s of Bitcoin at the beginning of project. Like Bitcoin, most cryptocurrencies listed here have a fixed supply except Ethereum. Ethereum has unlimited supply. Ethereum has been created in 2015 (Srhir, 2019). Both of these cryptocurrencies are created with open-source computing codes, which means their codes can be viewed and used by anyone. Ethereum builds on Bitcoin's innovation, with some big differences.

A Russian-Canadian young programmer Vitalic Butterin developed theoretical project main principles of Ethereum and smart-contracts. Ethereum is a Swiss startup launched the Ether cryptocurrency and implemented programmable money called "smart contracts" that leads to dApps. Basically, Ethereum is an open-source software platform that enables blockchain developers to create, manage and deploy decentralized applications on top of it. Ethereum represents a gateway platform to a world-wide, de-centralized computing paradigm. This platform enables application developers to run dApps and smart contracts that have no "single point of failure" or control, integrate with a payment network, and operate on an open geographically distributed public blockchain. (Antonopoulos, Wood, 2018). The chart shows Ethereum ecosystem and its business models below.

Before Ethereum, there were limited blockchain developers and applications designed to perform a series of operations. For example, Bitcoin and other majority of altcoins have been developed primarily to work as peer-to-peer payments of digital currencies. Developers had a lot of fundemantal problems and had to expand the set of functions offered by Bitcoin and other very complex, time-consuming types of applications and there was a strong need for a completely new platform. As one of the creators of Ethereum, Vitalik Buterin offered and adopted a new approach and created Ethereum Virtual Machine (EVM) which is a Turing-complete aka Turing machine, enables the execution of all programs regardless of the time and programming language (Kızılbey, 2019). Turing completeness denotes a data manipulation system that can read programming language using a simple set of information. Among all cryptos, Ethereum is the most recognized as Turing-completed (Url-2, 2021). Ethereum is the first, and most widely used, blockchain that allows for the development of programmable applications which operate on its network.

A smart contract is one of the key components of Ethereum that executes when pre-defined conditions are met. Smart contracts are crucial because they enable creation of de-centralised applications (dApps) that can automate processes and run distributedly with no possibility of censorship or downtime. Solidity programming language is commonly used as Ethereum's high level programming language of smart contracts. Exeecuting and verifying

smart contracts requires transaction fees paid in ETH. Ether (ETH) is the platform's native coin. However, one of the important features of Ethereum blockchain platform is the ability for anyone to create unique tokens that exist and operate on the Ethereum blockchain – which can have multiple utility-like purposes. Decentralized applications is another key feature of Etheretum platform which are applications use blockchain data and smart contracts. Ethereum provides application programmers and developers a worldwide programmable blockchain infrastructure (Wef, 2021). The Ethereum Virtual Machine (EVM) runs on top of the Ethereum's blockchain network and enables everyone to run an application, making the process of building blockchain programs much simpler. For each application, blockchain developers do not require to build a new blockchain network from scratch.

One of the most remarkable smart contract standards on Ethereum blockchain is known as ERC-20, which has emerged as the technical standard used for all smart contracts on the Ethereum and enables creation of fungible token implementations. ERC stands for Ethereum Request for Comments which is an application-level and a token-level standard, name registries and library/package formats etc. ERC-20 defines a common list of rules that all fungible Ethereum tokens should obey (Url-3, 2020). Other most popular standards are ERC-721 and ERC-1155 for creating non-fungible tokens (NFTs). Fungible tokens can be divided but NFTs are unique and can not be divided. NFTs can represent ownership over physical or digital assets such as videos, images, arts, event tickets etc. With NFTs, any digital art artwork can be "tokenised" to create a digital certificate of ownership that can be bought and sold on blockchain (Url-4, 2019).
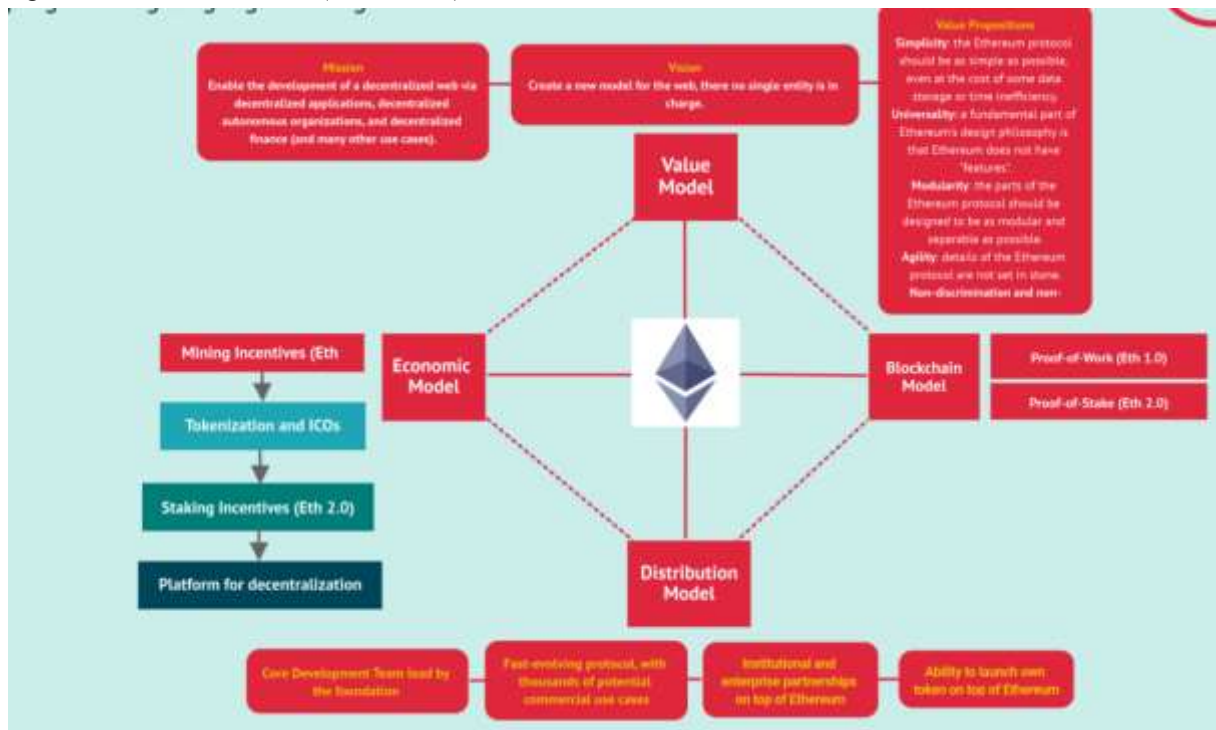

Figure 3. *Ethereum Ecosystem and Its Business Models* **Source:** Url-1, 2021

3   Non-Fungible Tokens

The concept of non-fungible tokens originally proposed from a token standard of Ethereum, and it is purpose to distinguish each token with distinguishable signs. Most of NFTs are part of the Ethereum blockchain. NFTs are type of cryptocurrencies that is derived by smart contracts. It is worth noting that other blockchains can implement their own versions of NFTs. There are a lot of cryptocurrencies which has its own blockchain such as Avalanche that supports Ethereum Virtual Machine (EVM) and smart contracts. NFTs are unique tokens which can not be exchanged like-for-like, making it suitable for identifying something or someone in a unique way. It can be used Intellectual Property protection. There could be an NFT that represents ownership of a real-world piece of art; each piece of digital art, assets like each NFT, is unique. NFTs represent digital scarcity. Examples of NFT include tickets, collectibles, game items, crypto artwork, financial products, deeds and more (Url-5, 2021). The non-fungible token market cap for as of June 29, 2021 is $17,408,786,221.48 with a total trading volume of $1,147,366,236.48 in the last 24 hours. The table below shows top 10 NFT coins by market capitalization by Coingecko (Url-6, 2021).

In another words, non-fungible tokens are cryptographic assets created mostly on Ethereum blockchain with unique identification codes and metadata that makes NFTs distinguish from each other. NFTs can't be traded or

exchanged at equivalency unlike cryptocurrencies, because they are not "fungible" (Sharma, 2021). Detailed model of NFT systems is shown below Figure 4.

Name	Symbol	Market Cap
Theta Network	THETA	$7,364,196,518
Tezos	XTZ	$2,465,935,638
Chiliz	CHZ	$1,385,584,301
Enjin Coin	ENJ	$1,044,463,535
Decentraland	MANA	$741,926,850
Flow	FLOW	$453,847,508
Ecomi	OMI	$424,239,427
Ultra	UOS	$423,975,468
BakerySwap	BAKE	$353,014,298
Axie Infinity	AXS	$249,011,623

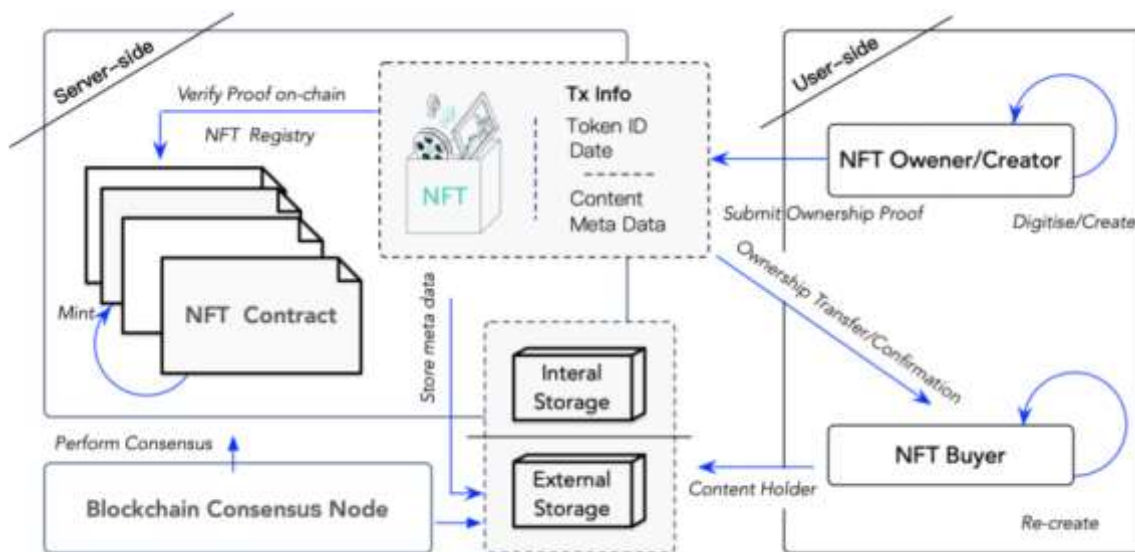**Table 3.** *Top 10 NFT tokens by market cap* **Source:** *(Coingecko, 2021)*

Figure 4. *Model of NFT Systems* **Source:** *Wang et. al, 2021*

The first example of NFTs is CryptoKitties, a blockchain game on Ethereum that allows players to purchase, collect, breed and sell virtual cats in 2017 (Url-7, 2021). While the gaming industry's adoption has already reached a certain maturity, the production of digital content such as music, digital art or video, are experimenting with the technology. In December 2020, the market of NFT art started to grow again. The NFT volume has exceeded 2 USD billions, ten times larger than the entire trading volume in 2020, just in the first four months of 2021 (Url-8, 2021). And NFT market attracted a huge attention in March 2021, when the artist known as Beeple sold an NFT of his work called "Everydays: The first 5000 days" sold for $69.3 million at Christie's, a single-lot sale that marks the first time a purely digital work of art (Url-9, 2021). Following days, three Cryptopunks were sold at $7.5 million, $1.54 million and $1.3 million dollars, respectively; the first tweet of the Twitter CEO Jack Dorsey was sold at $2.9 million dollars to Sina Estavi; and the Auction Winner Picks Name, an NFT with music video and dance track, sold at $1.33 million dollars (Phillips, 2021). NFTs profitability has attracted several celebrities, who created their own NFTs, as well as the most popular sports, with collectibles of NBA and famous football players that are currently sold for hundreds of thousands of dollars (Devlin, 2021).

4 Non-Fungible Token Platforms and Predictions

Since the success of cryptokitties in 2017, NFT market gets a huge attention in 2021 and become one of popular blockchain application market. According to Dappradar web site, there are 25 marketplaces as of June,30 2021 and top 10 are shown in Table 4 (Url-10, 2021).

There are six NFT categories in general: "Art", "Collectible", "Games", "Metaverse", "Utility", or "Other". The operative definitions of these categories are inspired from the definitions given by NonFungible Corporation and summarized in Table 5.

People can buy NFTs on a variety of platforms, and which they choose will depend on their wish for instance, if they want to buy baseball cards they may visit a website like digital trading cards, but other marketplaces sell more generalised pieces. NFTs are linked to digital assets of different types, including videos, text, animated gifs, 3d images and audio. Nowadays, the vast majority of NFTs consists of images (Nadini et al, 2021). Anyone who want to get an NFT need a soft or cold (software or hardware) crypto wallet, should connect to the platform and fill that wallet with cryptocurrency. Worldwide NFT sales with breakdown for the past year are shown in Figure 5 (Url-8, 2021).

Market	Trades	Volume
OpenSea	141,712	$659.86M
NBA Top Shot	408,609	$620.97M
CryptoPunks	3,317	$364.37M
Axie Infinity	100,234	$174.67M
Rarible	58,341	$163.04M
Sorare	25,704	$88.62M
SuperRare.co	3,923	$74.33M
AtomicMarket	504,72	$57.75M
PUNKS Comic	2,379	$48.36M
Foundation	10,694	$46.66M

*Table 4. Top 10 NFT markets by volume **Source:** (Dappradar, 2021)*

Category	Description
Art	Art NFTs of digital artworks, such as images, videos, or gifs
Collectible	Collectible NFTs of interest to a collector
Games	Games NFTs used n competitive games
Utility	Utility NFTs for specific purposes (e.g. secure and decentralized name service)
Metaverse	Metaverse Piece of virtual worlds
Other	Other NFTs of small collections that are not included in the other categories

*Table 5. Operative Definitions of NFT Categories **Source:** (Nonfungible.com, 2021)*
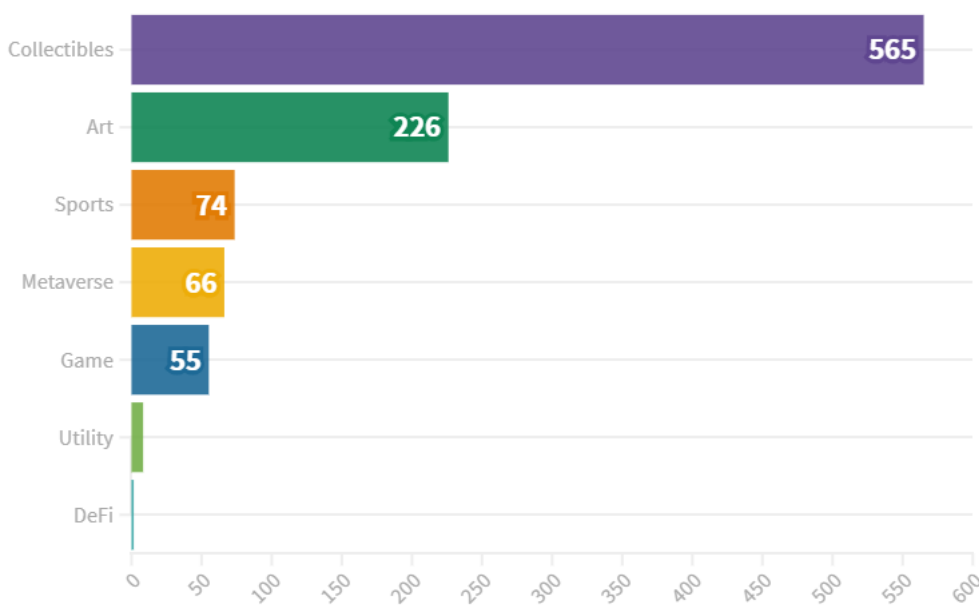

*Figure 5. NFT sales in the past year **Source:** Nonfungible.com, 2021*

Non-fungible tokens' market is expected to maintain its rapid growth trajectory in 2021 as demand for digital collectibles continues to grow day by day. The actual growth was largely triggered by growing retail adoption of digital collectibles, building on the initial success of CryptoKitties in 2017. The market for NFTs was worth approximately $338 million in 2020 and ever since that $69.3 million sale hit the headlines. NFT trading volume is expected to reach $175 million by last quarter of 2021, leading to an industry market capitalization of $470 million (Url-11, 2021). In 2021, we are witnessing the NFT market exceeding expectations with analyses showing between 1785% and 2100% growth in the first quarter of 2021, totalling more than US$2 billion spent on NFT collectibles (Url-12, 2021).

Even forecasts are positive for NFT market, there's some controversy surrounding NFTs because of their portential impact on climate change. As Ethereum is mostly used for creating NFTs, ethereum mining consumes too much electricity. Ethereum relies on a computational competition called proof of work (PoW) and will plan to switch this mechanism to proof of stake (PoS) to consume less energy and make it greener (Fairley, 2019).

5 Conclusion

Blockchain technology is constantly evolving, and there have been some massive developments in just the last few years especially for NFTs, thanks to Ethereum blockchain. Non-fungible tokens (NFTs) are unique, non-interchangeable and non-hackable digital tokens powered mainly by public blockchains like Ethereum, Avalanche, Flow and Tezos. NFTs are stored in "smart contracts," programs stored on a blockchain that run when predetermined conditions are met, and these are automatically executable codes that run on top of the distributed ledger on which the NFT is recorded. The NFTs are intended for the pleasure of collecting and financial gain through the scarcity and uniqueness afforded to each NFT. Since the first NFT project called Cryptokitties went live in 2017, the market for digital assets has witnessed a parabolic growth. The NFT market is available for less than four years old and has become more popular for just over six months to date. Forecasts for 2021 look extremely positive for the emerging market, already valued $20 billion higher than 2020 for non-fungible tokens. The biggest challenge and critics to NFTs are mainly for its energy consumption. As most of NFTs created on Ethereum or blockchains which has proof of work mechanism, they consume too much energy and it is harmful for climate. Ethereum has plans to change its proof-of-work algorithm by Ethereum 2.0 project to energy efficient and more green proof-of-stake algorithm and modern crypto projects do not use proof of work soon. So when Ethereum 2.0 proof of stake mechanism will be available and when NFTs will be created on mostly proof-of-stake blockchains, there will be no longer debate for NFTs potential impact on climate change.

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