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Emerging Trends in Non-Fungible Tokens (NFT) Across Industries: A Comprehensive Review and Research Agenda

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Abstract:- Non-Fungible Tokens (NFTs) are unique digital assets using blockchain technology that represent ownership or proof of authenticity of unique content. The ongoing development of NFTs in various industries beyond art and gaming addresses sustainability issues. Nevertheless, widespread NFT applications encounter significant challenges, encompassing usability issues, concerns related to security and privacy, as well as governance considerations. The purpose of this article is to assess the current state of blockchain technology development, focusing on NFTs (Non-Fungible Tokens) as an illustrative example. It aims to identify the existing issues and challenges within this domain, while also exploring its potential applications across various business sectors. Moreover, the chapter explores how tokenization of both digital and physical assets can be leveraged to provide a diverse range of services. In this study, an analysis was conducted on NFT products, examining their fashion characteristics and trends within NFT applications. Additionally, the study investigates the opportunities and challenges presented by NFT applications, including the exploration of sustainable NFT options. The rise and subsequent crash of NFT and related crypto markets in mid-2022 have vividly demonstrated the sector's volatility, leading to concerns about its sustainability, environmental consequences, and exploitative practices. These issues have prompted discussions about the potential existence of socially responsible applications for NFTs and whether such use cases are feasible. We firmly believe that the outcomes of our research hold valuable insights and strategies for future researchers, creators, and entrepreneurs interested in advancing NFT applications.

Keywords*: Blockchain, Cryptocurrency, Non-Fungible Token, Smart Contracts.*

1. Introduction

As Industry 4.0 continues to advance, various novel technologies are emerging, and among them, blockchain stands out as particularly noteworthy and gaining significant popularity. Alongside this trend, a diverse array of businesses is flourishing around blockchain, with NFTs (Non-Fungible Tokens) aiming to be a notable player in this domain.

NFT products hold significant significance in industrial applications and have witnessed rapid growth in the blockchain domain in recent years. These non-fungible tokens serve as unique units on a digital ledger, marking each product sold and representing distinct digital data. As of early 2021, NFTs had achieved widespread public recognition, becoming the advanced application of blockchain technology that enables the trade of digital assets such as arts, music and audio, videos, and virtual creations [1].

Over time, numerous industries have been able to reap the benefits of NFTs creatively to explore fresh business innovation and entrepreneurship opportunities, thus making this a broader field of technology. Despite this, only a few studies have been done analyzing the pros and cons of various NFT characteristics and the prevailing trends in NFT products.

A. History

It becomes really important to understand the underlying concept of NFTs before diving into the social and ethical considerations of NFTs. First, we need to know how they are built and how their transactions are made.

1. Blockchain and cryptocurrency

A blockchain functions as a distributed ledger, diligently recording all transactions. It remains accessible to the public and is replicated across multiple computers (peers) that validate transactions, preventing any fraudulent modifications to the ledger. Essentially, it operates as an immutable, decentralized database, with verified entries that cannot be altered or deleted, only appended. Each entry is known as a "block" and possesses specific data along with a unique hash assigned to it. The "chain" refers to the linkage of these blocks, each containing the hash of the preceding one [2].

Meanwhile, cryptocurrency operates as a decentralized digital exchange system, facilitating peer-to-peer transactions through using cryptography to create and distribute currency units [3].

Various blockchains are distinguished primarily by the method used to validate entries, which is achieved through peer consensus. In this process, one peer serves as the validator while others verify the validation action. The validator receives a cryptocurrency reward specific to that chain if the validation is correct. Conversely, suppose the validation is incorrect, such as inserting false data. In that case, the validator loses their reward and any contribution they made towards validation (this may vary depending on the blockchain type).

The key differentiating factors among various blockchain types are the selection of peers as validators and the requirements for becoming a validator. For instance, in blockchain systems employing Proof-of-Work (PoW) such as pre-merge Ethereum and Bitcoin blockchains, participants need to compete and solve complex mathematical puzzles in order to get a chance to add a block into the network and thus receive a cryptocurrency reward. The hardware used for solving these puzzles consumes significant energy, creating an incentive to provide accurate answers due to the associated cost of energy use. The blockchain's inherent feature is the increase in puzzle difficulty and energy cost over time, which helps control inflation [4].

In Proof-of-Stake (PoS) chains like Tezos, Cardano, Solana, and Ethereum 2.0 PoS implementation, a different approach is employed for validation compared to Proof-of-Work chains (Ibañez & Rua, 2023). Instead of competing with computing power, peers in PoS chains contribute a certain amount of the built-in cryptocurrency of the blockchain as their 'stake.' An algorithm selects validators from the group of individuals staking cryptos based on the value of their wallet holdings (the exact decision-making algorithm may vary depending on the specific blockchain) [4]. Additionally, if there are issues with the validation, such as attempted manipulation of the result, the staker will lose their stake.

The major contributions of this paper are outlined as follows:

1. This paper discusses all the fundamentals of Non-Fungible Tokens (NFTs) and their technical details.
2. A detailed analysis of NFT applications in several industrial sectors, such as healthcare, supply chain management, electricity maritime industry, and many more, have been discussed in detail in this paper.
3. Moreover, probable solutions to the problem faced by various industries primarily focused on safety, security and sustainability issues of NFT have been discussed.

2. Literature Review

A. Concepts and Attributes of NFTs

NFTs are distinctive digital identifiers built on blockchain technology. They serve as a means to record and authenticate ownership of digital assets, providing each item with unique and non-replicable qualities [5]. When a unit of data is exchanged within the blockchain network, its details, such as the buyer, price, and data source, become accessible to everyone through a public ledger. This collective information forms a "block" comprised of several nodes [1]. As numerous individuals contribute data to create this block, it evolves into a "blockchain."

Using blockchain technology each NFT can be encrypted with a unique identity that is difficult to alter once recorded. Consequently, NFTs offer transparent and irreplaceable proof of transactions. [1].

An NFT represents a decentralized application that utilizes the advantages of an open book encompassing several attributes, namely atomicity, availability, tamper-resistance, tradability, transparent execution, usability and verifiability [1] [5] [6]. In this section, we investigate into the discussion of these attributes:

1. Atomicity: NFTs trading can be done in an atomic, isolated, consistent, and without degradation, enabling the efficient operation of NFTs in the same shared-execution state.
2. Availability: Within the NFT system, the issuance of an NFT and all associated transactions can occur seamlessly without interruption, ensuring continuous availability for buying and selling.
3. Tamper-Resistance: NFT data is permanently stored after a transaction record is generated, preventing any potential tampering or modification of transaction details.
4. Tradability: Every NFT and its associated product can be freely exchanged and traded as desired.
5. Transparent Execution: NFT activities, such as mining, purchasing, and trading, are conducted openly and transparently, accessible to all participants.
6. Usability: Each NFT provides the most current, user-friendly, and transparent ownership information.
7. Verifiability: NFT data and ownership are publicly verifiable, enabling users to confirm their authenticity.

The emergence of NFTs has sparked the creation of numerous business opportunities across various industries in the digital world.

B. NFT Prospects and Use Cases

In this section, we examine the broad range of applications of NFTs and classify them into four distinct groups: "Art," "Event," "Entertainment," and "Science and Technology" [7].

2.2.1 Art

The state of art provides a platform and environment for the limitless exploration of human creative potential, digging into the intersections between technology and creative results within the broader scope of creative industries [8]. (a prime illustration of this is the sale of Beeple's "Everydays: the first 5000 days" for a staggering 69 million Dollars) [7]. NFT-oriented artworks can be further classified into the following subgroups:

- Digital Art: Digital art in the form of NFT can be bought and sold [7].
- Music Album: A "Music NFT," serving as proof of ownership for an original piece of music or audio, can be purchased and sold. [9]. Artists can reap the benefits without the need to arrange concerts or festivals [7].
- Video Clip: NFT-based video clips and music videos often encompass loop videos (e.g., *.GIF) or brief segments capturing memorable moments [10] [7].

2.1.2 Virtual Events

Digital events are particularly advantageous for companies or individuals seeking to host large-scale international meetings or exhibitions [11]. The following use cases are foreseen for these types of NFTs:

- Tickets: NFT tickets can be utilized as a mechanism for ticketing or offer discounts for sports matches, concerts, exhibitions, and various events [12].
- Fashion: Fashion brands such as Louis Vuitton and Gucci are actively showing interest in NFT designs [13], primarily showcasing clothing, dresses, and similar items, which are considered in the following two aspects:

i) Virtual Apparel: Digital clothes designed for virtual life, and ii) Offering distinctive real-world clothing items with NFTs representing ownership rights for these garments.

- Voting: NFT voting token enables the owner to own a vote [14]. Voting to NFT and voting through NFT (NFT-based voting) are two distinct aspects of this concept, both relying on the distinctiveness of NFTs. Unique NFTs can be considered as candidates for collecting submitted votes, or each user linked to a distinct NFT can be seen as a voter [7].

2.1.3 Entertainment Industry

The target audience for this category comprises individuals who engage in internet-based entertainment [4]. Now, let's explore some applications of NFTs in this particular category.

- Trading Card: Collectible cards having various information or illustrations often associated with a popular game, sports, or entertainment. In NFT markets, quality concerns are virtually non-existent, as digital goods do not experience degradation over time, retaining its value, thus eliminating the necessity for expensive third-party verification [15].
- Traveling: Traveling is one of the main sources of entertainment for people, and blockchain products have the potential to enhance their quality. Recently gaining significant popularity, medical health tourism has shown substantial adaptation in NFT features to track passengers, gather and analyze customer data, and elevate service levels [16].

2.1.4 Science and Technology Sector

In the science and technology sector, data protection, ownership, sharing, and product tracing are of paramount importance. Text-based NFTs, widely recognized in these domains, have significantly aided scholars and businesses.

The other subgroups of these NFTs are listed as follows:

- Supply Chain: Ensuring product traceability from the manufacturer to the end user, safeguarding against fraud, and maintaining physical integrity are crucial concerns in product management and supply chain operations. It can solve issues such as underprivileged logistics [17] with its traceability feature. Employing NFT-based supply chains as a cutting-edge concept greatly aids product managers in addressing these challenges [7].
- Web Domain: An Ethereum Name Service (ENS) domain now represents an individual's Web 3 identity. It focuses on selling domains, much like the current functionality of .com or .org domains. Users have the option to register for domain on their platform by making a payment and subsequently utilize it as an alternative to their wallet address [18].
- Real Estate: Physical land or property can be represented as an NFT encompassing all its features. Uniqueness is a fundamental aspect of properties traded in the real estate market, necessitating essential digital monitoring, which would be very beneficial for real estate owners [14].
- Patent and Intellectual Property: While NFTs have diverse applications, their use in addressing real-world issues is insignificant, particularly in contrast to intellectual property, patents, trademarks, and copyrights. Traditional processes of patent and trademark applications are time-consuming and costly, taking months for copyrights or trademarks and years for patents. NFT technology's unique features offer potential acceleration in the process, ensuring confidence in protecting intellectual property ownership. [19].
- Medical Records: Most medical records are being stored digitally and are sold to medical researchers and big pharma companies these days. NFT technology has the potential to offer a solution that enhances overall transparency and even involves patients in the entire process [20].
- Physical Assets: The ability to trace ownership on the blockchain enables the trading of digital and physical goods through NFT technology. Organization for Economic Cooperation and Development (OECD) has reported the trade of fake merchandise accounts for 3.3% of global trade. Implementing NFT technology could serve as a solution for authenticating genuine products [20].

Table 1 No. of NFTs Circulated in Different Quarters (Analysis of NFT Trend)

	Q1 2022		Q2 2022	
	Volume of NFTs circulating	**% of the supply**	**Volume of NFTs circulating**	**% of the supply**
Art	1,79,876	9.52%	1,15,245	5.76%
Collectibles	16,56,569	20.21%	6,54,642	7.63%
Gaming	20,89,706	9.23%	7,41,342	3.26%
Metaverses	38,237	7.10%	87,547	13.30%
Utilities	2,85,533	16.79%	7,12,666	29.56%

Source: nongungible.com, https://www.slideshare.net/secret/r0QVu2GhFiibrh

Table 1 illustrates that the adoption of NFTs is not limited to a particular category; instead, a shift from digital to physical assets tokenization can be observed in the above data. In this context, the utilities section has exhibited a significant increase from 16.79% of the total supply to 29.56%. This trend is expected to further grow as various industry sectors begin to acknowledge the benefits of blockchain technology.

Table 2. Study of NFT use cases

Reference	Industry	Description	Contribution of the Paper	Disadvantages
[21]	Construction Waste Management	Waste Material Passport offers a solution for managing construction waste.	Reduced information asymmetry, Digitized management, Enhanced information transparency, and Improved trading efficiency.	Lack of systematic performance metrics, Doubt in the feasibility of framework.
[22]	Food Industry	The NFT-based solution streamlines trading of high-value food products through digital certification and smart contracts, ensuring ownership.	Cost and security analyses, Trading and managing expensive packaged food products, and facilitation of the trading process using smart contracts.	Absence of quantitative or qualitative results and a lack of comprehensive analysis on the cost-effectiveness or economic feasibility of the proposed solution.
[23][24][25]	Automobile	Proposal for a car ownership and revenue generation model using the ERC-1155 token standard.	NFTs, blockchain in the automotive sector with ERC-1151 model for fractional ownership, flexible for various fleets, revenue based on ownership. Urban mobility in smart cities is a target. Blockchain is enhancing security and charging systems for electric vehicles.	Test network-based model limits real-world use, focuses on a single cryptocurrency, and lacks details on vehicle unlocking and microtransactions.
[9]	Music	Implementing NFTs in music using Blockchain to secure copyrights and revenue rights from untrusted holders.	The model solves problems such as inadequate data, unreliable cultural structures, and decreased artists' wages. The use of blockchain allows for the examination of efficiency and cost.	It does not address legal challenges, lacks a detailed analysis of limitations, and lacks empirical evidence for model feasibility.

Reference	Industry	Description	Contribution of the Paper	Disadvantages
[26] [27]	Healthcare Sector	Healthcare product management with NFTs: Ownership via digital certification, smart contract-enabled trade, and dispute resolution with an arbitrator.	Readily available healthcare data, data analytics tool with the proposed algorithm, greater reach to the customer, combats counterfeit medical devices, and a reliable and efficient traceability system.	Requires large storage system, Lower adoption rate, Smart contract vulnerabilities and security risks, and Lack of technical experts.
[28][29]	Supply Chain and Logistics	Applying non-fungible tokens (NFTs) for digital certification, proof of ownership, sale history, quality verification, and proof of delivery of fine jewelry and gemstones. Integrating ERP and BCT for better information sharing and cooperation.	System design, sequence diagram, and algorithm showcase the interaction involved in jewelry production, buying, and selling.	Not mentioning the scalability issue of the proposed solution, detailed analysis of risks involved, and weak points of the solution are neglected.
[30]	Maritime Industry	NFTs streamline shipping: Digital ownership transfer, process documentation, and auctions at destination ports for efficient cargo release.	Optimized cargo auctions at ports enhance efficiency, minimize delays, and reduce costs, ensuring secure transactions on public or private blockchain platforms.	Empirical evidence supporting feasibility and scalability concerns are not adequately addressed. The paper lacks a detailed analysis of potential economic consequences tied to the proposed solution.

3. Methodology

A. Resource Gathering

First, we reviewed all related articles and research papers from different topics of interest, such as social Science, Decision Science, Science and Technology, Business, Accounting, Finance, etc. To keep things very precise and to have knowledge of recent trends and work in the field of NFTs we primarily focused on the papers that are in the time range from 2021 to 2023. We followed the methodology used by [31].

The authors used the keywords “Non-Fungible Tokens (NFTs)*” or “Blockchain*” to search for the relevant studies related to NFTs.

More than 655 publications were found. By limiting the publications to the “article” type, 419 journal papers were obtained. Furthermore, by selecting the publications belonging to the “Blockchain: Research and Applications,” “Research in International and Finance,” or “Computer Law & Security Review” and filtering through the year and other categories, 26 articles were finally selected for analysis.

The very first objective of this article was to provide a brief overview of the immense opportunity of NFTs in different sectors, and only few literatures have discussed this. With the help of a literature review, concepts concerning NFTs, their features, opportunities, and applications have been discussed. Next, we analyze the industry application of NFT to predict trends in different sectors, which will help industrialists and experts in those fields and help the government set policies and laws.

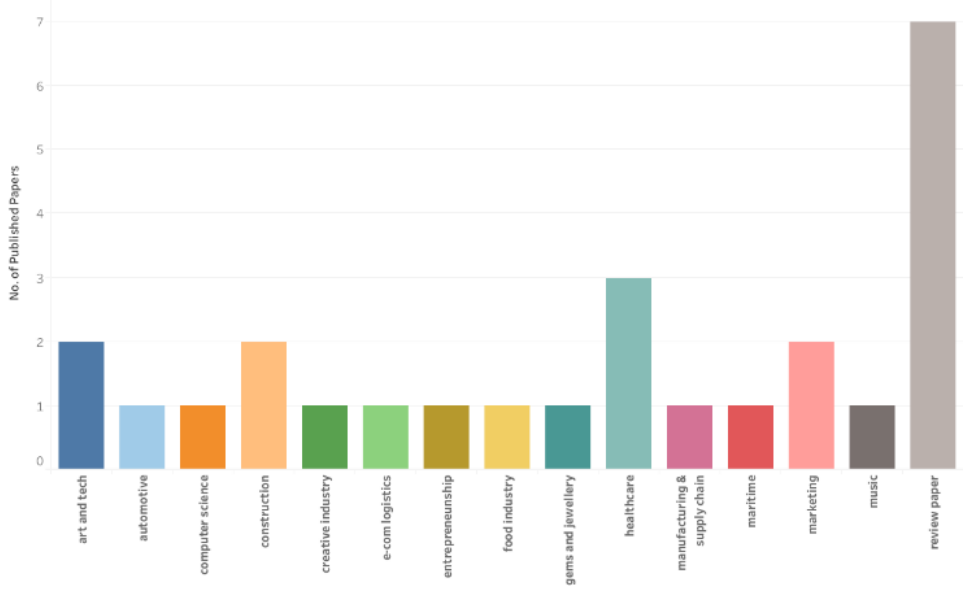

Figure 1 Papers on NFT Applications

B. Data Distribution

Here, we have analyzed the papers ranging year from 2021 to 2023, since in this period, the use of NFTs was prominent. Figure 2 shows the distribution of work on NFTs in research papers. Most work has been done in the field of healthcare, [26] have developed and evaluated an NFT-based traceability and ownership management solution to track and trace medical devices in the healthcare supply chain as well as in the retail market. [32] have designed and assessed an approach for lot traceability in medicines using both IoT and NFT technologies. This traceability method serves as a safeguard against counterfeit drugs in the pharmaceutical supply chain. Then comes the art and technology industry in which [8] examined various interconnections between Blockchain technology and Artificial Intelligence (AI), exploring their relation with the frequently mentioned contemporary art industry. Other papers concentrate on assessing the state of blockchain technology across different sectors. As it unfolds new technological possibilities, it enhances its form, addresses various topics, and questions the current status of development.

4. Discussion

The acknowledgment of the volatility in NFT and crypto markets, as demonstrated by the mid-2022 events, raises concerns about sustainability, environmental impact, and ethical considerations. These concerns prompt discussions about the feasibility of socially responsible applications for NFTs. In this section, we have discussed the current issues associated with Non-Fungible Tokens (NFTs) and Blockchain Technology and have provided constructive feedback to resolve those issues.

A. Discussion of Current Challenges and Their Probable Solution

Challenges in the NFT Space

NFTs pose challenges like theft, reselling, and hacking, along with difficulties in brand establishment amidst the abundance of NFT products. Moreover, prior research [7] has identified key issues in NFT applications, encompassing usability, security, privacy, and governance concerns.

Issues in NFT Transactions

Delayed confirmations and high gas costs hinder NFT transaction efficiency. Crucial governance measures include crafting regulations for cross-border NFT transactions and property tax rules [1].

Factors Contributing to High Energy Consumption and CO2 Emissions in Cryptocurrencies:

Cryptocurrency mining, driven by profit motives, intensifies power demands. To enhance environmental sustainability and cut Green House Gases (GHGs) and carbon (CO_2) footprint, adopting diverse energy sources, especially renewables, is a viable alternative. [33].

We pinpointed some key factors driving high energy use and CO_2 emissions in cryptocurrencies: Proof of Work, redundancy in operation and traffic, mining devices, and energy sources [34].

i. Consensus mechanism: proof of work

Finding the mining key is computationally expensive, miner need to provide proof of the amount of computational power, therefore giving this consensus mechanism the name PoW.

ii. Redundancy in traffic and operation

Non-PoW blockchains intensify energy use with redundant operations and network traffic. Storing the complete ledger on all nodes, each independently processing transactions, and redundant network traffic contribute to reduced system efficacy and increased electrical energy consumption [35].

iii. Energy sources

Bitcoin emits 64.18 $MtCO_2$ (Metric Tonn of Carbon Footprint) and 26.13 $MtCO_2$ for Ethereum, respectively, it is very close to carbon emissions by some countries [34]. This is alarming to see that the relative nation-level and industry-level carbon emissions from these transaction systems having a negative impact on the environment.

Solutions and Policy Implications:

The Chinese government introduced incentives, including subsidies, to promote blockchain technology development. Varied subsidies for traceability service providers and producers aim to benefit the entire supply chain, fostering the growth and application of blockchain technology [36].

The Proof-of-Stake (PoS) mechanism, firstly used in Peercoin, stands out as a promising alternative to PoW, eliminating the computational race and reducing energy consumption. "The Merge" in Ethereum notably decreased its energy consumption, with the latest global power estimated between 963 kW to 33 kW and energy per transaction between 0.02095 kWh and 0.0007188724 kWh [37].

NFT traders can reduce their carbon footprint by avoiding proof-of-work platforms. Regulatory measures may require this avoidance, with potential taxation tied to the platform's energy consumption or emissions, aligning with the principle that polluters bear associated costs in environmental law [38].

Alternative Solutions for Blockchain Sustainability:

Sharding, the division of the network into shards based on the consensus mechanism, is a promising solution [34]. Research on blockchain scaling proposes a stable sharding technique. Sharding is considered for Ethereum 2.0, and alternative options like ElasticChain aim to reduce redundancy and improve storage scalability [34]. Regardless of the consensus mechanism, using efficient devices like ASIC is crucial to reduce energy costs if PoW persists [39].

Taxation on mining devices can be levied at various points: manufacturing, sale, import, or usage. These points represent carbon taxes on household appliances. Domestic sales may face sales tax or VAT, with potential disallowance of hardware deductions from business profits. Consideration for upgrading to efficient devices, akin to capital allowances for machinery upgrades, is advisable during retirements and recycling.

Renewable Energy and Sustainable Practices:

A study on Sustainable Development Goals (SDG) advocates transitioning to renewable energy, eco-friendly production, green trade, education, and awareness for economic growth. These principles, originally for general economic sustainability, are also relevant to cryptocurrencies. Another study highlights the importance of legal criteria and energy supply in determining cryptocurrency mining locations, recommending wind and solar energy for environmental friendliness. Countries with high mining activity are urged to invest in renewable energy for sustainability [34].

Overall Recommendations:

To address the sustainability challenges posed by NFTs, the adoption of eco-friendly blockchain technologies featuring proof-of-stake consensus algorithms, in contrast to the energy-intensive proof-of-work, offers a solution characterized by decreased energy consumption. Also, NFT platforms and creators can enhance sustainability by introducing NFT products that advocate for environmentally conscious concepts, integrating incentives like tree planting, investments in renewable energy projects, and incorporating eco-friendly materials in NFT production.

5. Conclusion

Non-Fungible Token (NFT) is an emerging technology well established in the blockchain market. In this paper, we explore the state-of-the-art NFT applications to find out the industry readiness of blockchain technology, which may reshape the market of digital and physical assets stepping forward. The paper emphasizes the broader concept of tokenization, encompassing both digital and physical assets, and its potential to offer a wide range of services. The study conducts a detailed analysis of NFT products, shedding light on their fashion characteristics and trends within NFT applications. Furthermore, it explores into the opportunities and challenges presented by NFT applications, specifically focusing on sustainable options. We hope this report delivers a timely analysis and summary of existing proposed solutions and projects, making it easier for newcomers to keep up with the current progress.

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