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Tokenized Markets Using Blockchain Technology: Exploring Recent Developments and Opportunities

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Abstract: The popularity of blockchain technology stems largely from its association with cryptocurrencies, but its potential applications extend beyond this. Fungible tokens, which are interchangeable, can facilitate value transactions, while smart contracts using non-fungible tokens enable the exchange of digital assets. Utilizing blockchain technology, tokenized platforms can create virtual markets that operate without the need for a central authority. In principle, blockchain technology provides these markets with a high degree of security, trustworthiness, and dependability. This article surveys recent developments in these areas, including examples of architectures, designs, challenges, and best practices (case studies) for the design and implementation of tokenized platforms for exchanging digital assets.

Keywords: blockchain; tokenized markets; tokenized platforms; digital assets; cybersecurity; virtual economy; European dataspace; extended reality

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1. Introduction

A blockchain is a sequence of interconnected blocks that contain data with digital signatures within a decentralized and distributed network. As these blockchains are managed by a group of nodes in a decentralized network, they form a public and decentralized digital ledger (or record book) that is difficult for any one node to corrupt or influence. This creates a secure method for peer-to-peer transfer of digital assets without the need for a central authority or intermediary [1]. The chain of blocks continuously grows as new blocks are appended to the existing chain. Although cryptocurrencies are the most widely known application of blockchain technology, it has numerous other applications. Surveys exploring these applications, challenges, opportunities, and cryptocurrencies based on blockchain technology have been done [2–4]. This article focuses on one of these alternative applications, which involves using blockchain technology to create virtual markets where individuals can exchange tokenized digital assets.

Utilizing the public, decentralized, and distributed ledger that is provided by a blockchain, it is possible to create virtual representations of nearly any physical asset, such as a house, painting, or jewel. This process, known as asset tokenization or digitization, involves transforming asset rights into digital tokens that, in theory, can be securely and reliably bought, sold, and traded using blockchain technology. However, in practice, significant challenges remain in the development of these "tokenized virtual markets", such as cybersecurity threats and the absence of government and industry regulation. The tokenization process involves four primary steps [5]: (i) identifying the physical asset to be tokenized; (ii) assessing the asset's true value; (iii) determining the parameters that define the tokenized asset, such as the number and value of tokens; and (iv) creating and auditing smart contracts that govern the exchange of tokenized assets.

The Ethereum token standards ERC-20 and ERC-721 created two types of tokens on the blockchain (Figure 1): (i) fungible tokens that are identical and can be replaced (such as cryptocurrencies and carbon credits), and (ii) non-fungible tokens (NFTs) that represent a unique asset and cannot be easily exchanged for other tokens (such as music files or copyright certificates). NFTs are like digital IDs registered on the blockchain and cannot be divided further. Despite this, they can be traded using smart contracts on the blockchain, which supports decentralized and secure virtual markets.

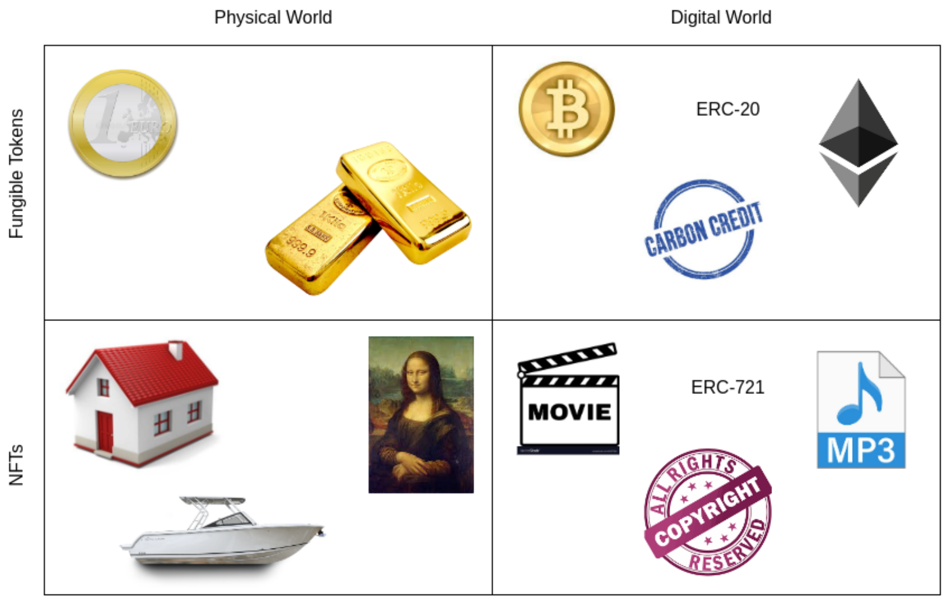

Figure 1. Fungible tokens vs. NFTs.

In this paper, we examine recent developments related to the design and implementation of tokenized platforms for exchanging digital assets. The paper covers a variety of topics, such as architectures, designs, challenges, and best practices (case studies). It is organized into several sections for easy reading. Section 2 provides an introduction to the basic concepts of tokenized platforms, using diagrams and other visual aids to make the material more accessible to non-experts. Section 3 outlines the methodology we used to conduct our review. Section 4 reviews recent research on the design of tokenized platforms for exchanging digital assets. Section 5 discusses the latest research on distributed data management infrastructure, with a focus on the European data strategy. Section 6 presents best practices for implementing tokenized platforms. Section 7 explores how artificial intelligence (AI) can be used to detect and combat cyber threats. Section 8 presents two case studies of platforms that use the blockchain and NFTs. Finally, Section 9 provides an overview of the key trends and challenges facing tokenized markets.

2. Basic Concepts and Conceptual Schemas

This section is intended to provide non-expert readers with a basic understanding of some technical concepts that will be discussed throughout the manuscript. The overview is designed to be accessible and avoids unnecessary technical details while providing all the necessary information to fully comprehend the rest of the paper.

2.1. Blockchain

As explained in Section 1, a blockchain is a chain of linked blocks in a distributed and decentralized network. Each block contains data associated with a transaction operation, a cryptographic hash of the previous block (a unique identifier generated using advanced cryptographic methods), and a timestamp of the operation (Figure 2). Since each new block is linked to the previous one, the data in any registered block cannot be changed without affecting its hash code, which would break the link connection with the next block, rendering the change invalid to other nodes in the distributed network. Consequently, a blockchain constitutes a secure and public digital ledger.

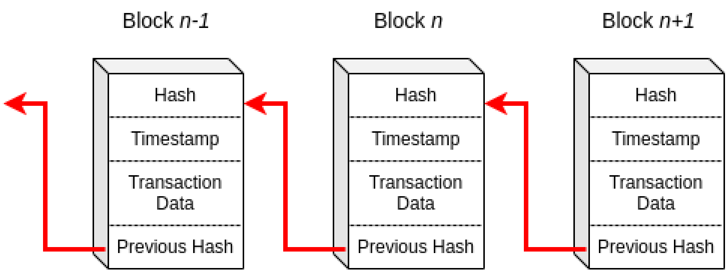

Figure 2. A blockchain as a series of linked blocks.

The process of how blockchain technology works is illustrated in Figure 3. When a new transaction request is made (step 1), a new block containing the transaction data is created (step 2). To be registered in the public ledger, the block must first undergo a process called "proof of work" (PoW) in some blockchains (e.g., Bitcoin-like ones) and "proof of stake" (PoS) in others (e.g., Ethereum-like ones), which involves analysis by the nodes in the distributed network (step 3). Nodes that successfully complete the PoW/PoS process receive a reward in the form of cryptocurrencies. The block must then be validated by achieving consensus among the nodes in the network (step 4). If a block is found to be invalid or modified, it will not be added to the blockchain, as it would differ from the copy of the valid blockchain that each node stores. The combination of secure hashing, a PoW/PoS process, and a consensus mechanism in a peer-to-peer network makes it extremely difficult to alter a block within a blockchain. Once validated, the new block is added to the blockchain and distributed throughout the network (step 5), and the transaction is considered completed (step 6).

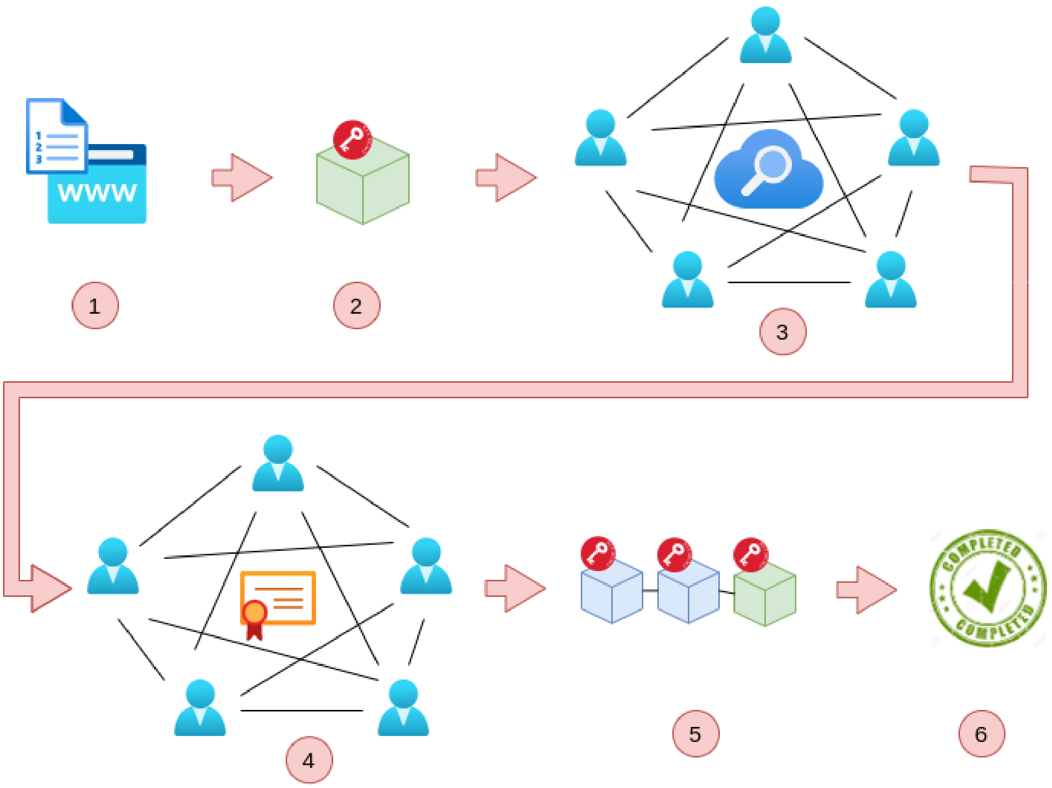

Figure 3. A 6-step process summarizing how blockchain works.

2.2. Smart Contracts and Tokenization

A smart contract is a type of digital contract that is securely and immutably stored within a blockchain network. It contains pre-agreed clauses and conditions that are automatically executed when specific predetermined criteria are met. This distributed nature of the smart contract ensures that it is secure and transparent for all parties involved.

The concept of 'tokenization' is the process of representing an asset (either digital or physical) with digital tokens that can be bought, sold, and traded on blockchains using smart contracts [6,7]. This process involves first creating a digital representation of the asset and then splitting it into individual and non-divisible parts called tokens. Virtually every physical asset could be tokenized, from a house to a boat or a painting. Ownership or other property rights over the asset can be transferred between parties without the participation of intermediaries or central authorities when a digital token is exchanged via a smart contract. However, legal issues may need to be addressed before these transactions can take place in a digital market [8].

3. Review Methodology

The use of blockchain technology is a promising approach to maintaining the traceability and immutability of data. This study aims to answer a series of questions about using blockchain technology in tokenized platforms. To achieve this, we followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) methodology, a well-established approach for conducting systematic reviews. The PRISMA methodology involves a comprehensive checklist of elements, such as search strategy, study selection criteria, data extraction, and risk of bias assessment, which ensures that systematic reviews are conducted consistently and transparently. By adhering to this methodology, researchers can enhance the quality and credibility of their findings [9].

We simplified and applied the PRISMA methodology to investigate questions pertaining to tokenized platforms. Our approach involved defining research questions, selecting inclusion and exclusion criteria, conducting a thorough search of pertinent databases, screening search results, extracting data from relevant studies, evaluating study quality, synthesizing results, and presenting findings according to PRISMA guidelines.

Our search strategy was designed to identify the latest and most relevant research on blockchain-based markets and their efficiency and included three major databases: Web of Science, Scopus, and IEEE Xplore. We limited our inclusion criteria to English-language documents published between 2013 and 2023, ensuring that our review included the most up-to-date and comprehensive research. We focused on identifying relevant books, journal articles, and conference proceedings, both final and in press, to provide a broad and accurate view of the topic. Following our search strategy, we found 1527 articles that contain the keywords "blockchain" and "tokens" in their title or abstract. The vast number of articles makes it difficult to review them manually, so we utilized state-of-the-art topic modeling techniques to automatically extract a selection of topics from this collection of documents (corpus). Specifically, we used the Non-negative Matrix Factorization (NMF) algorithm [10], one of the most popular approaches in topic modeling, to gain a better understanding of the underlying themes and patterns present within the corpus, which can be used for further analysis or generate new insights. Figures 4–6 graphically represent the information related to this first step of the content analysis of the literature review.

We set the number of selected topics to four. The ten most weighted descriptors of the four topics identified by the NMF model from the abstracts of the selected papers are: (i) blockchain, token, smart, system, technology, based, Ethereum, transaction, paper, platform; (ii) data, access, IoT, scheme, based, authentication, security, privacy, control, system; (iii) NFT, non, fungible, digital, art, ownership, asset, metaverse, data, research; and (iv) ICO, crypto, coin, initial, financial, offering, market, regulation, legal, investor.

Based on the identified topics, Topic 1 seems to focus on the technology behind blockchain and tokens, while Topic 2 is related to security and privacy. Topic 3 is related to non-fungible tokens (NFTs) and their applications, and Topic 4 is related to the financial aspect of blockchain and tokens.

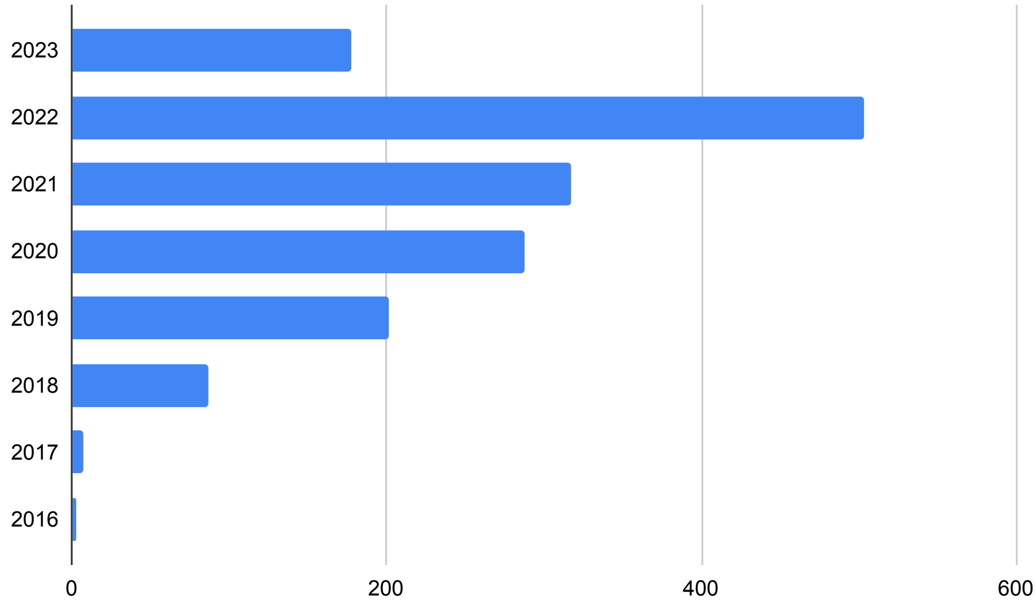

Figure 4. Annual distribution of publications.

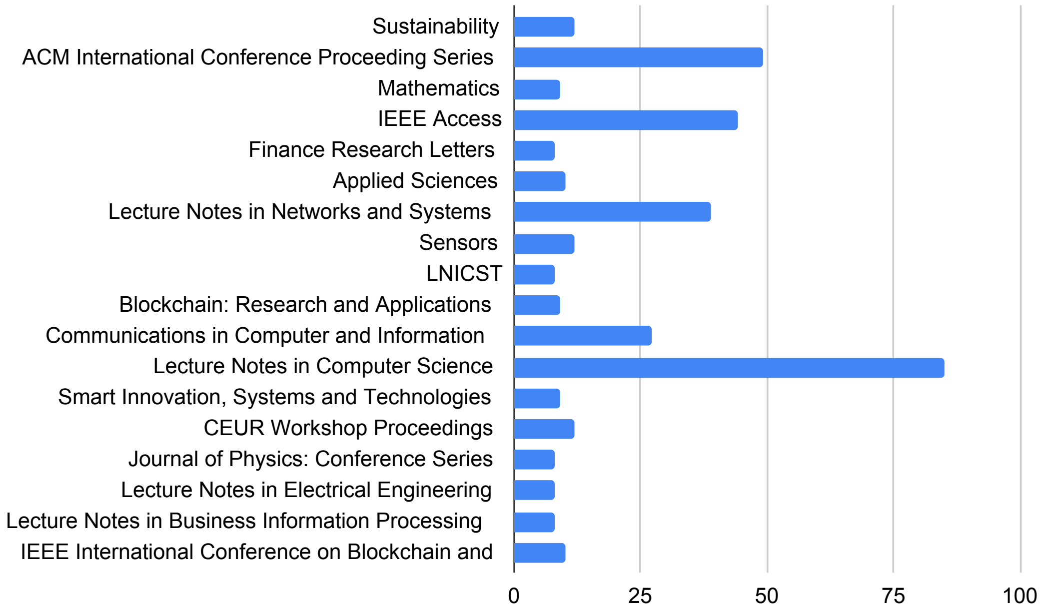

Figure 5. Articles per journal.

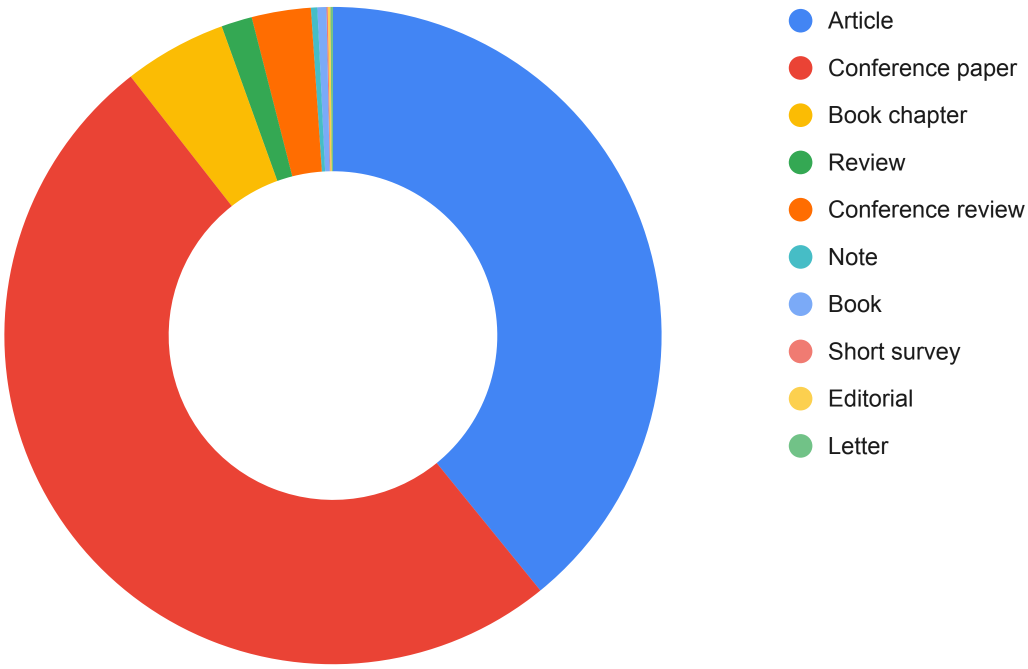

Figure 6. Article types.

To narrow down the scope of our research, we formulated five specific research questions and established corresponding criteria for each one. These questions center around the advantages and disadvantages of using tokenized platforms for digital asset exchange, the essential elements of the decentralized data management infrastructure, the optimal approaches for implementing tokenized platforms, the techniques for mitigating cybersecurity threats, and the principal developments and difficulties in tokenized markets. Additionally, for each question, its corresponding semantic fields are defined. Semantic fields refer to clusters of words or phrases that share a common meaning and are commonly used within a particular context or subject matter. These semantic fields are tailored to each research question in order to facilitate the discovery of relevant answers. Thus, the main questions and semantic fields employed in our review are provided next:

- What are the benefits and drawbacks of tokenized platforms for exchanging digital assets? Semantic fields: Design, token, digital assets.
- What are the key factors of a distributed data management infrastructure? Semantic fields: Data management, distributed systems, infrastructure.
- What are the best practices associated with the implementation of tokenized platforms? Semantic fields: Implementation, tokenization, best practices.
- What are the tools for fighting cyber threats? Semantic fields: Machine learning, cyber-threat detection, cybersecurity tools.
- What are the main trends and challenges associated with tokenized markets? Semantic fields: Market trends, tokenization, challenges.

Our focus was on tokenized platforms, which simplify the exchange and trade of tokens and have a significant impact on the liquidity and accessibility of tokenized assets. Through a comprehensive search and screening process, we identified a number of studies that met our inclusion criteria. These studies covered a broad range of topics related to blockchain technology's use in market tokenization, including its impact on market efficiency, challenges, opportunities, and emerging trends. We conducted a systematic review that followed PRISMA guidelines, ensuring that the findings were reliable and valid. Our study provides valuable insights and data-driven recommendations for researchers interested in understanding tokenized markets' mechanics and identifying opportunities for further research in this fast-evolving field.

4. Design of Tokenized Platforms for Exchange of Digital Assets

As already mentioned, tokenization is the conversion of an asset or its ownership rights into unique units called tokens. This term is often associated with blockchain technology, where tokens are utilized to represent the ownership of valuable assets. Various tokenized platforms exist, and a few examples are provided below:

- Bitbond (https://www.bitbond.com/, accessed on 2 May 2023): A peer-to-peer lending platform that uses blockchain technology to facilitate cross-border lending. It allows borrowers to access loans from investors globally using digital currencies such as Bitcoin.
- TrustToken (https://www.trusttoken.com/, accessed on 2 May 2023): A platform that enables the creation of asset-backed tokens. These tokens are backed by real-world assets, such as currencies or commodities, and can be traded on various exchanges.
- Harbor (https://goharbor.io/, accessed on 2 May 2023): A platform that streamlines the process of investing in private securities by using blockchain technology. It allows issuers to digitize their securities and investors to access and trade these securities in a secure and compliant manner.
- Polymath (https://polymath.network/, accessed on 2 May 2023): A platform that enables the creation of security tokens, which are digital tokens that represent ownership of a traditional security, such as stocks or bonds. It provides tools for issuers to create, issue, and manage security tokens in compliance with relevant regulations.
- Securitize (https://securitize.io/, accessed on 2 May 2023): A platform that specializes in the issuance and management of security tokens. It enables issuers to create and manage compliant security tokens and provides investors with a transparent and secure platform to buy and sell these tokens.

These platforms allow people and companies to establish a digital record of ownership for tangible assets that are easily tradable, such as real estate or funds. The tokens that represent these assets are distinct from security tokens because they represent actual capital and liquid value. The concept of tokenization has become a crucial topic in blockchain technology. By using blockchain, assets or rights can be tokenized and represented on a digital ledger. This connection between the off-chain and on-chain world is explored in Heines et al. [11]. Tokenization leverages blockchain technology to securitize both traded and non-traded assets, providing benefits such as increased liquidity, faster settlement, lower costs, and bolstered risk management, as explained in another article [11]. J.P. Morgan's Onyx Digital Assets is an example of a tokenization platform that aims to bring traditional assets into the blockchain ecosystem [11]. In the design field, design tokens have been introduced as a new paradigm for design deliverables, creating more efficient and consistent design systems, as described in Freni et al. [12] and Guggenberger et al. [13].

Tokenized platforms have emerged as a solution to the need for secure, transparent, and efficient methods of exchanging value. These platforms allow for the exchange of various types of digital assets, including cryptocurrencies, securities, and real-world assets, in a peer-to-peer manner, without intermediaries. These platforms have several advantages over traditional exchange platforms, including increased transparency and security. This is due to the use of blockchain technology, which records every transaction on a decentralized ledger accessible to all participants, ensuring that all transactions are secure, tamper-proof, and transparent. Another key feature of tokenized platforms is the use of smart contracts, which automatically enforce the terms of a transaction, enabling users to exchange digital assets in a trustless manner without the need for intermediaries such as banks. Smart contracts can also be customized to include various conditions, such as price limits, expiration dates, and other terms, providing a high degree of flexibility and control to users. However, designing a tokenized platform is challenging, as it requires careful consideration of various factors, such as security, scalability, and user experience. One of the main challenges is ensuring the platform is secure and resistant to attacks, which involves implementing various security measures, such as multi-factor authentication, encryption, and other mechanisms to prevent unauthorized access.

Designing a tokenized platform involves several critical factors, including scalability, security, and user experience. Scalability is vital as the platform should be able to handle a vast number of transactions without experiencing performance issues. High-performance computing infrastructure, such as cloud computing services and efficient consensus algorithms such as proof-of-stake or sharding are crucial in achieving this. Moreover, creating a user-centric design is essential to provide an intuitive, easy-to-use, and accessible platform for a wide range of users. This requires conducting user research, creating user personas, and implementing user feedback. In conclusion, building tokenized platforms to exchange digital assets is a complex task that demands careful consideration of various factors. Still, with blockchain technology, smart contracts, and advanced technologies, it is possible to develop secure, efficient, and transparent platforms that facilitate peer-to-peer asset exchange without intermediaries.

5. Distributed Data Management Infrastructure

In order to handle databases associated with real systems, scalable data models that can utilize distributed systems are required [14]. A distributed system is a collection of autonomous computing elements that appears to its users as a single coherent system [15] (p. 2). For these systems, an effective distributed data management system is necessary to manage, store, and process data across different locations. According to Moysiadis et al. [16], such systems must guarantee no loss of stored data in case of failure, process data from different sources (heterogeneity), be scalable, adaptive in bandwidth consumption, have low latency, be efficient in energy consumption, and comply with security and privacy standards.

To establish a distributed data management infrastructure, various frameworks such as Apache Hadoop, Apache Spark, and Apache Cassandra can be adopted. These frameworks provide fundamental tools, such as file systems and data processing engines, that are necessary for managing data across different locations. For example, the Hadoop distributed file system (HDFS) is used to store data as different blocks. Apache Hadoop and Spark are suitable for handling big data, and they rely on HDFS and MapReduce. In this system, the files are stored as small blocks at different nodes, classified as data nodes and master nodes. The master nodes request permission to access a file and receive a list of data nodes that store the different blocks of the file. MapReduce is used to split files into blocks. According to Ahmed et al. [17], Spark outperforms Hadoop in word count work and is more stable and faster. This advantage is due to the processing of data in memory before storage, although this performance degrades with large amounts of input data. On the other hand, Apache Cassandra has no defined master or data nodes, and all nodes in the network are equal. This framework has high update throughput and low latency, but it does not support privacy [16]. In general, when establishing a distributed data management system, it is crucial to use a framework that is scalable, adaptable in bandwidth consumption, efficient in energy consumption, and compliant with security and privacy standards while ensuring no loss of stored data in case of failure.

The European Union has initiated the European Dataspace for Digital Assets (EDSA) to enable the secure sharing and exchange of data, including digital assets, across Europe. As discussed by Scerri et al. [18], the establishment of a European digital market presents opportunities for businesses, citizens, science, and government to improve services and collect real-time statistics. However, technical, legal compliance, organizational, and national challenges must also be addressed, including issues related to data protection and digital transformation. The data strategy aims to facilitate the flow of data across different sectors in the EU while ensuring high-quality data and compliance with European rules and values, as well as fair and practical rules for accessing, sharing, and using the data. As a way to promote the EDSA, various measures have been proposed for establishing a common data space in the EU [19]. The aim is to unlock the potential benefits of the data economy and innovation opportunities while respecting European values and rules. The proposed actions include securing access to health data, promoting research, empowering citizens, and achieving person-centered care. The common data space is based on two types of data: public and publicly funded data and private sector data. For private sector data, key principles for contractual agreements have been defined, including transparency, shared value creation, respect for commercial interests, undistorted competition, and minimizing data lock-in, especially for business-to-business sharing.

6. Implementing Tokenized Platforms: Best Practices

Tokenization using blockchain technology and smart contracts enables any type of asset, including physical, intellectual, and creative property, to be converted into digital assets. This globalizes liquidity for all assets by creating a platform where these assets can be exchanged without the need for a central authority. However, it is crucial to design and implement these platforms with great care. To ensure the best practices for implementing such platforms, it is important to review case studies from the literature that illustrate the design and deployment of tokenized platforms.

In their article, Khan et al. [20] provided an exploratory analysis of the tokenization of sukuk, a financial instrument similar to bonds. The authors discussed the challenges involved in issuing sukuk and how blockchain technology can be used to resolve them. They reviewed different blockchain architectures and implemented a basic smart contract for Sukuk al-Murabaha on Ethereum. Finally, they conducted a cost-benefit analysis comparing conventional sukuk issuance to sukuk tokenization. Meanwhile, Tian et al. [21] explored how asset tokenization can create a new economic model that integrates non-financial values, such as social and environmental impacts, into tradable tokens. They analyzed SolarCoin, WePower Token, and ZiyenCoin as examples of how blockchain-enabled asset tokenization can be applied to support the economy and build social resilience. The authors identified that tokenization promoted inclusiveness and sustainability through shareholder empowerment, incentive monetization, and finance optimization, and they discussed obstacles to broader adoption and policy implications. Zarifis and Cheng [22] studied the business models focused on NFTs and identified four NFT business models, including NFT creator, NFT marketplace, a company offering their own NFT, and a computer game with NFT sales. Finally, Calandra et al. [23] took a multiple case study approach to explore the relationship between blockchain technology and sustainable business models (SBMs). Through an analysis of various databases, the authors demonstrated how blockchain could be used for environmental management and highlighted the main application of blockchain in relation to SBMs, which is supply chain cost reduction.

Recent case studies suggest some best practices for implementing asset tokenization platforms. Firstly, tokenized platforms must comply with relevant securities laws and regulations, including conducting KYC and AML checks on investors and ensuring proper classification of tokens as securities or utility tokens [24]. Secondly, these platforms rely on smart contracts to manage ownership and transfer of tokens, which requires careful design to protect against potential hacks or exploits. Using established standards such as ERC-20 for security tokens or ERC-721 for non-fungible tokens is recommended [25]. Thirdly, tokenized platforms must be scalable to handle large volumes of transactions, which can be achieved through selecting appropriate consensus mechanisms such as PoW or PoS, implementing off-chain solutions such as sidechains or state channels, and optimizing transaction fees to pay network validators for their services to the blockchain [26]. Lastly, tokenized platforms must be user-friendly and accessible to a broad range of investors. This requires a well-designed user interface, clear instructions for buying and selling tokens, and adequate support for investors and issuers [27]. Table 1 identifies which of the inferred best practices follow the tokenization platforms listed in Section 4. Based on publicly available information, it appears that all of these tokenized platforms follow the best practices listed in the table: require users to undergo KYC/AML checks in order to participate in token offerings on their platforms, use Ethereum-based smart contract standards such as ERC-20 and ERC-721 to create and manage tokens, use proof-of-stake (PoS) as their consensus mechanism, and offer user-friendly interfaces and resources, such as documentation and support, to help users participate in token offerings on their platforms. Additionally, some of these platforms offer features that make it easy for users to invest in tokens, such as integration with popular wallets or investor portals.

Table 1. Summary of best practices provided tokenized platforms.

Tokenized Platform	Compliance	Contract Standards	Consensus	User Experience
Bitbond	✓	✓	PoS	✓
TrustToken	✓	✓	PoS	✓
Harbor	✓	✓	PoS	✓
Polymath	✓	✓	PoS	✓
Securitize	✓	✓	PoS	✓

By examining recent case studies, best practices for developing asset tokenization platforms have been identified. These practices include ensuring compliance with regulations, carefully designing smart contracts, scaling the platform appropriately, and prioritizing user experience [24–27]. Asset tokenization platforms hold significant potential as a use case for blockchain technology.

7. AI Tools for Cyber-Threat Detection

Today's interconnected world faces increasing worry with the rise of cyber threats. Businesses, organizations, and individuals are at a greater risk of cyber attacks, which can lead to severe consequences such as sensitive data theft, critical infrastructure disruption, and financial loss. Cybersecurity or cyber-threat detection has emerged to address this concern, aiming to develop effective tools and methods to identify potential cyber threats and prevent them from causing damage. However, traditional approaches such as signature-based detection and rule-based systems are losing their effectiveness as cyber threats become more complex, serious, and sophisticated [28]. The exponential growth of data in cyberspace and the increasing computing power have made machine learning (ML) the most efficient and essential approach to counter cyber threats and overcome the restrictions of traditional security systems. Various ML techniques have been implemented to detect and categorize different types of cyber threats, including decision trees, ensemble methods, Bayesian networks, support vector machines, K-nearest neighbor (k-NN), and artificial neural networks. These are just a few examples of commonly used ML algorithms in cybersecurity, as documented by research surveys [29,30].

ML has been widely used in cybersecurity, particularly in applications such as intrusion detection, malware analysis, and spam detection [31]. Intrusion detection involves monitoring a network or computer system for unauthorized access or harmful activities, aiming to identify potential security breaches so that necessary measures can be taken to prevent damage. Malware analysis, on the other hand, entails examining malicious software to understand its behavior, purpose, and potential impact on a system or network. It is the responsibility of security researchers to conduct malware analysis to develop effective defenses against further infection or damage. Spam detection is a critical component of email and messaging security, which involves distinguishing and filtering unwanted or unsolicited messages from legitimate ones, such as those promoting a product or service, distributing malware, or phishing for sensitive information. Numerous ML algorithms, including random forest [32,33], support vector machine [34–36], and k-NN [37–40], have been investigated in the literature for developing intrusion detection models, malware analysis, and spam detection.

Over the past twenty years, ML has played an increasingly crucial role in the battle against cyber attacks. However, ML is not a panacea in cybersecurity. Cyber attackers are constantly evolving their methods and tactics, requiring ML algorithms to be retrained continuously on constantly changing data to keep up with these changes. Moreover, ML algorithms are also being employed for malicious purposes, such as developing more sophisticated and convincing social engineering attacks, creating malware that is harder to detect and analyze, and automating the process of identifying and exploiting system and network vulnerabilities. A study by Kaloudi and Li [41] examined prior research on AI-based cyber attacks and proposed a framework for categorizing several aspects of malicious AI use throughout the cyber attack life cycle, providing a basis for detecting and predicting future threats. For a more comprehensive review of ML for cybersecurity, interested readers can refer to [29,42,43].

8. Case Study: Axie Infinity and Solbeatz—Leveraging Blockchain Technology for Tokenized Markets

This case study explores the applications and recent developments of blockchain-based tokenized markets by examining two promising platforms: Axie Infinity (https://axieinfinity.com/, accessed on 2 May 2023) in the gaming industry and Solbeatz (https://www.solbeatz.xyz/, accessed on 2 May 2023) in the music industry. Axie Infinity, founded in 2018, is a pioneering play-to-earn gaming platform that has gained significant popularity. Solbeatz, on the other hand, is a recently founded platform with early access, showing promising potential in revolutionizing the music industry through tokenization.

The traditional music industry has long faced issues such as limited access for independent artists, and a lack of transparency in the revenue system. Solbeatz, founded in 2022, aims to address these issues by leveraging blockchain and tokenization. By utilizing the decentralized nature of blockchain and creating a marketplace for music creators and consumers, Solbeatz provides a transparent and fair ecosystem that empowers artists and rewards creativity. It connects music creators directly with their audience, enabling them to share their music, collaborate, and monetize their work. Artists can tokenize their music and associated rights, creating unique digital assets that can be bought, sold, and traded on the Solbeatz marketplace. Users can purchase and stream music using cryptocurrency, providing a seamless and transparent transaction experience.

Axie Infinity, on the other hand, is currently the most popular play-to-earn gaming platform that occupies a large portion of the online gaming market [44]. Axie Infinity is a game centered around digital creatures called Axies, which are unique NFTs that can be bought, sold, and bred on the Ethereum blockchain. Each Axie possesses different traits and abilities, players can build a team of Axies and engage in strategic battles with other players, earning in-game tokens called Smooth Love Potions (SLP) and Axie Infinity Shards (AXS). By combining elements of gaming, NFTs, and decentralized finance, Axie Infinity has created an innovative ecosystem that enables players to earn real money from their gameplay. Through its marketplace and breeding mechanics, Axie Infinity facilitates the buying, selling, and trading of NFTs, enabling players to build valuable collections and participate in a vibrant secondary market. The platform's success demonstrates the potential for tokenization to revolutionize the gaming industry, providing players with true ownership, transparent money exchange, and new economic opportunities.

The success of Axie Infinity and the emergence of Solbeatz showcase the potential of blockchain-based tokenized markets in different sectors. Axie Infinity provides players with economic opportunities and genuine ownership of their in-game assets by integrating tokenization, play-to-earn mechanics, and a thriving NFT marketplace. On the other hand, Solbeatz empowers artists in the music industry by enabling them to tokenize their music and associated rights. Artists have control over pricing, fan interactions, and royalties, fostering a direct and transparent connection between artists and their audience. Table 2 illustrates the main characteristics of Axie Infinity and Solbeatz. By leveraging blockchain technology and embracing tokenization, these platforms redefine traditional industries, offering participants enhanced ownership, transparent value exchange, and innovative economic models. As the blockchain landscape matures, the ongoing exploration and implementation of tokenized markets will likely unlock new frontiers, transforming industries and fostering novel possibilities within the global economy.

Table 2. Comparative table of Axie Infinity and Solbeatz.

Aspect	Axie Infinity	Solbeatz
Founding Year	2018	2022
Industry	Gaming	Music
Technology	Blockchain	Blockchain
Tokenization	Game creatures (Axies), SLP, AXS	Music and associated rights
Use Cases	Play-to-earn gaming, NFT marketplace	Tokenized music marketplace
Economic Model	In-game cryptocurrency rewards	Music rights transactions
User Community	Global community of players	Global community of artists and audience
Main Features	Collectible digital creatures, battles, marketplace	Tokenized music
Primary Focus	Gaming and play-to-earn model	Music industry disruption

9. Trends and Challenges of Tokenized Markets

Tokenized markets create and trade digital tokens representing a variety of assets, including real estate, commodities, currencies, and more. These markets offer numerous potential use cases:

- Real estate: Tokenized real estate allows for fractional ownership of property, increasing liquidity for an otherwise non-liquid asset. By buying and selling tokens representing a share of the property, investors can bypass intermediaries such as brokers and reduce transaction costs.
- Commodities: Tokenized commodities enable investors to trade fractions of assets such as gold, silver, and oil, providing easier exposure to these assets without the need for physical ownership.
- Currencies: Tokenized currencies represent fiat currencies in digital form and can be used for cross-border payments, reducing the time and costs associated with traditional currency exchanges.
- Loyalty programs: Loyalty programs can use blockchain to offer more flexible and valuable rewards, such as those offered by Loyyal (https://loyyal.com/, accessed on 2 May 2023). Tokens allow customers to use their points across multiple programs and earn rewards beyond just purchases.
- Identity verification: Civic's blockchain platform (https://www.civic.com/, accessed on 2 May 2023) allows individuals to securely prove their identity without sharing sensitive information with third parties. This has the potential to revolutionize industries such as finance, healthcare, and government.
- Digital gold: Platforms such as Rush Gold (https://rush.gold/, accessed on 2 May 2023) use blockchain to enable users to invest in digital gold, offering a secure and transparent way to invest in this traditional store of value and hedge against inflation.

Overall, tokenized markets have the potential to democratize access to assets and markets, increase transparency, and reduce transaction costs. However, as with any new technology, there are potential risks and challenges, such as regulatory uncertainty and technical issues with blockchain implementations.

10. Conclusions and Future Work

Blockchain technology has enabled secure and decentralized peer-to-peer transfer of digital assets without intermediaries, and asset tokenization has opened up opportunities for virtual markets. Li et al. [45] found that fintechs that use big data, cloud computing, blockchain, and other technical innovations can simplify consumer financial transactions, increase user satisfaction, and enhance enterprise marketing, especially on user word of mouth communication and promotion of the platform. However, challenges such as cybersecurity threats and the lack of government and industry regulation must be addressed. Tokenized platforms have advantages over traditional exchange platforms, such as increased transparency and security, using blockchain technology to record transactions on a decentralized ledger. Designing a tokenized platform requires consideration of security, scalability, and user experience.

Frameworks such as Apache Hadoop, Apache Spark, and Apache Cassandra can be adopted to manage distributed data for handling databases associated with real systems. The European dataspace for digital assets has been initiated to facilitate the secure sharing and exchange of data across Europe while ensuring high-quality data and compliance with European rules and values. Machine learning has become an effective approach to counter cyber threats, but attackers are constantly evolving their methods, requiring ML algorithms to be retrained continuously. Tokenized markets allow for the creation and trading of digital tokens representing various assets, providing benefits such as fractional ownership, cross-border payments, and flexible loyalty program rewards. However, as tokenized platforms continue to evolve, regulatory uncertainty and technical issues with blockchain implementations must be considered, and mechanisms to strike a balance between innovation and consumer protection, ensuring fair and transparent operations within tokenized markets, should also be studied. Additionally, to mitigate the massive energy consumed by blockchain operations, scalable blockchain solutions, such as sharding and layer-two protocols, and other energy-efficient consensus mechanisms to minimize the environmental impact of blockchain operations need to be explored.

Future research should focus on developing and implementing blockchain-based tokenized platforms that securely and efficiently exchange digital assets, improving distributed data management systems, continued research and development of machine learning techniques to detect and categorize cyber threats, and exploring the potential benefits and risks of tokenized markets for various asset types. Furthermore, while the initial focus of blockchain technology has been on cryptocurrencies and financial assets, there is significant potential for its application across various industries, such as supply chain management, intellectual property rights, healthcare, and voting systems.

Overall, future research should continue to explore the potential benefits and risks associated with tokenized markets for various asset types and industries. By addressing these research areas, we can unlock the full potential of blockchain-based tokenized platforms, enabling the secure, transparent, and efficient exchange of digital assets while promoting economic growth, innovation, and compliance with legal and ethical standards across industries.

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