POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Exploring the Dapps Ecosystem: Empirical Analysis of Decentralized Applications

TESI DI LAUREA MAGISTRALE IN
MANAGEMENT ENGINEERING
INGEGNERIA GESTIONALE

Author: **Lorenzo Iaccarino**

Student ID: 976535
Advisor: Alessandro Perego
Co-advisors: Davide Ghezzi, Valeria Portale, Giacomo Vella
Academic Year: 2022-2023

Abstract

In 2008 Satoshi Nakamoto explained through the famous Bitcoin WhitePaper how it is possible to transfer value in a peer-to-peer, totally decentralized and secure way thanks to the Blockchain, a technological infrastructure based on cryptographic tools and distributed ledgers.

Bitcoin, however, remains a protocol focused on storage and transfer of value, or bitcoin cryptocurrencies, also necessary to incentivize nodes to validate transactions. The programmability of the protocol remains very limited, and so Vitalik Buterin in 2013 writed the Ethereum WhitePaper, a new blockhain platform with much more extensive potential.

Ethereum establishes itself as a real decentralized world computer which allows you to perform operations and interact with smart contracts. These lines of code allow to perform any operation. Smart contracts allow the creation of tokens, both fungible and non-fungible, and decentralized applications. These elements play a fundamental role in the perspective of Web 3.0.

Decentralized Applications (dapps) are software whose front-end is constituted by a traditional web-interface, but whose back-end is based on smart contracts and Blockchain systems. Services are born that span various sectors, from decentralized finance to cryptoassets marketplaces passing through video games and gambling platforms.

The academic literature focuses mainly on the technical side of dapps and Blockchain protocols. The industry is constantly evolving and changing, and a general overview of the world of dapps can be useful.

The objective of this thesis is to investigate, considering the decentralized applications with the largest number of active users during a given time horizon, the main characteristics and trends of these services such as sectors and categories, implemented tokens, forms of governance and protocols.

Abstract in Italiano

Nel 2008 Satoshi Nakamoto spiega attraverso il celebre WhitePaper di Bitcoin come sia possibile trasferire valore in modo peer-to-peer, totalmente decentralizzato e sicuro grazie alla Blockchain, un'infrastruttura tecnologica basata su strumenti crittografici e registri distribuiti.

Bitcoin, tuttavia, rimane un protocollo incentrato sullo storage e sul trasferimento di valore, ovvero delle criptovalute bitcoin, necessarie anche a incentive i nodi a validare le transazioni. La programmabilità del protocollo rimane molto limitata, e così Vitalik Buterin nel 2013 redige il WhitePaper di Ethereum, una nuova piattaforma Blockhain dalle potenzialità molto più estese.

Ethereum si afferma come un vero e proprio computer mondiale decentralizzato che permette di eseguire operazioni e di interagire con gli smart contract. Si tratta di linee di codice che consentono di eseguire qualsiasi operazione. Gli smart contract permettono la creazione di token, sia di natura fungibile che non fungibile, e delle applicazioni decentralizzate. Questi elementi hanno un ruolo fondamentale nell'ottica del Web 3.0.

Le applicazioni decentralizzate (dapps) sono software il cui front-end è costutuito da una web-interface tradizionale, ma il cui back-end è fondato su smart contract e sistemi Blockchain. Nascono servizi che abbracciano svariati settori, dalla finanza decentralizzata, ai marketplace di cryptoassets passando per videogiochi e piattaforme di gambling.

La letteratura accademica si concentra principalmente sul lato tecnico delle dapps e dei protocolli Blockchain. L'industria è in perenne evoluzione e mutamento, e può risultare utile una panoramica generale sul mondo delle dapps.

L'obiettivo di questa tesi è di indagare, considerando le applicazioni decentralizzate con il maggior numero di utenti attivi durante un determinato orizzonte temporale, le principali caratteristiche e tendenze di questi servizi come settori e categorie, tokens implementati, forme di governance e protocolli.

Contents

Abstract **1**

Abstract in Italiano **2**

Contents **3**

1 Executive Summary **6**

2 Introduction **14**

3 Literature Review **16**

3.1. White Paper Bitcoin 16

3.1.1. General Elements 16

3.1.2. Encryption Elements 17

3.1.3. Proof of Work 18

3.2. Cryptocurrencies 19

3.2.1. General Elements 19

3.2.2. Types of Cryptocurrencies 20

3.3. Distributed Ledgers 20

3.3.1. General Elements 20

3.3.2. Types of Distributed Ledgers 20

3.4. Types of Blockchain 21

3.4.1. Permissionless, Permissioned, Private and Public Blockchain 21

3.4.2. Scalability and Buterin's Trilemma 21

3.4.3. Layer 1 Solutions 22

3.4.4. Layer 2 Solutions 22

3.5. Wallet 23

3.5.1. General Elements 23

3.5.2. Encryption Elements 23

3.5.3. Custodial and Non-Custodial Wallet 24

3.5.4. Hardware and Software Wallet 24

3.6. Bitcoin and Ethereum 25

3.6.1. General Elements 25

3.6.2. Technological Differences 25

3.6.3. Conceptual Differences 26

3.6.4. Implications of Ethereum in Web 3.0 26

3.7. Smart Contracts 27

3.7.1. General Elements and History 27

3.7.2. Operation and Security 27

3.7.3. Stages of Creation and Operation 28

3.7.4. Oracles 29
3.7.5. Examples 29
3.8. Tokens 30
3.8.1. General Elements and History 30
3.8.2. Fungible tokens Creation 31
3.8.3. Classification by Function 31
3.8.4. Classification by Fungibility 31
3.8.5. Fungible tokens 32
3.8.6. NFTs 32
3.9. Decentralized Applications 34
3.9.1. General Elements and Operation 34
3.9.2. Composability 34
3.9.3. Classification by Layers 35
3.9.4. Advantages over Traditional Applications 35
3.9.5. Disadvantages compared to Traditional Applications 36
3.9.6. Tokenomics 36
3.9.7. DeFi dapps 37
3.9.8. Gaming dapps 40
3.9.9. Gambling dapps 42
3.9.10. Marketplace dapps 43
3.9.11. Decentralized Autonomous Organizations 45
3.10. Regulation 47
3.11. Stages of Collection and Selection of Papers 48
3.12. Gaps Found in Literature 49
3.13. Objectives of the Research & Research Questions 49
4 Methodology 50
4.1. Introduction to dappradar.com 50
4.2. Framework 50
4.2.1. Variables Description and Collection Modalities 50
5 Findings 56
5.1. UAW 56
5.2. Sectors and Categories 57
5.3. Ownership Status 59
5.4. Native tokens 61
5.4.1. Utility tokens 62
5.4.2. Security tokens e Real World Asset tokens 64
5.4.3. Farming tokens 66
5.4.4. Governance tokens 67

5.5. NFTs 70
5.5.1. Collectibles 71
5.5.2. Gaming Assets 73
5.6. Balance, Volume and Transactions 75
5.7. Multichain and Layer 2 77
5.8. Protocols 78
6 Conclusions 80
6.1. Answers to Research Questions 80
6.2. Further Developments 81
List of Figures 82
Bibliography 83
Academic Literature 83
Gray Literature 87
Acknowledgments 90

1 Executive Summary

1.1. Introduction

Blockchain (and related topics) has quickly become a mass theme, following the dizzying changes in the value of assets such as cryptocurrencies, tokens or NFTs (non-fungible tokens). However, it is an extremely complex and interdisciplinary subject, which requires knowledge in the fields of economics, computer science and game theory to be understood.

Within this vast world, decentralized applications are rapidly establishing themselves, acting as a link between more experienced users and novices. This is enabled by the front-end of these solutions, developed as a classic web-interface.

This attention is validated by what was observed by the dappradar.com platform, which highlighted how 2021 was a year of strong growth for decentralized applications. The number of unique active wallets increased sevenfold, as did the Total Value of Assets locked in the DeFi sector. Non-Fungible tokens also reached a transaction value of $23 billion.

1.2. Literature Review

The scientific papers to be analyzed were taken from the following portals: Google Scholar, IEEE Xplorer, Science Direct and Scopus. The keywords through which the searches were carried out are the following: "Analysis of Blockchain Decentralized Applications", "Blockchain Decentralized Applications", "Dapps Blockchain", "Census of Blockchain Decentralized Applications", "Empirical Analysis of Blockchain Decentralized Applications".

Blockchain and the topics associated with it (cryptocurrencies, smart contracts, tokens, decentralized applications), are new areas, where innovation is a continuous process. The academic literature has therefore been largely flanked by gray literature from textual materials (articles, analyses) provided by authoritative websites. This kind of content covers a greater number of facets of the topics and provides information almost in real time about the latest news.

1.2.1. Gaps and Research Questions

The academic literature has highlighted a deeply technical and quantitative approach in the research areas, but usually limiting the analysis in terms of applications considered and / or variables considered.

It is therefore useful to conduct a census of decentralized applications that is able to observe these services during a given time horizon, aiming to understand how the various elements of dapps (fungible and non-fungible tokens, forms of decentralized governance, sectors and categories) best adapt to the various types of ecosystems and attract users.

The most popular decentralized applications in terms of user active wallets will be analyzed over a six-month time horizon, monitoring:

- quantitative aspects such as the number of user active wallets, the amount of the balance, the number and volume of transactions;

- technological aspects, such as the protocols on which decentralized applications are operational;

-qualitative aspects, such as the sector and the category to which they belong, the form of governance in force, the methods of value creation for both users and platform owners, the types of fungible and non-fungible tokens used.

The aim of the research is to answer the following questions:

- What are the most used Blockchain protocols, and why?
- How does the DAO decentralized governance model fit with the various types of decentralized applications?
- How do the various types of decentralized applications behave from the point of view of quantitative metrics? Which are the most representative according to the type of services?
- What are the most used tokens based on the type of decentralized application? How important is their role in digital ecosystems to capture users' interest?

1.3. Methodology

1.3.1. Dappradar Introduction and draws modality

Dappradar is an online platform that provides real-time analysis and information on decentralized applications. It includes qualitative information, such as descriptions, category and industry tags, protocol names, and quantitative information. For the latter, the following values are provided: “Balance” (total value of assets in dapp's smart contracts in dollars), “UAW” (number of unique active wallets interacting with dapp's smart contracts) “Volume” (total amount of incoming value to dapp's smart contracts in dollars), and “Transactions” (the total number of transactions made

between unique active wallets (UAW) and the dapp's smart contracts). It is possible to choose various time segments or protocols to analyze.

For each draw (from October to March), the 100 most popular dapps were examined, using as a selection criterion the value of UAW (The number of unique active wallets (UAW) interacting or performing a transaction with a dapp's smart contracts) for the last 30 days, provided by the dappradar.com portal. The final framework was achieved by entering the 100 most popular dapps for each extract, then removing the duplicates and obtaining a total of 180 unique dapps.

1.3.2. Framework Structure

The framework is structured through qualitative and quantitative attributes, which can take numeric values, text strings or binary values. The attributes are as follows: “Name”, “Sector”, “Main Category Keyworld”, “Category KeyWords” (multiple values), “Dapp Info”, “Year of Listing on dappradar”, “Types of Capital Raising”, “Amount” (of Capital Raising), “Balance” (for each draw), “Volume” (for each draw), “Transactions” (for each draw), “UAW” (for each draw), “Ownership Status” (and further decentralization level attributes with binary logic), “Revenue Model Owner” (multiple values), “Revenue Models User” (multiple values), “Protocols” (up to the three most popular protocols in terms of user active wallets), “Layer 2” (equal to 1 if the dapp is deployed at least on one layer 2 solution”) and “Multichain” (equal to 1 if the dapp is deployed at least on two protocols). There are also a series of attributes based on binary logic aimed at indicating whether the asset type (native fungible tokens or non-fungible tokens), indicated by the name of the attribute itself, is implemented or not: “Token”, “Native token”, “Utility token”, “Farming token”, “Security token”, “Real World Asset token”, “Governance Token”, “NFT”, “NFT: Collectibles”, “NFT: Event Tickets”, “NFT: Gaming and Virtual Items”, “NFT: Real World Assets”, “NFT: Identity & Membership”, “NFT: Domain Names”, “NFT: Music and Media". In reference to the "Native token" attribute, there are also the attributes "Token Technology" and "% of tokens of the core team". All the data are collected via the dappradar platform, whitepapers and websites of the individual decentralized applications.

1.4. Findings

1.4.1. Overview

The number of active users in the various months, calculated as User Active Wallets, remained more or less constant during the analysis horizon, showing a slight negative trend that however stopped in March. It should be noted that this is an approximate and not extremely precise indicator, as a single user could log in with the same wallet in multiple decentralized applications, thus being counted multiple times.

Of the 180 dapps analyzed, 66 are part of the DeFi (Decentralized Finance) sector. These are solutions that continue to innovate thanks to modular architectures usually open source, and that act as a catalyst for the entire Blockchain and decentralized web world, moving tokens and allowing a passive return for users. A clear example is provided by Decentralized Exchanges (DeXs), a category that constitutes exactly half of the entire DeFi sector, based on the exchange of tokens and the possibility for users to provide liquidity to platforms and receive passive income.

The Entertainment sector boasts 53 dapps out of 180, further subdivided into 42 Gaming dapps and 11 Gambling dapps. Decentralized video games have proved revolutionary compared to traditional counterparts, building real digital ecosystems in which in-game objects are non-fungible tokens, with aesthetic and functional parameters in terms of gameplay. The latter can be exchanged, transferred, bought or sold, through internal or external Marketplaces.

Virtual objects are therefore no longer tied to the single video game, and also take on an economic value. The latter, together with the Utility tokens used to access products and services, represent the pivots of the "Tokenomics" that are established, and that allow Play-to-Earn mechanisms. The gaming experience is no longer entertainment for its own sake, but it is also remuneration, since it involves a gain in terms of tokens and objects potentially resalable outside the game itself.

The two most popular fields, the DeFi sector and the Gaming category, are those that most embody the advantages offered by the decentralized technological infrastructures on which they are based, and that tangibly innovate the user experience compared to traditional counterparts.

1.4.2. DAO Model Adoption

The DAO (Decentralized Autonomous Organization) model is particularly popular in the DeFi sector, with 36 out of 66 dapps adopting this form. Decentralized Finance applications are usually used by an expert public, which demands transparency and reliability (especially considering the numerous scams concerning Centralized Exchanges).

In the Marketplace sector, decentralized governance is little used (6 out of 23 dapps), as in fact it would not add value to the experience and even the target of users is less pretentious and experienced. The Gaming category features 16 out of 42 dapps that adopt DAO model, which is not surprising considering that users are mainly driven by the desire for entertainment and lack knowledge of game design and balance of mechanics.

No Gambling application follows the DAO model: it is a type of static application, in which the services and related rules are standard, and a DAO would not add any value.

1.4.3. Fungible tokens

As for the implementation of native fungible tokens compared to the decentralized application, the situation is as follows.

Utility tokens (used to purchase goods and services) are a fundamental feature for the Gaming category: 35 out of 42 dapps adopt them. The dapps in this category are based on Play-to-Earn mechanisms and the purchase and sale of in-game items through currency. In the Gambling category and in the Marketplace sector they are almost unused, as cryptocurrencies or external tokens are usually used for these services. Even in DeFi adoption is poor, given that there are no real services or products to buy, but operations to be carried out.

Governance tokens (whose possession allows to have a certain decision-making weight in the forms of decentralized Governance, usually proportional to the quantity held) are obviously adopted in particular by sectors and categories with a higher rate of DAOs, which are mainly based on these instruments.

However, what is of greater interest was to note that in some specific cases, three situations were revealed:

-Non-DAO dapps that adopt Governance tokens or similar to create greater engagement with the community, increasing the level of interaction without concretely ceding decision-making power;

-Non-DAO dapps with Governance tokens that will become fully operational in the future: these are dapps that plan the decentralization of governance in various steps. This highlights how the adoption of this model is not just "a binary choice" but a grayscale. Before a definitive transition to the DAO model, it is necessary to provide a certain imprint on the project, direct the community towards certain objectives and transmit one's philosophy;

-DAOs that do not adopt Governance tokens: these cases, although quantitatively very irrelevant, show that there are alternative governance mechanisms, for example based on the use of non-fungible Identity & Membership tokens, which confer certain privileges to those who hold them.

Farming tokens (used in Staking and Liquidity Mining operations) are particularly popular in the DeFi sector (39 out of 66 dapps) and in the DeX category (25 out of 33 dapps). The Gaming category also boasts 24 out of 42 dapps that implement these tools. What unites the types of dapps mentioned above is the vision of a user experience in which a passive remuneration linked to the possession of a token is an integral and important part. They are almost not present in the Marketplace sector and in the Gambling category, where they would not add any value.

Real World Asset tokens and Security tokens, fungible tokens that represent real-world assets and classic financial instruments respectively, are almost completely unused. From my point of view, real world assets are more suitable to be tokenized in the form of NFTs, while as far as Security tokens are concerned, it seems that

traditional finance instruments such as stocks or bonds, have not yet really intersected the world of blockchain and decentralized finance (although from a theoretical point of view they lend themselves to being represented as fungible tokens).

1.4.4. NFTs

As for NFTs, the most popular categories and on which it is useful to reflect are those collectible representatives such as works of art, and in-game objects.

Speaking of Collectibles, it is the most popular category of NFTs mass audience. This kind of virtual objects has become, thanks to the influence of multinationals and celebrities. already iconic. Some specimens sold at exorbitant figures have in fact attracted the attention of the general public, who has been fascinated by the idea of being able to boast the possession of these works.

It is therefore not surprising that all dapps in the Marketplace sector allow the purchase and sale of these assets. Even in the gaming category, 19 out of 42 dapps implement these tokens, testifying to the fact that even purely aesthetic objects, and without peculiar characteristics in terms of gameplay, are quite sought after in games.

Speaking of Gaming assets, 39 out of 42 dapps in the Gaming category adopt them, and 13 out of 23 dapps in the Marketplace sector allow to buy and sell these items. This testifies how the representation of virtual objects in the form of NFTs is a fundamental feature, able to enhance them from an economic point of view and allow their transferability. These mechanics, also linked to the Play-to-Earn ones, allow decentralized video games to revolutionize the industry compared to traditional counterparts, in which digital equipment is "locked up" in the virtual environment and almost always devoid of real economic value.

1.4.5. Balance, Volume and Transactions

Moving on to the analysis of quantitative attributes, it emerges clearly which are the most important parameters for the various types of services.

Balance (Total Value of Assets locked) is the reference metric for decentralized applications in the DeFi category, which boasts a significantly higher average value than the rest of the landscape. High liquidity in services such as DeXs, Bridge or Lending & Borrowing services usually corresponds to a better performance, both from the quantitative point of view and from the side of the variety of the assets traded.

The values of Transactions (number of transactions) and Volume (transaction volume), combined, clearly show that the dapps of the Entertainment sector, both in the Gaming and Gambling categories, present a high number of transactions with a low amount. This is due to the type of minor operations that usually take place in a repetitive way in these services. Starting numerous gambling sessions or buying virtual equipment are some examples.

1.4.6. Protocols

From a strictly technological point of view, the three most widespread protocols are Polygon, BNB Chain and Ethereum, with respectively 60, 59 and 45 dapps operating on these protocols.

Polygon is a sidechain network of the Ethereum protocol, and therefore improves Ethereum from the point of view of scalability, on which it is lacking. BNB Chain was instead created by the giant of Centralized Exchanges Binance, it is EVM (Ethereum Virtual Machine) compatible and designed specifically for the creation of decentralized applications that require low resource transactions. Ethereum is, simply, the pillar of the decentralized web and the reference point for dapps, thanks to the possibilities offered in terms of programmability and operations that can be carried out. It is interesting to note that in the Gambling sector all dapps are deployed on ThunderCore, indicating how sometimes for certain categories there are protocols optimized for specific objectives and with peculiar technical characteristics.

1.5. Conclusions and Further Developments

The most popular protocols are Polygon and BNB Chain for their scalability and technical properties and Ethereum as pillar of the whole decentralized application ecosystem. The main quantitative metric of DeFi dapps is the Balance, which indicates the Total Value of Assets locked in a specific service and it is linked with the effectiveness of the solution itself. In Gambling and Gaming categories it is possible to observe a significative amount of low amount transactions, highlighting the importance of ad hoc and scalable protocols.

As regards the governance models of the different solutions, DAO (Decentralized Autonomous Organization) is particularly adopted by DeFi dapps, which are usually used by expert people demanding for transparency and trust. However, data showed that the adoption of a decentralized governance model is not always an immediate or decision, but an incremental process. The most popular fungible tokens are Utility tokens (fundamental in Gaming category, due to the necessity of a in-game currency to buy and sell virtual items), Farming tokens (often adopted by dapps from the DeFi sector and the Gaming category, where developers want to incentivize the possession of an asset by allowing users to earn a passive income) and Governance tokens, the main tool associated with DAOs.

The NFTs that have most captured the attention of users are the ones representing Collectibles (as digital or physical art pieces) and Virtual Gaming Assets (which allow to transfer gaming assets in different ecosystems or to trade them in exchange for cryptocurrencies or tokens). These two categories of non-fungible tokens are the most popular in the Marketplace sector.

Limited information and temporal resources have been the main limitations of this analysis, not allowing to fully understand the impact of certain events and

technological innovations in the Blockchain environment on the data. In the future, to contribute to the academic literature, a similar analysis could be carried out but with a greater time horizon and enriched by interviews with actors linked to specific and peculiar decentralized applications.

2 Introduction

Blockchain in recent years has become an increasingly popular topic talked about. It should be noted that the reason for so much attention most of the time was linked to the significant price fluctuations of the main cryptocurrencies such as Bitcoin and Ethereum, which captured the attention and curiosity of the masses who saw in these assets a way to get rich easily and in a short time. Fully understanding of the potential and tools offered by this technology is not easy: notions of very broad disciplines are required, including economics, game theory and computer science (cryptography in particular).

It is therefore clear that most users do not have the means to fully understand how technology works, and it is therefore essential that it evolves and works towards a greater degree of usability and accessibility.

In this sense, Decentralized Applications, thanks to the setting of the front-end almost identical to any web-app, have become increasingly popular and have shown a significant increase in the number of users (measured in terms of active user wallets). With an entry barrier therefore facilitated compared to other areas of the crypto world, these solutions express all the potential of the technologies on which they are based: governance and decentralized finance, fungible and non-fungible tokens to represent digital or real assets, revenue models that allow users to actively participate in the growth of digital ecosystems and receive an economic return.

As witnessed by the authoritative portal dappradar.com, 2021 was a year of remarkable growth for the decentralized applications sector. The number of unique active wallets increased by about 7 times, reaching at the end of the year the highest share up to that time: 2.7 million. The amount of Total Value of Assets locked in the decentralized finance sector has also grown by about 7 times, where new protocols such as Solana have proven their value, offering alternatives to the already established Ethereum.

The NFTs market, very close to the masses and absolutely one of the most popular topics related to the Blockchain among the less experienced, has reached 23 billion dollars in terms of volume traded. In the common imagination the Metaverse has become increasingly outlined due to the commitment of the former Facebook Group now called Meta, and over 27 billion dollars have been raised by companies related to Blockchain and cryptocurrencies in fundraising campaigns (testifying to the trust of traditional and high-profile companies and funds).

This sector is therefore on the rise, presenting a remarkable variety of applications, from entertainment to finance through interoperable and persistent virtual universes. Within the individual dapps, various services are often presented, making each ecosystem multifaceted and complex. Thanks to progressively more user-friendly interfaces and value creation models that often reward users of the various ecosystems also at an economic level, dapps have the potential to really bring the general public closer to the world of Blockchain.

The objective of the Literature Review is therefore to search for information about Decentralized Applications and in particular analysis that studies the totality of their characteristics, to understand which aspects of these platforms are of greatest interest to end users and which features adapt the most to each typology.

3 Literature Review

3.1. White Paper Bitcoin

3.1.1. General Elements

On October 31, 2008, the Bitcoin Whitepaper was released via a crypto-themed mailing list on the Metzdowd platform. The author is Satoshi Nakamoto, the pseudonym under which the individual or collective behind the birth of the first cryptoasset in history is hiding. Still no other information related to this mysterious identity has been revealed, despite several rumors that have followed over the years, making this figure almost legendary. The document is only 9 pages long, and aims to explain the mathematical, computer science and economic concepts underlying the functioning of Bitcoin in a concise and clear way, adopting simple language.

Bitcoin is based on the use of cryptographic tools and on elements of game theory, making use of the technology of distributed databases. The latter already existed before 2008, albeit with different uses, and will be explored in the ad hoc paragraphs. Bitcoin is a technology for exchanging value between individuals directly, adopting a peer-to-peer system (in jargon p2p) rather than relying on a central entity such as a financial institution. From a conceptual point of view, this represents a shift from a single "source of truth" scenario to a "common source of truth" one, in which knowledge of the transaction log is distributed, which overcomes the problem of the single point of failure and of transaction costs. To make such a system possible and sustainable, it is necessary to implement rules to be respected, in order to prevent the so called double-spending, a situation in which the same unit of value is spent twice due to an attempted scam.

It is necessary that the nodes that make up the Bitcoin network cooperate with each other. The nodes, in fact, are represented by thousands of computers scattered around the world, which contribute to the functioning of the ecosystem. The coordination between the nodes is almost completely automated, as are their calculations, and therefore they can act without the need for human intervention. The more nodes that participate in the network, the more secure the system as a whole is, as the likelihood that a large portion of the nodes are malicious or that computers are simultaneously destroyed (and with them copies of the distributed registry) drops dramatically. It is also essential that the authorized transactions cannot be modified later, thus guaranteeing the property of immutability. According to certain rules, it is then

required that the validity of the transactions be verified, in order to obtain a distributed consensus among the participants of the protocol.

Bitcoin, understood not as the protocol in its entirety but as the unit of value to be exchanged (indicated as bitcoin), as electronic money is nothing more than a sequence of lines of code, inextricably linked to the previous lines, thus forming a chain. In fact, as the name suggests, the distributed ledgers of Blockchain systems are organized into grouped transaction blocks, linked to each other and immutable thanks to cryptographic tools.

References: Academic Literature [30] Gray Literature [1]

3.1.2. Encryption Elements

To transfer value between users, an asymmetric key encryption system is implemented, based on two elements: a public key, known to all network users and which represents a sort of current account number, and a private one, known only to the user who holds it, and that for anyone else it must remain unknown. The two keys are related, but it is impossible to trace the private key starting from the public one, which represents the address of individuals on the network. Public keys do not indicate the real identity of individuals on the network, so complete anonymity exists within the protocol. At the same time, each transaction is traced, and it is possible to analyze backwards, up to the beginning of the register, all the transactions in the protocol history associated with a given public key.

The asymmetric key system is used in conjunction with hash functions (in the case of Bitcoin, the function used is Secured-Hash-Algorithm 256, commonly abbreviated as SHA-256, which generates 256-bit output values). The sender digitally signs by encrypting the fingerprint of the transaction (output of the hash function) with his private key and the recipient's public key, which he will then decrypt using the sender's public key and his own private key. What is encrypted using a private key is decrypted using the corresponding public key, and vice versa. This procedure ensures the authorship of the transaction, that it is read by a particular recipient and that it has not been modified.

A Hash function receives any file or text as input (pre-image) and returns in a very short time a string of alphanumeric values of finite length (image), regardless of the size of the pre-image. It is not possible from a computational point of view to go back to the pre-image starting from the image. A pre-image, used multiple times as input, will always return the same image. Since the domain of the Hash function is unlimited, while the co-domain is a finite set, the collision probability (same image associated with two different pre-images) is not null but must be extremely low. A very small variation in the pre-image also implies a completely different image from the previous one.

Once the truthfulness of the transactions present in a block has been ascertained, it is transmitted to all nodes and its hash will be used for the hash of the next block, linking

the blocks in the chain. The longest chain is always considered the correct one, and this occurs if two nodes simultaneously validate two different blocks, an event that creates a momentary fork that does not represent a danger for the protocol. Furthermore, all nodes will always have an interest in continuing the longest chain in the event of a fork, and this makes it reasonably impossible from a computational point of view to continue a fork linked to a scam attempt, since the malicious agents should govern the majority of the chain network computing power.

In the hash of the block containing the transactions, there is also a timestamp added by a timestamp server, simultaneously on all network nodes. In this way, a timestamp is obtained which certifies the existence of the data at a certain instant. Each timestamp also includes the previous one in the input to the hash function, binding the blocks ever more tightly from a security standpoint as more are added.

References: Academic Literature [30] Gray Literature [1]

3.1.3. Proof of Work

To obtain a concretely immutable sequence of transactions, Satoshi Nakamoto devised the "Proof of Work" consensus mechanism, i.e., bitcoin mining. This process consists in solving a cryptographic problem, demanding on computational resources but whose verification is immediate. It consists in the search for the "nonce" (number used once), a number which, added to the input of the hash function together with all the other information contained in the block, returns as an image a value lower than a certain threshold called “target”. Depending on the overall power of the Bitcoin network, seen as the set of computers of all nodes and measured in hashrate (hash per unit of time) the target value is modified, influencing the time required to solve the puzzle and making the time between mining two consecutive blocks constant. In the case of the Bitcoin protocol, through this algorithm, a block is mined approximately every 10 minutes.

The network nodes participate in the mining process with their own computational resources, and the first one to solve the cryptographic problem validates the block and adds it to the chain. It is impossible to modify the block later, as the way the chain is structured, this would require the modification of all subsequent blocks as well. The more blocks are then validated later, the more secure and immutable that block is. The miner who solves the problem receives a reward, since he has spent computational resources (and therefore energy) to contribute to the functioning of the protocol. This forms the fundamental incentive to actively participate in the network and highlights the need for a cryptocurrency in a Blockchain protocol. The compensation received is linked both to a fee paid by the sender of the transaction (the higher the fee, the higher the priority with which the transaction will be processed by the miners) and to new cryptocurrencies put into circulation. In the case of the Bitcoin protocol, it is useful to remember that the amount of money in circulation is limited, in the sense that over time it will reach its limit beyond which new liquidity will not be injected.

However, it is important to point out that the "proof of work" consent model is only one of the processes that can be adopted. Although it guarantees high security, it is an extremely energy-intensive procedure due to the computational effort required of the network nodes. Among the alternatives, there is the "Proof of Stake" model, now adopted by Ethereum, which is based on game theory and therefore does not require huge energy resources. In this case, the probability of a node being selected as the validator of the next block is proportional to the amount of protocol cryptocurrencies held. In this way, nodes will be selected which, due to their availability, will have an interest in validating non-malicious transactions, so as not to damage the reputation of the blockchain in question and consequently the value of the cryptocurrencies they hold in significant quantities.

Therefore, wanting to summarize the functioning of the Bitcoin protocol as explained in Nakamoto's whitepaper, it is a peer-to-peer system for transferring value between users in a trustless, tracked, immutable, automated way (the nodes work without any particular need for coordination) and secure (as long as the malicious nodes don't control the majority of the network's computational resources).

References: Academic Literature [30, 19] Gray Literature [1,2]

3.2. Cryptocurrencies

3.2.1. General Elements

In the light of what has been explained, we can define a cryptocurrency as a totally digital unit of value, based on cryptographic systems, non-existent in any physical form. It is an asset that exists as a sequence of transactions in a distributed electronic ledger, usually based on Blockchain protocols, and it is not controlled by any centralized institution.

According to Jan Lanksy, Ph.D in the Computer Science and Mathematics department of the University of Finance and Administration in Prague, every cryptocurrency should respect the following 6 properties:

-there is no central authority, and the system is governed by a distributed consensus method;

-the system has full control over units and their properties;

-the creation of new cryptocurrencies is governed by the rules of the protocol;

-the only way to determine ownership of a cryptocurrency is through cryptography;

-it is possible to move ownership of units of cryptocurrencies through transactions, which must be confirmed;

-if two transactions involving the same cryptographic unit are provided simultaneously, the system executes at most only one of the two (thus avoiding the double-spending problem).

References: Academic Literature [2, 11, 33] Gray Literature [3,4]

3.2.2. Types of Cryptocurrencies

Having been the first crypto asset to become popular and known by the masses, Bitcoin is considered the major player in the crypto landscape. Thus, there is a tendency to identify all cryptocurrencies that are not strictly Bitcoin in the "AltCoin" category, sometimes neglecting how certain projects are quite different from Bitcoin from a technical point of view and the features offered, and therefore more than simple alternative versions. Ethereum, whose comparison with Bitcoin will be placed later, is a clear example of this, constituting not only a network for exchanging value but a real decentralized virtual machine on all computers in the world to carry out an impressive variety of operations, allowing to build decentralized applications and smart contracts on it.

Cryptocurrencies whose value is less volatile as it is anchored to that of a stable medium of exchange are called "StableCoins". The term "Cryptotoken" or more simply "Token" identifies a very large category of digital assets, which perform multiple functions within decentralized ecosystems and can be issued through smart contracts. They are therefore not native assets on a given protocol as cryptocurrencies. They will be explored in the appropriate section below and in the one related to decentralized applications.

References: Academic Literature [2, 33] Gray Literature [3, 4]

3.3. Distributed Ledgers

3.3.1. General Elements

Platforms based on distributed digital ledgers predate the advent of the Blockchain, which is based on them. Distributed Ledger technologies, often abbreviated with the acronym DLT, are systems in which each participant, or node, holds the same copy of the ledger, with the possibility of consulting and modifying it independently.

Compared to the classic distributed but not decentralized databases, it is possible to modify the register without having to be authorized by a central institution, based on a consensus algorithm. This is made possible by cryptographic tools, which also guarantee immutability of the registry and system security, making it possible to pass from a “single source of truth” paradigm to a “common source of truth” one. These are append-only structures, where it’s possible only to add data to the registry.

References: Academic Literature [8, 11, 13, 18, 19] Gray Literature [5,6]

3.3.2. Types of Distributed Ledgers

We can distinguish the Distributed Ledger Permissioned platforms and the Permissionless ones. In the former, it is mandatory to follow a registration,

identification and authorization procedure to gain access to the register, while in the latter, the data is visible to everyone, and anyone can take part in network activities. In platforms that follow the Distributed Ledger Permissionless model, such as Blockchains in their original conception, the implementation of assets such as cryptocurrencies is required to incentivize individual nodes to participate in the ecosystem and consensus algorithms.

References: Academic Literature [8, 18, 19] Gray Literature [5, 6]

3.4. Types of Blockchain

3.4.1. Permissionless, Permissioned, Private and Public Blockchain

Within the Blockchain panorama, it is possible to identify mainly 3 configurations that the platforms tend to follow. It is interesting to note that there is a real dispute between those who consider only the public and permissionless ones as real Blockchain systems, which fully embrace the decentralization philosophy, and those who instead think that the other configurations can also be fully defined as Blockchains.

1) Public and permissionless Blockchan

In this category it is possible to include the most famous and popular protocols, such as Bitcoin and Ethereum. Being permissionless, anyone can potentially become a validating node and participate in network activities, and being public, the data register is visible to anyone.

2) Public and permissioned Blockchain

This is a solution in which the role of validator is allowed only to trusted nodes, while the registry data can be visible to everyone. Usually, this configuration is adopted by communities pursuing a common goal, and Hyperledger Fabric and Ripple are popular protocols in this category.

3) Private and permissioned Blockchain

In this scenario, the validators are trusted nodes, and the data log is not visible to the public. It is the most restrictive solution, and in fact it is adopted by government or financial institutions that require very high control of the nodes and data on the network.

References: Academic Literature [8, 18, 19] Gray Literature [7]

3.4.2. Scalability and Buterin's Trilemma

To introduce the concept of scalability in the Blockchain environment, it is first necessary to discuss the so-called trilemma formulated by Vitalik Buterin. This is a theorem that is based on studies carried out as early as the 80s regarding decentralized databases. Buterin, Russian-Canadian creator of the Ethereum platform, explained how a Blockchain system cannot be improved simultaneously under all 3 of the

following points of view: security, decentralization and scalability. In other words, these factors are in trade-off with each other, and it will be necessary to sacrifice one of these qualities to improve another. To cite one example, the Bitcoin protocol is highly decentralized and secure, but weak in terms of scalability. Ripple's, on the other hand, is more centralized in order to be secure and scalable at the same time.

Scalability is one of the most delicate issues concerning Blockchain protocols, as networks previously designed for a small number of users could face great difficulties when they become mass adopted. Bitcoin, for example, compared to transactions that are carried out daily through banking institutions, is very efficient for large transactions, but much less valid for payments of very low amounts.

It is possible to act on the factors of the trilemma at Layer 1 level, i.e., by modifying the structure of the basic protocol, or at Layer 2 level, by creating protocols that rely on pre-existing Blockchains to enhance their functionality.

References: Academic Literature [34, 37] Gray Literature [8-9]

3.4.3. Layer 1 Solutions

1) Modification of the consensus mechanism: as carried out by Ethereum, it is possible, for example, to switch from a Proof of Work mechanism to a Proof of Stake one, which is much less demanding on time and energy resources. Obviously, the implication at the ecosystem level is extremely impactful, as the incentive for nodes shifts from mining to staking activities.

2) Sharding: the initial protocol is fragmented into several networks, in order to distribute the data to be processed on different groups of nodes. A strategy of this type makes communication within the network faster, although it also increases the degree of complexity.

References: Academic Literature [34, 37] Gray Literature [8-9]

3.4.4. Layer 2 Solutions

1) State Channel: this is the possibility for network members to communicate bidirectionally off-chain, thus being able to carry out transactions quickly without going through validation processes. These data exchanges take place thanks to smart contracts or multi-signatures (or multisig) wallets, which then go on to record the start and end on the main protocol. Lightning Network is an example of this system.

2) Rollup: as already happens on Ethereum, it is possible to make smart contracts work off-chain, then reporting the results on the main protocol.

3) Sidechain and Nested Blockchain: these are two solutions for moving the execution of a certain number of operations from the main chain to others. In the case of Nested Chains, still in an immature stage of development, the main blockchain imposes the rules of the system, while the transactions are carried out by multiple levels of the Blockchain, between which levels a father-child dynamic is established. Sidechains

also lighten the load of the main one, but with respect to the latter they can implement different rules such as another consensus mechanism, making use of a token whose utility is to facilitate transmission between the main chain and the adjacent ones.

References: Academic Literature [34, 37] Gray Literature [8-9]

3.5. Wallet

3.5.1. General Elements

It is useful to explain what a wallet consists of, in order to better understand its role within the Blockchain protocols and in particular within decentralized applications, which will be analyzed in detail later.

The term wallet means a digital wallet, necessary to certify the possession of cryptocurrencies and tokens (both fungible and non-fungible), as well as to manage their custody and exchange. The security of a wallet is linked to the cryptographic tools on which it is based. It is possible to operate with your wallet in an absolutely independent and autonomous way, without having to report to a central authority capable of freezing its contents. It is also possible to open a wallet and operate with it anonymously, without providing one's real identity credentials.

It is good to specify that the wallets do not contain the assets, which are present on the Blockchain network, but rather present the cryptographic data that identifies it as the wallet that holds them and that can interact with them. The wallets are based on asymmetric encryption mechanisms.

References: Academic Literature [32] Gray Literature [10]

3.5.2. Encryption Elements

The seed phrase is a sequence ranging from 12 to 24 words and can be used as a root key. The purpose of this dataset is to generate and allow access to all addresses and keys managed by the wallet. If the user deems it necessary, these words can be used to regenerate keys and addresses. It represents the most important information to keep secret, as it constitutes complete access to the wallet. The private key, on the other hand, is a 256-bit long number that allows access to the wallet and the signing of transactions. Using a special algorithm, the public one is generated starting from the private key, but it is impossible to trace the private key from the public one. By then applying a further algorithm starting from the public key, the wallet address is obtained, which identifies the position of the wallet on the protocol data register. It could be said, to make an analogy with traditional finance, that the address acts as an IBAN (International Bank Account Number), indicating to other users where to send cryptoassets, while the private key represents a sort of PIN (Personal Identification Number).

References: Academic Literature [32] Gray Literature [10]

3.5.3. Custodial and Non-Custodial Wallet

We can then distinguish two types of wallets, namely custodial and non-custodial ones. The former attribute the ownership of the wallet to the user, while the latter only grant the right to access it, assigning the management (and responsibility) of the assets held to another entity. In non-custodial wallets you will have no intermediary and you will enjoy total control of your assets, but it goes without saying that in the event of loss of cryptographic data it will not be possible to solve the problem in any way. In custodial wallets, you will enjoy a direct relationship with the Exchange or digital wallet manager, who will be able to trace the access data of the account to which the wallet is associated through customer assistance. Of course, it's necessary to blindly trust this third party.

Sending assets such as cryptocurrencies is very simple, as it is sufficient to type in the address of the recipient and then decide the amount of the transaction. The management of non-fungible tokens (NFTs) is instead linked to the type of wallet. If you have a custodial wallet, you will need to rely on a marketplace for the creation of NFTs and their sale, which will be managed automatically by the chosen platform. It is useful to remember that in this case, to carry out the minting on the Blockchain data register, it will be necessary to have a certain amount of cryptocurrencies to bear the costs of the operation. If, on the other hand, you have a non-custodial wallet, it will be sufficient to associate the wallet with the chosen platform, upload the file relating to the NFT with the supporting metadata. For the sale, in this case the platform will be used without the need for other intermediaries, thanks to specific smart contracts.

References: Academic Literature [32] Gray Literature [10]

3.5.4. Hardware and Software Wallet

We can also categorize wallets according to another criterion: Hardware Wallet (cold storage) and Software Wallet (hot storage):

1) Hardware Wallet: this is the safest and most suitable solution for keeping your assets for a long time, without exchanging them frequently. Cryptographic data is saved on an electronic device, which can be plugged into computers. A classic example is a USB stick. In this case, security is given by the fact that one's assets cannot be reached except by those who are physically close to the storage device. It is also possible to sign transactions through the device itself, without needing to be connected to the Internet.

2) Software Wallet: they are based on an Internet connection, and are the main option offered by wallet and trading services. They are particularly suitable for those who frequently carry out buying and selling transactions with their assets. However, the access data is saved on servers on the network, and therefore more exposed to hacker attacks by malicious people. Within this category we can then identify three proposals:

2a) Web Wallet: the Wallet is accessed via smartphone or PC via a browser interface and can be both custodial and non-custodial;

2b) Desktop Wallet: accessed by running software on the computer via credentials. As far as security is concerned, this solution is safer to the extent that your PC is protected from computer threats. Usually, this type of Wallet is non-custodial;

2c) Mobile Wallet: this is the version of the desktop Wallet for iOS and Android, thus being able to work on smartphones and tablets. It's sufficient to simply scan QR codes to authorize transactions quickly and easily.

There is also a last option, which does not precisely fall into the two categories described above, but which by philosophy is closest to the category of Cold Storage Wallets: these are Paper Wallets. In this case, the user's encrypted data is reported, in the form of a QR code, on a printed sheet of paper. The major limitation of this solution, in addition to its very nature, is dictated by the impossibility of carrying out transactions that do not concern the entire wallet balance.

For all subdivisions, both hardware / software and custodial / non-custodial, hybrid proposals have arisen over time that seek to combine the advantages of the different types.

References: Academic Literature [32] Gray Literature [10]

3.6. Bitcoin and Ethereum

3.6.1. General Elements

Bitcoin and Ethereum are the most popular and well-known cryptocurrencies in the world. They are metaphorically compared to gold and silver respectively, being Bitcoin the one with the currently highest market value and with the highest trading volume. However, the two assets are profoundly different, both from a technical point of view and above all from a conceptual point of view: Ethereum is not a competitor of Bitcoin and never has been, setting itself completely different and broader-minded objectives.

References: Academic Literature [37] Gray Literature [11-13]

3.6.2. Technological Differences

Bitcoin features a highly energy-intensive "Proof of Work" (PoW) consensus mechanism that shines with security and decentralization at the expense of scalability. Ethereum has recently switched to a "Proof of Stake" (PoS) mechanism, which requires almost no energy to operate and is therefore much more scalable, albeit less decentralized. Each new block of Bitcoin is mined approximately every 10 minutes, thanks to an algorithm that adapts the difficulty of the cryptographic puzzle to be solved to the hashrate of the entire network. On Ethereum, however, the time to validate a block is around 10 seconds. The working capital of Bitcoin is fixed at 21

million units, while on Ethereum it is limited but only in the amount issued each year, equal to 18 million units.

References: Academic Literature [20, 30, 37] Gray Literature [11-13, 17]

3.6.3. Conceptual Differences

The real difference between bitcoin and ether (Ethereum cryptocurrency) lies not so much in the technical characteristics, but in the purpose of the two cryptocurrencies. The bitcoin currency was conceived as a digital store of value, comparable to gold, while ether mainly represents the tokens to be spent to exploit the functions of the Ethereum Virtual Machine (EVM), a real own decentralized computer able, thanks to smart contracts, to perform almost any type of operation. The Bitcoin protocol was in fact designed to move value, and does not provide for the variety of uses with which Ethereum was conceived by its founders, among above all Buterin. The programmability of Bitcoin is deliberately much more limited than that of Ethereum, so as to avoid complex situations with unpredictable implications.

Another difference, apparently secondary but in its own way very impactful, is precisely the fact that Ethereum, however decentralized, sees in its founder a guide and an important point of reference. A figure of this type is totally absent in Bitcoin, as explained extensively above. Although Bitcoin is by far the most popular cryptocurrency in terms of recognition and capitalization, many large companies in various traditional sectors have invested in projects based on the Ethereum protocol to innovate their way of doing business.

The source code of Ethereum, extremely open source and full of possibilities for developers, has been designed to host any type of decentralized application (in jargon, dapps). Decentralized applications, the creation and management of digital assets and identities in the form of tokens, the possibility of scheduling complex transactions and operations, are just some of the possibilities offered by the Ethereum protocol, thanks to the versatility offered by smart contracts.

References: Academic Literature [20, 37] Gray Literature [11-13]

3.6.4. Implications of Ethereum in Web 3.0

The concept of digital identity, ownership of assets in the form of digital tokens and decentralized applications are some of the founding aspects of Web 3.0. The term Web 3.0 commonly refers to the new era of the web that the world is entering.

In the Web 1.0 phase, a few (usually authoritative) bodies published content and information (the paradigm from the point of view of users is read-only). In the 2.0 phase, a relatively small group of technology companies have established themselves, becoming giants, and users from simple receptors of information have transformed into creators of multimedia content (the paradigm from the point of view of users is read-write). Furthermore, in this phase, more and more business models based on the management of user data have established themselves.

In the Web 3.0 phase, there will be more and more decentralization with respect to a few companies that control much of the content on the net, providing users with greater freedom and control of their data, with the opportunity to monetize their experience on the web. The ownership of digital and real assets in the form of tokens and disintermediation with financial institutions for payments will be other crucial aspects of this digital revolution, together with other key concepts such as the extensive use of Blockchain-based data ledgers, the implementation of more and more profound Artificial Intelligence and Machine Learning tools. In this last phase, from the user's point of view the paradigm is read-write-own.

References: Academic Literature [36, 37] Gray Literature [14-17]

3.7. Smart Contracts

3.7.1. General Elements and History

The concept of smart contract was born in the 90s, when the expert in cryptography Nick Szabo had theorized algorithms and protocols designed to execute certain commands and authorize transactions based on the occurrence of certain conditions. In that historical period, however, this type of tool failed to take hold due to the absence of Blockchain systems and the lack of the Internet of Things and Big Data. To date, thanks to the security, immutability, decentralization and public data transparency properties of Blockchain protocols, smart contracts can really express their potential.

The first smart contracts were structurally very simple and had the main function of managing crowdfunding collections and the issuance of tokens. The Initial Coin Offerings (in jargon, ICOs) were therefore the main field of application, and contributed to affirming the ERC-20 technological standard for tokens on the Ethereum protocol. Over time, however, smart contracts have become increasingly complex and interconnected, functioning as building blocks for the construction of decentralized and modular applications, the dapps, which will be analyzed in detail later. To date, some of the most interesting real-world application fields for smart contracts are legal/insurance and finance, as will be shown in the examples paragraph below. It is with the birth of Ethereum that this type of codes in constant execution is defined with the name of smart contract.

References: Academic Literature [1, 6, 9, 11, 13, 14, 17, 18, 20, 21] Gray Literature [18-24]

3.7.2. Operation and Security

The purpose of smart contracts is to disintermediate, saving on transaction costs, the drafting and verification of compliance with agreements between multiple parties, in trustless and common knowledge mode. This happens thanks to the implementation of a code that, basically, is structured as a series of if / then clauses. Depending on the

occurrence of certain conditions, the smart contract automatically performs certain actions based on the rules it was created to respect.

Over time, smart contracts have become increasingly complex and interoperable, so as to allow the existence of increasingly sophisticated and complete dapps. However, this also has a downside to be aware of: the likelihood of errors in the programming phase, and the consequent creation of bugs and exploits, has increased. Since a smart contract is immutable and unstoppable once created and "placed" on a Blockchain protocol, it is clear how important it is to refine it in every aspect related to security. It is no coincidence that ad hoc figures such as that of the auditor were born, whose objective is to analyse the lines of code and find any weaknesses and errors. Even this solution, however, does not offer a total guarantee of security, and only time and extensive use by the community can reveal which smart contracts (and consequently which dapps) are actually solid and which present risks.

Therefore, it is essential that during the creation phase not only the rules that dictate its functioning are taken care of, but also those for managing anomalous situations.

References: Academic Literature [1, 6, 9, 11, 13, 14, 17, 18, 20, 21] Gray Literature [18-24]

3.7.3. Stages of Creation and Operation

The creation and operation of a smart contract follow several stages:

1) The parties agree and translate the agreement into a smart contract in the form of computer language, planning all the possible cases and the respective rules to be respected.

2) The smart contract is loaded on the Blockchain protocol, as happens on Ethereum, for example, and the system itself validates it making it fully functional. It is necessary that those registering the smart contract have funds in their wallet, as this operation requires cryptocurrencies. Smart contracts are thus composed of lines of code that dictate their functions and data that dictate their status.

3) Upon receipt of certain inputs in the form of transactions sent to the smart contract address, visible to the entire network, the latter performs the operations for which it was programmed in an automated and deterministic way.

Concretely, to create a smart contract on the Ethereum protocol, it is sufficient to know the Solidity programming language, probably the most popular within this network thanks to its simplicity and the fact that it is very similar to other well-known and used languages such as C++. It is also a Touring Complete language, i.e., able to carry out practically any type of operation.

Taking Ethereum as an example, a smart contract is to all intents and purposes an account with its own balance and address, so it is possible to send transactions to it. Since the smart contract acts and modifies the state of the entire Ethereum network, its use requires a certain amount of cryptocurrency, to reward the nodes that contribute

to its correct functioning through their participation in the network. The required fee is obviously linked to the type and complexity of the operations that the smart contract will perform and are usually charged to whoever sends an input to the smart contract to use it. The higher the computational power required, the higher the fee. The unit of measurement that expresses the computational effort required is Gas, which in practice is nothing more than a different denomination of ether, the native cryptocurrency of the protocol.

References: Academic Literature [6, 9, 11, 13, 14, 18, 20, 21] Gray Literature [18, 23, 24]

3.7.4. Oracles

It is also useful to explore another concept, fundamental in the field of smart contracts: oracles. Often, as happens for example in solutions related to supply chain processes, it is necessary to find data from the real world or from portals external to the Blockchain, or rather off-chain sources. This information, which cannot be found internally in the protocol, can be part of the inputs of smart contracts. A clear example can be that of travel insurance: if the flight is delayed by at least an hour, a refund is issued. If we wanted to implement a policy of this type on a Blockchain protocol, it would be necessary to inform the smart contract in question of any flight delay. The existence of an intermediary between the real world and the Blockchain is therefore necessary, which is not limited only to communicating information, but also to certify it and ensure its truthfulness. The immutability of the Blockchain and its security properties could not guarantee the validity of data taken as input from external sources, and which could therefore be corrupted or manipulated from the outset.

The oracles are thus invoked by functions present in the smart contract code, and therefore their use requires computational power and consequently a gas fee, as explained above. The oracle function can be performed by hardware components, such as sensors or various devices, by software such as websites, or even by human individuals who demonstrate their identity to the Blockchain network and therefore reliability. Oracles can then be divided into two further subcategories: centralized and decentralized. The first case concerns oracles that consist of a single data source: it is easier to implement them in lines of code, but they could represent a single point of failure. The second includes oracles that draw on multiple data sources, and then manage them through consensus algorithms: this makes the process more complex but also more reliable.

References: Academic Literature [35] Gray Literature [18,23]

3.7.5. Examples

The usefulness and potential of smart contracts do not only concern the Blockchain world per se: the fields of application closely linked to traditional and physical businesses are numerous and span very different sectors. Smart contracts can be implemented for the management of copyright and in general for the respect of

intellectual property, to ensure greater security measures in the field of the Internet of Things, to create decentralized and transparent digital voting systems, automate some processes related to exchange, stock market and the world of finance in general. As previously mentioned, it is possible to make insurance policy services for travel and logistics more efficient and simpler, to guarantee authenticity and traceability along the supply chains of sectors such as the manufacturing and food ones.

References: Gray Literature [18, 19, 21, 22]

3.8. Tokens

3.8.1. General Elements and History

Cryptotokens are nothing more than data present in the data register of a blockchain protocol that represent a right, such as the ability to access a particular service, the possession of an asset or the right to have a weight in the choices relating to the governance of a decentralized application. One of the very first fields of application of the tokens is that relating to the Initial Coin Offerings, in which the tokens were used as a means of financing for new solutions in the Blockchain field.

In particular, between 2012 and 2016, loans of this type had acquired enormous popularity, also thanks to the Exchanges that offered them to users. While the Exchanges ostensibly moved to make sure they didn't promote scams masquerading as projects, many bad actors took great advantage of the euphoria around this type of capital-raising initiative, creating tokens solely to attract reckless investors. The bubble then burst in 2018, also following a growing attention from the authorities towards this type of initiative with a very high-risk rate. Historically, the first tokens were born on the Bitcoin protocol with the name of "Colored Coins", but they have not been successful as they have not found a real application. Tokens will become extremely popular thanks to Ethereum, which through smart contracts will make them simple tools to create and use, versatile in various situations.

Although they are often used as synonyms, the terms “Cryptocurrency” and “Cryptotoken” indicate two very different concepts. Cryptocurrencies, such as bitcoin or ether, are native to a certain protocol (respectively Bitcoin and Ethereum, in the example). They have the main objective of making their decentralized ecosystem sustainable, by rewarding nodes for participating in the network, and act as a means of exchanging value. Tokens operate on an already existing protocol, therefore they are non-native. In this way, they take advantage of the properties of the network on which they are present, such as transparency, decentralization and security, without the need to create a new ad hoc Blockchain. Many cryptocurrencies, in fact, were then defined as "dead coins" since the respective protocols, not having reached the critical mass of users necessary to be sustainable, have fallen into disuse losing their economic value.

References: Academic Literature [19, 31, 38] Gray Literature [25-29]

3.8.2. Fungible tokens Creation

Tokens creation has now become a very simple process. It is possible to do this using specific platforms, such as "Create ERC20 token - CoinTool.App", which, taking the parameters we have chosen for the new token as input, will create a smart contract on the desired blockchain which will issue the tokens themselves. Among the parameters to choose, in addition to the name, the symbol and the decimals, there are a series of characteristics related to the tokenomics that we intend to establish: initial supply, possibility of burning and minting the tokens, blacklists, strategies to artificially combat inflation and roles in the management of the tokens, as well as the ownership of the same. If you intend to create NFTs (this type of token will be explored in the next paragraphs), you can specify further parameters.

Although each token can be technically designed and built in a unique way, over time some technological standards have been established to facilitate their creation and interoperability.

References: Academic Literature [38] Gray Literature [30,31]

3.8.3. Classification by Function

Classification according to function performed:

- Utility tokens: allow access to goods and services within a decentralized application;

- Security tokens: their value is linked to factors external to the Blockchain, and they usually represent financial assets such as the shares of a company;

- Asset tokens: indicate the ownership of a particular asset, physical or digital;

- Governance tokens: they allow you to influence the governance decisions of a decentralized application, often the decision-making weight is proportional to the amount of tokens held;

- Farming tokens: they are used in staking and liquidity provision processes to obtain other tokens as a reward and incentive.

References: Academic Literature [31, 38] Gray Literature [26-29]

3.8.4. Classification by Fungibility

- Fungible tokens: all tokens are equal, interchangeable and divisible into sub-parts;

- Non-fungible tokens: each token is uniquely identifiable, non-interchangeable and cannot be divided into sub-parts.

References: Academic Literature [31, 38] Gray Literature [26-29]

3.8.5. Fungible tokens

3.8.5.1. General Elements

The properties of fungible tokens are shared by Stablecoin and Central Bank Digital Currency (CBDC). Conceptually, even the cryptocurrencies themselves have the characteristics of fungible tokens, being interchangeable, divisible and not unique. However, as specified above, cryptocurrencies are native to a given Blockchain and their main purpose is to exchange value and make protocols sustainable, while tokens are not native assets and have various application fields.

References: Academic Literature [38] Gray Literature [26-29]

3.8.5.2. Main Types of Fungible tokens

The most common types of fungible tokens are:

- Utility token: in decentralized gaming platforms, for example, tokens are often used as in-game currency, used to purchase equipment and aesthetic items, which also generate Play-to-Earn mechanisms for the user;

- Governance token: in decentralized applications that follow the DAO (Decentralized Autonomous Organizations) model, Governance tokens are usually used to express one's will in the governance decisions of the ecosystem in question. Often the weight of one's vote is linked to the amount of tokens held;

- Farming token: following the revenue sharing strategy, users are encouraged to keep their tokens to passively have an economic return. Users can, for example, provide liquidity to the platform or stake their resources for the functioning of the ecosystem;

-Security token: these are traditional financial instruments traded on crypto platforms;

-Real World Asset token: tokens represent real assets or fractions of real assets in digital ecosystems.

References: Academic Literature [38] Gray Literature [26-29]

3.8.5.3. Technology Standards

Some of the main technological standards on which Fungible tokens are based are: CKD-20, CKD-721 (used for the creation of NFTs), PSL (native standard of the SOLANA protocol), BEP-20 (native standard of the Binance Smart Chain protocol), TRC-20 (TRON protocol native standard) and ERC-20 (Ethereum standard).

References: Academic Literature [38] Gray Literature [26-29]

3.8.6. NFTs

3.8.6.1. General Elements

This particular type of token is used to certify the ownership of an asset, physical or digital, represented on a Blockchain protocol. They also act as a certificate of

authenticity and digital scarcity. The popularity of these cryptographic tools has increased exponentially thanks to the virality achieved by CryptoKitties. The latter is a video game developed by the Canadian team Dapper Labs, a decentralized application that runs on the Ethereum Blockchain. Within the game, users could create, buy and resell virtual cats represented by non-fungible-tokens. In December 2017, the game came to congest the entire Ethereum protocol, causing it to slow down overall.

Another important stage in the history of NFTs dates back to February 2021, when one of the most important auction houses in the world, the English Christie's, included "Everydays. The first 5000 days", by Beeple, a digital artist from the United States.

References: Academic Literature [31] Gray Literature [25, 32,]

3.8.6.2. Main Types of NFTs

The main fields of application relating to non-fungible tokens are the following:

- Collectibles: this category includes all NFTs that represent works of art, images or similar collectible objects;

- Event Tickets: they are intended to guarantee access to certain events;

- Music and Media rights: they certify the ownership of a specific multimedia or musical content and allow you to earn royalties from the use of the same;

- Gaming and Virtual Items: they represent virtual objects that can be used in certain video games. Each asset of this type has its own in-game stats and various cosmetic characteristics, and can often be purchased and resold within the video game Marketplaces themselves;

- Real World Assets: these NFTs represent ownership of physical assets in the real world;

- Identity & Membership: these non-fungible tokens certify a certain identity in the various decentralized ecosystems, with the possibility of enjoying the associated advantages and privileges;

- Domain Names: these are tokens that certify the ownership of specific domains such as .eth, .dao, etc. Domains of this type, being decentralized, cannot in any way be censored by authorities and institutions.

Other fields of application for NFTs are related to digital twins of plants and digital voting.

References: Academic Literature [31] Gray Literature [25]

3.8.6.3. Technology Standards

The main technology standard for non-fungible tokens is the ERC-721 (Ethereum Request for Comments 721) model. This is the first standard adopted for these cryptographic tools, programmable in the main language of the Ethereum Blockchain, Solidity.

References: Academic Literature [31] Gray Literature [33]

3.9. Decentralized Applications

3.9.1. General Elements and Operation

Blockchain protocols have three main areas of application: they can innovate some traditional business aspects, contribute to the Internet of Value, where there is a focus on the exchange of value thanks to instruments such as stablecoins, cryptocurrencies and digital currencies issued by government entities, or position themselves within the Decentralized Web. In the latter case, innovative businesses are created, which see the Blockchain and its characteristics as the infrastructure on which to base their value proposition. Within the panorama of the Decentralized Web, decentralized applications (in jargon, dapps) have a prominent role.

Dapps are software that run on a Blockchain infrastructure, creating decentralized ecosystems that don't need human labor to function. The dapps back-end is based on one or more smart contracts, which operate in a peer-to-peer, public and decentralized context, as opposed to the centralized servers of classic applications. The code can be open-source, closed-source or partially closed-source. The front-end consists of a user interface that can be programmed in any language that is compatible with the back-end, and usually consists of a web-interface.

References: Academic Literature [4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 24, 25, 27, 28, 29, 39] Gray Literature [36-39]

3.9.2. Composability

As regards the smart contracts that constitutes the skeleton of dapps, it is important to underline how the modularity is one of the most important aspects and falls within the concept of composability: they can be combined to give life to new solutions, being interoperable and going to exploit the properties of the blockchains on which they are registered. The level of composability is related to the simplicity and ability of a protocol to work well with others. Although the concept of composability in the software development field has existed since the 90s, in the Blockchain and Web 3.0 context it has expressed its full potential, thanks to the permissionless and open-source environments that usually characterize these technological contexts. Composability can be analyzed from 3 points of view:

- Syntactic composability: ability of decentralized applications to integrate each other, with smart contracts that, operating on public Blockchains, can be invoked by different dapps;

- Atomic Composability: multiple operations related to multiple dapps can be managed and performed as a single transaction;

- Morphological Composability: tokens are interoperable and can be moved between decentralized applications.

References: Academic Literature [4, 9, 11, 12, 13, 14, 15, 16, 17, 19, 21, 25, 27, 29] Gray Literature [37-39]

3.9.3. Classification by Layers

Since dapps are in fact made up of smart contracts, their use requires the payment of fees as it is necessary to reward the validators who verify the transactions associated with the operations in the network. It is also possible to classify decentralized applications in:

- Type 1: dapps run on their own proprietary Blockchain. Ethereum and Bitcoin, for example, are considered Type 1 decentralized applications;

- Type 2: dapps operate on Blockchains related to type 1 decentralized applications, and therefore not having cryptocurrencies, native to the protocol, they usually rely on non-native tokens (fungible and non-fungible tokens) for management and sustainability of the ecosystem;

- Type 3: dapps that operate on type 2 dapp protocols, and like the latter they are usually based on the use of tokens.

References: Academic Literature [4, 9, 11, 12, 13, 14, 15, 16, 17, 19, 21, 25, 27, 29] Gray Literature [36-39]

3.9.4. Advantages over Traditional Applications

The main advantages compared to applications based on traditional architectures are:

- Data integrity: since the information is kept on immutable Blockchain protocols, malicious users cannot alter the transactions or the data already published on the register;

- Privacy: it is not necessary to provide data regarding your real identity to take advantage of the functions of the dapps;

- No Downtime: it is impossible for malicious users to launch denial of service (ddos) attacks as it is the entire Blockchain protocol, with all its nodes, that supports the functioning of decentralized applications;

- Non-existence of censorship: no network actor can prevent other users from using decentralized applications;

- Reliable behavior: it is possible to directly view the code of the smart contracts, which will work in a deterministic and automated way.

References: Academic Literature [4, 9, 11, 12, 13, 14, 15, 16, 17, 19, 21, 25, 27, 29, 39] Gray Literature [36-39]

3.9.5. Disadvantages compared to Traditional Applications

The most impactful disadvantages concerning dapps are instead related to:

- User Experience: the set of tools required to operate in a blockchain ecosystem makes it more complex to create truly user-focused interfaces;

- Maintenance: due to the properties of the Blockchain and smart contracts, modifying the code of a dapp is extremely complex, even in the event of bugs and security-related problems;

- Performance and Network Congestion: to guarantee the properties of immutability, security and transparency typical of Blockchain protocols, it is necessary that the nodes validate each transaction, and this makes scaling very complex. It is therefore possible that in certain situations the network can become congested due to too many operations;

- Centralization: developing more friendly interfaces both for users and developers can push them to rely on partially centralized services anyway, which undermine the advantages of the Blockchain compared to traditional architectures.

References: Academic Literature [4, 9, 11, 12, 13, 14, 15, 16, 17, 19, 21, 25, 27, 29, 39] Gray Literature [36-39]

3.9.6. Tokenomics

One of the most important concepts related to the world of decentralized applications is that of tokenomics. There is no exact definition for tokenomics, but commonly it means the management of tokens (fungible and not) within a digital ecosystem, the goods, services and features to which they regulate access, how they are distributed and what monetary policies they follow.

The ultimate goal, fundamental for the long-term sustainability of decentralized applications that rely on tokenomics, is to make the tokens themselves useful and valuable, so as to create revenue models that can be pursued both by users, encouraged to remain within the ecosystem and to adopt behaviors aimed at its prosperity, and by owners.

There are several models for managing tokens, which are most often hybridized and combined with each other depending on the needs. The main strategies adopted are three:

- Revenue Sharing: this includes tokens whose holders earn, usually passively, from the possession of the tokens themselves. This can be done through a fee system or through farming. In the latter situation, the tokens that you own are blocked for a certain time horizon, being rewarded with new tokens distributed by the ecosystem itself;

- Utility tokens: these are tokens implemented to regulate access to goods and services within a digital ecosystem. A clear example is represented by virtual currencies within

decentralized video games that allow the purchase of cosmetic or functional objects to the gaming experience. This type of token has often been associated with Initial Coin Offering capital raising. The value of the tokens is therefore linked to that of the services they allow access;

- Governance token: holding tokens to have a proportional decision-making weight within the community can be an important incentive. This strategy is obviously particularly popular in Decentralized Autonomous Organizations, which have in their Governance tokens the core of their tokenomics.

References: Academic Literature [1, 3, 5, 6] Gray Literature [36-39]

3.9.7. DeFi dapps

3.9.7.1. General Elements and History

The term Decentralized Finance (DeFi in jargon) indicates a category of decentralized applications based on Blockchain protocols that deal with providing financial products and services. Being built on Blockchain networks, they share its properties: transparency, decentralization and disintermediation, security and automation. In this way, the related markets and financial services are available without interruption, human error cannot compromise the success of the operations.

The first DeFi dapp was the Bitcoin protocol itself, which made it possible to move value in the form of cryptocurrencies and in a programmable way (albeit with the limits of an undesigned platform, unlike Ethereum, for the development of further and complex applications). To date, Ethereum, due to its aforementioned intrinsic characteristics, is the reference point for the development of DeFi dapps. This is evidenced by the fact that the Ethereum protocol is the first in terms of Total Value of Assets Locked. This value is usually the most considered metric in the DeFi environment and indicates the total value of the cryptoassets staked in DeFi platforms on a given protocol.

However, this type of solution also brings with it various challenges, which must be faced in order to really provide these services to ever more numerous and less expert masses of users. If compared to the centralized counterparts, these dapps are also slower and it is necessary to optimize the operations according to the logic of the Blokcchain protocols. For novice users with this kind of tools, the user interfaces can be unintuitive and if due attention is not paid it is very easy to make mistakes, since being decentralized services, the user cannot contact a customer service and must take full responsibility for one's actions.

Furthermore, being entirely structured on smart contracts, whose code is open-source, it is essential that these algorithms do not present bugs or exploits that malicious people could exploit to their advantage. It must also be considered that information from external sources does not share the security and transparency properties of

Blockchain protocols, and therefore could have been, theoretically, manipulated or simply be not correct.

Specifically, the decentralized finance services provided by this kind of applications are manifold. It is important to underline that the following typologies do not exclusively represent dapps. In most cases, a single platform delivers multiple services, exploiting a sort of modular design made possible by the open-source architecture of the source codes.

References: Academic Literature [7, 22, 23] Gray Literature [49-55]

3.9.7.2. Aggregators

The solutions of this type provide, for the services offered within the dapp, multiple sources and options in the same dashboard. This makes operations significantly more efficient, quicker and easier, allowing users to easily monitor multiple Decentralized Exchanges or Liquidity Pools, for example, so as to choose the most cost-effective option. The only real con of this kind of solutions is the slightly higher fee rate than those of individual aggregate services, justified by the presence of an intermediary.

References: Academic Literature [7, 22] Gray Literature [52]

3.9.7.3. DEXs

These are applications that allow the peer-to-peer exchange of cryptoassets, in a decentralized and disintermediated way. They do not admit fiat currency, and the tokens offered in exchange are provided directly by other users, who replenish their liquidity reserves and in exchange obtain rewards in the form of tokens (liquidity mining). Taking Centralized cryptoassets Exchanges as a benchmark, these solutions feature open-source code, lower transaction fees and greater community engagement with decentralized governance features, as well as not being limited to listed tokens as in the case of centralized counterparts. However, there is no insurance against cyber-attacks on tokens reserves, and they can only be used through non-custodial wallets.

Conversely, Centralized Exchanges such as Coinbase have their own liquidity reserve, insure against any fraud and allow users to use integrated custodial wallets. It is interesting to underline how the two types of Exchange are not in direct competition with each other, as they follow different philosophies and structures, which allow each option to offer certain services, and are aimed at users with different backgrounds and technical knowledge.

References: Academic Literature [7, 22] Gray Literature [54]

3.9.7.4. Staking Services

These are services that allow to deposit in certain cryptocurrency wallets, so as to benefit proportionally from staking activities and associated incentives. In fact, in protocols based on certain consensus mechanisms, additional currencies are received

in exchange for participation in ecosystem validation activities, providing passive incoming flows.

Staking is a popular consensus model for validating transactions in a Blockchain protocol, recently adopted by Ethereum as well. It is based on the random extraction of a validator node. Each node of the network has a probability of being extracted proportional to the amount of cryptocurrencies of the network that it puts "in staking". If the Proof of Work mechanism relies on computational energy to make sure that malicious attacks are not reasonably possible, the Proof of Stake mechanism relies on the fact that a node holding a large amount of cryptocurrencies is in no way inclined to behave in a malicious, as in addition to receiving penalties directly, it would compromise the reputation of the network and consequently the value of the assets it holds. Staking services facilitate this procedure, by converging large quantities of cryptocurrencies in wallets, increasing the probability of being chosen and receiving a reward (which obviously will have to be split) and saving the technical difficulties related to setting up a node for staking independently.

References: Academic Literature [7, 22] Gray Literature [50]

3.9.7.5. Lending and Borrowing Services

In decentralized applications that offer lending and borrowing services, users provide liquidity, receiving interest on blocked assets in return. The commissions received may vary depending on the time horizon in which you agree to block your resources. Those who borrow liquidity must have collateral at least equivalent to the loan contracted, always in terms of cryptoassets, which is liquidated in case of non-repayment of the debt contracted.

Compared to classic bank loans, these services of the crypto world do not require checks on the credit situation, except for the concession of collateral. Compared with traditional solutions, this kind of loans are usually more convenient in economic terms both for those who contract debts and for users who provide liquidity to platforms. It is important to remember that, through the rules codified in smart contracts, changes in the value of the assets involved can result in the liquidation of the collateral.

References: Academic Literature [22] Gray Literature [51, 55]

3.9.7.6. Wallet and Custodial Services

These kinds of decentralized applications offer services for managing users' cryptoassets. In this way, relying on a third party, you can access your resources through an account on a platform, giving up full control of your assets but gaining, for example, the ability to recover access codes and passwords in case of loss.

Users will in fact have to access the platform, and not their wallet, overcoming the obstacle of the rigidity of the cryptographic access rules of non-custodial wallets (but also giving up the very high security). These services may require the payment of fees.

References: Academic Literature [7, 22] Gray Literature [53]

3.9.7.7. Bridge Services

This is a service that allows you to move cryptoassets such as tokens and currencies between Blockchain protocols. It works as follows: if we want to move tokens from protocol A to protocol B, special smart contracts will take care of blocking the amount on protocol A and releasing the corresponding amount relating to protocol B on the latter. This mode of operation requires that the smart contract be equipped with a certain liquidity to draw on, of course.

Mainly there are two mechanisms that bridges follow: they can release on the second protocol a sum of tokens equivalent in value compared to the first (in this case liquidity provided by users is required), or release tokens whose value is anchored to that of the deposited. Bridges are economically sustainable as they charge fees at the time of transactions, and if liquidity is provided by users, the latter earn fees.

References: Academic Literature [7, 22] Gray Literature [59]

3.9.8. Gaming dapps

3.9.8.1. General Elements and Operation

This category includes a wide range of video games, apparently similar to their traditional counterparts, but with one fundamental difference: virtual items (equipment, cosmetic items, avatars, and so on) can be traded between users, bought or sold for tokens or cryptocurrencies or transported to other digital universes. These in-game objects are usually represented by non-fungible tokens, which certify the ownership of a specific cryptoasset to the user who holds them. The buying and selling of these resources determine the development of an internal tokenomics, in which one or more tokens (native or otherwise of the dapp) can be used as an in-game currency, and of a secondary market that can also expand outside the dapp itself (often on external Marketplaces). Users, upon reaching certain objectives within video games, can thus unlock NFTs and then, if desired, resell them. This creates a Play-to-Earn type mechanism: thanks to the possibility of NFTs to "exit" from the game and their value in tokens or cryptocurrency, users can make their gaming experience financially profitable.

Traditional video games, with very rare exceptions related to competitive and professional contexts, do not allow users to "monetise" the time spent within the application, nor to transport the virtual objects of a certain software elsewhere or sell them. Although it depends on a case-by-case basis, in general, in the Blockchain environment, video games give an important weight to the community, which is often called upon to make decisions regarding the structure of the game or even to propose their ideas to developers and other users. This depends on the form of governance of the dapp, which can either be under the control of the developers or be totally decentralized, embracing the DAO (Decentralized Autonomous Organization) model, which will be explored later.

To date, most of the decentralized applications dedicated to gaming are made up of management games (which often focus on the creation of a metaverse, an alternative virtual reality), role-playing or card games, in which the action is therefore not particularly frenetic. From a graphic point of view, at the moment these games are far from the production and graphic standards of the most famous triple AAA (video game productions with very high budgets, which can even reach hundreds of millions of dollars).

References: Academic Literature [9, 19, 26] Gray Literature [40, 41]

3.9.8.2. Impact on Traditional Industry

In 2018, the famous French publisher and developer Ubisoft presented itself as one of the founding members of the Blockchain Game Alliance, a consortium created to explore and promote the potential of the Blockchain in the video game sector. Subsequently, other giants of the traditional industry, such as Square Enix, Electronic Arts and Take Two Interactive also said they were evaluating the possibility of including elements related to the Blockchain and NFTs in their titles. Two of the leading video game Marketplaces on Windows, Steam and the Epic Games Store, have respectively spoken out against and in support of games that integrate NFTs and other Blockchain elements within them.

Steam has made the decision to ban titles with these features due to, they say, too many malevolent actors related to this field. The gray area in terms of legislation relating to the elements in video games with a monetary value, often obtainable in a random way, has also pushed towards this decision.

In December 2021 Ubisoft revealed the Ubisoft Quartz program, founded on the Tezos cryptocurrency. The purpose of the project was to allow users to buy and sell in-game items in an energy-efficient way, and this system was adopted for the title "Tom Clancy's Ghost Recon Breakpoint". Ubisoft itself was later criticized because the Quartz program was so centralized as to undermine the very benefits of a Blockchain system. In general, in the traditional gaming sector there is a lot of skepticism towards the integration of Blockchain and NFTs elements, as they are seen more as simple speculation than a new way of offering value to the gaming experience.

References: Academic Literature [26] Gray Literature [40, 41]

3.9.8.3. Metaverse and Web 3.0 Games

The decentralized video game CryptoKitties, which we mentioned earlier, was the first application of its kind to become extremely popular. Axie Infinity, on the other hand, is a game with "Play-to-Earn" mechanics launched by the developers of Sky Mavis in 2018. Thanks to the low cost of living, some users in the Philippines were able to support themselves financially thanks to their progress in the game. In 2022, however, a cyber-attack stole more than 600 million of dollars from Sky Mavis, causing a significant player crash and disrupting the economy at stake. The result was the

removal of the wording "Play-to-Earn", given the collapse in terms of the value of the game tokens.

As for the metaverse, it is an interesting feature that concerns decentralized applications in the field of video games. The metaverse, understood in the whole of all its potential, refers to a persistent virtual context, in which users, represented by digital avatars, can make transactions and perform actions, moving themselves and virtual objects through interoperable contexts.

These digital universes are still quite immature. First, from a graphic and technical point of view the level is not yet convincing: not only software development must improve the graphic field, but also from the hardware point of view a greater degree of maturity is required. Given the intrinsically immersive nature that the metaverse aims to achieve, more performing and widespread augmented and virtual reality peripherals are necessary to allow a high level of identification for the general public. Also, from the point of view of interoperability, the existing systems are deficient, as well as often perceived by the masses as scams or exaggeratedly overestimated.

It is important to point out that the metaverse aims to integrate different areas of real life, without being limited to that of entertainment and video games. The intention is to create virtual environments to work remotely, socialize and much more. The Blockchain (and the tools associated with it) represents a solid foundation for these solutions, and it is no coincidence that the metaverse is back in vogue thanks to the growing popularity of Blockchain systems. Fungible tokens and cryptocurrencies as bargaining chips for the purchase of goods and services, non-fungible tokens to attest ownership of digital assets, modular architectures and Web 3.0 services are ideal Blockchain tools for developing decentralized video games in the Metaverse.

References: Academic Literature [26] Gray Literature [40, 41]

3.9.9. Gambling dapps

3.9.9.1. General Elements and Operation

Among the most popular types of decentralized applications there is also that of gambling, which becomes more efficient and immediate by exploiting the characteristics of the Blockchain protocols. The trend related to gambling using cryptocurrencies has taken hold so much that even traditional digital casinos have included electronic coins as a payment method. Over time, crypto casinos have in turn begun to accept fiat currency to participate in gambling sessions. It is therefore important to distinguish casinos that only accept cryptocurrencies and those actually built on Blockchain infrastructure, functioning through smart contracts.

The latter allow you to make payments automatically, instantly credit your winnings to your wallet, conceptually going beyond the "deposit-withdrawal" paradigm typical of gambling websites. The efficiency linked to a Blockchain based management usually allows the casino (intended as the decentralized application) to structure the activities

with a lower house-edge compared to traditional counterparts, as well as not having to resort to intermediaries for the management of withdrawals (which makes withdrawals much faster and cheaper in terms of fees). Other advantages related to online casinos operated on Blockchain are the open-source code, transparent and independent from third parties. It is generally possible to register by providing a few data, creating an account consisting of an email and password or simply connecting your wallet, rather than sharing sensitive data as is the case with traditional solutions.

One of the most popular Blockchain protocols for this kind of decentralized applications is ThunderCore. The main strengths of this network based on a Proof-of-Stake mechanism are the speed and low cost of transactions, full compatibility with the Ethereum Virtual Machine and all associated tools, interoperability with other Blockchains such as Ethereum and Binance Smart Chain and scalability. The cryptocurrency of the protocol is the TT, which is used within decentralized applications.

References: Academic Literature [21] Gray Literature [42, 44]

3.9.9.2. Regulation

It is interesting to investigate how this type of applications is considered from a legislative point of view, being based on gambling which is usually prohibited for minors of a certain age. Generally speaking, if classic casinos are legal in a country, so are those built on Blockchain, although there may be restrictions. Various countries, including the United States, require all casinos, even crypto ones, to have a local gambling license. Gambling portals (both traditional and crypto) that boast an official license are obviously more secure and offer certain guarantees of reliability to users. In countries where online gambling is illegal, the same goes for blockchain-based gambling, except for countries where cryptocurrencies are not recognized as money and where therefore the legal situation is absolutely gray and unclear. Equally uncertain is the situation in places where online gambling itself is not regulated.

References: Gray Literature [42, 44]

3.9.10. Marketplace dapps

3.9.10.1. General Elements and Operation

The Marketplaces based on a Blockchain infrastructure allow the use of tokens and cryptocurrencies for payments and a more streamlined and convenient sale, as there are no classic intermediation figures linked to traditional solutions of the same type. The characteristics of the protocols also make transactions safe and authentic, with the buyer being able to trace back the history of the asset in question, a guarantee of maximum transparency and trust. Blockchain-based Marketplaces, whose business model is based on applying commissions on transactions, can sell both digital and physical objects (such as merchandising items). However, by far the most popular

asset category is non-fungible tokens involving art, collectibles, and gaming items. The main methods of sale are direct sales at a set price or auctioning.

The main advantages of these decentralized platforms compared to traditional counterparts, beyond the tradable assets, concern, as mentioned, greater efficiency, lower transaction costs and usually higher margins for sellers, privacy and security. However, it must be kept in mind that not all Stores pay attention to the actual "quality" of the assets in the catalogue, and that due to the strong recent speculation it is easy to come across assets that will absolutely not maintain the reported value.

Marketplaces can then decide to sell all sorts of assets or specialize in a single type. Each decentralized application of this type allows the exchange of assets compatible with the Blockchain network on which they were created. However, industry leaders are now compatible with many protocols, boasting high interoperability. There are also NFTs Marketplace Aggregators, which allow through a single dashboard to have all NFTs listed on different platforms available.

Even for this kind of dapps the degree of decentralization can vary: some solutions like OpenSea are managed by a private company, while others like Rarible adopt the DAO model.

Through the Marketplaces it is also possible to "mint" non-fungible tokens. The procedure usually involves uploading the digital file (whether it is a .mp3, .jpeg etc.) and inserting a caption that serves as a description and related metadata. It is obviously necessary to connect a suitable wallet, so as to be able to boast the ownership of the NFT, in order to receive any payments from buyers but first of all to support the small costs that the minting operation entails.

References: Academic Literature [9, 19] Gray Literature [34, 43, 45, 46]

3.9.10.2. Royalties

A very interesting implication related to NFTs is the possibility for artists, taking the example of non-fungible tokens regarding artistic works, to collect royalties linked to subsequent sales compared to the first. In this way, each time the NFT is transferred, part of the price paid is destined for the original creator. This is made possible by the traceability of these cryptoassets, linked to the logic of the Blockchain.

The only limitation, on which various proposals are already underway to solve the problem, is that the NFT ERC-721 standard provides this mechanism only for sales that take place in the same Marketplace, so if a sale subsequent to the first takes place on a different platform, it will be at the discretion of the Marketplaces themselves to manage the situation of royalties and not directly and deterministically controllable.

References: Gray Literature [35]

3.9.10.3. Open and Closed Marketplace

In fact, it is useful to distinguish two types of decentralized Marketplaces: open ones and closed ones. The former, including OpenSea, to cite an illustrious example, do not apply controls and authorize anyone to sell whatever they want. Thus, it happened that some malicious actors tried to implement scams, for example by trying to sell duplicates of works by other artists. Closed Marketplaces, on the other hand, monitor the artists who sell on their platforms more carefully, raising the average quality level and significantly lowering the probability of fraud (at the expense of higher transaction fees to cover this additional service).

References: Gray Literature [43, 45, 46]

3.9.11. Decentralized Autonomous Organizations

3.9.11.1. General Elements

The term DAO indicates a Decentralized Autonomous Organization, sometimes also referred to as a Decentralized Autonomous Corporation. Vitalik Buterin, founder of Ethereum, already in 2014 spoke of a very near future in which management of companies and organizations could be the responsibility of computer software, without depending on the work of human beings. The systems that embrace this structure are based on Blockchain protocols, acquiring the properties of immutability, transparency, security and decentralization. A DAO is a multi-subject organization, in which several individuals (even completely unknown) aggregate by providing their own resources in the form of cryptocurrencies and tokens (both non-fungible and fungible, but the latter are far more popular). Its operation is automated, based on the algorithmic and deterministic behavior of the smart contracts on which the decentralized application is built.

Conceptually, the great innovation brought by DAOs to the world of management is the overcoming of a vertical organizational structure, in favour of a horizontal one in which decision-making power is distributed based on the parameters of smart contracts. This guarantees an important bureaucratic and organizational streamlining, making coordination by far easier between all the actors involved, who in these contexts are distributed all over the world and do not know each other.

Furthermore, the comparison between the holders of Governance tokens and the shareholders of a traditional company is imprecise: in traditional organizations, the holders of shares do not actually have governance power, although they do have a certain influence. DAOs therefore represent a managerial paradigm never seen before the advent of the Blockchain, and which in fact at the legislative level still moves in a gray area without shared regulations.

References: Academic Literature [1, 21, 27] Gray Literature [47, 48]

3.9.11.2. Lifecycle of a DAO dapps

Usually, the establishment of a DAO starts from the team founder of the project, who create smart contracts that incorporate the rules and parameters that will determine the functioning of the DAO (for example, circulating quantity and distribution of tokens, delivery methods). In this sense, the smart contract represents a sort of statute, which due to its intrinsic properties is visible to all users and therefore completely transparent. Then follows a funding phase, in which the application collects funding by issuing cryptotokens and cryptocurrencies. The very value of the tokens is directly linked to the privileges in terms of governance and participation in the community that they themselves guarantee to their holders. Usually, the founding team still maintains a certain percentage of the Governance tokens under its control.

However, these steps are not the only way to start operating through a DAO: many decentralized projects are initially configured under the guidance of the team, which then foresees the transition to the DAO model during the roadmap. The reasons behind this lie in the desire to "stabilize" the dapp from an operational point of view in the delicate initial phase, while at the same time giving a clear direction to the ecosystem and the community.

References: Academic Literature [1, 21, 27] Gray Literature [47, 48]

3.9.11.3. Parameters of a DAO dapp

A decentralized governance model has many nuances, allowing founders to choose from a wide range of options to choose from to shape their organization. It's possible:

- To decide what types of choices are directly influenced by token holders, for example leaving changes relating to the structure or business model of the dapps in the hands of the founders or establishing that holders can only vote on the team's proposals without formulating them themselves;

- To establish whether to delegate decision-making power only to some authorized wallets or to all token holders, and in the latter case, whether to assign decision-making weight proportionally to the amount of tokens;

- To require the signature of one or more authorized wallets on all decisions or those affecting certain aspects of the decentralized application;

- To leave the technical implementation of user proposals to the team or make this step automatic.

The community's proposals can be formulated and discussed on the forums related to the individual dapps and on platforms such as Discord, to poll the opinion of the various users (the so-called “temperature check”) and possibly move on to a voting phase. Votes can be recorded both through On-Chain and Off-Chain systems, thanks to decentralized Governance tools such as Snapshot (off-chain governance) or Tally (on-chain governance), able to take into account the tokens held by your wallet to assign weight to the vote.

References: Academic Literature [1, 21, 27] Gray Literature [47, 48]

3.9.11.4. Risks of DAO adoption

It is important to remember that adhering to this model also involves some risks, which if not mitigated can potentially compromise the prosperity of the digital ecosystem. The decentralization of governance exposes us to the danger of loss of control. It is essential that, as often happens, developers in the very early stages of the project point the community in the right direction, providing a roadmap and transmitting the strategic and conceptual objectives to the users who will then make the decisions.

Since the main method of assigning decision-making weight is the amount of Governance tokens held, their value is exposed to the risk of speculation. It is also necessary to avoid situations in which a plutocracy emerges, in which a few users who hold a significant amount of tokens come to clearly control the entire organization. In such a scenario the very concept of decentralization collapses, in favour of the interests of a small group of actors.

References: Academic Literature [1, 21, 27] Gray Literature [47, 48]

3.10. Regulation

The regulations concerning the Blockchain, smart contract, tokens and everything related to these elements are still strongly in development and updating. These are innovative and evolving technological tools, which often move in gray areas from a legislative point of view. Moreover, individual countries, also depending on their relationship with cryptocurrencies, often adopt very different laws. The main regulatory trends concern the DAO model, the management of privacy and sensitive data on electronic registers, copyright compliance (especially in the NFTs area) and the regulation of cryptoassets and the markets in which they are traded. However, there are areas where legislation still needs to mature, such as the areas of DAOs and NFTs, while others where the overall picture is much clearer.

One example is the Digital Financial Package legislative package. It is a set of three regulations: the MiCA, the DLT and the DORA. The aim of the Digital Financial Package is to outline a Europe-wide strategy in the field of digital finance, to mitigate its risks and exploit its potential, pushing European companies and safeguarding consumers.

DLT (Distributed Ledger Technology) aims to regulate the exchange of traditional financial instruments that take place through smart contracts and platforms based on distributed ledgers. The instruments in question shall be issued, recorded, stored and exchanged on distributed ledgers. The DORA (Digital Operational Resilience Act) deals instead with indicating the requirements in terms of cyber security, both logically and physically, for companies in the financial sector.

The MiCA (Markets in cryptoassets Regulation) aims to establish obligations to be respected for those who issue ART, EMT or other cryptoassets. The acronym ART refers to Asset-Referenced Tokens, whose value is anchored to that of other cryptoassets, commodities or legal tender currencies, or to a combination of the aforementioned elements. EMTs, or E-Money Tokens, are stabilized only with reference to a legal tender currency. The last category identified is that of Utility tokens, used to access a good or service and which is accepted only by those who issued it.

According to the MiCa, issuers of such products must be authorized for use in the European Union, in addition to having to fulfil other obligations according to different situations. Stablecoin issuers, for example, must secure a reserve with 1:1 liquidity in the form of deposits, as well as being supervised by a dedicated body of the European Banking Authority (EBA).

Due to poor usability in the financial field, NFTs (except for fractional NFTs) are not regulated by the MiCA.

References: Gray Literature [57-58]

3.11. Stages of Collection and Selection of Papers

The scientific papers to be analyzed were taken from the following portals: Science Direct, Scopus, Google Scholar and IEEE Xplorer. The keywords through which the searches were carried out (on each of the aforementioned portals) are the following: "Analysis of Blockchain Decentralized Applications", "Blockchain Decentralized Applications", "Dapps Blockchain", "Empirical Analysis of Blockchain Decentralized Applications", "Census of Blockchain Decentralized Applications".

Among the main search criteria: articles in each language and sorting according to relevance to keywords. For each keyword and for each platform, among the articles on the first three pages of results, those whose title and description are most in line with the objectives outlined at the end of the “Introduction” section have been taken into consideration.

It is essential to take into account two factors: Blockchain and the topics associated with it (cryptocurrencies, smart contracts, tokens, decentralized applications), are relatively young areas and, above all, constantly evolving. The academic literature has therefore been largely flanked by gray literature from textual materials such as articles and analyses, provided by authoritative websites. This kind of content, by its very nature, is able to cover a greater number of facets of the topics under analysis and to provide information almost in real time about the most impactful news.

3.12. Gaps Found in Literature

The academic literature has highlighted a deeply technical and quantitative approach in the research areas, but usually limiting the analysis in terms of applications considered (e.g., evaluating only those present on the Ethereum protocol) and / or variables considered.

It is therefore useful to conduct a census of decentralized applications that is able to observe these services during a given time horizon, monitoring the various facets that make certain platforms attractive to users. It will be essential to understand how the various elements of dapps (fungible and non-fungible tokens, forms of decentralized governance, sectors and categories.) best adapt to the various types of ecosystems.

3.13. Objectives of the Research & Research Questions

The most popular decentralized applications in terms of user active wallets will be analyzed over a six-month time horizon, monitoring:

- quantitative aspects such as the number of user active wallets, the amount of the Balance, the number and volume of Transactions;

- qualitative aspects, such as the sector and the category to which they belong, the form of governance in force, the methods of value creation for both users and platform owners, the types of fungible and non-fungible tokens used;

- technological aspects, such as the protocols on which decentralized applications are operational.

The aim of the research is to answer the following questions:

- What are the most used Blockchain protocols, and why?
- How does the DAO decentralized governance model fit with the various types of decentralized applications?
- How do the various types of decentralized applications behave from the point of view of quantitative metrics? Which are the most representative according to the type of services?
- What are the most used tokens based on the type of decentralized application? How important is their role in digital ecosystems to capture users' interest?

4 Methodology

4.1. Introduction to dappradar.com

Dappradar is an online platform that has been providing analysis and information on decentralized applications since 2018, and which over time has established itself as a reference source for industry players. Among the services offered, there are also reports, NFTs evaluations and portfolio management. As of April 22, 2023, there are over 13800 dapps tracked, across 49 protocols, and monthly users reach 1 million.

Dappradar provides real-time rankings on decentralized applications. The values associated with each dapp that can be chosen as sorting criterion are the following: “Balance” (total value of assets in dapp's smart contracts in dollars), “UAW” (number of unique active wallets interacting with dapp's smart contracts) and “Volume” (total amount of incoming value to dapp's smart contracts in dollars). It is possible to choose various time segments to conduct analyses.

Dappradar, for each analyzed dapp, provides its description, tags relating to the category of the dapp and the functions it performs, the protocols on which the dapp is deployed, data relating to NFTs and tokens and other numerical values such as "Transactions" (the total number of transactions made between unique active wallets (UAW) and the dapp's smart contracts). It is possible to analyze numerical values relating to the attributes "Balance", "UAW", "Volume" and "Transactions" filtered both by time segments and by single protocol.

4.2. Framework

4.2.1. Variables Description and Collection Modalities

The framework is designed to analyze decentralized applications (hereinafter referred to as dapps). For each draw, the 100 most popular dapps were examined, using as a selection criterion the value of UAW (The number of unique active wallets (UAW) interacting or performing a transaction with a dapp's smart contracts) for the last 30 days, provided by the dappradar.com portal. The draws were held on the following dates: 15 October 2022, 15 November 2022, 15 December 2022, 15 January 2023, 15 February 2023 and 15 March 2023. The comprehensive framework was achieved by entering the 100 most popular dapps for each extraction, then removing the duplicates and obtaining a total of 180 unique dapps.

The "Name" attribute indicates the name by which the dapp is identified at the time of extraction, according to the dappradar.com portal. Each dapp is assigned the attributes "UAW", "Delta UAW", "Volume ($)", "Transactions" and "Balance ($)", according to data provided by the dappradar.com. For each draw where a dapp was among the top 125 most popular dapps based on the value of "UAW", the values of the attributes above are shown. The "Delta UAW" attribute indicates the percentage change in the value of the "UAW" attribute over the previous 30 days. The attribute "Volume ($)" indicates the fiat value of incoming dapp transactions over a period of time, "Transactions" indicates the total number of transactions made between unique active wallets (UAW) and the dapp's smart contracts, "Balance ($)" indicates the total fiat value of assets in a dapp's smart contracts. The previous definitions concerning the quantitative attributes listed so far have been provided directly by dappradar.com.

4.2.1.1. Sector and Category Keywords

The "Sector" attribute indicates the macro-category that best describes the characteristics and type of the dapp. This information has been taken mainly from the WhitePapers provided by the dapps themselves, from the websites of the dapps themselves, and / or from what is indicated by the descriptions of the dappradar.com portal. The values that "Sector" can assume are "DeFi" (dapps that provide Decentralized Finance services), "Marketplace" (dapps that provide cryptoassets trading services, in particular non-fungible tokens), "Social" (dapps whose usefulness is based on communities of users who collaborate and exchange services), "Entertainment" (dapps based on providing entertainment services, in particular gaming and gambling services), "Other Sector" (other unspecified macro-categories, which do not fall within those mentioned above) and "Unknown Sector" (in case, due to lack of data, it was impossible to identify the value of the "Sector" attribute).

The "Main Category Keyword" attribute indicates the single Category Keyword that describes the type of dapp in the most concise and unambiguous way possible. This information has been taken mainly from the WhitePapers provided by the dapps themselves, from the websites of the dapps themselves, and / or from what is indicated by the descriptions of the dappradar.com portal. The possible values of this attribute, depending on the value of the "Sector" attribute, are as follows:

-"DeFi": "Bridge" (dapps that allow you to move cryptoassets from one chain to another, according to the methods provided by the Bridge itself), "Staking" (dapps that provide services related to the staking of cryptoassets to obtain a passive economic return), "DeFi Aggregator" (dapps that provide, in a single dashboard, one or more decentralized finance services combining the products offered by multiple platforms), "DeX" (dapps that provide decentralized Exchange services), "L&B" (dapps that provide collateralized Lending and Borrowing services), "Wallet" (dapps that allow you to store and manage users' cryptoassets), "Other DeFi Category", "Unknown DeFi Category";

-"Entertainment": "Gambling" (dapps that provide services related to gambling based on crypto elements), "Gaming" (dapps that provide services related to video games that incorporate crypto elements such as NFTs or Play-to-Earn mechanics related to the use of tokens);

-"Marketplace": "Classic Marketplace" (dapps that allow the purchase and sale of cryptoassets, in particular non-fungible tokens), "Marketplace Aggregator" (dapps that provide, in a single dashboard, one or more cryptoassets buying and selling services combining the products offered by multiple platforms), "Other Marketplace Category";

-"Social": "Classic Social" (dapps whose usefulness is based on communities of users who collaborate and exchange services);

-"Other Sector": "Other Sector & Other Category";

-"Unknown Sector": "Unknown Sector & Category".

The attributes related to the "Category Keywords" section indicate the types of dapps and services offered by them that identify the dapp in question. This information has been taken mainly from the WhitePapers provided by the dapps themselves, from the websites of the dapps themselves, and / or from what is indicated by the descriptions of the dappradar.com portal. The values that can be associated with the columns in this section are the same as "Main Category Keyword", however the categories not identified or different from those described, beyond the sector of origin, are indicated respectively with the terms "Unknown" and "Other".

The “Dapp Info" attribute is associated with the text description of the dapp provided by the dappradar.com portal. The attribute "Year of Listing on dappradar" indicates the year in which the dapp was cataloged by the dappradar.com portal, which provides the data itself. The attributes of the "Types of capital raising" section indicate the methods through which the dapp has raised money, the total amount indicated by the "Amount ($)" attribute. The data relating to this section are provided by the crunchbase.com portal and were extracted on 23 March 2023.

4.2.1.2. Ownership Status

The variable "Ownership Status" can take three different values: "Company", "Developers" or "DAO" (Decentralized Autonomous Organization), and the associated value refers to the current form of Governance, which does not necessarily correspond with the original one at the time of launch of the dapp. This information was mainly taken from the whitepapers provided by the dapps themselves, from the websites of the dapps themselves, and/or from what is indicated by the descriptions of the dappradar.com portal or other online sources considered reliable. The "Decentralization Level" section includes 5 binary attributes, which can then take a value of 0 or 1. The "Proposals from Users" attribute takes on a value of 1 if users can make proposals in addition to voting, 0 if they can only vote. The attribute "Token Holders or Authorized Wallets" assumes a value of 1 if the decision-making power is

entrusted to all token holders, 0 if only to the authorized wallets. The attribute "Off-chain Platforms Usage" assumes a value of 1 if, during phases such as the Temperature Check or the vote of a proposal, external platforms such as Snapshots are exploited. The "Multisig signature" attribute takes a value of 1 if there is a group of wallets that can, for example, veto a certain proposal, 0 if this feature is not present. The "Team or Direct Implementation" attribute takes a value of 1 if a proposal, once accepted, is implemented by the dapp Team, while it takes a value of 0 if the execution process is automated.

4.2.1.3. Revenue Models

The attributes of the "Revenue Models Owner" and "Revenue Models User" section indicate the mechanisms present in the dapps for the creation of value and economic return for platform owners and users respectively. This information was mainly taken from the whitepapers provided by the dapps themselves and from the websites of the dapps themselves.

Attributes in the "Revenue Models Owner" section can take value:

-"Tokenomics": increase in value of the tokens linked to their use, and/or value creation linked to the use or possession of the tokens;

-"DeX Fees": the dapp charges fees on Decentralized Exchange activities;

-"Staking Fees": the dapp charges fees on Staking activities;

-"Return On L&B": the interest that the dapp earns by granting collateralized loans;

-"Bridge Fees": the dapp applies fees on the activities of moving cryptoassets from one protocol to another;

-"In App Sales & Royalties": earnings destined to the dapp from the sale of cryptoassets on a Marketplace;

-"House Edge": gains from the dapp linked to the intrinsic mathematical advantages of gambling;

Attributes in the "Revenue Models User" section can take value:

-"Tokenomics": increase in value of the tokens linked to their use, and/or value creation linked to the use or possession of the tokens. In the case of gaming apps, this item also includes Play-to-Earn mechanics;

-"Liquidity Mining": gain by users linked to the granting of liquidity in terms of cryptoassets for DeX (Decentralized Exchanges) services, Bridge or collateralized loans;

-"Staking Fees": commissions intended for users in staking activities;

-"In App Sales & Royalties": earnings intended for users from the purchase of cryptoassets on a Marketplace;

-"Gambling": possibility, on the part of users, to earn through gambling. Mathematically, it is impossible to make money in the long run because of the House Edge boasted by dapps.

In the sections "Revenue Models User" and "Revenue Models Owner", in the event that farming tokens were present, the mechanisms exploited by the latter dictated the insertion in the aforementioned sections of corresponding values only if these functions were highlighted as main. Otherwise, the presence of farming tokens has limited itself to dictating the inclusion of the "Tokenomics" attribute in the aforementioned sections.

4.2.1.4. Protocols

The attributes in the "Protocols" section correspond to the main protocols on which the dapp is deployed. There are up to 3 protocols, and in case the dapp is deployed on more than one of them, the highest protocols associated with a value of UAW (user active wallets) relative to the dapp have been considered. These measurements were calculated on March 31, 20223 based on the UAW value of the dapp on a given protocol in the last 30 days, provided by the dappradar.com portal. The "Multichain" attribute is binary: it takes a value of 1 if the dapp is deployed on more than one protocol, 0 otherwise. The "Layer 2" attribute is binary: it takes a value of 1 if the dapp is deployed on at least one Layer 2 protocol, 0 otherwise.

4.2.1.5. Fungible and Non Fungible tokens

The "Token" attribute is binary: it takes a value of 1 if the functions of the dapp involve the use of tokens (fungible and/or non-fungible), 0 otherwise. The "Native token" attribute is binary: it takes a value of 1 if the functions of the dapp involve the use of fungible tokens native to that ecosystem. This information was mainly taken from the whitepapers provided by the dapps themselves and from the websites of the dapps themselves. The "Token Name" attribute indicates the naming of the Native token(s) within the dapp. The "Token Technology" attribute indicates the technical standard of compatibility of the token. The attribute "% of tokens of Core Team" indicates the percentage of tokens indicated by the attribute "Token Name" belonging to the Core Team of the dapp in question. The attributes "Utility token (tokens used as a means of down payment and exchange for goods and services within the dapp), "Governance token" (tokens that give owners decision-making power within the dapp), "Security token" (tokens that represent the legal possession of real-world financial instruments, such as gold, shares or bonds), "Real World Asset token" (tokens that represent the legal possession of physical assets in the real world) and "Farming token" (tokens that confer the possibility of increasing their tokens through operations such as liquidity mining or staking) are binary: they assume the value 1 if the functions of the dapp involve the use of native fungible tokens of the type represented by the attribute itself, 0 otherwise (“//” if “Token” attribute or “Native Token” attribute is equal to 0, “?” if it has not been possible to obtain this information).

The "NFT" attribute is binary: it takes a value of 1 if the functions of the dapp involve the use of non-fungible tokens, 0 otherwise. This information was mainly taken from the WhitePapers provided by the dapps themselves and from the websites of the dapps themselves. The attributes "NFT: Collectibles (Artwork, memes, collectable etc)", "NFT: Event tickets" (tokens representing the right to access to certain events), "NFT: music and media"(tokens representing rights on media contents)", "NFT: Gaming and virtual items" (tokens present in decentralized games, featuring in-game statistics), "NFT: Real world assets" (tokens that represent the legal possession of physical assets in the real world), "NFT: Identity & Membership" (tokens representing identity and privileges in digital ecosystems), "NFT: domain names"(tokens representing domain names in a decentralized environment, i.e. .eth) are binary: they take the value 1 if the functions of the dapp involve the use of non-fungible tokens of the type represented by the attribute itself, 0 otherwise ("//" if "NFT" attribute or "Token" attribute is equal to 0, "?" if it has not been possible to obtain this information).

5 Findings

In this section the most interesting data will be analyzed, from which it is possible to structure constructive reflections.

5.1. UAW

As for the number of users active wallets (UAW) during the analysis horizon, the final data are as follows:

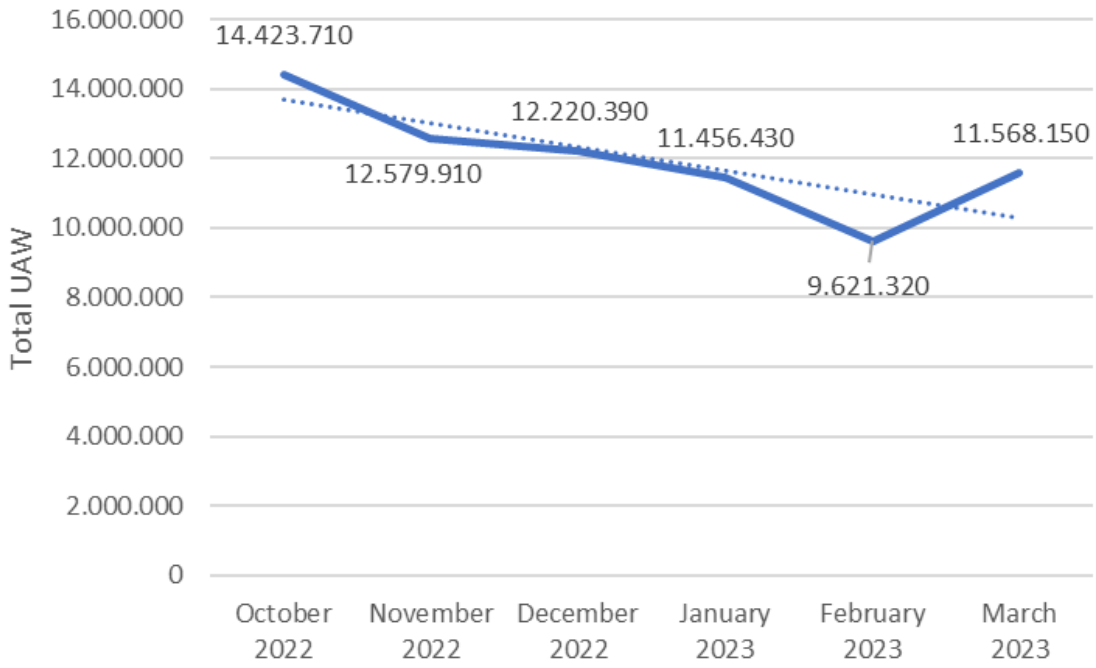

Figure 1: UAW in each draw

It is important to specify that the number of UAW in all the dapps extracted in that particular month is only an indicator, and not a precise reference. A single user, with the same wallet, could log in during the same month in multiple decentralized applications, and in doing so would be counted multiple times. However, it is a number able, in the case of significant differences (such as different orders of magnitude) to signal a change in overall users.

During the months of analysis, as evidenced by the graph, there was no significant change in the activity of users. It is possible to identify a slight negative trend that was reversed in March. The situation can therefore be considered as fairly stationary from this point of view, without significant upheavals.

5.2. Sectors and Categories

It is essential to point out that framing a decentralized application in a specific sector and, in particular, in a certain category, can be complex and reductive. Thanks to the continuous innovation made possible in a highly open source and modular environment, the individual dapps often perform multiple functions, offering users complementary services and products suitable for multiple needs.

Decentralized Finance applications, for example, often offer multiple types of services, just as decentralized video games integrate NFTs marketplaces within them. For the purposes of analysis, however, it was essential to distinguish the values of the most adherent and synthetic attributes for each decentralized application, so as to be able to carry out more correct and methodical analyses.

Sector & Category	#
DeFi	**66**
Bridge	3
DeFi Aggregator	11
Dex	33
L&B	3
Other DeFi Category	7
Staking	4
Unknown DeFi Category	2
Wallet	3
Entertainment	**53**
Gambling	11
Gaming	42
Marketplace	**23**
Classic Marketplace	20
Marketplace Aggregator	2
Other Marketplace Category	1
Other Sector	**10**
Other Sector & Other Category	10
Social	**7**
Classic Social	7
Unknown Sector	**21**
Unknown Sector & Category	21
Total	**180**

Figure 2: Sectors and Categories (Table)

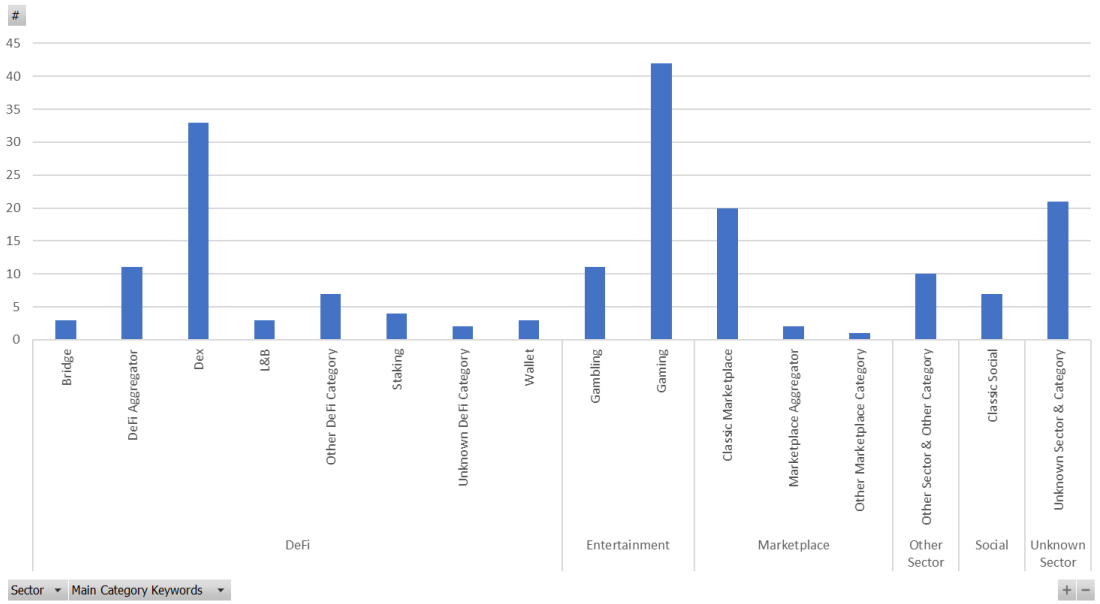

Figure 3: Sectors and Categories (Graph)

The DeFi sector boasts the largest number of decentralized applications, with a total of 66 out of 180. It is the most representative sector of the entire world of decentralized applications, which thanks to an open source and modular context, continues to offer increasingly complete and interoperable solutions.

These are solutions that, as will be analyzed later, often adapt the DAO (Decentralized Autonomous Organization) model, favouring a high engagement by the community and thus being able to boast transparency and reliability. It is also a type of solution that acts as a catalyst for the entire decentralized world, allowing the exchange of tokens and other cryptoassets useful for multiple purposes and in different ecosystems.

This is evidenced by the strong presence of Decentralized Exchanges (DeXs) within the DeFi sector, with 33 out of 66 dapps. The DeFi sector also offers users the opportunity to obtain an economic return by providing their tokens and assets to flesh out the liquidity of the platforms in various categories (DeX, Bridge, Staking and Landing & Borrowing).

The Entertainment sector also stands out for popularity, with 53 dapps out of 180 total. The merit is largely of the Gaming category, which drags the sector with 42 dapps out of 53. Decentralized video games, thanks to Play-to-Earn mechanics and the introduction of digital gaming objects in the form of NFTs, have revolutionized the world of traditional video games. The ability to make the time spent on a game economically profitable and to move from one environment to another, exchange or sell one's in-game items (a concept that can be further expanded in the perspective of

the Metaverse), are features that clearly distinguish the experience linked to these applications compared to the classic ones.

The reflection that emerges is clear: The two most popular sectors are those that most incorporate the benefits and technological innovations related to the Blockchain, which clearly distinguish them from traditional counterparts. In addition, various categories of the DeFi sector and dapps in the Gaming category allow, even if with different logics, to obtain an economic return and to make their resources passively profitable.

5.3. Ownership Status

Ownership Status	Company	DAO	Developers	Unknown Ownership Status	Total
DeFi	**15**	**36**	**6**	**9**	**66**
Bridge	1	1		1	3
DeFi Aggregator	4	5	1	1	11
Dex	8	20	3	2	33
L&B		2	1		3
Other DeFi Category		3	1	3	7
Staking	1	2		1	4
Unknown DeFi Category		1		1	2
Wallet	1	2			3
Entertainment	**35**	**16**		**2**	**53**
Gambling	11				11
Gaming	24	16		2	42
Marketplace	**11**	**6**	**5**	**1**	**23**
Classic Marketplace	10	4	5	1	20
Marketplace Aggregator		2			2
Other Marketplace Category	1				1
Other Sector	**5**	**3**	**1**	**1**	**10**
Other Sector & Other Category	5	3	1	1	10
Social	**3**	**2**	**1**	**1**	**7**
Classic Social	3	2	1	1	7
Unknown Sector				**21**	**21**
Unknown Sector & Category				21	21
Total	**69**	**63**	**13**	**35**	**180**

Figure 4: Ownership Status (Table)

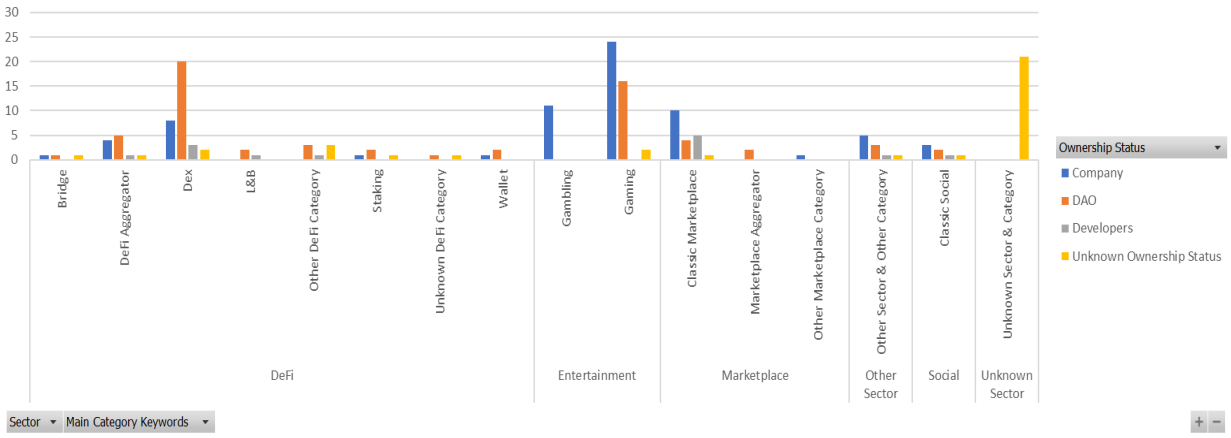

Figure 5: Ownership Status (Graph)

In the DeFi sector, the DAO model is very popular, with 36 out of 66 dapps adopting this form of governance. This allows a greater degree of engagement with community members, often made up of experienced individuals who have an interest in monitoring the functioning of the dapp and proposing improvements. This is due to the fact that in decentralized finance services many times users provide their assets as

liquidity and in general aim for an economic return or access to the most convenient services. It must also be taken into account that Centralized Exchanges that allow the purchase and sale of tokens have often been at the center of illegal behavior and scams that have stolen huge sums of money from users. Adopting decentralized Governance certainly creates a more transparent and accountable environment.

As for the Entertainment section, in Gaming the DAO model is not widespread, with only 16 DAOs out of 42. Users of these platforms aim for a more entertainment-centric experience and are likely less experienced than those who populate DeFi services. In addition, a very high degree of transparency is not required and for the community to tangibly influence a video game can be really complex, as this would require knowledge in terms of game-design and balancing game mechanics.

In the Gambling category, however, no dapp follows this form of Governance. It is not difficult to understand why: dapps based on gambling offer content that is all in all quite standardized, offering more or less classic games of chance. The rules and the house edge of the platform are usually very clear, and simply the DAO model would not create additional value in any way.

The same can be said for the Marketplace sector, which has only 6 dapps out of 23 adhering to the DAO model. Users are usually not very experienced, also because of the media hype that has attracted the masses to NFTs, the rules of operation are quite static and DAOs simply would not add value significantly.

5.4. Native tokens

Native Token	0	1	//	?	Total
DeFi	12	44	2	8	66
Company	8	5	1	1	15
Bridge	1				1
DeFi Aggregator	4				4
Dex	2	4	1	1	8
Staking		1			1
Wallet	1				1
DAO	2	34			36
Bridge		1			1
DeFi Aggregator	1	4			5
Dex	1	19			20
L&B		2			2
Other DeFi Category		3			3
Staking		2			2
Unknown DeFi Category		1			1
Wallet		2			2
Developers	1	4		1	6
DeFi Aggregator		1			1
Dex		2		1	3
L&B		1			1
Other DeFi Category	1				1
Unknown Ownership Status	1	1	1	6	9
Bridge				1	1
DeFi Aggregator				1	1
Dex	1	1			2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	3	36	10	4	53
Company	3	18	10	4	35
Gambling			10	1	11
Gaming	3	18		3	24
DAO		16			16
Gaming		16			16
Unknown Ownership Status		2			2
Gaming		2			2
Marketplace	14	9			23
Company	9	2			11
Classic Marketplace	8	2			10
Other Marketplace Category	1				1
DAO	1	5			6
Classic Marketplace	1	3			4
Marketplace Aggregator		2			2
Developers	3	2			5
Classic Marketplace	3	2			5
Unknown Ownership Status	1				1
Classic Marketplace	1				1
Other Sector	1	6		3	10
Company		2		3	5
Other Sector & Other Category		2		3	5
DAO		3			3
Other Sector & Other Category		3			3
Developers	1				1
Other Sector & Other Category	1				1
Unknown Ownership Status		1			1
Other Sector & Other Category		1			1
Social	2	4		1	7
Company	2	1			3
Classic Social	2	1			3
DAO		2			2
Classic Social		2			2
Developers		1			1
Classic Social		1			1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector				21	21
Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	32	99	12	37	180

Figure 6: Native tokens (Table)

Native tokens are related only to fungible tokens, native to a certain decentralized app. In the DeFi sector, native tokens of a decentralized app are particularly popular, with 44 out of 66 dapps adopting them. There are two main reasons for this. As explained earlier, the DAO Governance model is adopted by many services that are part of this industry, and consequently Governance tokens are very common. In addition, in the DeFi sector, Farming tokens are also widely used tools.

In the category of decentralized video games, almost every dapp uses native tokens (36 out of 42). In this case, it is the Utility tokens that are an almost essential feature of this type of service: they are the basis of the in-game economy, allow you to buy and

sell in-game objects with aesthetic and / or functional elements in terms of gameplay, and build the basis for distinctive Play-to-Earn mechanisms.

As far as the Marketplace sector is concerned, dapps that exploit native tokens are a minority (9 out of 23) as there are few DAOs and consequently governance tokens are not widespread, and as buying and selling actions take place mainly through cryptocurrencies and other non-native assets compared to the single Marketplace. In gambling, the same trends are noted but even more exasperated (use of cryptocurrencies, absence of DAO and in addition absence of products / services to buy), and there is no dapps with tokens native to the ecosystem.

5.4.1. Utility tokens

Utility Token	0	1	//	?	Total
DeFi	26	15	14	11	66
Company	2	3	9	1	15
Bridge			1		1
DeFi Aggregator			4		4
Dex	1	3	3	1	8
Staking	1				1
Wallet			1		1
DAO	22	10	2	2	36
Bridge	1				1
DeFi Aggregator	2	2	1		5
Dex	12	6	1	1	20
L&B	2				2
Other DeFi Category	3				3
Staking	1	1			2
Unknown DeFi Category				1	1
Wallet	1	1			2
Developers	2	2	1	1	6
DeFi Aggregator		1			1
Dex	1	1		1	3
L&B	1				1
Other DeFi Category			1		1
Unknown Ownership Status			2	7	9
Bridge				1	1
DeFi Aggregator				1	1
Dex			1	1	2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	1	35	13	4	53
Company		18	13	4	35
Gambling			10	1	11
Gaming		18	3	3	24
DAO	1	15			16
Gaming	1	15			16
Unknown Ownership Status		2			2
Gaming		2			2
Marketplace	5	4	14		23
Company		2	9		11
Classic Marketplace		2	8		10
Other Marketplace Category			1		1
DAO	4	1	1		6
Classic Marketplace	2	1	1		4
Marketplace Aggregator	2				2
Developers	1	1	3		5
Classic Marketplace	1	1	3		5
Unknown Ownership Status			1		1
Classic Marketplace			1		1
Other Sector	3	3	1	3	10
Company	1	1		3	5
Other Sector & Other Category	1	1		3	5
DAO	2	1			3
Other Sector & Other Category	2	1			3
Developers			1		1
Other Sector & Other Category			1		1
Unknown Ownership Status		1			1
Other Sector & Other Category		1			1
Social	1	3	2	1	7
Company	1		2		3
Classic Social	1		2		3
DAO		2			2
Classic Social		2			2
Developers		1			1
Classic Social		1			1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector				21	21
Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	36	60	44	40	180

Figure 7: Utility tokens (Table)

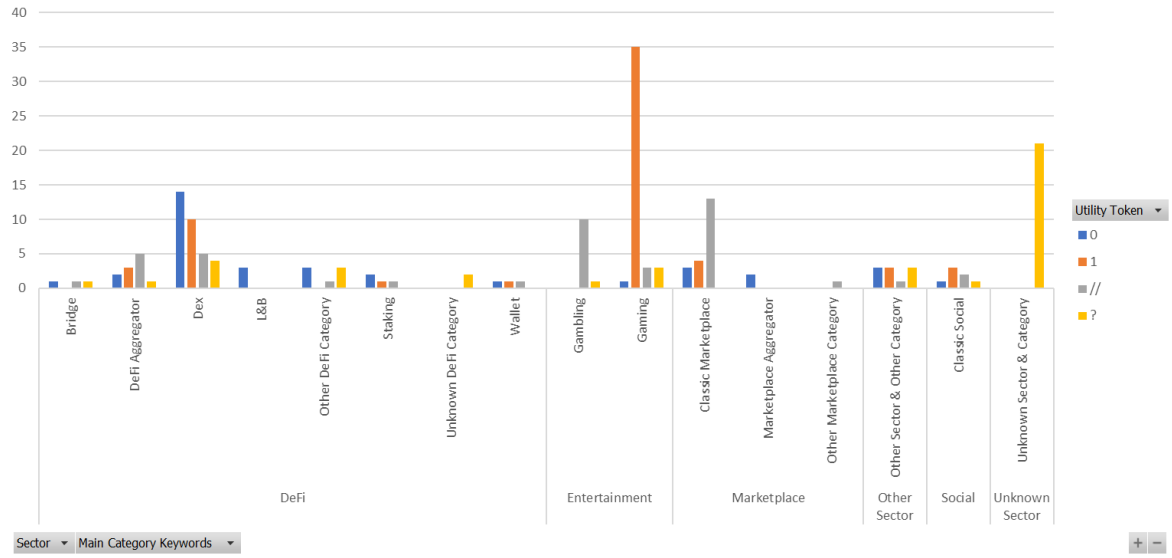

Figure 8: Utility tokens (Graph)

In the DeFi and Marketplace sectors, these tokens are very little used (respectively 15 out of 66 and 4 out of 23 dapps). In the sector of decentralized finance, they are not a common tool because there are no real services or goods to be purchased, but operations to be carried out. In the Marketplaces, trading operations take place mainly through cryptocurrencies or external assets, not native to the single ecosystem.

In the Gaming category it is a fundamental element of the digital environments and tokenomics on which they structure the user experience. Utility tokens are the means by which it is possible to create Play-to-Earn mechanisms, regulate access to in-game items and direct users to perform certain actions. 35 out of 42 dapps implement these cryptoassets.

5.4.2. Security tokens e Real World Asset tokens

Security Token	0	//	?	Total
DeFi	41	14	11	66
Company	5	9	1	15
Bridge		1		1
DeFi Aggregator		4		4
Dex	4	3	1	8
Staking	1			1
Wallet		1		1
DAO	32	2	2	36
Bridge	1			1
DeFi Aggregator	4	1		5
Dex	18	1	1	20
L&B	2			2
Other DeFi Category	3			3
Staking	2			2
Unknown DeFi Category			1	1
Wallet	2			2
Developers	4	1	1	6
DeFi Aggregator	1			1
Dex	2		1	3
L&B	1			1
Other DeFi Category		1		1
Unknown Ownership Status		2	7	9
Bridge			1	1
DeFi Aggregator			1	1
Dex		1	1	2
Other DeFi Category			3	3
Staking		1		1
Unknown DeFi Category			1	1
Entertainment	36	13	4	53
Company	18	13	4	35
Gambling		10	1	11
Gaming	18	3	3	24
DAO	16			16
Gaming	16			16
Unknown Ownership Status	2			2
Gaming	2			2
Marketplace	9	14		23
Company	2	9		11
Classic Marketplace	2	8		10
Other Marketplace Category		1		1
DAO	5	1		6
Classic Marketplace	3	1		4
Marketplace Aggregator	2			2
Developers	2	3		5
Classic Marketplace	2	3		5
Unknown Ownership Status		1		1
Classic Marketplace		1		1
Other Sector	6	1	3	10
Company	2		3	5
Other Sector & Other Category	2		3	5
DAO	3			3
Other Sector & Other Category	3			3
Developers		1		1
Other Sector & Other Category		1		1
Unknown Ownership Status	1			1
Other Sector & Other Category	1			1
Social	4	2	1	7
Company	1	2		3
Classic Social	1	2		3
DAO	2			2
Classic Social	2			2
Developers	1			1
Classic Social	1			1
Unknown Ownership Status			1	1
Classic Social			1	1
Unknown Sector			21	21
Unknown Ownership Status			21	21
Unknown Sector & Category			21	21
Total	96	44	40	180

Figure 9: Security tokens (Table)

Real World Asset Token	0	1	//	?	Total
DeFi	40	1	14	11	66
Company	5		9	1	15
Bridge			1		1
DeFi Aggregator			4		4
Dex	4		3	1	8
Staking	1				1
Wallet			1		1
DAO	31	1	2	2	36
Bridge	1				1
DeFi Aggregator	4		1		5
Dex	18		1	1	20
L&B	2				2
Other DeFi Category	2	1			3
Staking	2				2
Unknown DeFi Category				1	1
Wallet	2				2
Developers	4		1	1	6
DeFi Aggregator	1				1
Dex	2			1	3
L&B	1				1
Other DeFi Category			1		1
Unknown Ownership Status			2	7	9
Bridge				1	1
DeFi Aggregator				1	1
Dex			1	1	2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	36		13	4	53
Company	18		13	4	35
Gambling			10	1	11
Gaming	18		3	3	24
DAO	16				16
Gaming	16				16
Unknown Ownership Status	2				2
Gaming	2				2
Marketplace	9		14		23
Company	2		9		11
Classic Marketplace	2		8		10
Other Marketplace Category			1		1
DAO	5		1		6
Classic Marketplace	3		1		4
Marketplace Aggregator	2				2
Developers	2		3		5
Classic Marketplace	2		3		5
Unknown Ownership Status			1		1
Classic Marketplace			1		1
Other Sector	6	1	1	2	10
Company	3			2	5
Other Sector & Other Category	3			2	5
DAO	2	1			3
Other Sector & Other Category	2	1			3
Developers			1		1
Other Sector & Other Category			1		1
Unknown Ownership Status	1				1
Other Sector & Other Category	1				1
Social	4		2	1	7
Company	1		2		3
Classic Social	1		2		3
DAO	2				2
Classic Social	2				2
Developers	1				1
Classic Social	1				1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector				21	21
Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	95	2	44	39	180

Figure 10: Real World Asset tokens (Table)

The very low adoption of these two instruments, from my point of view, is based on two different motivations. Real World Asset tokens, understood as fungible tokens, do not fit well with real-world assets, which can be represented more intuitively via unique NFTs. As for Security tokens, I assume that a real intersection between decentralized applications and traditional finance instruments has not yet taken place, despite the fact that at theoretical level fungible tokens are well suited to represent and manage stocks, bonds and so on.

5.4.3. Farming tokens

Farming Token	0	1	//	?	Total
DeFi	4	39	14	9	66
Company		5	9	1	15
Bridge			1		1
DeFi Aggregator			4		4
Dex		4	3	1	8
Staking		1			1
Wallet			1		1
DAO	4	29	2	1	36
Bridge		1			1
DeFi Aggregator	2	2	1		5
Dex	1	18	1		20
L&B		2			2
Other DeFi Category	1	2			3
Staking		2			2
Unknown DeFi Category				1	1
Wallet		2			2
Developers		4	1	1	6
DeFi Aggregator		1			1
Dex		2		1	3
L&B		1			1
Other DeFi Category			1		1
Unknown Ownership Status		1	2	6	9
Bridge				1	1
DeFi Aggregator				1	1
Dex		1	1		2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	12	24	13	4	53
Company	7	11	13	4	35
Gambling			10	1	11
Gaming	7	11	3	3	24
DAO	5	11			16
Gaming	5	11			16
Unknown Ownership Status		2			2
Gaming		2			2
Marketplace	2	7	14		23
Company	1	1	9		11
Classic Marketplace	1	1	8		10
Other Marketplace Category			1		1
DAO	1	4	1		6
Classic Marketplace	1	2	1		4
Marketplace Aggregator		2			2
Developers		2	3		5
Classic Marketplace		2	3		5
Unknown Ownership Status			1		1
Classic Marketplace			1		1
Other Sector	2	4	1	3	10
Company	1	1		3	5
Other Sector & Other Category	1	1		3	5
DAO	1	2			3
Other Sector & Other Category	1	2			3
Developers			1		1
Other Sector & Other Category			1		1
Unknown Ownership Status		1			1
Other Sector & Other Category		1			1
Social	2	2	2	1	7
Company	1		2		3
Classic Social	1		2		3
DAO	1	1			2
Classic Social	1	1			2
Developers		1			1
Classic Social		1			1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector				21	21
Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	22	76	44	38	180

Figure 11: Farming tokens (Table)

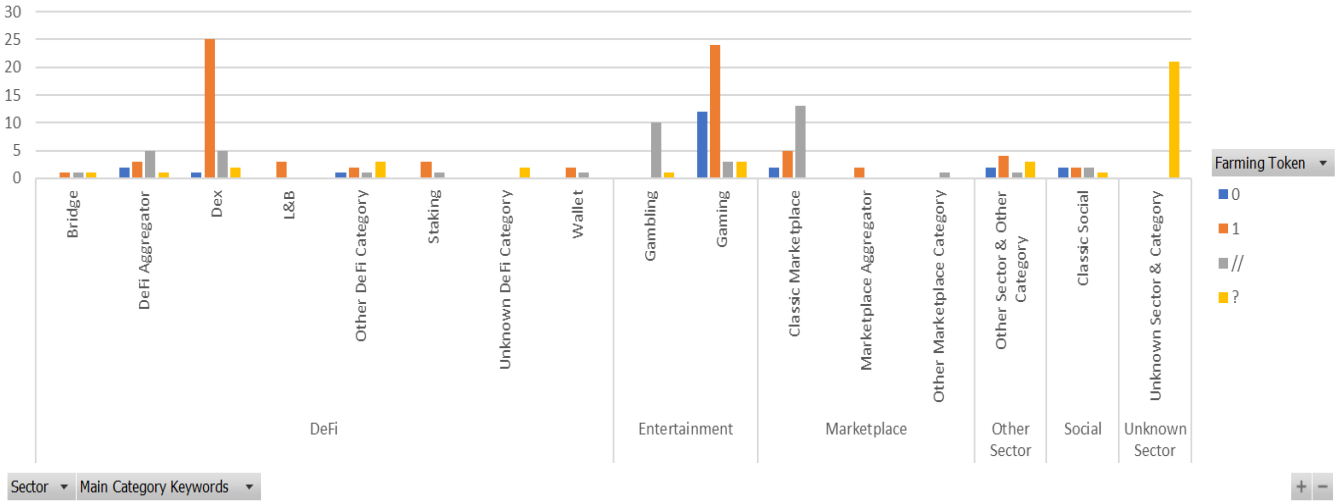

Figure 12: Farming tokens (Graph)

This type of token is very popular in the DeFi sector (39 dapps out of 66) (and in particular in the Decentralized Exchanges category, with 25 dapps out of 33) and quite in the Gaming category (24 dapps out of 42). This underlines an aspect common to the aforementioned types: part of the experience is linked to obtaining passive remuneration, a return also from an economic point of view linked to the possession of certain assets and their use in this type of practices.

In the Marketplace sector, with only 7 out of 23 dapps implementing Farming tokens, it highlights the little usefulness that these tokens have in the field under analysis.

5.4.4. Governance tokens

In general, a Governance Token is the main tool adopted by the DAO to regulate operations, allowing users to vote and usually assigning a weight proportional to the amount of tokens held. Although this type of token can involve some risks, such as speculation on the tokens themselves and plutocratic environments, it is evident that among the advantages there is immediacy, intuitiveness and appreciation of the tokens themselves.

Governance Token	0	1	//	?	Total
DeFi	6	37	14	9	66
Company	5		9	1	15
Bridge			1		1
DeFi Aggregator			4		4
Dex	4		3	1	8
Staking	1				1
Wallet			1		1
DAO		34	2		36
Bridge		1			1
DeFi Aggregator		4	1		5
Dex		19	1		20
L&B		2			2
Other DeFi Category		3			3
Staking		2			2
Unknown DeFi Category		1			1
Wallet		2			2
Developers	1	3	1	1	6
DeFi Aggregator	1				1
Dex		2		1	3
L&B		1			1
Other DeFi Category			1		1
Unknown Ownership Status			2	7	9
Bridge				1	1
DeFi Aggregator				1	1
Dex			1	1	2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	12	24	13	4	53
Company	12	6	13	4	35
Gambling			10	1	11
Gaming	12	6	3	3	24
DAO		16			16
Gaming		16			16
Unknown Ownership Status		2			2
Gaming		2			2
Marketplace	4	5	14		23
Company	2		9		11
Classic Marketplace	2		8		10
Other Marketplace Category			1		1
DAO		5	1		6
Classic Marketplace		3	1		4
Marketplace Aggregator		2			2
Developers	2		3		5
Classic Marketplace	2		3		5
Unknown Ownership Status			1		1
Classic Marketplace			1		1
Other Sector	3	3	1	3	10
Company	2			3	5
Other Sector & Other Category	2			3	5
DAO		3			3
Other Sector & Other Category		3			3
Developers			1		1
Other Sector & Other Category			1		1
Unknown Ownership Status	1				1
Other Sector & Other Category	1				1
Social	1	3	2	1	7
Company	1		2		3
Classic Social	1		2		3
DAO		2			2
Classic Social		2			2
Developers		1			1
Classic Social		1			1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector				21	21
Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	26	72	44	38	180

Figure 13: Governance tokens (Table)

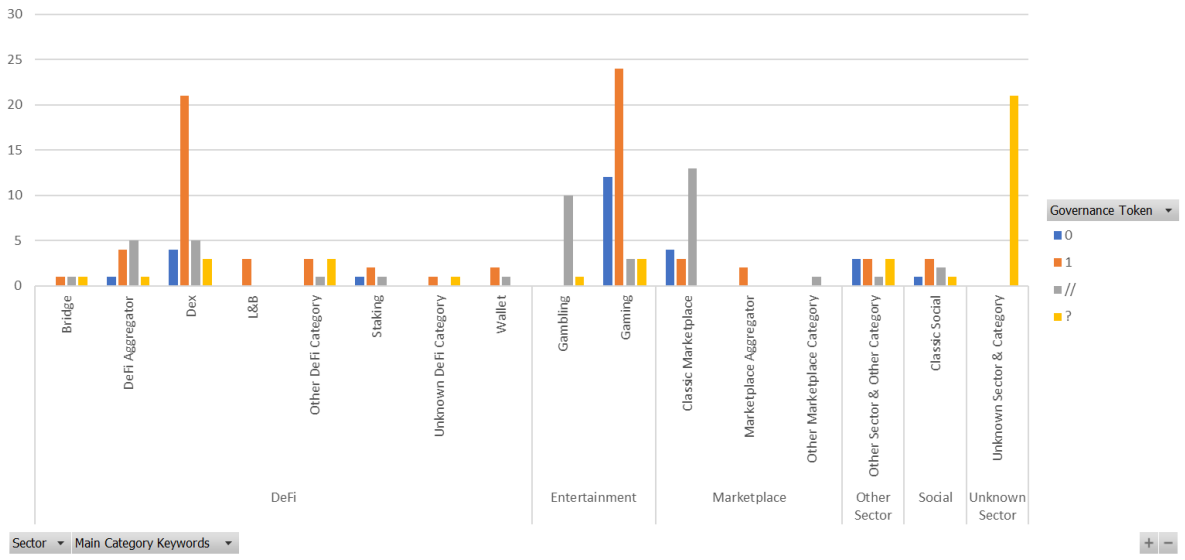

Figure 14: Governance tokens (Graph)

Beyond the mere quantitative analysis, which obviously sees the Governance tokens dominant among the DAOs and consequently the sectors and categories that most adopt this form of governance, it is of absolute interest the analysis of three phenomena, which, although quantitatively of little impact, provide very interesting reflections.

There are DAOs that do not take advantage of Governance tokens but rely on other tools to autonomously regulate the activities of the digital environment. An example is represented by particular non-fungible Identity & Membership tokens, which, depending on certain parameters, provide certain privileges to those who hold them.

There are dapps that adopt Governance tokens, but they are not DAOs. They leverage these tools to create a greater sense of community, interaction and engagement with end users, to gather ideas, but developers/owners hold almost all decision-making power.

Then there are dapps that are not yet DAO, but that will be in the future, and that have already implemented the tokens that will work for governance. This highlights how the choice to adopt a DAO model is not a binary decision and completely polarized between two extremes: it is rather a grayscale. It is in fact quite common for a decentralized project to start with centralized governance, giving full power to developers and other major players, and then progressively cede control to users according to their own roadmap. It is important to give the direction of the project, transmit a certain philosophy to the community and ensure that a certain degree of maturity is reached.

5.5. NFTs

NFT	0	1	//	?	Total
DeFi	35	22	2	7	66
Company	8	5	1	1	15
Bridge	1				1
DeFi Aggregator	3	1			4
Dex	3	3	1	1	8
Staking	1				1
Wallet		1			1
DAO	22	13		1	36
Bridge	1				1
DeFi Aggregator	2	3			5
Dex	12	8			20
L&B	2				2
Other DeFi Category	2	1			3
Staking	2				2
Unknown DeFi Category				1	1
Wallet	1	1			2
Developers	3	3			6
DeFi Aggregator	1				1
Dex	1	2			3
L&B	1				1
Other DeFi Category		1			1
Unknown Ownership Status	2	1	1	5	9
Bridge				1	1
DeFi Aggregator		1			1
Dex	2				2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	2	40	11		53
Company	2	22	11		35
Gambling			11		11
Gaming	2	22			24
DAO		16			16
Gaming		16			16
Unknown Ownership Status		2			2
Gaming		2			2
Marketplace		23			23
Company		11			11
Classic Marketplace		10			10
Other Marketplace Category		1			1
DAO		6			6
Classic Marketplace		4			4
Marketplace Aggregator		2			2
Developers		5			5
Classic Marketplace		5			5
Unknown Ownership Status		1			1
Classic Marketplace		1			1
Other Sector	2	7		1	10
Company		4		1	5
Other Sector & Other Category		4		1	5
DAO	2	1			3
Other Sector & Other Category	2	1			3
Developers		1			1
Other Sector & Other Category		1			1
Unknown Ownership Status		1			1
Other Sector & Other Category		1			1
Social		6		1	7
Company		3			3
Classic Social		3			3
DAO		2			2
Classic Social		2			2
Developers		1			1
Classic Social		1			1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector		1		20	21
Unknown Ownership Status		1		20	21
Unknown Sector & Category		1		20	21
Total	39	99	13	29	180

Figure 15: NFTs (Table)

As for the DeFi sector, with only 22 dapps out of 66 implementing these cryptoassets, it is highlighted that this type of tools is not particularly useful in the sector, in an environment where fungibility is a common characteristic of the resources treated.

All dapps in the Marketplace sector have NFTs in them. This testifies that this type of asset is the fulcrum on which these platforms are based. NFTs, and especially those related to the artistic field, have become extremely popular in mass culture, even among users who are not at all experienced in Blockchain. This is mainly due to the various celebrities who have advertised and / or bought some non-fungible tokens at astronomical figures, making them iconic and desired.

Even in the Gaming category, with 40 out of 42 dapps adopting these tools, their importance is highlighted. For decentralized video games, NFTs are the main way in which cosmetic and functional objects in terms of gameplay are bought, sold or traded. This is a key aspect of this kind of digital ecosystem, which clearly differs these services from traditional counterparts. The objects in play with NFTs become unique, transferable outside the game, and to which an economic value can be attributed.

5.5.1. Collectibles

Collectibles NFT	0	1	//	?	Total
DeFi	5	8	37	16	66
Company	1	2	9	3	15
Bridge			1		1
DeFi Aggregator			3	1	4
Dex	1	1	4	2	8
Staking			1		1
Wallet		1			1
DAO	3	5	22	6	36
Bridge			1		1
DeFi Aggregator		1	2	2	5
Dex	2	4	12	2	20
L&B			2		2
Other DeFi Category	1		2		3
Staking			2		2
Unknown DeFi Category				1	1
Wallet			1	1	2
Developers	1	1	3	1	6
DeFi Aggregator			1		1
Dex	1	1	1		3
L&B			1		1
Other DeFi Category				1	1
Unknown Ownership Status			3	6	9
Bridge				1	1
DeFi Aggregator				1	1
Dex			2		2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
Entertainment	21	19	13		53
Company	10	12	13		35
Gambling			11		11
Gaming	10	12	2		24
DAO	9	7			16
Gaming	9	7			16
Unknown Ownership Status	2				2
Gaming	2				2
Marketplace		23			23
Company		11			11
Classic Marketplace		10			10
Other Marketplace Category		1			1
DAO		6			6
Classic Marketplace		4			4
Marketplace Aggregator		2			2
Developers		5			5
Classic Marketplace		5			5
Unknown Ownership Status		1			1
Classic Marketplace		1			1
Other Sector	2	2	2	4	10
Company	1	1		3	5
Other Sector & Other Category	1	1		3	5
DAO	1		2		3
Other Sector & Other Category	1		2		3
Developers		1			1
Other Sector & Other Category		1			1
Unknown Ownership Status				1	1
Other Sector & Other Category				1	1
Social	3	2		2	7
Company	2	1			3
Classic Social	2	1			3
DAO	1	1			2
Classic Social	1	1			2
Developers				1	1
Classic Social				1	1
Unknown Ownership Status				1	1
Classic Social				1	1
Unknown Sector		1		20	21
Unknown Ownership Status		1		20	21
Unknown Sector & Category		1		20	21
Total	31	55	52	42	180

Figure 16: Collectibles NFTs (Table)

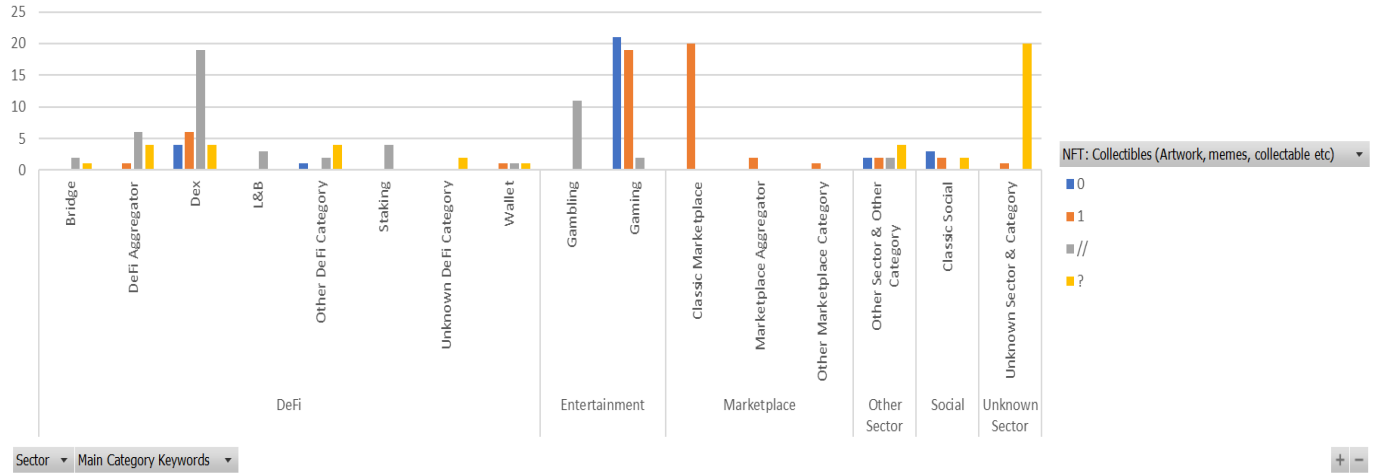

Figure 17: Collectibles NFTs (Graph)

All decentralized applications in the Marketplace industry feature this kind of NFT. As already explained, these are by far the cryptoassets that have achieved maximum popularity among the non-specialized public. They quickly became, thanks to investments reasonably defined as speculative and reckless, a trendy topic, with famous people who immediately made some iconic by buying them at very high figures.

Only 8 out of 66 dapps in the DeFi sector integrate this type of token, and this is not surprising given the low usefulness of this type of NFT in these applications.

In the Gaming category, 19 out of 42 dapps implement collectible tokens, testifying to the fact that among the game objects so sought after by users there are often also purely cosmetic elements, in most cases to embellish the equipment and appearance of their virtual avatar.

5.5.2. Gaming Assets

Gaming Item NFT	0	1	//	?	Total
⊟DeFi	8	4	37	17	66
⊟Company	1		9	5	15
Bridge			1		1
DeFi Aggregator			3	1	4
Dex	1		4	3	8
Staking			1		1
Wallet				1	1
⊟DAO	5	4	22	5	36
Bridge			1		1
DeFi Aggregator	1		2	2	5
Dex	3	3	12	2	20
L&B			2		2
Other DeFi Category	1		2		3
Staking			2		2
Unknown DeFi Category				1	1
Wallet		1	1		2
⊟Developers	2		3	1	6
DeFi Aggregator			1		1
Dex	2		1		3
L&B			1		1
Other DeFi Category				1	1
⊟Unknown Ownership Status			3	6	9
Bridge				1	1
DeFi Aggregator				1	1
Dex			2		2
Other DeFi Category				3	3
Staking			1		1
Unknown DeFi Category				1	1
⊟Entertainment	1	39	13		53
⊟Company	1	21	13		35
Gambling			11		11
Gaming	1	21	2		24
⊟DAO		16			16
Gaming		16			16
⊟Unknown Ownership Status		2			2
Gaming		2			2
⊟Marketplace	9	13		1	23
⊟Company	5	6			11
Classic Marketplace	4	6			10
Other Marketplace Category	1				1
⊟DAO	2	3		1	6
Classic Marketplace	2	1		1	4
Marketplace Aggregator		2			2
⊟Developers	1	4			5
Classic Marketplace	1	4			5
⊟Unknown Ownership Status	1				1
Classic Marketplace	1				1
⊟Other Sector	3		2	5	10
⊟Company	2			3	5
Other Sector & Other Category	2			3	5
⊟DAO	1		2		3
Other Sector & Other Category	1		2		3
⊟Developers				1	1
Other Sector & Other Category				1	1
⊟Unknown Ownership Status				1	1
Other Sector & Other Category				1	1
⊟Social	3	2		2	7
⊟Company	2	1			3
Classic Social	2	1			3
⊟DAO	1	1			2
Classic Social	1	1			2
⊟Developers				1	1
Classic Social				1	1
⊟Unknown Ownership Status				1	1
Classic Social				1	1
⊟Unknown Sector				21	21
⊟Unknown Ownership Status				21	21
Unknown Sector & Category				21	21
Total	24	58	52	46	180

Figure 18: Gaming Items NFTs (Table)

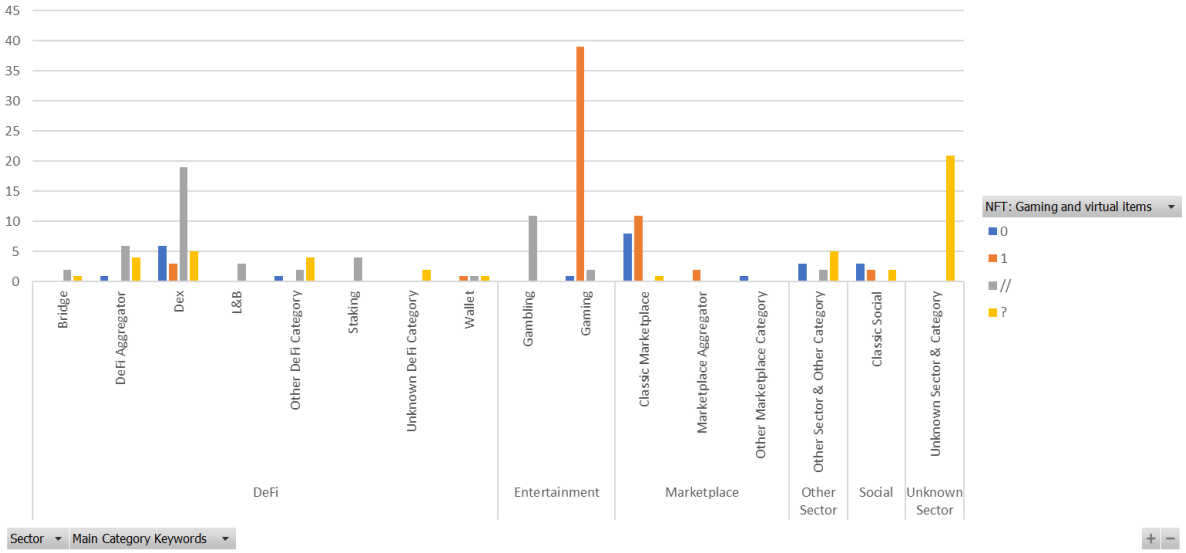

Figure 19: Gaming Items NFTs (Graph)

As for the in-game objects represented by NFTs, obviously almost all decentralized applications in the gaming category implement them (39 dapps out of 42). As already mentioned, this is the feature that revolutionizes the traditional video game sector, making in-game objects transferable, no longer imprisoned in a specific virtual world and in the inventory of a single player, and able to acquire economic value.

Given their importance, it is not surprising that 13 out of 23 dapps in the Marketplace sector deal with this type of objects, so used and popular among end users. Almost unused, as predictable, in the DeFi sector, where they can play neither a central role nor be of particular use.

5.6. Balance, Volume and Transactions

Balance, UAW, Volume	AVG Balance ($)	AVG UAW	AVG Volume ($)
DeFi	199.248.164	81.568	3.394.908.155
Company	27.243.804	51.908	1.999.846.644
Bridge	752.175	27.870	155.570.000
DeFi Aggregator	10.960	62.407	85.385.417
Dex	42.964.911	47.186	3.669.983.958
Staking	86	22.595	41.320
Wallet	64.141.667	101.040	140.675.000
DAO	193.629.208	69.960	5.110.553.654
Bridge	39.145.000	36.615	276.490.000
DeFi Aggregator	1.677.522	100.654	2.884.961.500
Dex	323.737.861	56.256	8.407.395.132
L&B	49.468.750	38.115	402.401.250
Other DeFi Category	16.237.238	38.318	21.215.682
Staking	149.429.229	35.689	131.012.500
Unknown DeFi Category	327	70.163	17.283
Wallet	926.828	260.413	119.779
Developers	112.274.237	275.481	1.438.883.601
DeFi Aggregator	895.928	34.193	25.308.333
Dex	154.081.498	529.295	2.829.066.368
L&B	6.350.000	17.007	19.556.667
Other DeFi Category	204.155.000	13.803	101.237.500
Unknown Ownership Status	566.380.539	48.156	161.445.050
Bridge	3.748.333.333	23.270	822.683.333
DeFi Aggregator	1.165.000.000	29.062	33.195.000
Dex	91.875.833	53.373	297.053.333
Other DeFi Category	109.630	39.307	678.233
Staking	10.965	142.210	367.438
Unknown DeFi Category	0	14.200	618.310
Entertainment	33.416.295	73.426	2.389.998
Company	21.087.035	63.767	2.813.361
Gambling	2.838	62.016	710.089
Gaming	30.750.625	64.569	3.777.361
DAO	61.147.964	91.735	1.603.371
Gaming	61.147.964	91.735	1.603.371
Unknown Ownership Status	27.325.000	95.984	1.274.167
Gaming	27.325.000	95.984	1.274.167
Marketplace	36.562.614	97.892	363.000.334
Company	54.059	106.559	25.191.108
Classic Marketplace	40.037	104.105	25.740.719
Other Marketplace Category	194.285	131.100	19.695.000
DAO	139.926.462	155.492	1.306.041.309
Classic Marketplace	9.305.526	132.357	162.395.297
Marketplace Aggregator	401.168.333	201.763	3.593.333.333
Developers	157.324	26.357	47.125.805
Classic Marketplace	157.324	26.357	47.125.805
Unknown Ownership Status	87	14.635	28.615
Classic Marketplace	87	14.635	28.615
Other Sector	9.433.566	87.689	3.029.283
Company	342.226	148.965	148.815
Other Sector & Other Category	342.226	148.965	148.815
DAO	13.354.844	22.606	167.917
Other Sector & Other Category	13.354.844	22.606	167.917
Developers	0	37.260	0
Other Sector & Other Category	0	37.260	0
Unknown Ownership Status	52.560.000	26.988	29.045.000
Other Sector & Other Category	52.560.000	26.988	29.045.000
Social	523.023	216.845	101.347
Company	6.695	85.785	33.436
Classic Social	6.695	85.785	33.436
DAO	1.813.408	294.918	240.419
Classic Social	1.813.408	294.918	240.419
Developers	14.258	613.218	128.285
Classic Social	14.258	613.218	128.285
Unknown Ownership Status	0	57.503	0
Classic Social	0	57.503	0
Unknown Sector	2.398.365.321	213.917	2.323.272.381
Unknown Ownership Status	2.398.365.321	213.917	2.323.272.381
Unknown Sector & Category	2.398.365.321	213.917	2.323.272.381
Total	367.922.506	102.298	1.563.107.434

Figure 20: Balance, UAW, Volume (Table)

Transactions	AVG Transactions
DeFi	569.899
Company	244.874
Bridge	100.510
DeFi Aggregator	153.243
Dex	306.037
Staking	275.620
Wallet	235.709
DAO	450.041
Bridge	102.096
DeFi Aggregator	350.760
Dex	235.770
L&B	164.652
Other DeFi Category	113.348
Staking	2.888.049
Unknown DeFi Category	530.647
Wallet	944.421
Developers	2.175.611
DeFi Aggregator	1.448.598
Dex	3.844.823
L&B	29.371
Other DeFi Category	41.228
Unknown Ownership Status	435.968
Bridge	42.071
DeFi Aggregator	52.397
Dex	374.261
Staking	1.758.681
Unknown DeFi Category	14.140
Entertainment	13.900.886
Company	7.223.823
Gambling	1.057.201
Gaming	9.466.231
DAO	27.794.049
Gaming	27.794.049
Unknown Ownership Status	2.911.531
Gaming	2.911.531
Marketplace	3.491.100
Company	2.550.007
Classic Marketplace	2.765.764
Other Marketplace Category	392.430
DAO	7.952.279
Classic Marketplace	11.434.413
Marketplace Aggregator	988.010
Developers	208.090
Classic Marketplace	208.090
Other Sector	127.037
Company	176.740
Other Sector & Other Category	176.740
DAO	27.762
Other Sector & Other Category	27.762
Developers	214.480
Other Sector & Other Category	214.480
Unknown Ownership Status	88.908
Other Sector & Other Category	88.908
Social	1.957.778
Company	411.120
Classic Social	411.120
DAO	2.433.754
Classic Social	2.433.754
Developers	5.283.922
Classic Social	5.283.922
Unknown Ownership Status	2.319.656
Classic Social	2.319.656
Unknown Sector	1.865.569
Unknown Ownership Status	1.865.569
Unknown Sector & Category	1.865.569
Total	5.257.574

Figure 21: Transactions (Table)

The average value over the entire horizon for the Balance attribute is significantly higher for the DeFi sector. This result highlights the importance of Total Value of Assets locked in this type of service. In platforms that offer Decentralized Exchange, Bridge, Lending & Borrowing or Staking services, the amount of cryptoassets deposited directly influences the quality of the offer. A richer pool generally implies a greater quantity (and probably variety) of tradable tokens, considering Decentralized Exchanges, for example.

As for the values relating to the Volume attribute (referring to the volume transacted) and Transactions (number of transactions) it is of absolute interest to dwell on the values relating to the Gaming and Gambling categories. The number of transactions related to these two types of services is significantly higher than that of applications belonging to the Marketplace and DeFi sectors. This is due to the fact that in applications such as video games or decentralized casinos, numerous transactions are made of low amount and with high frequency, for example to repeatedly take part in gaming sessions that require a low amount of entry, or to purchase in-game items. This interpretation is reinforced by the analysis of the relationship between transaction volume and number of transactions: for the Gaming and Gambling categories it stands at 0.17 and 0.67 respectively, while for the dapps of the DeFi and Marketplace sectors at 5957.03 and 103.97 respectively. For dapps with a high number of low amount transactions, properties such as the scalability of the protocols on which they operate are fundamental, to avoid incurring network congestion or fees that are too high compared to the amount of the payment itself.

5.7. Multichain and Layer 2

Multichain	0	1	?	Total
DeFi	**26**	**40**		**66**
Bridge	1	2		3
DeFi Aggregator	1	10		11
Dex	17	16		33
L&B	1	2		3
Other DeFi Category	2	5		7
Staking	1	3		4
Unknown DeFi Category	2			2
Wallet	1	2		3
Entertainment	**39**	**14**		**53**
Gambling	9	2		11
Gaming	30	12		42
Marketplace	**14**	**9**		**23**
Classic Marketplace	11	9		20
Marketplace Aggregator	2			2
Other Marketplace Category	1			1
Other Sector	**7**	**3**		**10**
Other Sector & Other Category	7	3		10
Social	**5**	**2**		**7**
Classic Social	5	2		7
Unknown Sector	**12**	**6**	**3**	**21**
Unknown Sector & Category	12	6	3	21
Total	**103**	**74**	**3**	**180**

Figure 22: Multichain (Table)

As for the data relating to dapps operating on more than one protocol, there are mainly two reflections that emerge. With 40 out of 66 dapps operating in a multichain mode, the DeFi sector appears to be the most interoperable and whose services are compatible

with multiple protocols. It also emerges that the dapps of the Entertainment sector are more tied to individual protocols and their specific priorities: in the Gaming category only 12 dapps out of 42 are deployed on more than one chain, and only 2 out of 11 dapps in the Gambling category do the same.

Layer 2	0	1	?	Total
DeFi	17	48	1	66
Bridge	1	2		3
DeFi Aggregator	1	10		11
Dex	8	24	1	33
L&B	1	2		3
Other DeFi Category		7		7
Staking	2	2		4
Unknown DeFi Category	1	1		2
Wallet	3			3
Entertainment	18	34	1	53
Gambling	10	1		11
Gaming	8	33	1	42
Marketplace	16	7		23
Classic Marketplace	13	7		20
Marketplace Aggregator	2			2
Other Marketplace Category	1			1
Other Sector	3	7		10
Other Sector & Other Category	3	7		10
Social		7		7
Classic Social		7		7
Unknown Sector	8	10	3	21
Unknown Sector & Category	8	10	3	21
Total	62	113	5	180

Figure 23: Layer 2 (Table)

As highlighted above, it is reasonable to think that scalability is a great prerogative in particular for dapps that are part of the Entertainment sector, which by their nature involve a high number of low-value transactions to perform often repetitive operations. The Gaming category operates on at least one Layer 2 protocol in 33 out of 42 cases, while the Gambling category only in 1 out of 11. This is related to the fact that the dapps in this category are based on the ThunderCore protocol, which although not a Layer 2 solution, intrinsically has the properties, including scalability, required by this kind of services.

5.8. Protocols

The most popular protocols are Polygon (60 dapps), BNB Chain (59 dapps) and Ethereum (45 dapps). Polygon is a Layer 2 protocol, an Ethereum sidechain network, so its massive presence is not surprising. This is a way to overcome the scalability problem that afflicts Ethereum, which remains the reference platform for decentralized applications for programmability and functionality.

BNB Chain is the second chain developed by the giant of Centralized Exchanges Binance. It has been designed specifically for the development of decentralized applications, focusing on the possibility of transferring digital assets between different protocols and offering low-latency services.

As for the presence in the ranking of Ethereum, this is a fully predictable figure. This is the protocol that accompanied the birth of decentralized applications, constituting a real decentralized computer born to perform almost any operation.

It is interesting to note that the ThunderCore protocol is used in all dapps in the Gambling category. This protocol is not only EVM-compatible (Ethereum Virtual Machine compatible) but is structured to be efficient and scalable in making transactions. All these characteristics, as mentioned in the previous paragraphs, are fundamental for this category of services.

6 Conclusions

6.1. Answers to Research Questions

The analysis carried out made it possible to successfully answer the research questions.

The protocols of greatest interest in general are:

- Polygon, which improves the scalability of the Ethereum network as a sidechain network;

- BNB Chain, thanks to its compatibility with Ethereum Virtual Machine and its properties that make it suitable for the development of decentralized applications;

-Ethereum, a real pillar on which the world of Web 3.0 and decentralized applications is based, the first true decentralized computer at a global level;

- ThundeCore, a protocol that thanks to its features has become the reference point in practically the entire category of decentralized gambling.

Decentralized governance models are ideal for Decentralized Finance (DeFi) applications, which have a typically experienced user base and require transparency and accountability on the use of the resources they provide and on the activities of the platforms. In any case, the results highlighted how the adoption of a DAO (Decentralized Autonomous Organization) model is not just a binary choice but a path, the evolution of a project that gradually passes from total control of developers into the hands of a community that over time must mature and understand the correct direction.

The quantitative metrics highlighted the importance of Total Value of Assets locked in DeFi applications, which is necessary for the services provided to be effective. It also emerged that the applications of the Gaming and Gambling categories present a high number of transactions of low amount, requiring technological solutions suitable for this dynamic.

The fungible tokens most used by decentralized applications are Governance tokens, the favorite tool of almost every DAO, Farming tokens, implemented in ecosystems where you want to encourage the possession of a certain token to earn passively, and Utility tokens, a fundamental resource especially in the Gaming category, to regulate access and sale of services and / or products.

As for non-fungible tokens, the most popular are certainly those related to the art world, which crowd the virtual windows of the Marketplaces and have become a real mass trend, and Gaming Assets, which have revolutionized video games allowing the purchase and sale of objects no longer imprisoned in a single virtual environment and devoid of economic value.

6.2. Further Developments

However, a new census of this kind could provide additional information. With more resources in terms of time and information sources, similar research could be conducted with a longer time horizon, and adequately investigating the impact of certain events on quantitative data.

Blockchain and decentralized applications are a constantly evolving environment subject to rapid innovations that disrupt the status quo. Both decision-making and technological events (such as the passing of the Ethereum protocol to the Proof of Stake consensus algorithm) and of a legal / social nature (scandals related to scams such as in some cases of Centralized Exchanges, computer crimes against certain actors, legislative changes that undermine the value or functioning of certain cryptoassets in some countries) can have a decisive impact on the services offered and on the behavior of users.

However, observing consequences of this type requires precise work, to avoid establishing unfounded and fallacious causal relationships, and therefore without being able to really grasp the consequences and externalities of these phenomena.

It would also be interesting to have the opportunity to carry out interviews with actors linked to prominent realities and who stand out in the panorama of decentralized applications. In this way, we could better understand the path of evolution that has characterized some decentralized applications, which over time have diversified the services offered to become varied ecosystems and / or have incrementally decentralized governance. In this second case, for example, we could better understand every difficulty that the steps of this path entail, and at the same time the change in the relationship with the community.

List of Figures

Figure 1: UAW in each draw 56
Figure 2: Sectors and Categories (Table) 57
Figure 3: Sectors and Categories (Graph) 58
Figure 4: Ownership Status (Table) 59
Figure 5: Ownership Status (Graph) 59
Figure 6: Native tokens (Table) 61
Figure 7: Utility tokens (Table) 62
Figure 8: Utility tokens (Graph) 63
Figure 9: Security tokens (Table) 64
Figure 10: Real World Asset tokens (Table) 65
Figure 11: Farming tokens (Table) 66
Figure 12: Farming tokens (Graph) 67
Figure 13: Governance tokens (Table) 68
Figure 14: Governance tokens (Graph) 69
Figure 15: NFTs (Table) 70
Figure 16: Collectibles NFTs (Table) 71
Figure 17: Collectibles NFTs (Graph) 72
Figure 18: Gaming Items NFTs (Table) 73
Figure 19: Gaming Items NFTs (Graph) 74
Figure 20: Balance, UAW, Volume (Table) 75
Figure 21: Transactions (Table) 76
Figure 22: Multichain (Table) 77
Figure 23: Layer 2 (Table) 78

Bibliography

Academic Literature

1. Carlos Santana, Laura Albareda; *Blockchain and the emergence of Decentralized Autonomous Organizations (DAOs): An integrative model and research agenda;* Technological Forecasting & Social Change 182 (2022) 121806; https://doi.org/10.1016/j.techfore.2022.121806

2. Jei Young Lee; *A decentralized token economy: How blockchain and cryptocurrency can revolutionize business;* Business Horizons (2019) 62, 773e784; https://doi.org/10.1016/j.bushor.2019.08.003

3. Yuen C. Lo, Francesca Medda; *Assets on the blockchain: An empirical study of Tokenomics;* Information Economics and Policy 53 (2020) 100881; https://doi.org/10.1016/j.infoecopol.2020.100881

4. Yi Sun, Shiqing Jiang, Wanjiao Jia, Yu Wang; *Blockchain as a cutting-edge technology impacting business: A systematic literature review perspective*; Telecommunications Policy 46 (2022) 102443; https://doi.org/10.1016/j.telpol.2022.102443

5. Zhiyong Liu, Yueping Li, Qingfei Min, Mengting Chang; *User incentive mechanism in blockchain-based online community: An empirical study of steemit;* Information & Management 59 (2022) 103596; https://doi.org/10.1016/j.im.2022.103596

6. Tharaka Hewa, Mika Ylianttila, Madhusanka Liyanage; *Survey on blockchain based smart contracts: Applications, opportunities and challenges*; Journal of Network and Computer Applications 177 (2021) 102857; https://doi.org/10.1016/j.jnca.2020.102857

7. Yan Chen, Cristiano Bellavitis; *Blockchain disruption and decentralized finance: The rise of decentralized business models;* Journal of Business Venturing Insights 13 (2020) e00151; https://doi.org/10.1016/j.jbvi.2019.e00151

8. Daniel Burkhardt, Maximilian Werling, Heiner Lasi; *Distributed Ledger*; 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC); DOI: 10.1109/ICE.2018.8436299

9. Kaidong Wu; *An Empirical Study of Blockchain-based Decentralized Applications;* https://doi.org/10.48550/arXiv.1902.04969

10. Peilin Zheng; Zigui Jiang; Jiajing Wu; Zibin Zheng; *Blockchain-Based Decentralized Application: A Survey*; IEEE Open Journal of the Computer Society (Volume: 4); DOI**:** 10.1109/OJCS.2023.3251854

11. Samiur Khan, Md. Al-Amin, Hrittik Hossain, Nawshad Noor, Md. Wahid Sadik; *A Pragmatical Study on Blockchain Empowered Decentralized Application Development Platform;* ICCA 2020: Proceedings of the International Conference on Computing AdvancementsJanuary 2020Article No.: 82Pages 1–9; https://doi.org/10.1145/3377049.3377136

12. Chibuzor Udokwu, Henry Anyanka, Alex Norta; *Evaluation of Approaches for Designing and Developing Decentralized Applications on Blockchain;* ICACS '20: Proceedings of the 4th International Conference on Algorithms, Computing and SystemsJanuary 2020Pages 55–62; https://doi.org/10.1145/3423390.3426724

13. Sourav Verma, Sonali Das, Ankita Joshi, Kavita; *A Detailed Study of Blockchain and dapps*; 022 International Conference on Cyber Resilience (ICCR) | 978-1-6654-6122-1/22/$31.00 ©2022 IEEE; DOI: 10.1109/ICCR56254.2022.9996003

14. Rajkumar Banoth, Maharshi B. Dave; *A Survey on Decentralized Application based On Blockchain Platform*; 2 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS) | 978-1-6654-7884-7/22/$31.00 ©2022 IEEE; DOI: 10.1109/ICSCDS53736.2022.9760861

15. Shanthi P, Dr.K. Venkatesh; *An Analysis of Various Techniques in Blockchain Applications*; 2022 6th International Conference on Intelligent Computing and

Control Systems (ICICCS) | 978-1-6654-1035-9/22/$31.00 ©2022 IEEE; DOI: 10.1109/ICICCS53718.2022.9788137

16. Maximilian Wohrer, Uwe Zdun; *Architectural Design Decisions for Blockchain-Based Applications*; 2021 IEEE International Conference on Blockchain and Cryptocurrency (ICBC) | 978-1-6654-3578-9/20/$31.00 ©2021 IEEE; DOI: 10.1109/ICBC51069.2021.9461109

17. Wei Cai,Zehua Wang, Jason B. Ernst, Zhen Hong, Chen Feng, Victor C. M. Leung; *Decentralized Applications: The Blockchain-Empowered Software System*; Digital Object Identifier 10.1109/ACCESS.2018.2870644

18. Bilal Bin Mahmood, Muhammad Muazzam, Nadia Mumtaz and Sajjad Hussain Shah; *A Technical Review on Blockchain Technologies: Applications, Security Issues & Challenges;* International Journal of Computing and Communication Networks, ISSN: 2664-9519 (Online); Vol. 1, Issue 1, August 2019; DOI: 10.1109/ICSGRC53186.2021.9515276

19. Claudia Antal, Tudor Cioara, Ionut Anghel, Marcel Antal, Ioan Salomie; *Distributed Ledger Technology Review and Decentralized Applications Development Guidelines;* https://doi.org/10.3390/fi13030062

20. Tian Min, Wei Cai; *Portrait of decentralized application users: an overview based on large-scale Ethereum data;* CCF Transactions on Pervasive Computing and Interaction (2022) 4:124–141; https://doi.org/10.1007/s42486-022-00094-6

21. Wu, K., Ma, Y., Huang, G., Liu, X.; *A first look at blockchain-based decentralized applications;* (2021) Software - Practice and Experience, 51 (10), pp. 2033-2050.; DOI: 10.1002/spe.2751

22. Pham, V.-B., Trinh, T.-D.; *Analysis Model for Decentralized Lending Protocols;* (2022) ACM International Conference Proceeding Series, pp. 405-412.; DOI: 10.1145/3568562.3568650

23. Eikmanns, B.C., Mehrwald, P., Sandner, P.G., Welpe, I.M; *Decentralised finance platform ecosystems: conceptualisation and outlook;* (2023) Technology Analysis and Strategic Management; DOI: 10.1080/09537325.2022.2163886

24. Pincheira, M., Donini, E., Vecchio, M., Giaffreda, R.; *Towards an Infrastructure Cost Model for Blockchain-Based Applications;* (2023) Lecture Notes in Networks and Systems, 595 LNNS, pp. 345-355.; DOI: 10.1007/978-3-031-21229-1_32

25. Cui, W., Sun, Y., Zhou, J., Wang, Y., Huang, L., Yan, Y.; *Understanding the Blockchain Ecosystem with Analysis of Decentralized Applications: An Empirical Study;* (2021) ACM International Conference Proceeding Series, pp. 38-44.; DOI: 10.1145/3459012.3459018

26. Tian Min; Hanyi Wang; Yaoze Guo; Wei Cai; *Blockchain Games: A Survey*; 2019 IEEE Conference on Games (CoG); DOI: 10.1109/CIG.2019.8848111

27. Alessandro Fusco; *Decentralized Applications: an Empirical Analysis of their Revenue Models and Governance Systems*; Master of Science Thesis; https://www.politesi.polimi.it/handle/10589/179487

28. Santosh Kumar Singh, Vikas Rao Vadi, Rajesh Kumar Tiwari, Ajay Kumar Pathak; *The Role of Blockchain in Commercial Revolution;* 2021 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST) | 978-1-6654-6633-2/22/$31.00 ©2022 IEEE; DOI: 10.1109/ICRTCST54752.2022.9781869

29. Yue Zeng, Yue Zhang; *Review of research on blockchain application development method*; IOP Conf. Series: Journal of Physics: Conf. Series 1187 (2019) 052005; doi:10.1088/1742-6596/1187/5/052005

30. Satoshi Nakamoto; *Bitcoin: A Peer-to-Peer Electronic Cash System;* https://bitcoin.org/en/bitcoin-paper

31. Qin Wang, Rujia Li, Qi Wang, Shiping Chen; *Non-Fungible Token (NFT): Overview, Evaluation, Opportunities and Challenges;* https://doi.org/10.48550/arXiv.2105.07447

32. Saurabh Suratkar, Mahesh Shirole, Sunil Bhirud; *Cryptocurrency Wallet: A Review;* 2020 4th International Conference on Computer, Communication and Signal Processing (ICCCSP); DOI: 10.1109/ICCCSP49186.2020.9315193

33. Luke Tredinnick; *Cryptocurrencies and the blockchain;* Business Information Review 2019, Vol. 36(1) 39–44; DOI: 10.1177/0266382119836314

34. Anamika Chauhan, Om Prakash Malviya, Madhav Verma, Tejinder Singh Mor; *Blockchain and Scalability*; IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C); DOI: 10.1109/QRS-C.2018.00034

35. Giulio Caldarelli; *Understanding the Blockchain Oracle Problem: A Call for Action;* Information 2020, 11(11), 509; https://doi.org/10.3390/info11110509

36. Amit Kumar Goel, Rahul Bakshi, Krishna Kant Agrawal; *Web 3.0 and Decentralized Applications*; International Conference on Innovative Research in Renewable Energy Technologies, West Bengal, India, 16–17 March 2022; https://doi.org/10.3390/materproc2022010008

37. Vitalik Buterin; *Ethereum: Platform Review*; Opportunities and Challenges for Private and Consortium Blockchains; https://files.gitter.im/cyberFund/cyber.fund/P8Xb/314477721-Ethereum-Platform-Review-Opportunities-and-Challenges-for-Private-and-Consortium-Blockchains-_1_.pdf

38. Oliveira, Luis; Zavolokina, Liudmila; Bauer, Ingrid; Schwabe, Gerhard; *To Token or not to Token: Tools for Understanding Blockchain Tokens.* In: International Conference of Information Systems (ICIS 2018), San Francisco, USA, 12 December 2018 - 16 December 2018, ICIS; https://doi.org/10.5167/uzh-157908

39. Léo Besançon, Catarina Ferreira Da Silva, Parisa Ghodous, Jean-Patrick Gelas; *A Blockchain Ontology for DApps Development*; IEEE Access (Volume: 10); DOI**:** 10.1109/ACCESS.2022.3173313

Gray Literature

1. [https://www.bitpanda.com/academy/it/lezioni/il-whitepaper-di-bitcoin-spiegato-in-maniera-semplice/]
2. [https://bottinelli-marina.medium.com/https-medium-com-bottinelli-marina-blockchain-il-protocollo-di-consenso-ea13afdd48f3]
3. [https://it.wikipedia.org/wiki/Criptovaluta#Crypto_token]
4. [https://www.researchgate.net/profile/Jan-Lansky-2]
5. [https://blog.osservatori.net/it_it/distributed-ledger-technology-significato]
6. [https://it.wikipedia.org/wiki/Registro_distribuito]
7. [https://www.spindox.it/it/la-classificazione-delle-blockchain/#:~:text=Esistono%20principalmente%20tre%20tipologie%20di%20

Blockchain%3A%20pubbliche%2C%20permissioned,modalit%C3%A0%2C%20per%20creare%20registri%20personalizzati%20per%20applicazioni%20specifiche.]
8. [https://www.blockchain4innovation.it/mercati/industria4-0/blockchain-layer-2-cose-e-come-funziona-la-soluzione-per-incrementare-velocita-e-scalabilita/]
9. [https://academy.youngplatform.com/blockchain/scalabilita-soluzioni-layer-2/]
10. [https://knobs.it/cose-un-wallet-e-come-funziona/]
11. [https://rankia.it/criptovalute/bitcoin-vs-ethereum-quali-sono-le-differenze/]
12. [https://www.finaria.it/criptovalute/ethereum-vs-bitcoin/]
13. [https://blog.bitpanda.com/it/bitcoin-vs-ethereum-confronto-tra-le-piu-grandi-criptovalute-al-mondo]
14. [https://it.wikipedia.org/wiki/Web_3.0#Innovazioni_associate_con_il_Web_3.0]
15. [https://www.html.it/pag/408677/web-3-0-tra-intelligenza-artificiale-e-blockchain/]
16. [https://ethereum.org/it/web3/]
17. [https://ethereum.org/it/developers/docs/transactions/]
18. [https://www.ilsole24ore.com/art/smart-contract-cosa-sono-e-come-funzionano-clausole-blockchain-ACsDo2P]
19. [https://www.blockchain4innovation.it/mercati/legal/smart-contract/blockchain-smart-contracts-cosa-funzionano-quali-gli-ambiti-applicativi/]
20. [https://thecryptogateway.it/cosa-sono-gli-smart-contract/]
21. [https://www.punto-informatico.it/smart-contracts-tutto-cio-che-ce-da-sapere/]
22. [https://it.wikipedia.org/wiki/Smart_contract]
23. [https://ethereum.org/en/developers/docs/smart-contracts/]
24. [https://ethereum.org/en/developers/docs/gas/]
25. [https://it.m.wikipedia.org/wiki/Non-fungible_token]
26. [https://www.investopedia.com/terms/c/crypto-token.asp]
27. [https://www.coinhouse.com/learn/blockchain-technology/what-is-a-token/]
28. [https://academy.bit2me.com/it/que-es-un-token/]
29. [https://blog.osservatori.net/it_it/token-blockchain-come-funzionano]
30. [https://cointool.app/createTokenView/eth]
31. [https://topflightapps.com/ideas/how-to-create-cryptocurrency-token/]
32. [https://en.wikipedia.org/wiki/CryptoKitties]
33. [https://ethereum.org/en/developers/docs/standards/tokens/erc-721/]
34. [https://nftmagazine.it/mint-nft-cosa-significa/]
35. [https://brightnode.io/it/nfts-royalties-e-monetizzazione/]
36. [https://www.investopedia.com/terms/d/decentralized-applications-dapps.asp#:~:text=Key%20Takeaways%201%20Decentralized%20applications

%E2%80%94also%20known%20as%20%22dApps%22,censorship%2C%20and%20the%20flexibility%20of%20development.%20Altri%20elementi]
37. [https://ethereum.org/en/dapps/]
38. [https://en.wikipedia.org/wiki/Decentralized_application]
39. [https://ethereum.org/en/developers/docs/dapps/]
40. [https://blog.rapidinnovation.io/blockchain-gaming-a-complete-guide-2022/]
41. [https://en.wikipedia.org/wiki/Blockchain_game]
42. [https://casinosblockchain.io/]
43. [https://en.wikipedia.org/wiki/OpenSea/]
44. [https:/www.thundercore.com/index.html]
45. [https://www.scnsoft.com/blockchain/decentralized-marketplace]
46. [https://www.commercialistatelematico.com/articoli/2022/10/cosa-sono-e-come-funzionano-marketplace-nft.html]
47. [https://www.agendadigitale.eu/documenti/dao-decentralized-autonomous-organization-cose-le-finalita-e-le-prospettive-giuridiche/]
48. [https://en.wikipedia.org/wiki/Decentralized_autonomous_organization]
49. [https://ethereum.org/en/defi/]
50. [https://www.blockchain-council.org/defi/staking-vs-yield-farming-vs-liquidity-mining/]
51. [https://www.dodao.io/blog-posts/introduction-to-lending-and-borrowing-in-defi#:~:text=By%20definition%2C%20Borrowing%20is%20the%20act%20of%20receiving,to%20have%20against%20assets%20you%20already%20have%20%28Collateral%29.]
52. [https://coinmarketcap.com/alexandria/article/what-is-a-defi-aggregator-and-why-should-i-care]
53. [https://thecryptogateway.it/defi-bridge-wallet/]
54. [https://defipedia.com/answers/dexs/swap-vs-dex-what-s-the-difference]
55. [https://www.forbes.com/advisor/investing/cryptocurrency/crypto-lending/]
56. [https://dappradar.com/blog/2021-dapp-industry-report]
57. [https://finance.ec.europa.eu/publications/digital-finance-package_en]
58. [https://cms.law/it/ita/publication/la-proposta-di-regolamento-mica-sulle-cripto-attivita]
59. Introduction to blockchain bridges | ethereum.org

Acknowledgments

First, I would like to thank my family for supporting me during these years that have proved to be full of challenges, from various points of view. Your constant support has been crucial. Thanks to my friends, both from Sorrento and Milan, for making these years so rich in good memories.

I would also like to thank professors Alessandro Perego, Davide Ghezzi, Valeria Portale and Giacomo Vella who guided me on this journey and transmitted precious tools and knowledge.