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Survey on Decentralized Applications

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Abstract

Blockchain technology is evolving rapidly and has attracted concern not only in economics, but also has social, political and legal implications. Blockchain, referred to as Distributed Ledger Technology (DLT), makes any digital asset inalterable and transparent through the use of decentralization and cryptographic hashing. Specifically, the blockchain is a distributed database of records of all transactions that have been executed and shared among participating parties into the network. At the top layer of blockchain, there are applications that run on the network. These applications are called Dapps. Decentralized application is an application which is built on a decentralized network that combines a smart contract and a user interface. DApps are currently developed and deployed on blockchain platforms like Ethereum, Eos, Tron, Cardano, Neo, Tezos.

The thesis focuses on decentralized applications, stating the need for them, their advantages and categorizing them in the above reported scopes. Especially types and core components of blockchain are analysed. Also, decentralized applications are categorized in the paper as gaming, financing, socialization and referred to in the way they operate and the benefits of using them.

Finally, I indicate my opinion regarding the concerns about using them and the reasons which they have not been massively adopted. On the other side, I exhibit the usefulness of decentralized applications and potential ways for their improvement regarding their adoption from a wider group of users.

Περίληψη

Η τεχνολογία του Blockchain αναπτύσσεται ραγδαία και έχει προσελκύσει το ενδιαφέρον όχι μόνο στον τομέα της οικονομίας ,αλλα και σε επιπλέον τομείς όπως κοινωνικο και πολιτικό.Το blockchain μπορεί να χαρακτηριστεί ως ένα μητρώο (ledger) στο οποίο αποθηκεύονται κι επαληθεύονται πληροφορίες και δεδομένα, τα οποία εντάσσονται σε μπλοκ, με τη χρήση κρυπτογραφικών μεθόδων και με τέτοιο τρόπο ώστε να δημιουργείται μία συνεχής αλυσίδα δεδομένων.Συγκεκριμένα,το Blockchain μέσω της αποκεντρωμένης τεχνολογίας και κρυπτογράφησης καθιστά αναλλοίωτο οποιοδήποτε ψηφιακό περιουσιακό στοιχειο πραγματοποιώντας διαφανής συναλλαγές.Στο ανώτερο επίπεδο του blockchain, υπάρχουν εφαρμογές οι οποίες εκτελούνται στο δίκτυο. Αυτές οι εφαρμογές ονομάζονται Dapps. Η αποκεντρωμένη εφαρμογή (Dapp) είναι μια εφαρμογή που βασίζεται σε ένα αποκεντρωμένο δίκτυο το οποίο συνδυάζει ένα έξυπνο συμβόλαιο (smart contract) και μια διεπαφή χρήστη. Επί του παρόντος, οι αποκεντρωμένες εφαρμογές αναπτύσσονται σε πλατφόρμες blockchain όπως Ethereum, Eos, Tron, Cardano, Neo, Tezos.

Η εργασία αυτή εστιάζει στις αποκεντρωμένες εφαρμογές, αναφέροντας την ανάγκη τους,τον τρόπο λειτουργίας τους, τα οφέλη από την χρήση τους τους και κατηγοριοποιώντας αυτές στα παραπάνω αναφερόμενα πεδία. Ειδικότερα αναλύονται, τα είδη και τα βασικά στοιχεία του blockchain.

Τέλος, αναφέρω την άποψή μου σχετικά με τις ανησυχίες περι τη χρήση τους και τους λόγους για τους οποίους δεν έχουν υιοθετηθεί μαζικά. Ωστόσο, επιδεικνύω τη χρησιμότητα των αποκεντρωμένων εφαρμογών και τους πιθανούς τρόπους βελτίωσής τους όσον αφορά την υιοθέτησή τους από μια ευρύτερη ομάδα χρηστών .

1.Introduction

Over the past decades, the Internet has observed the appearance of many applications which solve problems in a collaborative, allocated manner. A number of these community-driven, non-commercial systems has become noted and extensive, examples include anonymous communication (Chaum,1981), PGP (Zimmermann,1995), Hashcash (Back,2002), and BitTorrent (Cohen,2003).

The term blockchain was first described back in 1991. A group of researchers wanted to create a tool to timestamp digital documents so that they could not be changed. Further, the technique was adapted by Satoshi Nakamoto. In 2008, Nakamoto created the first cryptocurrency, the blockchain-based project called Bitcoin. Since then, it has seen huge growth with the capital market, reaching 10 billion dollars in 2016. **(Monrat et al., 2019)**

Blockchain can be applied to more applications than cryptocurrencies. Since it allows payments to be finished without any bank or any intermediary, blockchain can be used in various financial services, such as digital assets, money transfer and online payment. The blockchain permeated a broad range of applications across many industries, including finance, healthcare, government, manufacturing, and distribution.

The blockchain is poised to innovate and pervade a broad range of applications-industries, including goods transfer (supply chain), digital media transfer (sale of art), remote services delivery (travel and tourism), platforms for example, moving computing to data sources and distributed credentialing. Addable applications of blockchain include allocated resources (power generation and distribution), crowdfunding, electronic voting, Identity management and governing public records.

Blockchain technology is being used in many areas, during the last few years. In general, blockchain technology has the core characteristics of decentralization, accountability, and security. This technique can meliorate operational productivity and save costs remarkably. The demand and usage of applications built on blockchain architecture will only evolve. Furthermore, different application opportunities are still being investigated. Blockchain relies on and permits to implement the concept of Decentralized Application (DApps). This makes the applications more transparent, distributed and flexible. The complexity of blockchain and its integration problems require expertise that differs from traditional application development approaches. **(Tschorsch & Humboldt, n.d.)**

Blockchain is considered to be one of the top technological advances of the 21st century.

2. Blockchain

Blockchain is a distributed database that is shared among the nodes of a computer network. As a database, a blockchain stores information in digital format. Blockchain is basically a chain of blocks that store all perpetrated transactions using a public ledger. The chain multiplies constantly when new blocks are annexed to it. Each block composed of a range of transactions and each new block generated is linked with the previous block so that every transaction implemented, can be tracked. **(Christodoulou & Andreou, 2018, 13)**

Blockchain works in a decentralized environment that is enabled by comprising variant core technologies, such as digital signatures, cryptographic hash, and distributed consensus algorithms. All the transactions arise in a decentralized mode that abstracts the demand for any intermediaries to validate and verify the transactions. Blockchain has some key characteristics, such as decentralization, transparency, immutability, and auditability.

The entire network as opposed to a central entity such as a bank or government is continuously verifying the integrity of it. This way, users do not have to trust a central entity, but security is guaranteed by the strength and computing power of the entire network participating in the blockchain. **(Sharma, 2017)**

Blockchain has already been affiliated in many applications of variant dependencies as decentralized getting near to computing without a trusted authority. **(Chen et al., 2018)**

Unlike traditional methods, blockchain enables peer-to-peer transfer of digital assets without any mediators.

Despite the fact that blockchain technology shows great potential that may replace many of the current digital platforms, it has some technical restrictions. Scalability is a huge concern for blockchain based platforms.

Although Bitcoin is the most famous application of blockchain, it can be applied to diverse applications far beyond cryptocurrencies. Since it allows payments to be finished without any bank or any intermediary, blockchain can be used in various financial services, such as digital assets, remittance and online payment.

There were many attempts in the past to develop a digital currency, but all of them failed as they could not solve the double spending problem without the requirement of a trusted third party. Bitcoin was the first application that managed to deal with this problem using a peer-to-peer network, once a transaction is confirmed it is impossible to double spend it. **(Christodoulou & Andreou, 2018, 13)**. With the coming of Bitcoin, instant, decentralized, pseudonymous value transfer is finally possible. Effecting decentralized consensus in Bitcoin meant that no one had to come over through a central authority or trust the other group to share information, including information in the form of value transactions.

2.1 Blockchain architecture

Blockchain architecture can serve some assets to organizations. First of all, blockchain transactions are validated and reliable due to the complex computations and cryptographic proof among demanded parties.

Also, it provides stability, any records that are made in a blockchain cannot be changed or deleted. It is possible to track the provenance of every transaction inside the blockchain ledger. Any new record or transaction within the blockchain implies the building of a new block. Each record is then proven and digitally signed to ensure its genuineness. Before this block is added to the network, it should be verified by the majority of nodes in the system.

In addition to the above, blockchain procures anonymity, each blockchain network participant has a generated address and not a user identity. This maintains user's anonymity in the public blockchain structure.

Finally, blockchain architecture as it is known, provides decentralization and transparency. With decentralization, each member of the blockchain structure has access to the whole allocated database. As opposed to the central-based system, consensus algorithms allow for control of the network. As well, with transparency, the blockchain system cannot be demoralized. To make it happen, it requires huge computing power to overwrite the blockchain network entirely. **(Lastovetska, 2021)**
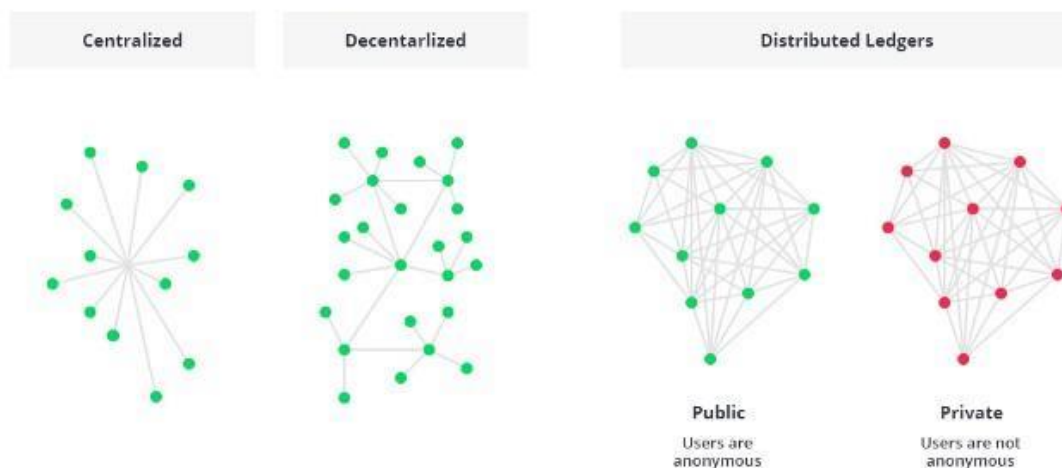
Figure 1 Difference between Centralized, Decentralized, and Distributed Ledger((Lastovetska, 2021)

The blockchain is a chain of blocks which contain specific information (database), but in a secure and genuine way that is grouped together in a network (peer-to-peer). In other words, blockchain is a combination of computers linked to each other instead of a central server, meaning that the whole network is decentralized.
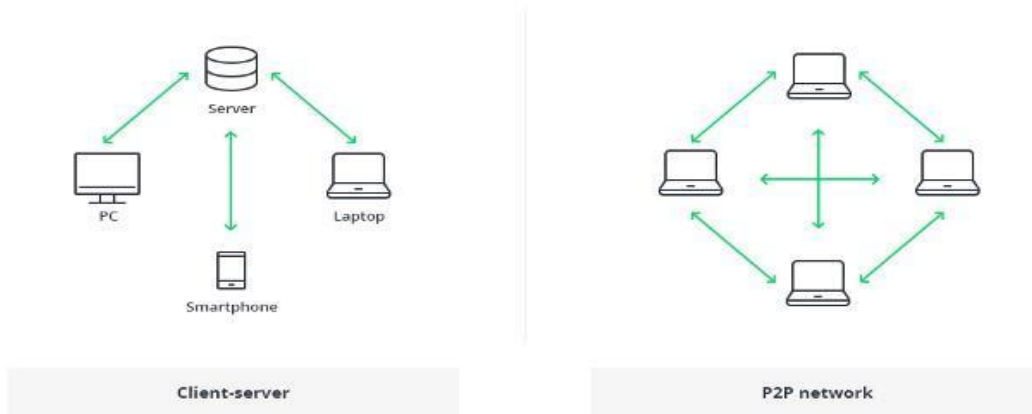
The difference between a blockchain system and a database is that the conventional architecture of the World Wide Web uses a client-server network. In this case, the server keeps all the required information in one place-database so that it is easy to update and controlled by an administrator. *(Figure 2)*

In the case of the distributed blockchain network, each participant within the network maintains, approves, and updates the new entries *(figure 3).* The structure of blockchain technology is represented by a list of blocks with transactions in a particular order.

Two data structures which are used in blockchain include pointers and linked lists. Pointers are variables that keep information about the location of other variables. Linked lists are a following of blocks where each block has specific data and links to other following blocks with the help of a pointer.
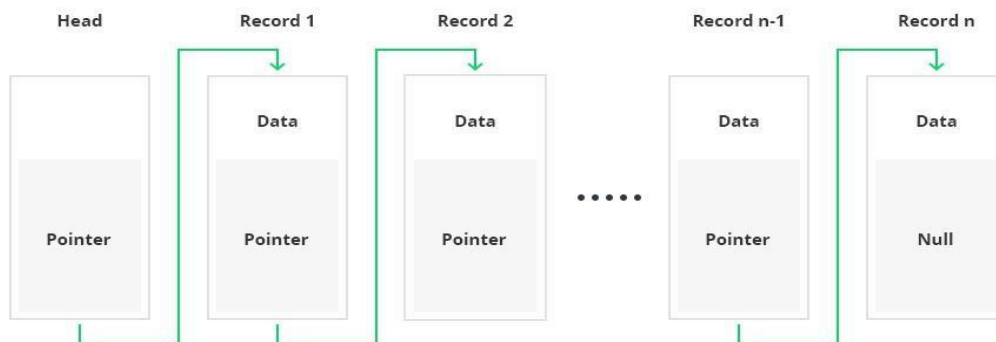
Logically, the first block does not contain the pointer since it is the first in a chain. At the same time, there is potentially going to be a final block within the blockchain database that has a pointer with no value. *(Figure 4)*

The following blockchain sequence diagram is a connected list of records.
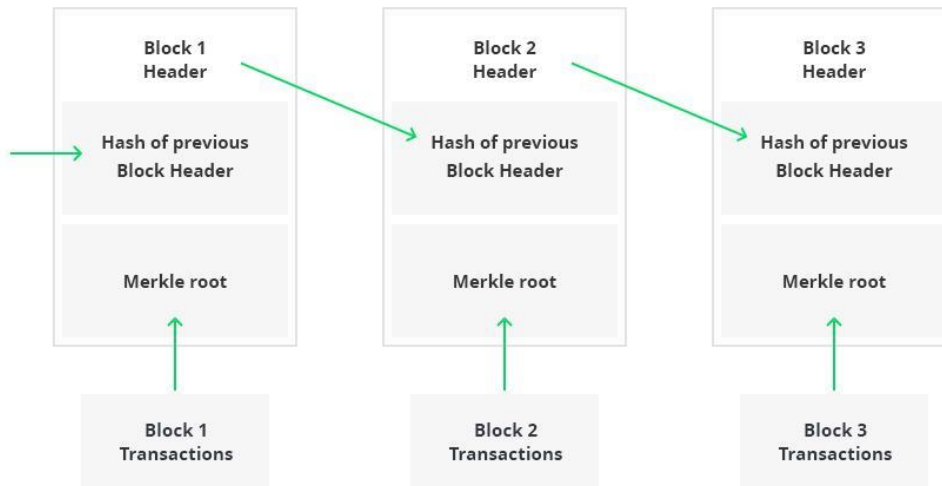
Figure 4 Blockchain Structure(Lastovetska, 2021)

Epigrammatically, core components of blockchain architecture will be analysed:

- Node - user or computer into the blockchain architecture (each has an unconventional copy of the whole blockchain ledger).
- Transaction - smallest building block of a blockchain system (records, information) that serves as the purpose of blockchain.
- Block - a data structure used for keeping a set of transactions which is distributed to all nodes in the network.
- Chain - a sequence of blocks in a specific order.
- Miners - specific nodes which perform the block confirmation process before adding anything to the blockchain structure.
- Consensus (consensus protocol) - a set of rules and arrangements to carry out blockchain operations.
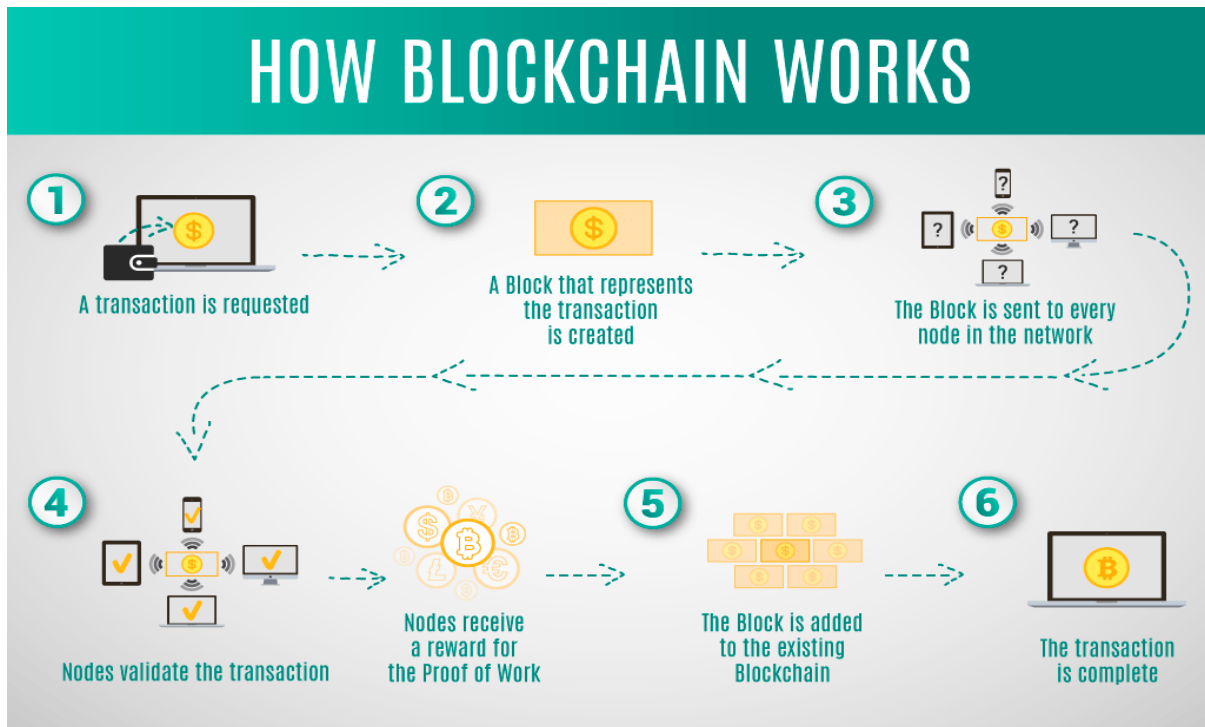
Figure 5 How Blockchain works(Lastovetska, 2021)

The above figure is a blockchain architecture diagram that shows how this actually works in the form of a digital wallet *(Figure 5).*

Each blockchain block consists of certain data, the hash of the block and the hash from the previous block. The data stored inside each block depends on the type of blockchain. For example, in the Bitcoin blockchain structure, the block keeps data about the receiver, sender, and the quantity of coins.

A hash is like a fingerprint. Each block hash is generated with the help of a cryptographic hash algorithm (SHA 256). Therefore, this helps to identify each block in a blockchain structure easily. The moment a block is created, it automatically attaches a hash, while any changes made in a block affect the change of a hash too. So, hashes aid to discern any changes in blocks.

The final principle within the block is the hash from a previous block. This creates a chain of blocks and is the main element behind blockchain architecture's security. The first block in a chain is a bit special, all confirmed and validated blocks are supplemental from the origination block. Any corrupt attempts cause the blocks to change. All the following blocks then carry incorrect information and render the whole blockchain system invalid.

On the other hand, in theory, it could be possible to adapt all the blocks with the help of strong computer processors. However, there is a solution that eliminates this possibility called **proof-of-work.** Proof of Work (PoW) is the original consensus algorithm in a blockchain network. This algorithm is used to confirm the transaction and creates a new block to the chain. In this algorithm, miners (a group of people) compete against each other to complete the transaction on the network. This allows a user to slow down the process of creation of new blocks. In Bitcoin blockchain architecture, it takes around 10 minutes to

determine the necessary proof-of-work and add a new block to the chain. This work is done by miners - special nodes within the Bitcoin blockchain structure. Miners get to keep the transaction fees from the block that they verified as a reward.

Proof-of-work prevents the consumption in the network which is a problem that has tortured cryptographic researchers for decades. Consumption meant that a bad actor could spend the same funds twice, denying the first transaction happened. This problem is solved by having miners in the network solve cryptographic proofs using their hardware. Miners are Bitcoin nodes that verify a transaction and check it via its blockchain history, a timestamped record of all transactions ever made in the network. Someone could theoretically alter their blockchain history, but with proof-of-work, they would also need to have the majority of computational power.

Each new user **(node)** joining the peer-to-peer network of blockchain receives a full copy of the system. Once a new block is created, it is sent to each node within the blockchain system. Then, each node verifies the block and checks whether the information appointed there is correct. After that, unless there is a problem, the block is added to the local blockchain in each node.

All the nodes inside a blockchain architecture create a **consensus protocol**. A consensus system is a set of network rules, and everyone should conform to them into the blockchain.

For example, the Bitcoin blockchain has a consensus rule stating that a transaction amount must be cut in half after every 200,000 blocks. This means that if a block produces a verification reward of 10 Bitcoins, this value must be halved after every 200,000 blocks.

As well, there can only be 4 million Bitcoins left to be mined, since there is a maximum of 21 million Bitcoins laid down in the Bitcoin blockchain system by the protocol.

This makes blockchain technology invariable and cryptographically secure by eliminating any third-parties. It is not possible to violate the blockchain system, as it would be requisite to tamper with all of its blocks, recalculate the proof-of-work for each block, and also control more than 50% of all the nodes in a peer-to-peer network.

2.1.1 Types of blockchain architecture

Based on the sort of blockchain structure and its circumstances, the system can be more centralized or decentralized. This simply refers to the blockchain architecture design and who controls the ledger. All blockchain structures fall into three categories, public, private and consortium blockchain.

Public blockchain architecture means that the data and access to the system is available to anybody who is eager to participate. (e.g. some of blockchain systems that are public, are Bitcoin, Ethereum, Litecoin). In a public blockchain, all records are visible to the public and anyone can participate in the agreement process. On the other hand, this is less profitable since it takes a significant amount of time to accept each new record into the blockchain architecture. Private blockchain, in contrast to public blockchain architecture, the private system is implemented only by users from a special organization or deputed users who have the

capability to participate. A private blockchain is considered more centralized since it is controlled by a particular group with increased privacy. Contrariwise, a public blockchain is open type and so it is decentralized.

Finally, Consortium blockchain structure can consist of a few organizations. In a consortium, procedures are set up and controlled by the preparatory delegated users.

In terms of productiveness, the time for each transaction in a public blockchain is less eco-friendly since it requires a huge amount of computation power compared to private blockchain architecture.

The following table provides a detailed comparison among these three blockchain systems. *(table 1)*

Table 1 Detailed comparison among these three blockchain systems (Lastovetska, 2021)

Property	Public blockchain	Consortium blockchain	Private blockchain
Consensus determination	All miners	Selected set of nodes	Within one organization
Read permission	Public	Public or restricted	Public or restricted
Immutability level	Almost impossible to tamper	Could be tampered	Could be tampered
Efficiency (use of resources)	Low	High	High
Centralization	No	Partial	Yes
Consensus process	Permissionless	Needs permission	Needs permission

2.2. Smart contracts

Smart contracts operate among with the blockchain technology leading blockchain to its full potential. Smart contracts are referred as the components to Blockchain platform of next generation. **(Sharma, 2017)**

Smart contracts are simply programs stored on a blockchain that run when predetermined conditions are met. They define the rules and conditions for querying a ledger and generating new transactions that are recorded on it. They are used to automate the implementation of an agreement so that all participants can be instantly assured of the outcome, without any mediator's participation or time loss. They can also automate a workflow, executing the next action when conditions are met.

Each smart contract has its own blockchain address, so any user can call a function on the smart contract by adjusting a transaction and passing the function hash code into the contract. Smart

contracts allow trusted transactions to happen among diverse groups without the need for a central authority or a mediator. Smart contracts fall to all capabilities of blockchain, and therefore, all transactions are transparent, secure and traceable.
(Christodoulou & Andreou, 2018, 13)
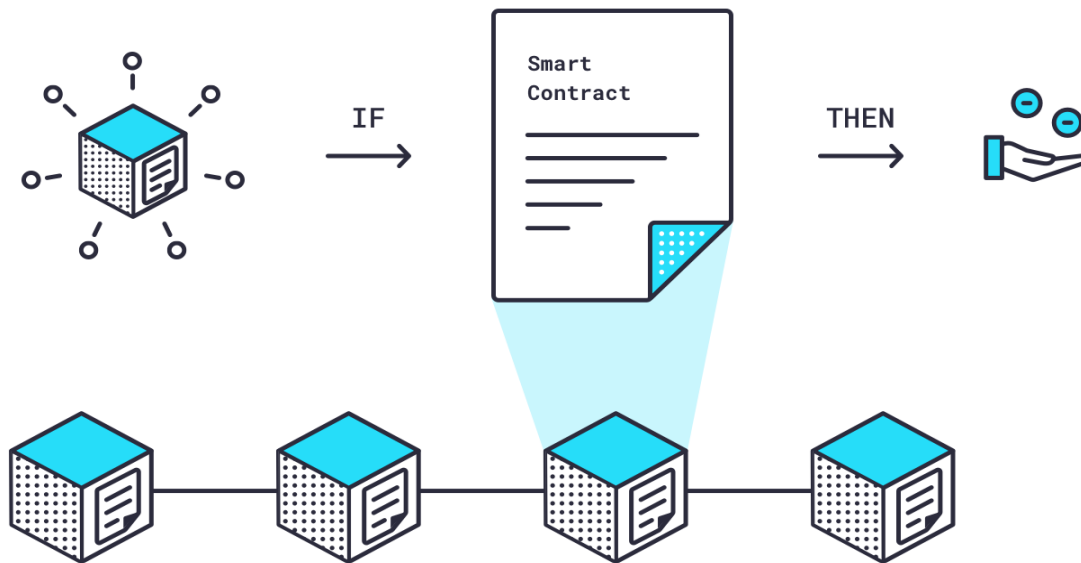
Figure 6 Smart contracts operation (Cryptopedia Cryptopedia staff- Gemini.- Gemini, 2021)

Specifically, crowdfunding is a good example to appreciate how smart contact operates. A payment will be released to a fundraiser if a certain amount of Ether is deposited into a smart contract by a certain date. Instead, if this will not happen, then the payment will be returned to contributors. Because smart contracts exist on a blockchain, they are immutable (can't be changed) and affirmable (everyone can see them), guaranteeing a high level of trust.

Also, at smart contracts, there is a software known as oracle. Oracle is a middleware that acts as a mediator, converting the data from real world to smart contracts on the blockchain in bidirectional way,
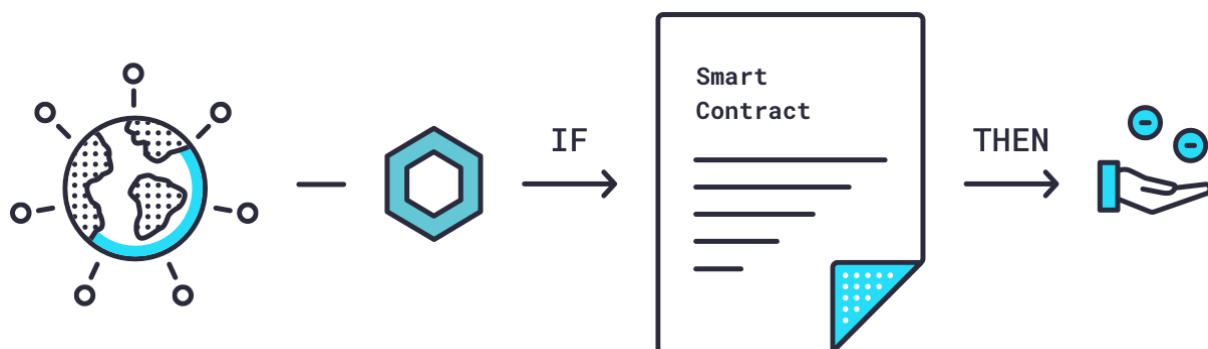

Figure 7 Smart contracts operation (Cryptopedia Cryptopedia staff- Gemini.- Gemini, 2021

2.2.1 Advantages of smart contracts

Smart contracts, as mentioned, are applications that run exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference. As mentioned, there is no downtime on smart contracts. The applications never shut down suddenly. Also, they provide accuracy and transparency as terms are predefined in a smart contract. When a condition is met, the transfer occurs automatically and is recorded. Instead, if a transfer is involved with a conventional contract, it's a manual process involving approvals workflows. Traditionally, transparency is imposed by the users who are involved. Any user who is involved can review, audit, and validate the archived transactions. Transactions in smart contracts may be tracked right from the point of provenance, and archiving occurs automatically, creating a fully accessible history. **(Arora, 2021)**

Also, another advantage of using smart contracts is the elimination of censorship. Ethereum nodes are distributed around the world eliminating censorship from a central authority. This offers automation and time savings because of smart contracts are automated and programmable, running under predefined conditions. There is no need for middlemen and intermediate layers which are involved in the execution of a traditional contract slowing the process. **(Arora, 2021)**

Also, the contract cannot be changed, hacked or manipulated so there is no existence of fraud. At traditional contracts, because of the elaboration of many medians parties, security can be violated at any part in the process. Security is sustained through cryptography, public key, and private keys when using smart contracts. The data is too difficult to be modified. Smart contracts are digitally signed using private keys and can only be decrypted by using the public key which is shared among the parties which are involved.

Finally, smart contracts are more economical compared to traditional contracts. Because they are self- executed and they don't require mediators, and the only transaction encumbrance produced from the fundamental infrastructure of the blockchain network running the smart contract.

2.3 The era of NFT

A new phenomenon began to appear in the crypto sphere by last summer, the non-fungible token (NFT). Non-fungible tokens or NFTs are cryptographic assets on a blockchain with unique identification codes and metadata that differentiate them from each other. Unlike cryptocurrencies, they cannot be traded or exchanged at equivalency. An NFT is a unique and non-interchangeable unit of data stored on the blockchain that can track a unique digital asset's transfer, ownership and properties.

In the crypto world, currency units are similarly fungible and exchangeable, but not all digital assets are. This is the way that NFT contributes, at the digitization of media including art, music, videos, books and even news or blog posts has confounded the nature of ownership, copyrights, and intellectual property. This is largely due to the ease with which digital media

can be copied and reproduced. Nevertheless, NFTs provide a means for owners of different types of digital content to sell and trade their property using the advantages provided by the decentralized crypto space. **(Napoli & Forbes Technology Council, 2021)**

Furthermore, characteristics of non-fungible tokens (NFTs) are designed to be cryptographically verifiable, unique and easily transferable. A non-fungible token is created by an artist, creator, or license-holder through a process called minting. Minting is a process that involves signing a blockchain transaction that outlines the fundamental token details, which is then broadcasted to the blockchain to trigger a smart contract function which creates the token and assigns it to its owner. A non-fungible token consists of a unique token identifier, or token ID, which is mapped to an owner identifier and stored inside a smart contract. When the owner of a given token ID wishes to transfer it to another user, it is easy to verify ownership and reassign the token to a new owner.

Non-fungible tokens can be created to represent virtually any asset, whether physical, digital or metaphysical. However, the most common NFT assets are digital art, digital collectible items, pieces of content like video or audio, and event tickets.

Especially, non-fungible tokens being utilized

- NFT event tickets, companies can distribute and sell tickets to events using NFTs, reducing procedure for verification of ownership and authenticity and helping to eliminate fraud.
- Also, for customer engagement, brands or organizations can issue or sell NFTs that represent exclusive collectibles, products, experiences, or voting rights for the future development of a product or service in order to deepen the engagement customers have with the brand/organization.
- In-game items, NFTs can be used to create a widely varied ecosystem of in game digital items that can be bought sold and exchanged on open secondary markets and used across a broader gaming ecosystem rather than tied up to one game
- Credentialing, identity credentials like driver's licenses or professional certifications can be issued as NFTs to reduce the load of proof for these credentials and eliminate the siloed nature of credentials today.

Nevertheless ,there are some challenges and risks that may affect the adoption of non-fungible tokens:

- Complexity: The technology and tooling behind non-fungible tokens and the decentralized applications (dapps) that maintain them are still new. Many of the complexities associated with building NFT-related solutions are not yet abstracted by quality tooling.
- Legal Implications: With the introduction of new and innovative technologies, particularly ones that involve speculative or high-value assets, come distinct regulatory and legal considerations including but not limited to know your customer procedures, and securities law compliance.

- Rapid Innovation: The rapid pace of innovation in the NFT ecosystem and the blockchain networks on which they are issued presents challenges for those adopting the technology in the form of consistent change; agility and modularity are critical.
- Concerns regarding Ecological Impact: Conservation continues in regard to the impact that energy-intensive blockchain networks that utilize the Proof-of-Work consensus mechanism have on climate change, and NFT-focused products have been a target for such criticism. However, solutions already exist to ameliorate this concern, such as the adoption of less energy-intensive consensus mechanisms and the use of L2 networks where transactions that mint NFTs can be validated more rapidly and efficiently outside of the main blockchain network. **(AWS Amazon, 2021)**

Finally, the global NFT market value is currently estimated to stand at around $43 billion, with a daily trading volume of over $3 billion. GFT Exchange (GFTX), is the company that brought to market the first NFT movie promotion in May 2018, with 20th Century Fox and Atom Tickets, releasing a limited-edition Deadpool 2 digital posters to promote the film. The NFT's were available on Opensea.io via the GFT exchange.

Also, by the recent launch of MekaVerse, an NFT gaming project centred around 'mecha' robots made popular by prominent Japanese anime shows and manga comics. In just two weeks since MekaVerse launched, the project has racked up over $139 million in trading volume, making it the 13th most traded NFT collection to date. **(Wintermeyer, 2021)**

3. Decentralized Applications

DApp is the acronym for "Decentralized Applications". dApp is a type of application, which function does not depend on a central authority, it operates based on a decentralized network. DApps allow people to access different services securely. These applications can be used on personal computers, smartphones or even be accessible via the web. **(Cryptopedia staff- Gemini., 2021.)**

Most people are familiar with the term "application" as it relates to software. The most of web software applications that are currently used, obey a centralized server-client model. There are three models of applications which are centralized, distributed and decentralized

First of all, **centralized** applications which are the most used model- system for software applications operate with a single central authority. All units, the flow of information, the individuals are dependent on the central authority for sending and receiving information. This model is used from Facebook, Amazon, Google and other mainstream services. Afterwards, **distributed** means that the computation of a process is lay out beyond to one node. A lot of companies have affiliated a distributed architecture internally to accelerate computing and data latency. This means that a system can be both centralized and distributed.

Finally, **Decentralized** means that any computation is independent in any node. A decentralized app has some characteristics like they should be open source, protocols and data are stored cryptographically in a blockchain, the cryptographic tokens are used for rewarding system users as well as for application access and the tokens are generated using an algorithm that motivate the members to conduce to the system.

Also, a system can be both distributed and decentralized. Bitcoin is distributed because its time stamped public ledger, the blockchain, inhabits on multiple systems. It is also decentralized because if one node fails, the network is still able to handle it. **(Raval, 2021.)**

Decentralized applications can be sorted in three types according to whether the dapps have their own blockchain or if they depended on another dapps blockchain.

- Type I dApps - Financial Blockchain Applications: These are dApps which have their own blockchain. It provides users with manners of controlling their finances. There is no centralization to the control of the network and so there is no single authority to be responsible for controlling all the funds. Users are the possessor of their money in these applications.
- Type II dApps - Semi-Financial Blockchain Applications: These dApps base their application on the block of Type I dApps. They are protocols and must have tokens to operate. It compromises both funds and information that inhabits outside the blockchain.
- Type III dApps - Fully - Functioning Decentralized Applications: They use the protocol of type II Dapps. They have protocols and tokens as a requirement for their operation. It uses all the features of both decentralized and distributed systems. They are the most popular type of Blockchain - based dApps. **(Medium Website, 2017)**

Decentralized applications run on a peer-to-peer network of computers instead of a single computer, and they are scheduled to incur without the existence of a central authority. Also, apps like BitTorrent, LimeWire, Tor which existed before the blockchain era can be characterized as decentralized applications. Decentralized applications that incur on the blockchain require the involvement of a smart contract in order to function suitably, as previously mentioned. **(Christodoulou & Andreou, 2018, 13)**

The term "DApp," which came from the Ethereum community, can be applied to anything that include a smart contract as the key component.
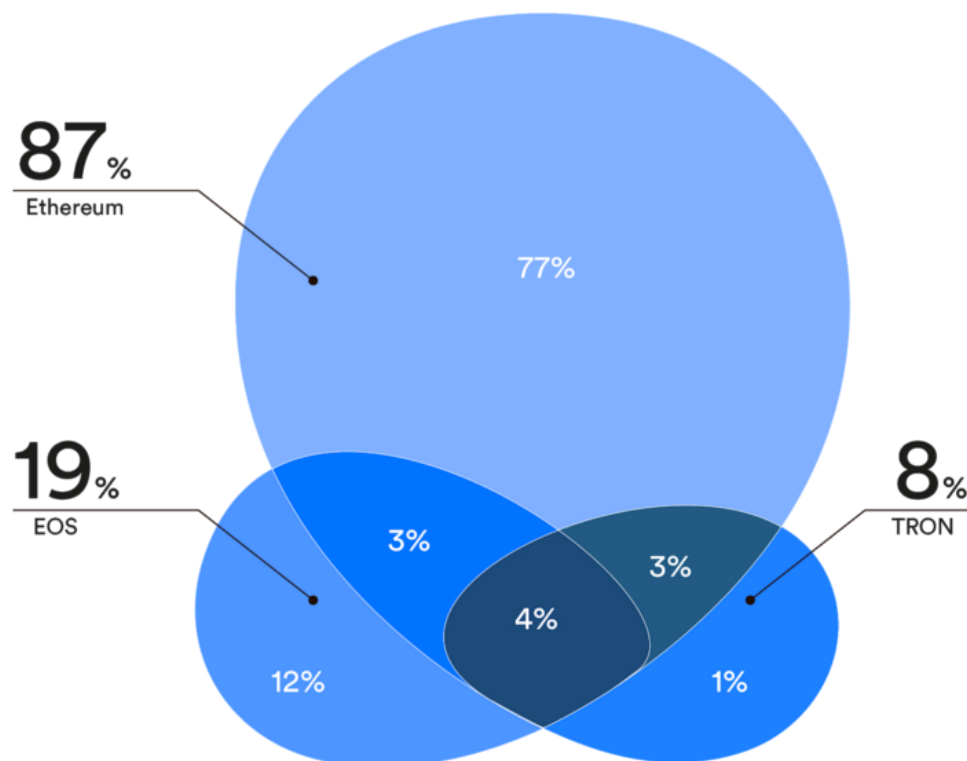
Platform distribution among the survey participants
a DApp can use more than one blockchain

Figure 8 Platform distribution among the survey participants (Ponomarev, 2019)

Regarding the platform distribution of dapps, the major part is used by Ethereum, with EOS ranking second and TRON ranking third. Some of the projects which surveyed were built on more than one chain. Thus, there are very few Dapps which use other chains.

The plural of Decentralized apps used a web-based frontend. Nearly the half of surveyed DApp projects were depend on a conventional cloud to run their backend code. Also, it is notable that the same number of decentralized apps were using a decentralized storage solution like Interplanetary File System (IPFS) as were using a centralized content delivery network (CDN).

As well, a similar percentage was found to databases, more than half of DApps relied on a centralized database while others DApps used a decentralized DB.
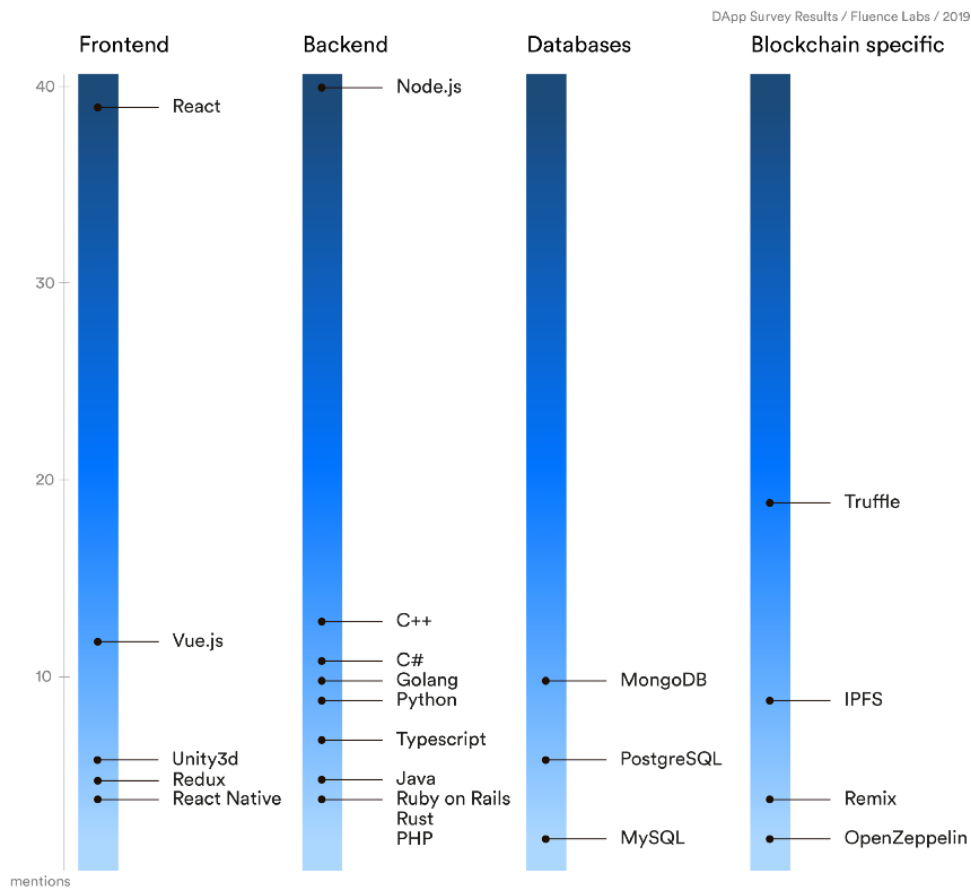
Figure 9 :Technologies used on dApps (Ponomarev, 2019)

Concerning the used technologies, React and Node.js took a notable lead, leaving behind other popular languages and frameworks like python, c#, java, php, vue.js.
In the sector of databases, dapps using MongoDB, PostgreSQL and MySQL, with MongoDB are the most used from the others mentioned. **(Gelbart, 2018)**

Decentralized apps and traditional applications have three basic piles. The front end, the backend and the data storage layer. The difference between decentralized and traditional apps issue on the way that they interact with these elements.
The **frontend** is the interface that users use to interact with the application. In this layer, the object is to give the user the ability to interact, receive and send information to the application.
This second layer, which is the **backend**, refers to the objective of the application. The backend in decentralized applications is associated with a smart contract which runs on a blockchain. Smart contract is the object which guarantees that the operation of the decentralized application

will be completed. Smart contract guarantees high level of transparency and security as they are visible and public to users. Also, backend is supported by the APIs (Application Programming Interface) and blockchain competences.

Finally, there is the **storage** layer. Ordinarily the data is stored on the user's computer or on servers controlled by third parties. The disadvantage of this condition, is that if the server is damaged or out of service, the user will lose the information of the application.

But in a decentralized applications network, data storage is completely decentralized likewise. The information, actions of a dApp user which performed are stored on the blockchain. In addition, all the data which are stored on the decentralized network are cryptographically secured, preventing unsanctioned access by third parties. This means that if a user loses his data, he can recover all his information using his dApp in a new device.
(Cryptopedia staff- Gemini, 2021.)

3.1 The way of decentralized applications operates

Decentralized applications operate like blockchain networks. Every dApp user is like a node in the network. Each user has the ability to monitor the operations that are performed in the network. In this network, each operation is recorded which goes through the smart contract. Smart contract is the object which accepts or rejects if an operation of dApps users will be done. In this way, it guarantees that all actions from users count in the network. Smart contract controls the validation of each operation.

The information of applications at nodes are updated every time when there is a new operation in the network. The information is cached in every node. Thus, the application is functioning with the resources of users' computers. Also, the network will always be in service, because it is impossible for all the nodes of the network to be erased at the same moment.

Consequently, dApps hold the positive assets of blockchain like security, privacy, anonymity as they run on its network. So, users retain the control of their data. **(Cryptopedia staff- Gemini., 2021.)**

3.2 Blockchain ecosystems on which dApps can be developed

In this section, it will be presented the most popular blockchain platforms and the features of each. Some of them are be using for the development of dApps. Since the launch of blockchain, they have been created over 4000 dApps. Most of them are built on Ethereum platform. Daily users reach about 150.000 and 90.000 of them are on Ethereum platform. (**State of the Dapps website, n.d.**)

- Ethereum

Ethereum is an open-source blockchain platform with its own cryptocurrency, called Ether (Eth) and with its own programming language called Solidity. Solidity is used for developers to build and run distributed applications on blockchain network. Ether, the digital currency is used for exchanges and also it is used to Ethereum network to run applications. **(bit2me website, 2020).** Ethereum was founded in 2013 by Russian-Canadian programmer Vitalik Buterin and several other crypto entrepreneurs, many of them, were previously involved in bitcoin. Ethereum is the largest and most well-established, open-ended decentralized software platform. **(Butterin, 2018)** As a blockchain network, Ethereum is a decentralized public ledger for verifying and recording transactions. Ethereum enables the deployment of smart contracts and decentralized applications to be built and run without any downtime, fraud, adjustment or intervention from a third party. **(bit2me website, 2020)**

Benefits of using the Ethereum platform can be assumed it's large, existing network. It is considered that it has a large global community with the largest ecosystem in blockchain and cryptocurrency. Ethereum includes a wide range of functions, as mentioned, it can execute smart contracts and store data for applications, besides of being used as a digital currency.

The community of Ethereum developers is constantly improving the network and developing new applications.

Nevertheless, Ethereum's growing popularity has led to higher transaction costs. For example, Ethereum transaction fees, also known as "gas," hit a record $23 per transaction in February 2021 which is a potential for "miner" users to earn money, but it is a disadvantage for users who are trying to use the network. This happens because unlike Bitcoin, where the network itself rewards transaction verifiers, Ethereum requires those participating in the transaction to cover the fee.

Also, Ethereum has not a strict lifetime limit on number of coins in contrast to bitcoin

Unlike the Bitcoin blockchain, the Ethereum blockchain was not created to support a cryptocurrency. The Ether cryptocurrency was created to provide an internal digital currency for applications built on the Ethereum blockchain. **(Lubin, 2019)**

Finally, Ethereum continues to evolve and improve, and the ongoing development of Ethereum 2.0 holds out the promise of new functions and greater efficiency.

- EOS

EOS or EOS.IO was launched in July 2017. Dan Larimar is the founder of the EOS. It is among the 20 most valuable blockchain tokens until to February 2021, characterized by market capitalization. The EOS ecosystem makes use of EOS.IO and EOS tokens.EOS.IO is behaving like the operating system of a computer. EOS.IO uses blockchain architecture that is used to enable the operation of decentralized applications in the network. EOS token in the cryptocurrency of the network.

The primary aim of the EOS platform is to create, host and support decentralized applications. It supports all required traits for providing secure access, authentication, usage management and communication between the dApps. EOS is leading in growth of gaming, gambling applications, and music sharing (Leeway Hertz, 2021.). EOS uses the concept of proof-of-

stake, which allows it to make instant decisions, like rollback and bug fixing, through the agreement from the majority of stakeholders has the aspirations to be better and faster that Ethereum. For example, Ethereum can handle 15 transactions per second, in contrast to EOS which aims for millions of transactions per second.

Also, EOS attempts to offer more scalability, flexibility and usability through its mechanism because the limited availability of resources in the blockchain network is a major issue. Because of EOS parallel execution and asynchronous communication method via network, it can support thousands of dApps without hitting performance problems. This happens, because different modes of an applications operate separately. For example, the authentication process of an account is executed apart from the implementation process. All of these, make the developer's job of creating and supporting the apps, easier. **(Rodeck & Curry, 2021)**

● TRON

Tron is a blockchain-based decentralized network system which was founded in 2017 by Tron foundation (a Singapore non-profit organization). Found by Justin Sun, who is also the CEO of BitTorrent, the file-sharing program. Primarily marketed in Asia and then gone global. As of August 2021, the platform had more than 50 million accounts. Tron network is built using the Solidity programming language. The native cryptocurrency of Tron is named Tronix (TRX). The transactions at the network were carried out using TRX. The users of the network use TRX to get access. Crypto-assets (TRX) can be stored in a desktop, mobile or hardware wallet. Tron as the other blockchain's platforms use the features of the blockchain technology to abolish the use of the mediator and allow developers to make their applications directly available to ordinary users. Tron platform form has been compared to Ethereum because both belong to blockchain technology and have the same features, like decentralized applications, smart contracts and tokens.

CoinDesk in July of 2021, reported that crypto traders upbring their interest to blockchains that provide cheaper transaction fees than Ethereum's provide. The supply of USD Coin, a cryptocurrency connected to the U.S. Dollar, which exists on Tron, transcends $ 108 million less than a month after it launched. According to CoinRanking, at 5 Aug, TRX ranked 31st among cryptocurrencies in market capitalization. Its price was $0.0705, giving it a market capitalization of $4.66 billion. Its all-time high on that date was $0.2180.6 (Seth, 2021)

● Cardano

Cardano was developed in 2015 and launched in 2017 by Ethereum's Co-Founder, Charles Hokinson and because of it they have a lot in common. Both are types of digital currencies that also function as programmable environments. Both platforms are used for similar applications such as smart contracts. Cardano aims to be a better version of Ethereum. The co-founder of the proof-of-work (PoW) blockchain Ethereum, distinguished the negative issues that face Ethereum. Such as scalability, sustainability on PoW networks are bounded

because of growing costs, energy use and slow transaction times at infrastructure. So, he commenced to create Cardano, and its cryptocurrency ADA.

Cardano is a third-generation decentralized proof-of-stake (PoS) blockchain platform according to Ethereum which is a proof-of-work (PoW). Also, the Cardano platform runs on the Ouroboros consensus protocol It is the first PoS protocol and it's in foundation phase. **(Investopedia Team, 2021)**

This year, Cardano plans to launch smart contracts and Ethereum will move to a proof of stake model. It is crucial if it is done without causing technical problems. The transactions are expensive right now because there is huge network congestion, this results in many developers to move away from Ethereum. The upgrade from Ethereum to Ethereum 2.0 is still pending but it will not be simple. Cardano is focused on ways that blockchain can solve real problems in developing countries. On the other hand, Ethereum aims at economic applications.

Cardano development process is being separated in five phases. Each of the five phases are named after an influential historical figure. The five phases are foundation, decentralization, smart contracts, scaling and governance. The organisations behind Cardano have released three products, Atala prism, atala scan and atala trace. The aim of the first product is to be used as an identity management tool that can be used to procure access to services. For example, it can be used to authenticate credentials, account for a bank account. The other two products are used to track a product through a supply chain.

Also, Cardano is developing a smart contract platform that will be used for development of decentralized applications. Also, for governance, the aim of cardano is to use a democratic on-chain governance system called project catalyst to manage the development and implementation of projects. **(Investopedia Team, 2021)**

The disadvantage of Cardano is that it works on a programming language called Plutus which is under-developed. **(Butterin, 2018**). As of June 20, 2021, 71.59% of Cardano's cryptocurrency ASA, is staked in 2,626 active pools with a value of approximately $31.4 billion.

- Tezos

Tezos (XTZ) is a blockchain network connected to a digital token, which is named tez or tezzie. Tezos, like Ethereum, is made to use smart contract technology and provide flexibility to the users of the network. One of the distinguishing features of Tezos is governance. That means that all decisions in the network are taken from the users. Also, Tezos additionally to other decentralized blockchains, includes a mechanism that permits users who hold tokens to decide for the development of protocols in the network. (Conway & Rasure, 2021). Users or holders of these tokens receive a reward for participating in its proof-of-stake consensus mechanism. The value of Tezos went through many fluctuations in the market. On July 1,2017 Tezos earned $232 million, making it one of the largest ICOs of all time. Tezos drew massive attention in its initial coin offering. But, because of a conflict between Tezos president Johann Gevers and Arthus and Kathleen Breitman, the owners of Tezos' intellectual property rights have as result to delay the launch of The Tezos platform. This is the reason that Tezos ran into legal problems. Investors initialized a series of lawsuits, arguing that tez were unregistered securities. So, Tezos launched in 2018.The price of Tezzie tripled in the end of 2019 year and

Tezos gained attraction again. Finally, the future of Tezos is optimistic. Tezos survived in the market and demonstrate the possibilities of platform (Conway & Rasure, 2021)

- Neo

NEO was founded by Da Hongfei and Erik Zhan in China in 2014.Firstly named as AntShares and then it was rebranded to NEO in June 2017. NEO crypto coins are divided into NEO and GAS. It can be programmed in all popular languages like C#, Java, Go, Python, and Kotlin, which facilitate developers to create their application to the platform. (Jahn & Rasure, 2021). NEO is known as Chinese Ethereum, a blockchain-based platform that supports its own cryptocurrency and enables the development of digital assets and smart contracts. NEO aims to use the characteristics of smart contracts like automating the administration of digital assets with the potential aim of creating a distributed network-based smart economy system. The system of NEO is characterized as a Smart Economy System. It combines Digital Assets, Digital identity and smart contracts which lead to a smart economy.

NEO aims to comply with regulations which is the key to differentiate from the other platforms. Assets at NEO, like in the other blockchain platforms, can be digitized in an open, decentralized, reliable, and diaphanous way that there are no costs and mediators. Also, assets can be exchanged, bought, sold by users. Assets are protected in the NEO network and they are registered on the platform having a digital identity which is validated and protected by law.

Digital identity is the asset which separates NEO from the other blockchain platforms. At NEO network, every entity is needed to have a unique digital entity that can be verified. Entities have the potential to perform transactions among themselves only if the other entity has the required digital identity. That has a result to make NEO network regulatory-compliant. The same applies to the diverse nodes on the NEO platform. They need to be identified before they can conduse to the transaction verification and in other activities.

Digital identity gives the opportunity to verify information about the participating individuals and other entities that exist in the digital network. Smart contracts permit the implementation of transactions and agreements among different entities without governance by any central mechanism. The implementation of these contracts is based on the programming code of the network, and smart contracts provide transparency and irreversibility of transactions.

In 2014, the founders of NEO cryptocurrency, Da Hongfei and Erik Zhan, created a company named Onchan which has as aim to provide blockchain solutions to various business. Onchain focuses to create private and consortium blockchains to respond to the special needs of the industry. The main product of Onchain's company is DNA (Distributed Networks Architecture). Onchain hopes that DNA is the blockchain platform that can use digital assets to face up all challenges in the private and public sector and to help businesses.

Neo and Onchain operate separately. The target of NEO is business-to-consumer (B2C), while at Onchain, the target is business-to-business (B2B) enterprise services. Also, NEO is funded by public community, while Onchain is funded by Fosun, an enormous private association of China. The founder of NEO, Da Hongfei chose Fosun as an investment partner because the

company is associated with finance, medical science, entertainment which can be combined with blockchain tech.

Blockchain-based systems continue to grow so teams of NEO and Onchain with the aim to succeed cross-chain interoperability among the variant blockchain platforms. Digital identity features will contribute to achieve the goal. This will allow users to connect and share information between blockchains. The NEO platform is the foundation of Onchain's DNA concept. NEO provides decentralized, public blockchains while Onchain's DNA aims for private blockchains. Onchain has been approved by the government of Guiyang.

Although, government of China is concerned about financial risks of cryptocurrency, speculations like the infinite cryptocurrency mining operations have become such a drain of the nation's electricity supply which threaten the environment. Nevertheless, they are looking for an alternate solution to corporate and integrate NEO into the companies in China, which they could control. **(Jahn & Rasure, 2021)**

- Solana

Solana is a type of cryptocurrency that exists exclusively online. Solana was initially released in April 2019 and started trading at less than $1 per coin. Since then, its price has risen remarkably fast, and as of November 2021, Solana traded for more than $200. It's among the top 10 largest cryptocurrencies by total value, according to CoinMarketCap.

Created by Anatoly Yakovenko, Solana operates on a decentralized computer network using a ledger called blockchain. This blockchain database manages and tracks the currency, and effectively records every transaction that's ever occurred in it, like a long running receipt. The computer network records the transactions in the currency and verifies the data's integrity. This decentralized setup makes the network more robust, and users can make transactions without the need of an intermediary. Solana calls itself the fastest blockchain in the world with the ability to verify 65,000 transactions per second. (Royal, 2021)

Also, Solana can power several applications that offer a variety of features:

- With a cryptocurrency wallet, you can use Solana to send or receive the coin or transfer it in exchange for goods and services.
- Smart contracts are apps that automatically execute the terms of the contract when its conditions have been fulfilled.
- Often associated with digital art, NFTs can be powered with Solana, allowing artists and others to sell them to consumers.
- With Solana, you can create and use permission-less payments, ones that can avoid centralized or government control and succeed decentralized finance.
- Besides its other functions, Solana supports the development of a range of other apps, including games, investing, social media and more.
- In addition to a proof of stake approach to validate transactions, Solana timestamps them, eliminating the ability to re-order transactions to a validator's advantage. This helps make Solana a "censorship-resistant" network.

Solana uses a "proof of stake" system to verify transactions, manage its coin supply and create new coins. However, as with other proof of stake systems, stakers can lose money if validated transactions don't meet the system's rules. For verifying transactions, validators receive staking rewards in the form of new coins and take a cut of the rewards as a commission. They then pass on the rest of the reward to those who have staked with them, proportionally to their ownership interest. **(Royal, 2021)**

● Polkadot

Polkadot is a blockchain network which can be described as a multichain. The project is maintained by Gavin Wood, the former CTO of the Ethereum project. Polkadot aims to build a framework that interconnects blockchains, even if each chain performs different functions to one another. The two main structural components of the Polkadot multichain are Relay chain and Parachains.

Relay chain is central to everything. It is responsible for security, consensus and cross-chain interoperability across the whole network, and has an intentionally reduced functionality. (Smart contracts are not allowed). Relay chain, just like any other blockchain, has validators staked with DOT – Polkadot's native currency – for using Proof of Stake to achieve consensus. The validation mechanism is actually called "Nominated Proof-of-Stake". Nominators bond their stake to particular validators in order to help them get recognized by the network and be allowed to mine the blocks. Profits and losses are shared with nominators.

Parachains are blockchains that connect to the Relay chain and delegate their consensus and security computations to it. In this way, Parachains become fast and congestion-free.

Each parachain can still has its own governance rules but it must be able to pass blocks that the Relay chain can understand. The job of transitioning from a given parachain to the Relay chain is done by special nodes called Collators. Parachains are built to serve a single purpose. For example, one of them might be good for fast transactions while another is designed for smart contract implementation. While Relay chain is permanent, parachain can disconnect and connect back to the network. The connection is established on a subscription basis.

Parachains are blockchains that run constantly and lease their space in the Polkadot network by locking the funds for the duration of the lease.

Parathreads use a pay-as-you-go model. Parathreads are blockchains that run less frequently.

By design, parachains and parathreads can communicate. Even existing blockchains like Bitcoin and Ethereum could join the Polkadot family via so called bridges. This resolves the isolation issue we discussed about existing blockchains. In addition, the costs of running such networks are significantly reduced because there is effectively one chain (Relay) responsible for operation.

Another important advantage of Polkadot is being developer- friendly. The majority of parachains are built using Substrate, a modular framework that allows blockchains to be built to specification within hours. Since the Relay Chain is built on Substrate, any Substrate-based blockchain can easily connect to the network. **(Knight, 2021)**

The Relay Chain of the Polkadot Network has been live since May 2020.Kusama can be thought of as a test network for Polkadot. Right now, the functionality of the Polkadot protocol is being tested on this network. A special mechanism of distributing subscriptions to parachains

– called candle auctions – is also checked. There is a lot of trust in the future of Polkadot as a lot of projects have already decided to use the Polkadot mechanisms in the past months. **(Knight, 2021)**

●   Avalanche

Avalanche (AVAX) is a smart contract-capable blockchain platform founded in 2019 by Dr. Emin Gun Sirer and focused on transaction speed, low costs, and eco-friendliness. Ultimately, what Avalanche hopes to deliver is a highly scalable blockchain that doesn't sacrifice decentralization or security. Once a transaction has achieved finality, it's literally final, it can't ever be altered.
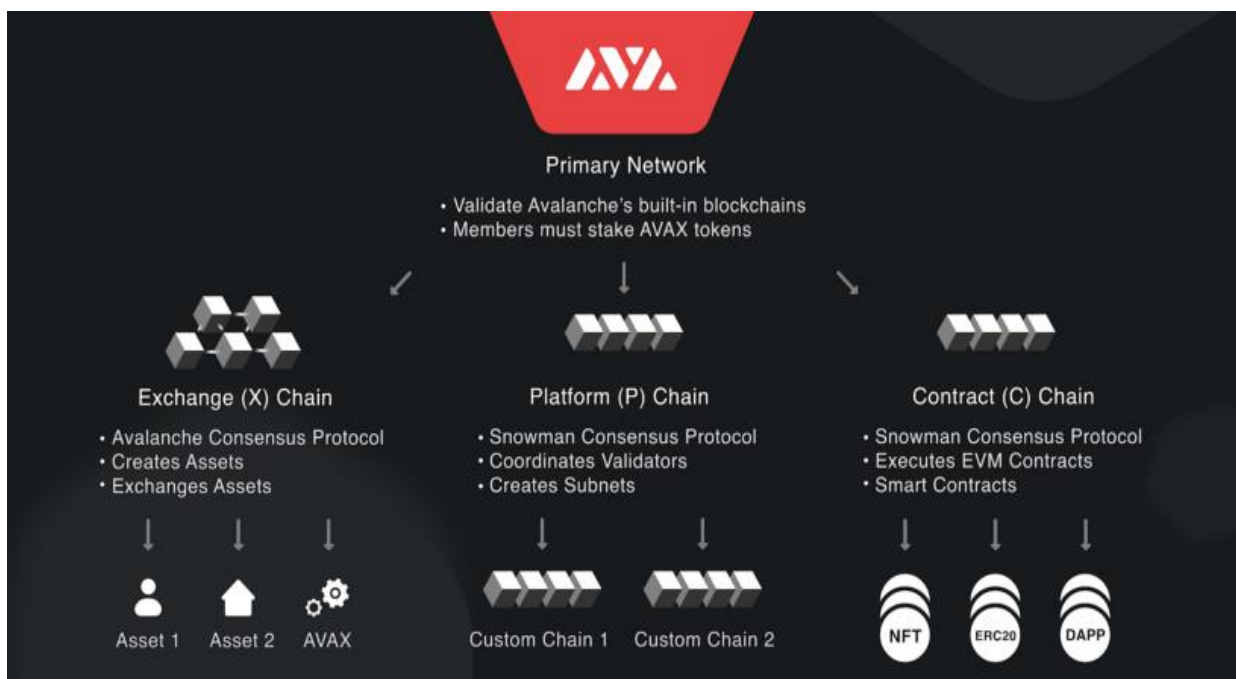
Figure 10 The way that avalanche operates

Avalanche's network consists of three component blockchains. Each blockchain specializes in a task within the broader Avalanche ecosystem instead of having one chain do them all. Distributing tasks amongst different chains helps keep the Avalanche platform agile, allowing it to achieve decentralization, security, and scalability.
The Exchange Chain (X-Chain) is the blockchain responsible for creating and transacting Avalanche assets. Avalanche's native token AVAX is the current most popular cryptocurrency on the platform. Transactions on the X-Chain generate fees paid in AVAX. That's similar to how gas fees on Ethereum are paid in ETH.
Smart contracts are Avalanche's key feature. This feature enables developers to build decentralized applications on Avalanche while leveraging the platform's security and scalability benefits. The C-Chain runs smart contracts for the Avalanche platform and is EVM

(Ethereum Virtual Machine) compatible. Being EVM compatible means anyone can deploy Ethereum smart contracts on Avalanche and the already existed Ethereum apps, can also exist in Avalanche platform. Avalanche is also compatible with Solidity, the programming language used by the Ethereum network.

Avalanche's P-Chain allows anyone to create an L1 or L2 blockchain. In Avalanche terms, these blockchains are called subnets, with the P-Chain being the default subnet common to all. The P-Chain manages the landscape of Avalanche subnets by keeping track of validators, but subnets are also responsible for validating the P-Chain. (The Shrimpy Team, 2021)

The Avalanche network can process an impressive 4,500 transactions per second, compared to just 15-30 transactions per second for Ethereum or 250 for Cardano.

3.2.1 Differences between blockchain ecosystems

Each blockchain platform has a different set of capabilities. My comparison table can give you this insight quickly.

The primary objective was a side-by-side comparison of selected platforms, and how they are prepared for the future when blockchains will not be seen only as isolated platforms for crypto coins but more as an extension to the current Internet where can exist applications, services, and communities in a pure decentralized and distributed space, where users are the only ones having control over their data, digital currency, and immutable, self-enforcing code, executed from a chain, is protecting their rights.

Table 2 Differences between blockchain ecosystems

	Ethereum	EOS	TRON	Cardano	Tezos	NEO	Solana	Polkadot	Avalanche
Blockchain Generation	2nd gen	2nd gen	3rd gen	2nd gen	3rd gen	2nd gen	2nd gen	3rd gen	2nd gen
Consensus Mechanism	PoW	PoS	Dpos	PoS	PoS	dBFT	Dpos	NPoS	DPos
Block Time	14s	5s	3s	20s	30s	20s	8s	6s	3s
Smart Contracts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dapps	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Decentralized Exchange (DEX)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Decentralized Finance(DeFI)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Describing the fields of the table, first of all Consensus Mechanism is a secure, fault-tolerant mechanism used to achieve agreement on a state of the blockchain network. This involves verification and authentication of every transaction, which becomes part of a new block. The main two mechanisms are PoW and PoS.

PoW (Proof-of-Work) computationally intensive algorithm, assures that miners can only validate a new block of transactions if the network nodes collectively agree that the block hash provided by the miner as proof of his work is accurate.

PoS (Proof-of-Stake) which is not computationally intensive. Instead of having miners with powerful HW, the next block producer is selected by the algorithm and based on each validator's stake. This process trust validators with the most stake that they will act responsibly for the whole network.

But there are and some other like, DPoS (Delegated PoS) which DPos system is maintained by an election system for choosing nodes which verify blocks. These nodes are called block producers.

Also, NpoS (nominated proof-of-stake) - a relatively new type of scheme used to select the validators who are allowed to participate in the consensus protocol.

Finally, dBFT (Delegated Byzantine Fault Tolerance) which allows large-scale participation, in a similar way to the Delegated Proof-of-Stake consensus. dBFT mechanism consists of absolute finality. After final confirmation, a block can't be bifurcated, so the transaction can't be revoked or rolled back.

Referring to block time, transactions are broadcasted immediately, but they are not trusted until they become a part of the next block. For that reason, it is important a low block time. As mentioned, in previous chapter of thesis, smart contract is actually a self-executed program stored in a blockchain that can be executed in a distributed and decentralized manner when predetermined conditions are met.

Decentralized Exchanges (DEX) are open markets for tokens or blockchain-based assets. They directly connect buyers and sellers without an intermediary. They use their code to safeguard transactions, so just when both sides comply, the transactions are completed. Key algorithm of DEX must exist as smart contract/dApp on the blockchain.

Finally, Decentralized Finance (DeFi) is another service provided by smart contract. DeFi provides access to decentralized banking and financial services for anyone. (Holovský, 2021)

3.3 Benefits of using dApps

It can be difficult to understand the idea of decentralization for those who are not familiar with the blockchain technology. Although, decentralization means that no single entity has control over the process that is being used. **(Pihl, 2018)**

The use of decentralized applications can offer some benefits to users. First of all, dApps proffer more autonomy and security from centralized applications. Decentralized applications are open source, that means that the source code is available ensuring a high level of transparency of the application. Community and users of a dApp can audit it and review the source code of the application. Users can inspect or improve the code as the source code of smart contract is maintained publicly. **(Cryptopedia staff- Gemini., 2021.)**

Also, one main feature of decentralized applications is security. They are more resistant to cyber-attacks than centralized applications. This happens because any computation is done to a different node, eliminating the need for a single entity. For example, if a single-server app goes down, then the entire system stops working. A dApp will only go down, if every node in the network falls, which is impossible. **(Pihl, 2018)**

Privacy is more enhanced at dApps too. Dapps work on blockchain that use strong cryptography to secure the data which they handle. This data is stored cryptographically to add transparency and security. The information can only be seen by the creator and the other users can only verify them for validity. All these actions which are handled by the application, can be publicly reviewed in the blockchain block explorer by the user. But only cryptographic interactions can be seen, the entire data is stored cryptographically secure. In addition to this, the fact that a DApp works on a blockchain means that a consensus protocol is used to verify each action. This may be that of Proof of Work (PoW) or the Proof of Participation (PoS) or the one chosen by the DApp developer. This seeks to guarantee the same level of security applicable to the blockchain on the DApp. Unlike centralized applications, dApps do not store information in the cloud or on external servers. **(Cryptopedia staff- Gemini., 2021.)**

4.Categories of Decentralized Applications (dApps)

In this chapter, it will mention some of the most interesting and popular decentralized applications on the market at this moment, in the respective categories.

4.1 Security dApps

These applications have the mission to safely certify and secure all digital assets. V-ID is a validation platform that secures any digital file against unlawful manipulation protecting businesses and processes against digital fraud. Their solution can serve as the de-facto standard for file protection. Also, the second dApp, Mysterium Network is an open-source project fighting censorship, surveillance and cybercrime through decentralized technology.

4.1.1 V-ID

V-ID is a platform which is used at medium to large organizations for file protection. It validates and secure digital file protecting business against digital fraud-ID uses blockchain technology, the software creates a fingerprint of the document that is embedded in the blockchain. The documents can be any type, from invoices to educational certificates. The document can be authenticated quickly from anywhere since it is a verified part of the blockchain. The files must be validated so as to be verifiable. The process of validation includes extracting the fingerprints of files and saving them in the blockchain. So, V-ID will detect if a file changes for just one byte, or anything else.

The validation can happen via 3 methods. First of all is the validation service, V-ID members will do the validation for users on the webpage. If the customer desires, a V-ID conveyancer there will be present to confirm ID and supervise the validation process.

V-ID STAFF ON-SITE   CHECK ID'S AND FILES   VALIDATE

Figure 11 Validation service (VIDT Datalink Awareness Team, 2019)

Afterward, with a self-validation method, an employee of the issuing organization can validate files at any time he wishes. Firstly, an employee of the publishing organization is defined to become a validator. This person's identity is established on site by a V-ID agent and V-ID-appointed conveyancer. After V-ID has created the Validator's profile on the platform, it has the ability to log in at a Validation Terminal. The Validation Terminal has a user-friendly interface, where files can be uploaded to be validated.

KYC   EASY INTERFACE   SELF-VALIDATED

Figure 12 Self - validation (VIDT Datalink Awareness Team, 2019)

Finally, with API validation, this method is a server-to-server process. The V-ID API extracts the fingerprint of a file from the code that the software uses to create that file. This means that, for example, in the case of a generated PDF file, the V-ID API does not need to handle the file itself to still be able to validate the file. This validation process is non-intrusive to the normal workflow at the company.

NORMAL WORKFLOW   API EXTRACTS FINGERPRINT   VALIDATED

Figure 13 API - validation (VIDT Datalink Awareness Team, 2019)

The V-ID Platform saves the coherent information of a file like the file's purpose. The digital fingerprint is saved on the blockchain. The coherent information of a file, like the publishing party and the file's purpose, is always saved on the digital fingerprint which is saved on the blockchain. For a blockchain to be useful for V-ID validation there are some conditions like the protocols of clients and the use-case. Currently there are four blockchains to save the fingerprint. These are Ethereum which has many nodes that ensure continuity and safety in

numbers. IBM's Hyperledger, this blockchain is more closed, with less nodes, but more control over the network. DigiByte, a very well-known blockchain with great community support, a high node count and low transaction rates. Bitcoin, the most well-known blockchain, with estimates of over 200000 nodes around the world.

Finally, the V-ID Token (VIDT) is the main factor that makes validation possible-ID appoints a wallet to the issuing organization, containing a balance of V-ID tokens. Organisations buy bundles of VIDT, of which the size depends on the expected monthly amount of validations. A transaction with VIDT will occur each time a validation is done, which records all necessary details to track back the filetype, validation location, timestamp and identity of the validator. The transaction of VIDT will be deducted from the VIDT bundle of the publishing organisation. The file can be verified in 5 seconds. **(VIDT Datalink Awareness Team, 2019)**

4.1.2 Mysterium VPN

Mysterium Network is an open-source project which aims to fight censorship and surveillance through decentralized technology. The decentralized architecture uses encryption and layered protection protocols to ensure privacy and anonymity for users in the network. The peer-to-peer node network of the Mysterium project includes the use of the first decentralized VPN. Mysterium Network is a quickly and scalable transport security layer. It cannot keep logs of user's traffic because it decentralized VPN on blockchain. Data of users is distributed across the network as everything is transparent and not any single node having complete access to user's profile.

The application is built with peer-to-peer architect ring using AES-256 encryption with SHA384 cryptographic hashing and layered protection protocols. Also, the Mysterium VPN mobile application uses the OpenVPN protocol. OpenVPN is an open-source software that executes virtual private network techniques to create secure connections (point to point or site to site) and remote access facilities. It uses SSL/TLS protocol for key exchange. **(Chacón, 2018)**

Figure 14 How Mysterium VPN operates (mysterium VPN documentation)

As we see in the picture above, a user uses Mysterium VPN to geo spoof to access the internet encrypting the traffic using OpenVPN and wide guard protocols. Then he accesses Mysterium network which is a Mysterium community of netizens who rent their residential IPs. In the case of Mysterium, the internet activity is rerouted through nodes offered by the community members and not servers. Users with unused network traffic can sell their internet as a node to the Mysterium marketplace. Finally, he appears to be connected from USA while he is browsing the web in other country. The first version of the application includes some basic functionality that will allow user to browse and connect to a list of available node countries in the decentralized network TestNet. User can also provide a secure connection to those in need by hosting his own VPN node. Also, in the application user will be able to see his current IP address and connection status at the top of the screen. The bottom part of the screen shows connectivity statistics like session time duration and amount of traffic received and sent. Other functionality includes a favourite feature so that you can save your preferred connections for quick and easy access.

4.2 Finances/Exchange dApps

These applications focus on building out financial services using cryptocurrencies. They offer the possibilities of lending, borrowing, earning interest, and private payments with no personal data required.

4.2.1 MakerDAO

MakerDAO is an open-source project on the Ethereum blockchain created in 2014.MakerDAO is one of the first and most well-known projects that focused on decentralized finance. MakerDAO uses the Maker protocol that allows users to borrow against a diversity of supported crypto assets as warranty that they deposit into smart contracts. The crypto loans that it accommodates are operated through Ethereum smart contracts as it is built on the Ethereum blockchain. The Maker Foundation has granted control of the Maker Protocol, in order to transfer its ownership completely and become a decentralised autonomous organisation (DAO). The DAO is composed of individuals all over the world who hold MakerDAO's governance token MKR, which gives to the users the capability to vote on changes to the network.

There are two tokens which incur in MakerDAO. Firstly, the Dai token is a stablecoin which aims to be attached to the US dollar through supply and demand. In the MakerDAO platform, when users seek to borrow, they deposit supported cryptocurrencies as a guarantee and receive their loans in Dai. Meanwhile, in case the system heaps bad debt in MKR, the token is providing supporting liquidity and holders of MKR also take on a role in the governance of the Maker Protocol. In more detail, the Maker Protocol's loan functionality is based on smart contracts on the Ethereum network, technically referred to as collateralized debt positions (CDP), or more recently Maker Vaults. For example, when someone wants to borrow dai, they deposit ETH or other warranty asset into the Maker Protocol to be held in a Maker Vault and

receive a loan in Dai relative to their collateral. The loaned Dai can be paid back at any time in return for the collateral or the Vault can liquidate the collateral to ensure the loan is secured, meanwhile when they are paid back, Dai tokens are automatically destroyed.

However, the MKR token is used for two purposes on the MakerDAO network. Firstly, the governance rights provided by MKR tokens allow holders to adjust the ecosystem: the addition of new collateral types and risk parameters for them, are regulated by a majority vote of MKR holders. In addition to governance, MKR holders also act as buyers of last resort for Dai loans. If the collateral ETH held in the Maker Vaults is insufficient to cover the amount of Dai in circulation, MKR is created and sold in a debt auction in order to raise the amount of collateral. The functionality of MKR is designed to urge holders to act responsibly in their collective governance of the network. The Maker Protocol aims to unlock the possibilities of decentralized finance and provide developers and users with a set of innovative financial tools. Relatively, the Maker Protocol and its Dai stablecoin are crucial base layer infrastructure for diverse other DeFi protocols.

Dai is used and accepted by a range of community -developed DeFi apps that use the Ethereum blockchain. For example, The Airbus Heritage platform is a blockchain-enabled fundraising and donation platform that allows charities to incorporate cryptocurrency and smart contracts and so open up funding possibilities to a new class of potential donors. UNICEF is also using the Dai token to allow donors to fund open-source explorations of blockchain for social projects: Dai donations to UNICEF in any amount go towards bounties and research funds for a range of tech projects designed to help vulnerable people. Other DeFi apps that currently operate in the Maker Ecosystem and utilize Dai, include, Outlet, a high-yield alternative to savings accounts, and Uniswap, a protocol which facilitates fast, efficient crypto trades on the Ethereum blockchain. In addition to applications in commercial finance, MakerDAO hopes that the adoption of Dai positively will impact regions suffering from hyperinflation by offering users a stable alternative to inconstant currencies. Dai is also making its way into the gaming industry as developers use the blockchain to monetize and grow in-game economies. Games like Axie Infinity, Skyweaver, and Battle Racers allow users to create and tokenize in-game assets, and earn rewards for those tokens on the blockchain. MakerDAO has launched the Dai Gaming Initiative to promote Dai within the gaming ecosystem, to induce the development of gaming apps that integrate with Dai rewards.

As a decentralized autonomous organization, MakerDAO's long-term objective is to transfer its governance entirely to its users, who will run the blockchain as a community. Those agreements are reached via a voting system that issues polls to MKR holders such as which cryptocurrencies to accept as collateral, where to set borrowing rates, and which individuals to appoint as Maker Representatives. In the latest governance polls, for example, users voted on whether to add the Gemini Dollar (GUSD) and Pax Gold (PAXG) to the list of accepted collateral currencies in the Maker Protocol. Both polls resulted in support for adding the cryptocurrencies. Developers continue to use Dai and the Maker Protocol to create innovative DeFi apps that grow the Maker Ecosystem and increase its accessibility to users around the

world. To support that effort, MakerDAO hosts a repository of resources for developers seeking to integrate Dai, while the community itself has developed the Awesome MakerDAO resource which also serves to introduce new users to the possibilities of DeFi. The daily active users are 8,598 and the transactions at one day reach to 14,061. **(bitcoinsuisse, 2020)**

4.2.2 PancakeSwap

PancakeSwap is the largest decentralized application on the Binance Smart Chain.It was launched by anonymous developers and its function is to allow tokens to be exchanged on the Binance Smart chain. PancakeSwap app is a decentralized exchange for swapping BEP-20 tokens. BEP-20 is a token standard on Binance Smart Chain that extends ERC-20 (Ethereum token standard). More specifically BEB-20 is used as a blueprint for tokens that defines different rules for the usage of tokens. **(Binance Academy, 2020)** PancakeSwap uses an automated market maker (AMM) model. That means that while users can trade digital assets on the platform, there is a liquidity pool to trade with. Those pools are filled with other users' funds. The user deposits his assets into the pool, receiving liquidity provider (or LP) tokens in return. They can use those tokens to reclaim their share, plus a portion of the trading fees. So, users can trade BEP-20 tokens, or add liquidity and earn rewards. Pancakeswap application gives some more additional options. For example, a simple description of the application and the assets of it, user can also farm inside the application to get LP tokens and earn *Cake. Finally*, user can bet it in *Syrup* plains. Once again, users need to approve the withdrawal of these tokens for staking it. When the *Cake* has been staked, user will be earning the reward token of the pool passively. At *Harvest* selection, user can cash out his rewards.

PancakeSwap has been audited by CertiK as depositing funds into a smart contract always carries the risk of bugs, even for audited and highly reputable projects. **(Binance Academy, 2020).** The daily active users are 51,360 and the transactions at one day reach to 58,070.

4.2.3 OpenOcean

OpenOcean is a fully decentralized liquidity aggregator on ETH, BSC, ONT and other public blockchains that offers users the best rates for cryptocurrency swaps. OpenOcean was set up in Singapore and the first version of platform (Antarctic Ocean) was launched in September 2020.The technical team consists of engineers and financial veterans from multinational IT companies like IBM, Intel. Open ocean application is offering traders price comparisons between both decentralized exchanges and centralized exchanges. Users of OpenOcean can trade Ethereum, Binance smart chain, Tron, Ontology, Solana and Polkadot. This makes OpenOcean unique from the other decentralized exchange aggregators. DEX aggregators usually use algorithms to find the best price for a trade, comparing multiple decentralized exchanges.

OpenOcean takes a security-first approach to protect users from security vulnerabilities and other incidents. Apart from their internal security auditing, OpenOcean decentralized application passed security auditing on all OpenOcean public contracts from Certik on March 9, 2021, and SlowMist on February 18, 2021, without any issues. Certik leads blockchain security by innovating the use of cutting-edge formal verification technology on smart contracts and blockchains. Unlike traditional security audits, formal verification mathematically proves program correctness and hacker resistance. Also, SlowMist is a company focused on blockchain ecosystem security. The company is already a top international blockchain security company, serving many global well-known projects through security solutions that integrate threat discovery and defence while tailoring to local conditions.

In the crypto industry, so far, there was no single entrance for one-stop crypto trading between DEXs and CEXs. DEXs was chosen by some users, taking responsibility for the safety of their own funds, choosing to trust smart contracts when they are taking part in trading. In other ways, CEXs was preferred by other users because of better liquidity and to transact with fiat currencies. However, price instability and price variations between exchanges mean mainstream users without programming skills cannot get the best prices in the market. As a result, OpenOcean using an optimized version of the Dijkstra algorithm called D-star which splits routing between different protocols for better transaction rates. So, it offers the best prices for users on DEXs. OpenOcean then compares the best prices on DEXs and the best prices on listed CEXs. Then the protocol offers to user, to trade at the best price either on the user's chosen DEXs or CEXs with their wallet. According to an article in DApp Journey, OpenOcean provided traders with a better price and lower gas fees. To this result, it's effective that OpenOcean has no extra free commitment.

OpenOcean is also friendly to both begin and experienced traders. It provides a simple user interface. The classic versions offer new users charts of price on DEXs and CEXs, also price comparisons between DEXs and CEXs. The pro version of DApp which is in the building phase, provides transactions tools like limit orders, profit and loss settings, real-time monitoring and alerts. In the future, the aim of the OpenOcean team is to provide a more complete app, to operate as an entry point for crypto traders to get access to all exchanges and facilitate any type of comprehensive trading strategy. Finally, OpenOcean has established itself as an app which cares about the user. According to statistics, active wallet addresses are around 60.000 and $500 million in trading volume. The daily users of OpenOcean are 568 and the transactions at one day access to 1,500. **(Cointelegraph, 2021**)

4.2.4 JustSwap

JustSwap is TRON's brand new decentralized Token exchange protocol that enables the instant exchange between all TRC20 tokens and asserts more reliable DeFi functionality on Tron. It was officially launched in August,2020 and founded by Chinese entrepreneur and crypto expert Justin Sun. The aim of the TRON founder Justin Sun, is to face up the high ETH

gas fees which have created important problems from many DeFi users. With the launch of JustSwap, DeFi on TRON will have reduced fees and will be 200x faster, because of the facility of instant settlements. Some other important features which are provided from JustSwap are, infinite liquidity for countless traders and applications. Also, JustSwap users would be able to earn mining rewards and trading fees. **(NEWSBTC, 2020).** The price is resolved by the number of tokens in each pool. Each swap happens by replacing some tokens with a certain number of another token. For using JustSwap user does not need to register an account, just use his decentralized wallet to log in. The project presently supports the TronLink wallet. The daily users are about 6.000

4.3 Gaming dApps

These are applications that focus on the creation of virtual worlds and battling other players using collectibles that hold real-world value.
Blockchain technology has a very unfair reputation for being dry, boring. But blockchain can also be fun and Gaming Dapps are proof of that.

4.3.1 Eos Dynasty

EOS Dynasty is a cryptocurrency decentralized application related to Player vs Player (PVP) and Role-Playing Game (RPG) that combined with EOS blockchain. The game launched in May 2019 and it's still one of the most popular blockchain games. The economy of Crypto Dynasty is the most important element of the game, and it is based at TKT (in game token). This token allows users to be able to participate in the in-game economy and gain more items, resources and real money. EOS allows users to buy characters and get more resources to upgrade these characters as more as they can. The more powerful these characters are, the higher the resources a player can have. All items can be traded on a marketplace driven by smart contracts. **(Hoogendoorn, 2019)**

Inside the game, the users can select among Warrior, archer and wizard for their character. Every character has special ability. Users have the ability to fight battles for gaining experience and materials, gain mounts to finally upgrade their heroes and supply them with better weapons, armors and equipment. There are 16 levels for heroes to upgrade, every level up will increase hero attributes. There are about 20 unique mounts in the game. Usually the routine in-game for the user is to collect his material, check his mounts, forge and melt his items. Subsequently, he can also start crafting tickets and participate in the boss raids. Finally, the user can participate in the Arena. In Arena, users can get some extra EOS, but this area is available only to high level characters. The equipment in the game is cryptographic Non-Fungible Token (NFT) stored on the blockchain, so it is unique and can be owned exclusively by the players and can be traded freely in NFT markets, for example on Scatter Marketplace. The company plans to release up to 1 billion TKT to the game. At this time, less than 25% of it is currently available, which means that there is still a lot of space for the game to grow. The

game recently transferred from EOS blockchain to Ethereum. The daily active users are 1,350 and the transactions daily reach to 21,800.

4.3.2 Cryptokitties

One of the first games which were created to be based on the blockchain technology was Cryptokitties. The game was created by Vancouver and San Francisco-based design studio AxiomZen. CryptoKitties is essentially like a digital version of Pokémon cards but based on the Ethereum blockchain. The user in-game has the aim to collect virtual cats which each of these cats have different characteristics from the rest which make them rare. The significant element that makes the game special is that every kittie has unique DNA that can lead to four billion possible genetic variations. The application releases a new cat every 15 minutes and the others are generated by the breeding of existing cryptokitties. The CryptoKitties can be traded, sold and purchased like any other digital asset. The transactions are carried out using only Ether. Cryptokitties affect over 10% of network traffic on Ethereum and the transactions become more expensive as the traffic increases. **(BBC, 2017).** One month after the release of the game, the number of players increased due to the sold of the first kitty for 247 eth (more than $100,000). This was a notorious action for the game. However, because of this, the gap increased between rich and poor players, and this was the reason that the user-base has decreased. As time goes, the active users have been reduced, daily users this moment are only about 75 and daily transactions are about 138.However on the past, people have spent over $24 million on Cryptokitties.

The CryptoKitties game has five smart contracts: the Core contract, Gene Science contract, Offers contract, Sales Auction contract, and Siring Auction contract. Based on these contracts, players can trade or transfer kitties with other players and breed new kitties.

Table 3 Cryptokitties smart contracts (Fan Liu & Jian Jiang, 2021)

Contract name	Main functions
Core	Record all kitties' attributes and owner information
SalesAuction	As an intermediary to help player trade kitties
Offers	As an intermediary to help player trade kitties
SiringAuction	As an intermediary to help player rent kitties
GeneScience	Calculate the genes of newborn kitties

Analysing the contracts, there are three ways to trade or to transfer a kitty. Firstly, Using the **SalesAuction** contract in which the seller lists a kitty for sale with a primary price, a final price, and a price change period to the **SalesAuction** contract. As usual, the primary price is higher than the final price. The price of the kitty will change when the vendue starts linearly

from the primary price to the final price at a stable rate during the price change period. The price will not change after this period. Unless there is an offer from a buyer or cancelled by the seller, the kitty will remain in the **SalesAuction** contract. Upon receiving an offer, the **SalesAuction** contract will send the kitty to the buyer and transfer the payment to the seller. Also, using the **Core** contract, provides the ability for a player to call the transfer function to transfer his kitty to another player or the approve function to allow other players to transfer his kitty. With this action, transferring the kitty means that a kitty cannot only be traded, but can also be gifted to another player. Using the **Offers** contract, the buyer settles a request to the seller and sends the purchase fee to the **Offers** contract. The **Offers** contract will transfer the kitty to the buyer's address if the seller accepts the offer, and send the purchase fee to the seller. When the kitties are traded through the **SalesAuction**, the game publisher charges the sellers for 3.75% of the dealing price as a handling fee. Same rate of dealing price will be charged to the buyers using the Offers contracts. The players also need to pay gas fees to Ethereum miners through their Ethereum wallet, when they call any function in each contract. The gas fee is usually between 0.0001eth and 0.01eth.

Finally, there are two ways to raise a new kitty. A player selects two of his own kitties as parameters and calls the breed with Auto function in the Core contract with a breeding fee. After this operation, the mother kittie will become pregnant for a period. After this period, a player, also called the midwife, will call the give birth function in the Core contract to give birth to the new kitty. The new born kitty will be transferred to the owner of the mother kitty. The breeding fee will be indemnified to the midwife for their Ethereum gas fees paid. The other way is, to a player breed with one of his own kitties and another rented from the Siring Auction contract, which lists a number of kitties owned by the lenders. A midwife is also needed in this case. When a kitty is rented out through the Siring Auction contract, the game publisher will charge the lender 3.75% of the rent as a handling fee. The breeding fee varied over time. At the game's release, it was set to 0.002eth. However, due to the congestion of the Ethereum network resulting from the gaming transactions, the gas fee was raised. The game publisher increased the breeding fee to 0.015eth and later adjusted it to 0.008eth. Such adjustment happened several times afterward, but despite that, the breeding fee has been stable at 0.008eth. **(Fan Liu & Jian Jiang, 2021)**

4.3.3 Axie Infinity

Many games even already implement blockchain, including NFTs, into their play. Games like Axie Infinity allow players to create digital NFT creatures with unique characteristics that can be traded for real cryptocurrency to other players.
Axie Infinity is a wildly popular digital pet universe in which players can battle, collect, and earn crypto, trading fantasy creatures dubbed Axies. To play, users need a digital wallet from which they can purchase Axies. Gamers can sell or trade token-fuelled game assets in exchange for cryptocurrency. Play-to-earn cryptocurrencies like Axie's have been among the best performing coins this year. The Axie (AXS) coin has soared from under $1 in early 2021 to over $100 at its peak, though it has since pulled back somewhat from that level. Axie Infinity has close to 100,000 users in the last 24 hours.

Developed by Vietnamese studio Sky Mavis, Axie Infinity is a blockchain game where NFTs in the form of Axie monster pets, can be utilized to play in-game battles, breed new Axies, or collect game items that serve different purposes.

All in all, Axie Infinity has not become only a mainstream game, it is creating a new digital economy. Due to the high importance of NFTs within the game, there is a strong correlation between usage and NFT sales volumes. In the last 30 days, Axie has registered the second-highest number of NFT sales across all dapps with more than 887,000 sales just lagging NBA Top Shot.

While the difference with the aforementioned NFT projects is overwhelming, what impresses even more is the exponential growth in the project's demand. Compared to the numbers seen in June, Axie has increased 475% in sales volume. Additionally, that's a whopping more than 800% when compared to Q1 numbers. The number of traders and sales have also increased exponentially. Axie registered a 304% and 290% increase from the previous 30 days respectively.
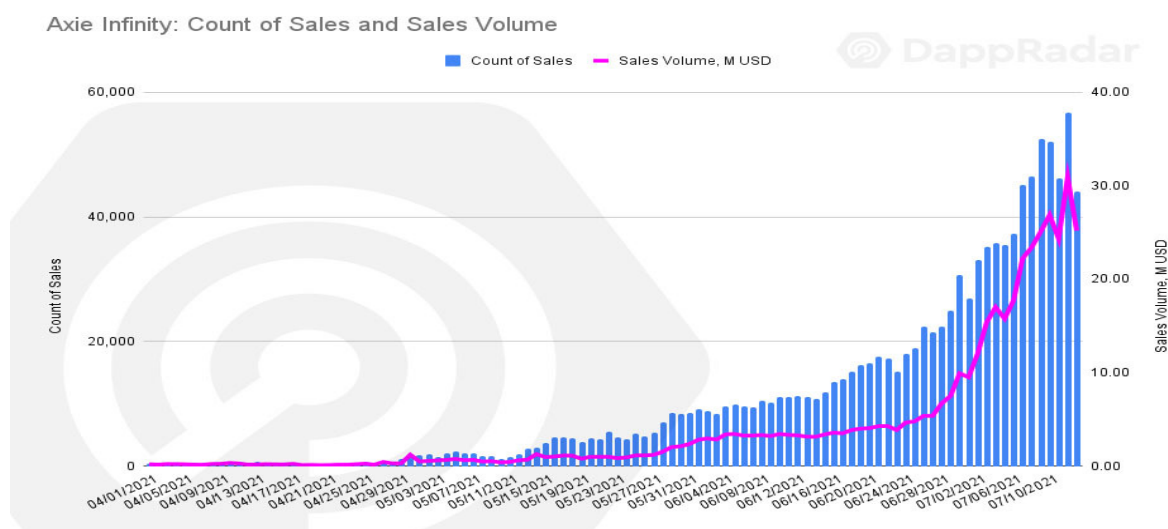

Figure 15 Axie Infinity- Count of Sales and Sales volume

In depth analysis shows that together with the number of sales, demand for Axies keeps substantially growing as well. As of July 12, there were more than 454,000 Axie holders, which represents a 220% increase from the previous month. For the second straight month, there are more Axies bred than sold every day. Moreover, as Skirmantas Januškas -Dappradar's CEO pointed out, "even with more Axies bred than sold every day, axie floor and average sale value keeps rising".

Another interesting insight is that the buyers and seller's ratio has totally changed in the last months. Not long ago, at the start of May, the trader's ratio was almost 1:1. It changed completely in the last two months where the buyers' demand almost duplicated the existing supply. This is a powerful factor to consider in the mass adoption narrative. Axie Infinity is managing to build a strong community across different platforms. As shown in the first image,

Axie's Discord membership has skyrocketed as well. This is a potentially strong signal of mass adoption.

Axie Infinity has enjoyed massive success since migrating to Ronin wallet. The launch of the sidechain has paved the way for a significant uptick in the game's demand. As a result, according to Token Terminal, Axie Infinity has spawned over $69 million in revenue for the team during 2021 alone.

Players can earn SLP (Smooth love Potion), the in-game currency, by battling in PvE or PvP modes. This digital asset can later be used to breed new Axies, or to generate real life income by selling it for local currency through centralized exchanges.

However, not everybody has access to the popular game. Axie Infinity requires players to have at least three Axie pets to start earning SLP. Currently, the cheapest Axies found on the Axie Infinity Marketplace are worth around $350 with one breed or more than $400 for new eggs. An initial investment of more than $1,000 is required, limiting the game access from an economic standpoint. Private initiatives like Blackpool Finance are adopting a business model commonly used for educational purposes to democratize the game's access in a certain way. This model can be related to widely known scholarships. Scholarships work as a shared revenue model where Axie owners "lend" their NFTs to players around the globe in order to enjoy the play-to-earn features. This type of model generates value in different ways. The social impact generated displays the potential of blockchain. On top of that, more people are getting to know this technology, improving their future outlook as well. Scholarships are being offered to players from different countries, with the biggest numbers coming from Philippines, Venezuela, Cuba, Qatar and the United Arab Emirates. It will be worth monitoring in the upcoming months, the real impact achieved by Axie Infinity as a whole.

Migrating to Ronin had an enormous effect on the project. This migration enabled a true gaming experience with seamless and virtually costless transactions. Although Ronin is just Ethereum's sidechain, it is more than fair to start viewing the network as a protocol on its own. During the last 30 days, Ronin generated more gas fees than BSC and MATIC. Only Uniswap produced more transaction fees on Ethereum's Layer 1. It looks like people are beginning to understand the true potential behind blockchain and play-to-earn games like Axie. **(Herrara, 2021)**

4.4 Social dApps

These are applications that focus on digital ownership, increasing earning potential for creators, and inventing new ways to invest in your favourite creators and their work.

Social media are interactive technologies that allow the creation or sharing/exchange of information, ideas, interests, and other forms of expression via virtual communities and networks. At the social media industry, in particular, decentralized technology has the potential to provide a new approach to data protection, user control, and content regulation.

4.4.1 Ecency

Ecency is a social network application which created in August 2016 as an alternative social network for content creators which is uncensored and based at blockchain and powered by hive. Hive is a blockchain that was designed to be fast, feeless, decentralized, uncensored platform for Web3.0 applications, with built-in features where stakeholders can earn rewards by posting, playing games, trading. The tokens of Hive blockchain called HIVE. Ecency dapp rewards content creators with the built-in stimulus mechanism of blockchain, with tokens (Hive, Hive Dollars, Hive Power) as well as Points. Tokens can be purchased and sold in major cryptocurrency exchanges (e.g., Binance, Bittrex). Points could be utilized within the platform and traded for goods, services. Points can be used for promoting, boosting user's context, and also can be gifted to another user. Ecency helps mainstream users to approach blockchain technology, rewarding them for their time, resources, and learn while they enjoy the social aspects of blockchain. Ecency is also open source, and innovative. Ecency provides mobile application for an on-going solution and also desktop application. Also, it provides security measures like public and private keys are encrypted.

The Hive network constantly creates new digital tokens to reward content creators. Some of the newly-created tokens are given to users who add value to the platform by posting, commenting, and voting on other people's posts. Promoted posts are mingled across the feeds to all users in mobile app, desktop app and web application There is no limit or restrictions, any post can be promoted to get more exposure and engagement. Also, points can be used for boosting content. Content is checked by moderators and should be original content, not detected by mackbot, or any other blacklists. Although there is content source which helps the user to understand how content was published. In some posts, there is a third-party client name, which indicates the content came from a non-Ecency application. Authors can also use third-party client applications to manage their blogs. Posts and comments remain active for 7 days and rewards are undulated depending on votes of the post and market price of token. When the period is over, pending reward changes to actual reward and user is able to claim it. Also, any user can create a suggestion and persuade community to vote on their proposal to get funded. When a suggestion reaches certain threshold of votes, it will start receiving funds each hour. If proposal falls below limit, system will stop funding for this proposal. Users can vote as many proposals as they want, there are no limits.Transactions on Hive blockchain has zero fees, transactions rate-limiting is employed to safeguard the blockchain from spam attacks. Every action will consume a small amount of resource credits. Action including posting, commenting, voting, transferring tokens but not viewing content. Every user has a limited amount of Resource Credits to use each week. The more transactions a user does, the less Resource Credits they will have left (until they recharge). Users with more Hive power will have more resource credits. **(ecency documentation, n.d.).** Ecency daily users reach at 617 and the transactions on one day are 3.830.

4.4.2 Livepeer

Livepeer projects concerns about a live video streaming application. Livepeer can be used from people who want to build applications that include live or on demand video to power their video functionality. Also, users who want to stream video, gaming, coding, entertainment, educational courses, and other types of content can use applications built on Livepeer to do so. Finally, Broadcasters such as Twitch who have large audiences and high streaming bills or infrastructure costs can use Livepeer to reduce costs or infrastructure overhead. The user can stream a video into the application, and the network will encode it into all of the formats that are needed to reach the majority of devices of other users. Also, the distribution of video is handling in a decentralized way without dependency on central servers. The goal of the Livepeer project is to provide an open platform that gives broadcasters, developers and users the ability to get their content and message out to network. The aim will be achieved, with the combination of an open-source media server, a peer-to-peer network and a designed blockchain based crypto-economic protocol. **(Petkanics, 2019)**

There are two key actors in the Livepeer network that ensure the quality of the live stream, Orchestrators and Delegators. Orchestrator is an any user who can join the network and become what's known as an orchestrator by running software that allows audience to contribute their computer's resources (CPU, GPU, and bandwidth) in service of transcoding and distributing video for paying broadcasters and developers. For doing this, audience can earn fees in the form of a cryptocurrency like ETH or a stablecoin pinned to the US dollar like DAI. But, in order to earn the right to do this type of work on the network, users must first earn or acquire Livepeer Token, also known as LPT.The purpose of the Livepeer token (LPT) is to coordinate, bootstrap, and motivate participants to make sure the Livepeer network is as cheap, effective, secure, reliable and useful as possible. In the Livepeer protocol, LPT is required to perform the work of transcoding and distributing video on the network. The more LPT users own, the more work they are able to perform on the network in exchange for fees. As the network's usage grows, so does the demand for orchestrators and thus LPT. It requires serious technical knowledge to perform the job of an Orchestrator. and can be a full-time job.

There's another set of actors in the Livepeer protocol who own a less active although equally important role within the protocol. They are called Livepeer Delegators. Delegators are Livepeer token holders who participate in the network by staking their tokens towards orchestrators. When users stake, tokens become locked up for a period of time and then user can take them back or stake them to a different Orchestrator. Doing this helps ensure that the network is more secure. When a broadcaster pays fees into the network, both orchestrators and Delegators earn a portion of those fees as a reward for ensuring a high-quality and secure network. In addition to earning fees, Livepeer mints new token over time, much like Bitcoin and Ethereum block rewards, which are split amongst Delegators and orchestrators in proportion to their total stake relative to others in the network.This has the effect of growing network ownership amongst those who participate and shrinking it amongst those who do not.It also gives orchestrators a powerful economic advantage over traditional centralized video providers since the value of the token offsets what they need to charge broadcasters to break

even. With traditional centralized video providers, they have to charge you their cost of service for transcoding and distributing video plus a margin.

In Livepeer, new tokens are minted every so-called round. Rounds are measured in Ethereum blocks, where one round is equal to 5760 Ethereum blocks. In Ethereum, one block is mined on average every 14.55 seconds, which means one Livepeer round lasts roughly 23.28 hours. The current rate of inflation as of today's round is 0.02325% and there is currently a total of 24,631,574.72 Livepeer tokens in supply. So, a total of 5,726.84 newly minted Livepeer tokens will be rewarded to all participants during the next round. Livepeer presupposes that a target rate of 50% is a healthy trade-off between network security and token liquidity, so in order to hit this target, the protocol incentivizes participation by increasing the inflation rate by 0.00005% for every round the participation rate is below 50% and decreasing it 0.00005% for every round the participation rate is above 50%. **(livepeer, n.d.)** Livepeer has 586 daily active users with over 688 transactions at one day.

5. Concerns about using Decentralized Applications

Blockchain, although is one of the most hopeful technologies that was revealed in last years, Decentralized applications have failed to receive mainstream attention until now. Maybe it is due to that blockchain term is meaningless, it is complicated for the average person to understand the technology. Because of it, those who adopted and used this technology originally, were users with interest or background in information technology. For the average user, it was more complicated to understand and use for the purposes this technology is built. The average user feels satisfied with the mainstream web -based servers for areas like entertainment, communication. So, the average user needs a motivation to change using from a well-established service to a dApp. This leads to low usability for dApps. Decentralized Applications are the way to release the potential of blockchain technology and achieve mass-adoption for dApps. The overall functionality of a dApp will make blockchain technology more understandable and user-friendly. **(Petkanics, 2019)**

Also, there is not enough effort from the community of dApps to educate users on Dapps. Users should already be educated about blockchain technology, before used a blockchain-based service. But the biggest issue is the accessibility to the information required to learn the basics. It is difficult for the mainstream user to find a starting point as most of the available information aims to people with knowledge in information technology. Another key concern is that most of these dApps don't offer oversupply of functionalities or something different than an existing web application with centralized architecture can offer. Very few dApps are being developed to provide different capabilities. Finally, the regular stories of hacking of exchange, access to wallets and investments, the fear of losing private keys are not allies to persuade users to use them. **(Glomann, n.d., 616)**

Another issue is related to user experience and user interface design of a decentralized application. This problem is created because there are just few usability engineers, designers that work in the field of blockchain at the moment. This leads that the whole design part is mostly covered as a secondary activity by developers. As it is reasonable, the majority of developers focus on functionality, stability and maintenance of the application and not in usability or accessibility. This leads to frustration and irritation at users because for each decentralized application, the user has to learn different services almost from scratch for every dapp.

An additional matter concerns certain features which are specific to blockchain, like account management, the management of password and the need for multiple system accounts. The major issue about password management is that the reset of password is absolutely impossible as there is no central authority to allow that technically. That means that it is unable

to access the user account if a user loses a password. So, all the value storage like the property of cryptocurrencies will be inaccessible for the owner of them. This issue must be understandable to newcomers in the technology, as it can be a huge risk if they are uninformed about it.In the same way, another speculation is that for using one single dApp, users need to register and use multiple platforms and respective accounts. A user who is interested in using a certain Dapp, needs to familiarize with the ecosystem prerequisites like setting up accounts, storing passwords. For example, for using an application based on the Ethereum ecosystem, he needs to own Eth digital coins.

Finally, consensus mechanisms like proof of work (PoW) and proof of stake (PoS) are also facing serious concerns. PoW is known for consuming a large extent of electrical energy because of mining for creating blocks. In PoS, the rich users become gradually richer as the chance of gaining blocks depends on how much stake the miners have. Furthermore, it is believed that blockchain technology may not reach its peak because of incertitude that arises with potential government bylaws.

5.1 Potential ways for improving Decentralized Applications

At the meantime, the majority of the problems are being addressed as a whole by the industry, and early returns on potential solutions are promising. The industry must persuade mainstream users to use blockchain technology. An example, users could use gaming dApps with crypto elements that do not require distributed ledger technology for actual gameplay and become future crypto users. Users will earn in-game rewards for their play time and for achievements in the form of cryptocurrency. Also, developers in gaming dApps should balance the gaming cost and protect the enjoyment of players, to restrict the gap, keeping balance between rich and poor and create an equal gaming community. This will also prevent the revenue from being gained by only a few players.

As mentioned before, very few development companies associated with dApps have specialized UX experts. Most dApp founders tend to be engineers which means that they are not dedicated to User interface (UI) or User Experience (UX).With the way the industry works at the moment ,it is conceivably even more important to have good UI/UX.**(Freiheit, 2018)** Development of new reusable cross-platform authentication tools that provide a better UX on mobile ,web and desktop platforms (like Scatter or UniversalLogin).A right balance has to be found between the cost of development and interaction design resources. Developers should be focused on usability and user experience. Developers in order to achieve a good user experience, they should consider all aspects including acceptable usability and improve it iteratively. Another way to improve application usability is to rigorous as far as possible to common standards in interaction patterns, that the user group has learnt by using traditional centralized apps and platforms.

For password management, some dApps try to address the issue, using the so-called mnemonic seed (~remember the device). It has to be plainly communicated to inexperienced users, that passwords once they lost, they cannot be restored. This information can be described to a short description pointing out the technical limitations about password restoration and specialities. Additionally, it would be useful the existence of shared accounts and single sign - on encouraging the mainstream users to utilize the technology. Such us at traditional centralized platforms, for example at Facebook, allow the user to re-use the login credential for associated services. This could be a key to allow for mass adoption of the technology. For example, registering on one specific traditional centralized platform, like Facebook, lets the user to re-use the login credentials for associated services.

Scalability is another major issue that a decentralized application will face. The restricted magnitude and frequency of the blocks along with the number of transactions in the network. Developers of dApps are worried about the limited number of users and the poor user experience. The median block creation time in bitcoin is 10 minutes and the block size is limited to 1 megabyte which imitates the network's throughput. At this moment, there are more that 36 million wallet users and as they grow, they will create a critical impact on the network's throughput. Matters such as the blockchain congeries problem, transaction delays and increased transaction fees will raise worries. As an outcome, blockchain technology may not be a viable approach for government or private sectors to build their business model. Also, it has become a great challenge to deal with the trade-off between blockchain size and trust, as it causes slower propagation in the blockchain network. Some things that could give solution to the reported issues could be deeper integration between web browsers and crypto wallets. For example, browsers integrating with crypto wallets (Opera browser is doing this right now) and wallets adding dapp browsers (Lynx for EOS, Status and Trust wallet for Ethereum) Also, broad adoption of solutions that remove gas costs for the end user (like Loom network, meta transactions). **(Gelbart, 2018)**

6.Conclusion

In conclusion, blockchain is a technology that is growing however the pace of adoption hasn't met expectations for many. There are various aspects behind it including technical, economic challenges. But addressing these challenges around dApps can lead us more near to the mass adoption of blockchain. The blockchain industry needs to make huge steps to differentiate dApps ecosystem from an existing ecosystem of centralized apps, offering unique capabilities to users and consume the technology to them without worrying about its complexity.

There are significant challenges for providers of decentralized applications and services to incur. Blockchain is a difficult technology to deal with because of the complexity of the technology, the performance issues, in conjunction with the main adaptation problems.

It is important to address the above-mentioned issues to achieve a delightful experience for user including a friendly approach for new users. Also, decentralized applications have to provide some technological advantages like increased trans-parency, higher privacy and security levels for personal data. End-users should understand the reason they use the corresponding dApp. **(Petkanics, 2019)**

Eventually, in this survey, they are discussed the possibilities and benefits of the blockchain along with decentralized applications. Also, they have reported transaction process, the system architecture, application areas and consensus mechanics of blockchain. Certainly, there are still many open issues that need to be moreover researched and analysed to fully take advantage of blockchain technology in sectors like security, privacy scalability ,integration with other systems. **(Seth, 2021)**

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