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Blockchain Layer 2 scalability solutions: a framework for comparison

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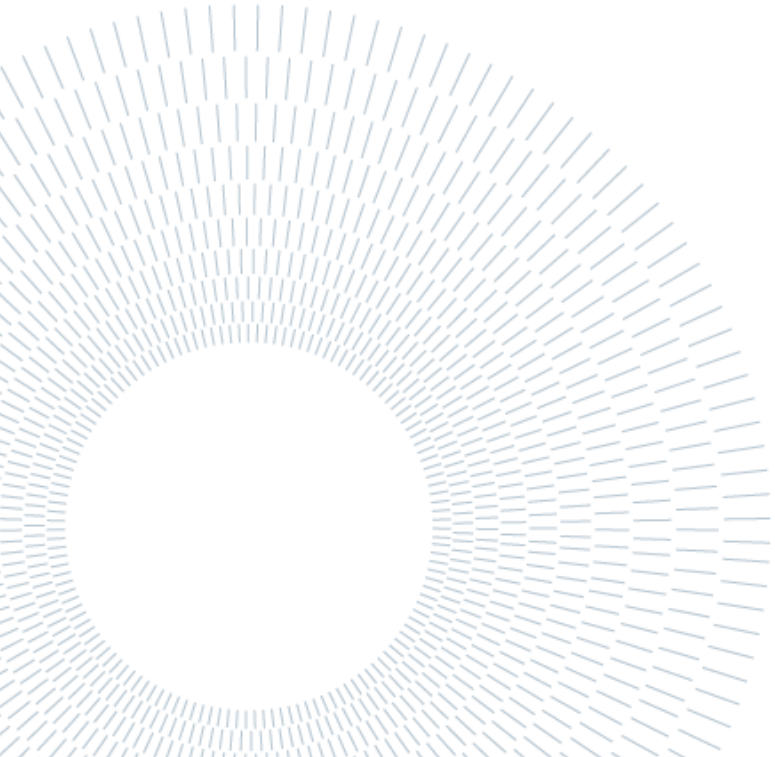
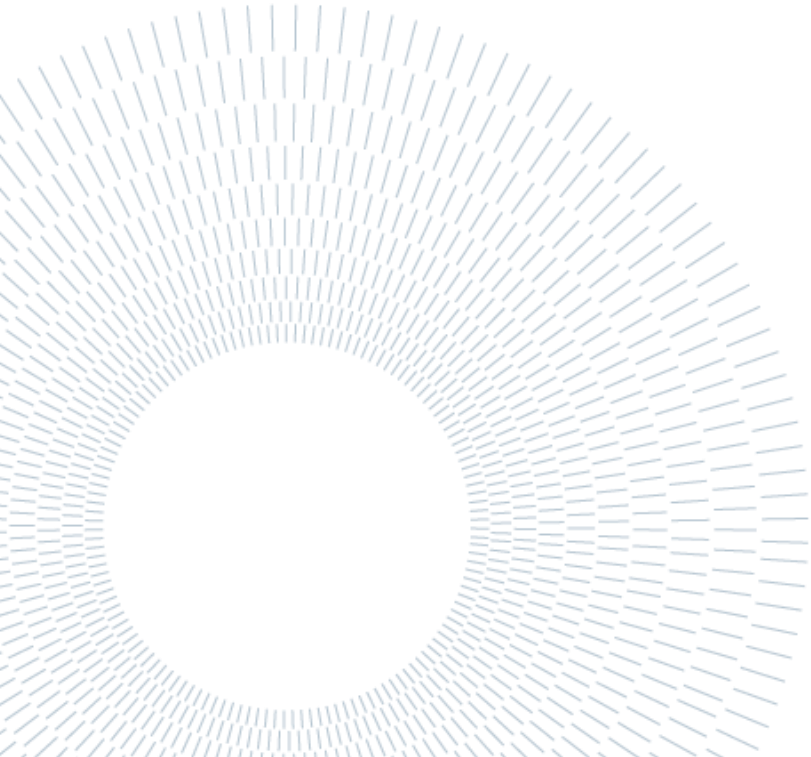


Abstract

Blockchain technology is disrupting the norm across a large number of industries. However, for it to have large-scale adoption, scalability needs to be improved. As various efforts to ameliorate scalability are on the rise, Layer 2 solutions seem to be the escape velocity the blockchain scene needs for success. Most of them being launched in 2021, Layer 2 solutions' TVL has risen 119% (denominated in ETH) this past 2022 [20] evidencing that not only they are technically a virtuous solution but also widely demanded, as numerous decentralized applications are migrating to these protocols. This thesis aims to study the more prominent Layer 2 protocols by, firstly, comparing the thesis surrounding them with the actual scene values and, providing an assessment of metrics considered relevant when analyzing blockchain protocols, especially for Layer 2 protocols. Therefore, the most relevant frameworks of study concerning these solutions are analyzed and further metrics not considered in them are presented. In the study, to validate the proposed additional metrics, a study regarding their validity and relevance is done. The importance of these solutions' community in terms a directly precursor of value is assessed comparing to their inherent value as a blockchain solution. Moreover, the ecosystem of decentralized applications is assessed, while also analyzing the theory of fat protocols [6]. Finally, the major investors in the L2 ecosystem are studied, as well as the total funding amount the solutions have gotten over time.

The results of this study are, firstly, a framework that can be used to assess layer 2 solutions, mainly general-purpose rollups, beyond technological intricacies, and give perspective on which protocol has more usability and success currently, and which may succeed or might be more widely used in the future. Secondly, the study reveals that community, measured in social media following, does not directly impact the valuation metrics of these protocols; that there are few major investors in the space with a lot of value accrued across this layer 2 space; that the protocols that have gotten higher investment (zk rollups) are not those with higher TVL (optimistic rollups); and, finally, that the dApps ecosystem is gaining value within the protocols, as all types of dApps are present in all the different protocols no matter the underlying used technology (optimistic or zk rollups). Also, it clarifies that DeFi continues to be the ruling category within dApps. Lastly, this study can set the grounds of further analysis regarding scalability-enhancing solutions.

Key-words: blockchain, scalability, L2 solutions, dApps, blockchain framework.



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Executive Summary

Challenges and Objective of the Research

Blockchain technology is an emerging technological field that has the potential to revolutionize the way servers interact across many industries. Its decentralization, immutability, and transparent nature offer a secure and trustworthy platform for recording and verifying transactions and data. However, for these blockchain solutions to succeed, a problem needs to be bypassed: the scalability trilemma [55]. Nowadays, the most prominent solutions, like Bitcoin and Ethereum, are very decentralized and secure but not scalable at all. In other words, they cannot withhold a large number of transactions, nothing comparable to the current centralized financial systems. For comparison, Ethereum can only withhold from 15 to 20 transactions per second [11] while Visa can have up to 63.000 transactions[3] every second. This, in turn, has caused the transaction fees to skyrocket [55] leading to prices up to $50 per transaction at some points.

As such, in order to fix this scalability issue and ameliorate the blockchain congestion, as well as cheapen it, different solutions have arisen. Among the solutions that have popped up that mitigate this problematic, the most prominent ones are layer 2 solutions. These solutions inherit the security of another blockchain, the mainnet (their layer 1) and offer a way higher throughput. As such, they seem promising for the blockchain technology to succeed [2]. This study aims to analyze them, the overall state of these solutions, and draft a framework for comparison among the different layer 2 solutions.

Literature review

In the first chapter of the thesis, the literature has been reviewed. After presenting the scalability trilemma [55], scalability is defined, and the different scalability solutions out there are introduced. In order to improve scalability, there are various solutions; but not all are considered layer 2 solutions. Only those solutions who inherit the security from the mainnets – the layer 1 blockchain – are considered to be layer 2 solutions [57]. Despite the controversy around it, in this thesis the approach suggested by Ethereum is the one taken. Therefore, Layer 2 solutions are considered to be, for this study, Rollups (both Optimistic and Zero Knowledge) and State Channels. Hence, Plasma Chains, Validiums and Side Chains will be out of the scope of this thesis. These solutions, layer 2 solutions, are currently only based on two layer 1 solutions or mainnets, Bitcoin and Ethereum.

Continuously, the technological overview of these solutions – optimistic rollups, zk rollups and state channels - is presented and their efficacy is also explicated. Firstly, it is evidenced that rollups can manage way higher TPS. In the case of optimistic rollups, that of 1,000–4,000 TPS [10], and in the case of zk rollups that of 9.000 to up to 100.00 TPS [41]. Additionally for dispute resolution, zk rollups are far faster (in the measure of seconds) while optimistic rollups take up to a week [11]. Finally, in the case of state channels, as it is the earlier solution [59], a lot of current availabilities cannot work in these protocols, leading to the solution getting obsolete [58].

Once the differences among the L2 solutions are seen, which also affect on their performance, as presented, the overall L2 performance in terms of TPS and TVL and in comparison to layer 1 is introduced. The literature suggests that the actual number of transactions in layer 2 solutions have outpaced those of layer 1 solutions [20]. Additionally, the performance in terms of total value locked (TVL) is higher in layer 2 solutions than in alternative layer 1 chains (all those blockchains that are not Bitcoin nor Ethereum) [20]. Finally, the list of layer 2 current solutions and a brief description of each is presented. In total, there are 2 state channels, 6 optimistic rollups and 10 zero-knowledge rollups. Of these, there are general-purpose solutions (they can be used by all types of dApps) and application-specific ones (only created for a specific purpose). The literature suggests that zk rollups are more focused on DeFi [11], but the situation should change in the future, but there is no proof of what the current state actually is.

Then, before studying the frameworks for comparison, the theory in which all are based, Fat Protocols [6], is explicated. This theory suggests that, with blockchain, the relevance is not in the applications (what would be Meta or Google to the internet) but the protocol itself. Therefore, that the protocol is the one that accrues more value. The four different existing frameworks for comparison are based on this idea, and, after their study, further metrics of relevance of these protocols are presented. Regarding the protocols for assessment, there is one that is general for all blockchain projects, the VBDE framework [53] which is a business model for blockchain protocols. It is based in four verticals: Value model, Blockchain model, Distribution model and Blockchain economic incentives. The value model focuses on developers, investors and consumers, in other words, how value is delivered to these. The blockchain model focuses on the rules of the protocol, the network shape and the applications ecosystem. Then, the distribution model, focuses on the developer's community, distribution and marketing, investor relationships and deal making and, finally, the economic model focuses on how the crypto asset gains value. Moreover, there are three other frameworks studied; these, are exclusively focused on L2 solutions. The first two, the Matter Labs framework [18] and the L2Beat risk analysis [13], focus on the technological intricacies of these solutions, focusing on security metrics mainly. In the case of the Matter Labs framework, also there is focus on finality and costs. Finally, a third L2 specific framework is studied: the one commissioned by Polygon to The Block

Research [54]. This last one, focus on four verticals: Project Overview, Technical Design, Throughput and Finality and Native Tokens. In each, different metrics are highlighted. In the Project overview, the team and the investors behind each protocol are pinpointed. Then, in the technical design, the purpose (general purpose or application specific) is detailed as well as the scaling approach (type of rollup) and the dispute resolution type. On the other hand, in the Throughput and Finality vertical the valuation is presented in TVL, transaction volume, active addresses and then the fees per transaction and the social media following are presented. Finally, there is a study of the native tokens of each protocol, but most protocols still not have a native token today [60].

Once these frameworks are reviewed further metrics of study are analyzed, those being: the whitepaper and team; the brand or community of these protocols as a possible metric of valuation; the funding in the space (investors relationships) and the dApps ecosystem. These metrics are detailed further as they are mentioned very lightly in the presented frameworks, or not mentioned at all. Additionally, the way these protocols are valued are presented, being, the most relevant ones for this study: TVL (Total Value Locked), and transaction volume or TPS (Transactions Per Second).

After reviewing all these, some gaps in the literature have been identified. Before stating those, a conceptual metrics framework for L2 solutions is presented, with all the accepted metrics, mixing the frameworks studied in the literature review. However, other metrics that are up to discussion, i.e. those that are gaps in the literature due to their relevance not being proved, are presented in italics, because they will be subject to further study. This further study is based on the found gaps in the literature. Firstly, the relevance of community is a widespread accepted metric, but its relevance or direct relationship to the numerical value of the protocol is not stated. Secondly, the investors behind the protocol are considered relevant in some frameworks but who these investment firms are, how many have invested in the space and the amount invested is not disclosed. Finally, the relevance of an additional metric: the dApps ecosystem of a protocol. This metric, according to the Fat Protocols theory [6] is not of essential importance but this theory has not been tested in the layer 2 scene. Moreover, there is the belief that not all solutions can work for all types of dApps (i.e. that zk rollups are only suitable for DeFi dApps solutions) and that belief is also analyzed.

Methodology

In order to resolve this, the research questions are presented, meaning that following points are studied: community relevance in terms of valuation, main investors of the L2 ecosystem, dApps ecosystem and fat protocols assessment for general-purpose L2 solutions. In order to study them, a subset of all the solutions available is taken. Only rollups are taken into account (and not state channels). The first subset, used for the first question of the study, the community relevance, has 15 protocols and, the second

subset, contains only the general-purpose solutions that have a TVL higher than $500k. This second subset contains 7 solutions.

Then, the data fetching, and its empirical analysis are explained. First, the data has been obtained with power searching and web scraping (with a custom python code for each general-purpose solution) and then, for each subject of study, a descriptive statistical study has been done (in some cases, very simple inference too). Firstly, the social media following in Twitter and the Discord members of each protocol are compared to the two valuation metrics (TVL and TPS). Then, the investors behind the solutions are presented, the total TVL accrued of the space by each investing firm is presented and which solutions have gotten more investment are graphically shown. Continuously, each protocol's ecosystem of dApps is presented both graphically and in a tabular way, and then the fat protocols theory is assessed by comparing the TVL of the most valuable (highest TVL) dApps with the overall TVL of each solution. Since not all the dApps TVL could be obtained, the following hypothesis is done: the dApps ecosystem TVL is that of the highest TVL solutions found (in other words, that the rest of the dApps TVL tends asymptotically to zero). With this hypothesis, the worst-case scenario is considered.

The methodology, despite being robust, is limited due to data unavailability and the simplistic approach taken due to the low maturity of the space.

Empirical Analysis and results

Overview on Community

When assessing the gaps in the literature, firstly, the number of followers on Twitter and the number of members on their Discord rooms are compared to the value in total value locked terms. This valuation is assessed both in the current TVL (that of the day of the data fetching, 1st of March) as well as the historical maximum TVL of the protocols. The bigger subset of protocols, 15 protocols, are compared. In both cases, we can see that there are many outliers, in other words, that there is no apparent direct linkage between the online communities measured in following or membership compared to the total value locked. As an example, we can see that the highest TVL solution, Arbitrum One, has less Twitter followers and Discord members than solutions like Zksync, whose maximum historical TVL ($176 M) is the 4% of Arbitrum's one ($4.1B).

Comparing the same two social media metrics with transaction activity, new variables were contrasted. Firstly, in this case, due to data unavailability, only 11 out of the 15 solutions had to be ruled out (zkSpace, Polygon Hermez, Fuel v1 and ApeX's information was not available). In this case, the variables to depict the transaction activity are the last 30 days transactions (30D tx) in millions and the TPS. In this case, the 30D tx refers to the month of February 2023 and the TPS is the one of March 1st (and it's the daily mean). In both cases, just like with TVL, no visual relationship is found meaning that there is no apparent linkage between the online communities and

the transaction activity. Again, looking at single points, the same is observed: the count of 30D tx of zkSync is that of 1.4M, a 6% of that of Arbitrum One, which has had 13.19M transactions in a month. Again, zkSync has more followers on Twitter and members on Discord than Arbitrum One.

In all cases, we can see that the number of followers on Twitter is comparable to the number of members on Discord, not in number but in proportion.

For this study, then - also applied in the final framework - it can be drawn that social media following is not impacting directly on the valuation on L2 protocols; not in TVL nor in transaction activity. In the protocols like zkSync, whose online communities are mismatched with the real value of the protocol, this difference can be attributed to bought bots to gain followers and members and create hype on the protocols. However, it could also be attributable to future success. That is why a study over time on online following and valuation would be interesting.

Overview on Investment

To see which firms are backing up these solutions, a subset of solutions was chosen. In this case, the second subset – that of 7 protocols – was chosen. However, in the case of Loopring, their funding was done by doing a coin offering (an ICO) and, therefore, the study does not make sense with this solution (not disclosed individuals or groups are the ones that have funded it). Finally, in order to ensure that the overall of solutions chosen represented enough the whole space both in terms of TPS and transaction volume, dYdX was added in this study. As such, with the subset studied the 96% of the total TVL and the 96% of the transaction volume of the space is assessed.

Firstly, for each protocol, all the funding rounds are presented, as well as which investment firms have invested in the solution for each round and the total amount the protocol raised. Continuously, assuming that only those who have led the rounds are the ones that have invested the total amount of that round, the amount invested by each firm is computed. We can see that, in the whole space the total investment has been that of $1.15B. In total, there are 18 firms that have majorly invested in the space, 5 of which very predominantly: a16z, BitDao, Blockchain Capital, LightSpeed VP and Paradigm. These 5 firms have invested more than 77% of the total amount invested in the space. Additionally, when the investments made are contrasted proportionally to the TVL of the protocol invested, we can see that a16z and LightSpeed VP "own" more than the 85% of the space.

Secondly, the total amount raised by each protocol is contrasted with the overall amount raised in the space. When assessing so, it can be seen that the solutions with the highest amount raised are those of zk rollups, which have raised almost the 70% of the amount raised.

In this vertical of study, the simplification done of the lead investor being the one attributed to the total amount raised is not optimal, but, since no more information

was made available, this was the most suitable approach. Additionally, it would be interesting to continue studying how zero-knowledge rollups evolve to see if the fact that they have gotten more investment improves their valuation over time.

Overview on dApps ecosystem

To assess this subject of study, the subset of the 7 protocols that have a TVL higher than $500k and are general-purpose rollups has been studied. After web scrapping the data of the official websites, and then aggregating it in the categories presented in the literature review - Defi, GameFi, NFT, Bridges, Wallets, Tools, Identity, DAO, and Other – the following results are observed.

Firstly, in the optimistic rollups subset, which are 4 solutions, we can see that the DeFi category rules in all ecosystems being the representing percentage range from 26% to 40%. Additionally, optimistic rollups have the two protocols with the highest number of dApps (Arbitrum One, with 276 and Optimism with 233 dApps). From all the protocols studied, just one, Metis, has GameFi type dApps, a total number of two.

On the other hand, three zero-knowledge protocols are studied. In one of these, the few solutions they have on their ecosystem are built by them and are focused on DeFi, allowing also for NFT trading. Regarding the other two solutions, ZkSync and StarkNet, their ecosystem are also ruled by DeFi solutions, being the 32% and 30% of their ecosystems respectively. It is seen that these solutions are not only focused on DeFi, and, on top of that, we can see that these two protocols have way higher diversity of dApps, seeing in both cases GameFi solutions in their ecosystem. In the case of StarkNet, remarkably, the protocol has 13 GameFi dApps. Additionally, in this case ZkSync has 150 dApps in its ecosystem showcasing that the generality of these solutions, zk rollups, can be as vast as optimistic rollups' one.

In this study, there can be discrepancies in how the types of dApps can be considered, despite these should limited because the categorization was done following thoroughly what is exposed in the literature review. The only controversial case is that of StarkNet, that in their website some dApps are tagged multiple times (named 'multitagging' in this study) fact that led to manual and, hence, personal decision to choose which of the tags was the one more representative of the dApp solution.

Overview on Fat Protocols assessment

For this last research question, the same subset used in the previous section was studied. However, only the information for the optimistic rollups protocols was available. Therefore, the study is more limited than desired due to this lack of public data. From the four protocols studied, the following analysis has been done: firstly, the top 10 dApps in terms of TVL is presented, and, then, the total number of dApps by TVL is added in terms of total value locked. This value, the TVL that the ecosystem accrues is contrasted with the total TVL of the protocol. From there, a percentage is found. As no more than the data presented could be found, then the following

hypothesis has been done: that the ecosystem's TVL tends asymptotically to the total TVL of the dApps found. In all cases, this hypothesis is proven to be somewhat realistic, and, in the last two cases, it seems to be the actual behavior.

In the case of Arbitrum and Optimism, only the top 50 dApps by highest TVL could be found, which represented the 18% and 21% respectively. In the case of Arbitrum, the percentage of TVL that the ecosystem of dApps is representing is the 59%. Actually, just the top 1 dApp by TVL, GMX, represents the 15% of the protocol's TVL. For Optimism, even a higher percentage is witnessed. The 71% of the protocol's TVL is attributed to its ecosystem of dApps, and the top 1 solution, Velodrome, represents the 16% of the protocol's TVL.

However, in the two other studied cases, the percentages observed are lower. Before mentioning those, it is important to note that both top 1 dApps of Arbitrum and Optimism have a higher TVL than these protocols. Actually, GMX has a TVL of $525M and Metis' TVL is that of $131M. Regardless of this fact, the same study for Metis and Boba is done and the percentages accrued by each ecosystem are 43% and 31% respectively. Therefore, we can see that in both cases it is lower.

Due to the data unavailability of zk rollups, the fact that not all the dApps of the ecosystems were studied and the disparity of the percentages obtained, the fat protocols theory [6] cannot be confirmed nor refused. However, with the data observed, the ecosystem of dApps is proven to be a relevant metric when assessing these protocols, directly affecting their value and, as such, it will be regarded as that in the final framework, both for optimistic and zero-knowledge rollups, despite not having proved it for the latter case.

Lastly, the study done only represents partially the space so the extrapolations done in this study, i.e., also considering the same observed behavior in zero-knowledge solutions, should be evaluated. Therefore, when more data is made available, both the asymptotically assumed and the extrapolation to zk rollups needs to be studied and checked.

Main findings and conclusion

After showcasing the results, they are analyzed and discussed leading to the following conclusions. The community is still relevant, but it does not directly impact the value of the protocol (not in terms of TVL and transaction activity), when measured in social media following. There are five investment firms that are behind most of the investment amount of these L2 solutions, and two of them accrue most of the TVL of the space. Additionally, most of the investment efforts are focused on zero-knowledge rollups, despite being more prominent and valuable optimistic rollups. Also, zk rollups have ecosystems of dApps varied, in other words, not merely focused on DeFi. DeFi remains to be the most prominent type of dApp across all protocols. The fat protocols theory, due to a lack of data availability cannot be ruled out but, the fact that the dApps ecosystem is relevant to the success in terms of TVL of the protocols is

evidenced. The results obtained are representative enough to oversee the metrics that wanted to be studied but not super accurate due to data unavailability and the low maturity of the space.

With the obtained results, the according amendments have been done to the framework for assessment and it is presented. Additionally, the sources to obtain the data for each vertical of the framework are presented. Accordingly, in the Appendix, the most prominent solutions are presented with the resulting framework.

The limitations of these results are, on the one hand, the low maturity of the projects that lead to a constant change of the studied variables. On the other hand, the lack of data availability has also affected on the observed results. In other words, if more data was made public and with less nuance (in the case of valuation metrics, active addresses could not be studied due to this fact). Additionally, the TVL of dApps is not public nor organized in most of the cases, leading to only being able to study the general-purpose optimistic rollups with highest TVL in the space.

This thesis can set the grounds for further analysis of the L2 solutions, especially when they are more mature, stable, and once they have all released an internal token, which will be another way to study their inherent value and the possible success of these protocols. Additionally, when more information is made available, a re-assessment of the fat protocols theory would be interesting to be made. Moreover, it would be interesting to make an automation of this framework, as the values change drastically across time due to the high growth of the market. Finally, the study of these metrics across time would be also relevant to identify unforeseen patterns.

Concluding, this thesis proofs the importance of the ecosystem of dApps in the success of general-purpose layer 2 protocols, investment state of these protocols, as well as the fact that the protocol's online communities – measured in social media following – don't impact directly on value. Finally, it provides a framework for assessing layer 2 (rollups) solutions.

Introduction

Blockchain technology has been acclaimed as a transformative innovation since its beginnings with the release of Bitcoin back in 2009. Ever since, it is considered a potential tool to revolutionize various industries. However, the current state of the different blockchain solutions, especially those that are Layer 1 solutions like Bitcoin and Ethereum, have been facing the scalability issue. In other words, as more users and transactions are appended to the network, there is higher congestion which results in high transaction fees and slow transaction processing times. Hence, the low scalability of these solutions limits blockchain technology to realize its full potential. There are various efforts to mitigate this problematic, the most promising one being Layer 2 solutions.

Academic research has highlighted the importance of Layer 2 solutions and their promise to improve the scalability problem. A study conducted in 2016 found that Layer 2 scaling solutions such as the Lightning Network can significantly reduce transaction fees and increase transaction throughput, in other words, ameliorate the scalability of the mainnet (Layer1) [1]. Moreover, there are not just studies that proof their efficacy, but also reinforce on the idea that they are critical for the long-term success of blockchain technology [2]. The paper by Alharbi et al. (2021) argues that Layer 2 solutions provide a feasible approach to address the scalability and efficiency challenges that blockchain networks face, making them more accessible and user-friendly. Additionally, they claim that these solutions should be further developed and adopted to support the growth of blockchain technology. Finally, another paper issued by the Politecnico di Milano also reinforced the idea that Layer 2 solutions certainly represent the present and future for solving blockchain scalability problem, without renouncing to a secure and decentralized architecture [3].

As the demand for blockchain-based applications continues to grow, Layer 2 solutions play a crucial role in addressing the scalability issues faced by blockchain networks.

1 Literature Review

Before revising the literature, it is important to stress the fact that this topic is quite novel and, consequently, most of the sources used to back it up are not so much from academic research but from alternative researchers that have published articles and blogs online.

Having said that, in this section, an analysis of the state of blockchain and the implicit need of Layer 2 solutions, the scalability problem, will be carried out. Continuously, the types of Layer 2 solutions will be presented and analyzed by explaining their underlying technology briefly. After reviewing that, the list of the different available Layer 2 solutions is provided, briefly describing each one of them.

As the aim of this study is to better understand these different L2 solutions and their future success, the different available solutions to analyze blockchain protocols and specifically L2 solutions is overviewed, which set the grounds for the future study. Other relevant metrics are presented and the valuation of blockchain solutions is assessed. Continuously, the conceptual framework is presented, and the subject of study introduced. Finally, the chosen L2 solutions subject to study are presented.

1.1. Blockchain Technology

The world's most valuable resource is no longer oil, but data. Smartphones and the internet have made data abundant, ubiquitous, and far more valuable [15]. After the 2009 Bitcoin whitepaper [4], a revolution started. Different blockchain-based solutions arose and a lot of different implementations for various purposes started appearing on the scene. This shift to this decentralized technology is changing the internet as we know it today. From decentralized servers (web 1.0) to the control of the 56.96%[5] of the internet traffic by the 6-top tech brands[1] (web2.0) to the current theory of fat protocols [6] that allow thin applications [7] (web 3.0).

Using blockchain technologies allows for the re-decentralization of networks, in other words, reclaiming open and trustless networks. However, for these blockchain protocols to be useful, i.e. the new norm, and admit high number of entries in the ledgers they form, there is a problematic that needs to be overcame: the blockchain trilemma, also known as the scalability problem.

[1] Alphabet (Google), Netflix, Meta (Facebook), Apple, Amazon, and Microsoft

1.1.1. The Blockchain Trilemma

Decentralization - Security - Scalability, the blockchain trilemma or scalability trilemma, as Vitalik Buterin refers to it, is the trade-off every blockchain project must assess when entering the web3 paradigm [55].

This trilemma claims that blockchains can only have two out of the three following properties:

where O(c) is the computational capacity of a node or validator (a regular laptop)

- **Decentralization**: characteristic of a system where each participant only has access to O(c) resources
- **Scalability**: characteristic where a system can process O(n) > O(c) transactions
- **Security**: characteristic of a system being secure against attackers with up to O(n) resources

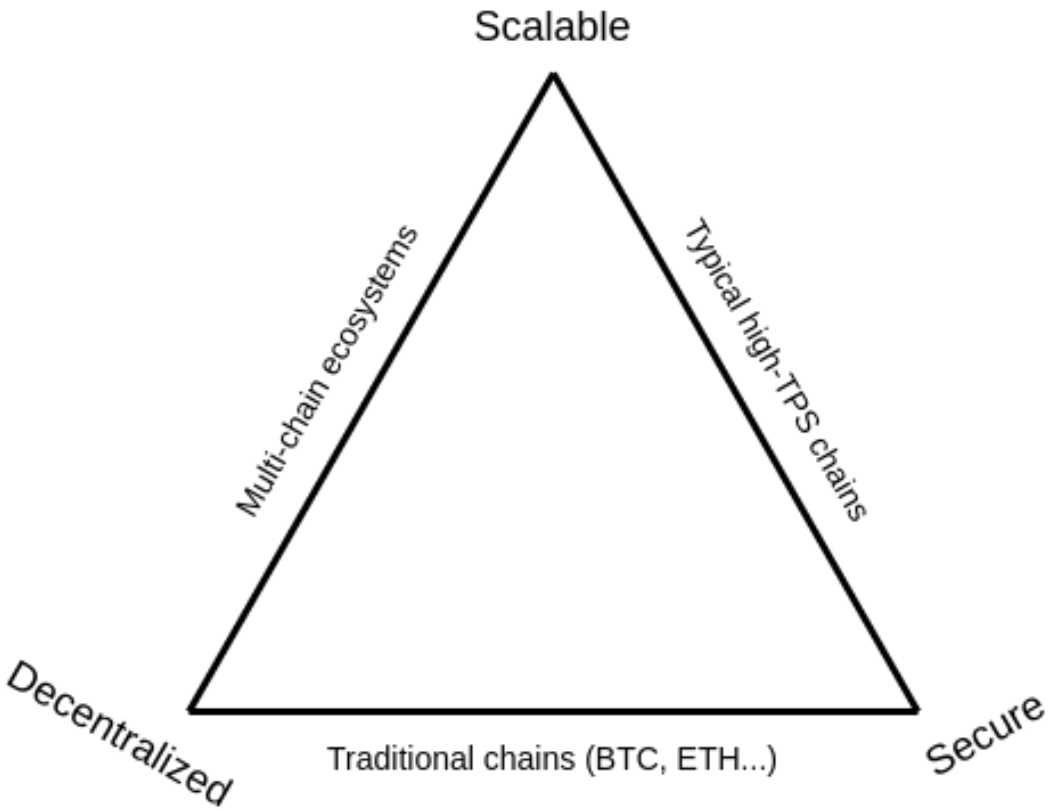

Figure 1: Representation of the blockchain trilemma (source: Vitalik Buterin's personal blog vitalik.ca)

1.1.2. Scalability

Scalability aims for faster finality and higher rate at which valid transactions are committed by the blockchain. In other words, higher throughput, or transactions per second (TPS). Efforts in ameliorating scalability without sacrificing decentralization and security are being made, yet it still is a trade-off. Scaling solutions have been made both on-chain, sharding, and off-chain. The latter can be divided in two groups: those who derive security from Layer 1, called Layer 2 solutions, and those that are new chains with their own security systems.

The most renowned blockchains, Bitcoin and Ethereum, are very decentralized and secure but not that scalable. Moreover, transaction fees are on the rise and, consequently, the cost of operating on these main networks (mainnets) are not worth it most of the times. They are starting to become inefficient [8]: the larger they grow (i.e., the more transactions they withhold), the less optimal it is to use them. While increasing on-chain capacity limits would yield higher transaction throughput, there are concerns that this would decrease decentralization and security, because it would increase the resources required to fully download and validate the blockchain [9]. Hence, if you require a low quantity, high volume transaction system, these Layer 1 solutions are not useful anymore, and high TPS chains are not the answer, as decentralization would diminish. A more scalable solution is needed, and despite there being various ways to do it, a one-size-fits-all blockchain scalability solution doesn't exist. However, rollups, which aggregate transactions and post them as one to layer 1, will have an edge to scale most decentralized applications due to their compatibility and security advantages [12].

"We think of [scaling Ethereum] as a whole spectrum. On the left extreme of the spectrum are fully sovereign chains with simple bridges to Ethereum … in the middle you will find something like Polygon PoS … it checkpoints to Ethereum but that checkpoint contains less information [than a layer-2] … On the right extreme you will find the pure layer-2s [rollups] which are actually putting both their data and the dispute resolution related to the data on Ethereum"

- Sandeep Nailwal, Co-Founder at Polygon Technology (Bankless Podcast, November 2021)

1.2. Introduction to Layer 2 protocols

Since blockchain is a rapidly evolving technological field, the terminology is constantly changing so it is necessary to note that, in this study, Layer 2 solutions term will comprise, exclusively, Rollups - both optimistic and zero-knowledge - and State Channels, i.e., off-chain scaling solutions. Therefore, all those protocols that do not derive their security from mainnet: Sidechains, Validiums and Plasma Chains are not

considered in the L2 category. It should be noted that this consideration is the same Ethereum – the community that started the movement of Layer 2 solutions – acknowledges [57].

As a general definition, L2 solutions are those that help scale applications by handling transactions off the mainnet (Layer 1) while taking advantage of the security of this Layer 1.

The motivation of creating these Layer 2 solutions (referred to L2 onwards) stems from the aforementioned economical inefficiency the main protocols are evolving to be. As it is shown in *figure 1*, in the Ethereum blockchain, high demand of the protocol has led to slower transactions that imply congestion and high gas prices[2].

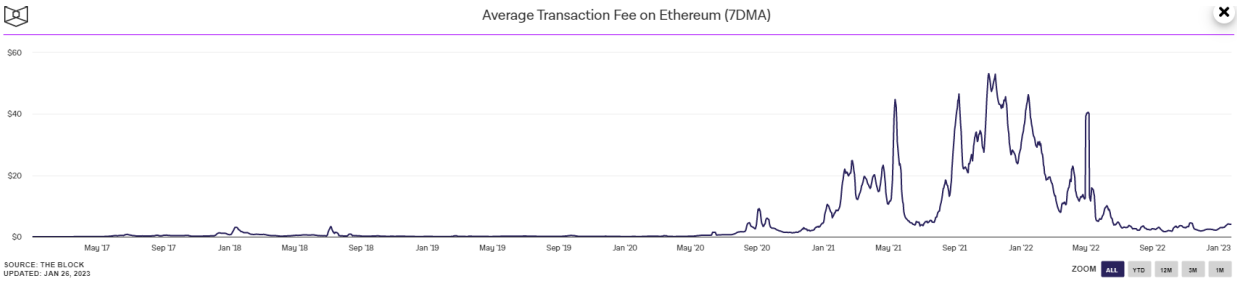

Figure 2: Daily transaction fees divided by the number of transactions made on the Ethereum network. Chart uses 7-day moving average. (Source: theblock.co)

The fact that a single transaction price can be over $50 - and could potentially even be higher - limits hugely the transactions that the demand will be willing to do on this protocol. In the case of Ethereum, not just the transactions but also all the decentralized apps that run smart contracts on it, as the prices augment, they are more willing to migrate to other solutions [56].

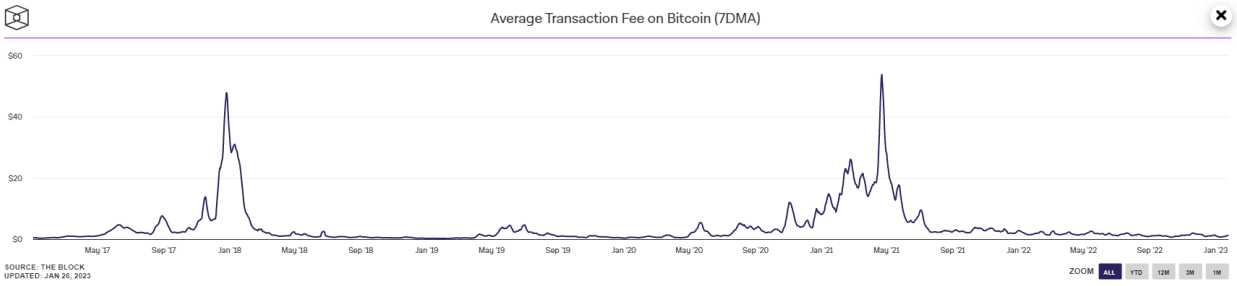

Figure 3: Daily transaction fees divided by the number of transactions made on the Bitcoin blockchain. Chart uses 7-day moving average. (Source: theblock.co)

Transaction fees are the consequence of network demand relative to its capacity. So, if the goal is to diminish this cost, network capacity or throughput must be changed.

[2] Nomenclature used to designate transaction costs in the Ethereum protocol

Capacity or throughput in blockchain analysis can be translated to the number of transactions per second (TPS) the protocol can assume. To ameliorate scalability and overcome the problematic, this is the metric that needs to be augmented for these blockchain protocols to succeed [11]. Below, by comparing *table 1* and *table 2* we can see the TPS different between some of the main protocols and current financial services used for transacting money evidencing that basic Layer 1 blockchain protocols are still very far from the reality of today's micropayment transaction rates. Additionally, they are all yet far from the TPS capacity company Visa claims to have.

Type	**Blockchain**	**TPS capacity**
Layer 1	Bitcoin	3-7
Layer 1	Ethereum	15-25
Alternative Layer 1	Solana	2.825
Layer 0	Polkadot	1.000
Alternative Layer 1	Avalanche	5.000
Alternative Layer 1	Ripple (XRP)	1.500

Table 1: TPS of main L0 and L1 blockchain protocols (Source: phemex.com)

Service	**TPS capacity**
Visa	65.000[3]
Mastercard	5.000[4]
Paypal	over 664[5]

[3] https://www.visa.co.uk/dam/VCOM/download/corporate/media/visanet-technology/aboutvisafactsheet.pdf

[4] https://cointelegraph.com/news/bitcoin-lightning-network-vs-visa-and-mastercard-how-do-they-stack-up

[5] https://www.globaldata.com/data-insights/financial-services/number-of-payments-transactions-made-using-paypal-global/

Table 2: TPS of widely used transactional financial services

Layer 2 solutions were created specifically for this sole purpose: to drastically improve the TPS and substantially reduce the transaction costs allowing for a possible chance of competitivity with the fiat transaction systems that are used nowadays [11]. Additionally, for decentralized apps (dApps onwards) to be more economically feasible, cheaper solutions are also needed. However, the fact that the scalability is being improved and that the security is inherited from the mainnet, means that, as presented with the blockchain trilemma, the decentralization of these solutions is diminished. Consequently, this lower cost cannot be afforded by all the applications; only those whose purpose and value can be still valid with a diminished level of decentralization can consider this alternative.

Finally, it is worth noting that sidechains, validiums and plasma chains are also good solutions to improve TPS and diminish this transaction costs. Even so, they will not be considered for this study due to the fact that they do not inherit the security of the underlying mainnet nor the data availability and, as a result, the analysis that they require would be too technical and out of the scope of this thesis.

1.2.1. Mainnets holding L2s

There are two mainnets or Layer 1 solutions that withhold L2 solutions and these are the two main blockchain protocols that have already been presented: Bitcoin and Ethereum. Bitcoin's only current L2 solution is the Lightning Network, and it is also its primary scaling solution. On the other hand, Ethereum counts with numerous scaling solutions, of which most are rollups.

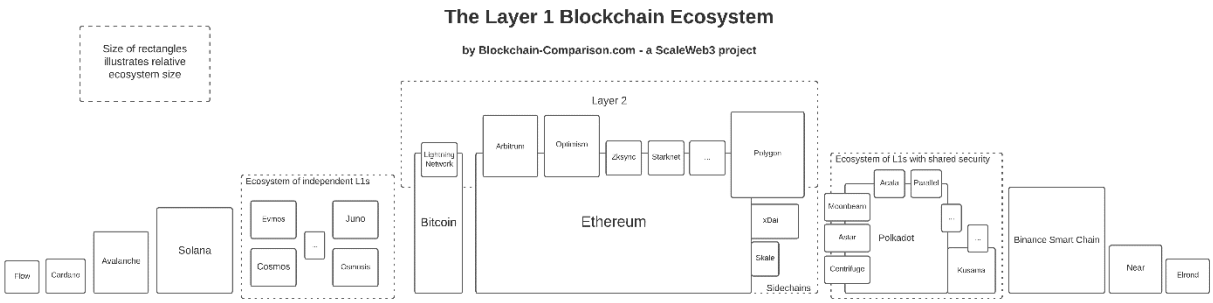

Figure 4: Schema of the blockchain ecosystem (Source: Blockchain-Comparison)

Lastly, there are another type of solutions: Parachains. These are the equivalent to L2 solutions for the mainnet Polkadot, a blockchain protocol created in 2016 by the co-founder of Ethereum Gavin Wood. Parachains inherit the security from the mainnet and offer better scalability. In theory they are like L2 solutions yet the creators of Polkadot claim that their blockchain protocol is a Layer 0 chain and, hence, Parachains

are 'advanced, next-generation layer-1 blockchains that transcend the limitations of legacy networks.'[6] For this reason and due to the fact that Polkadot still has not established a strong position in the general usage of blockchain solutions as Bitcoin and Ethereum have, Parachains will not be subject of study.

1.3. Types of L2s

As previously mentioned, there are different types of off-chain scaling solutions. All the solutions have not been disruptive findings but concepts that had been presented in the past and have been adapted for the scalability problematic within the blockchain context.

Before introducing the different types of L2 scaling solutions according to the algorithmic mechanism that underlies them, there is another categorization for these solutions: their specification. If a L2 protocol is shared or intended to be shared by various dApps, it is a **Generalized L2** solution. Whereas, if the protocol is built with one specific purpose in mind, then it is an **Application Specific L2** solution. Examples of these would be Optimism as a generalized L2 (has 100+ dApps on top) in contrast to Sorare, a football fantasy game that is clearly an application specific solution.

Below, a generalized explanation of the two different types of L2 solutions, Rollups and State Channels, is presented.

1.3.1. Rollups

Rollups batch hundreds of transactions into a single transaction in Layer 1, that contains information about the state. This bundle allows for a reduction in gas fees up to a 100x since costs are distributed among everyone in the rollup. Actually, as the number of users increases, the cheaper it is [10]. As they post the bundle in Layer 1, they inherit its security and the mainnet can focus on consensus and data availability. Additionally, since the batching is done off-chain, the only validation needed is that of the bundled transaction and, as a consequence, network congestion is lowered and TPS augmented.

Currently, Rollups can process 1,000–4,000 TPS [10], drastic improvement but still not valid for certain applications, such as global-scale micropayments (as seen in *table 1* current fiat transactional systems are far more efficient). However, there are zk rollups that claim their capacity is from 9.000 to up to 100.00 TPS [41], being more that those of Visa.

As the bundled data can be posted differently to Layer 1, there are two different approaches within Rollups: Optimistic and Zero-Knowledge.

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[6] https://polkadot.network/parachains/

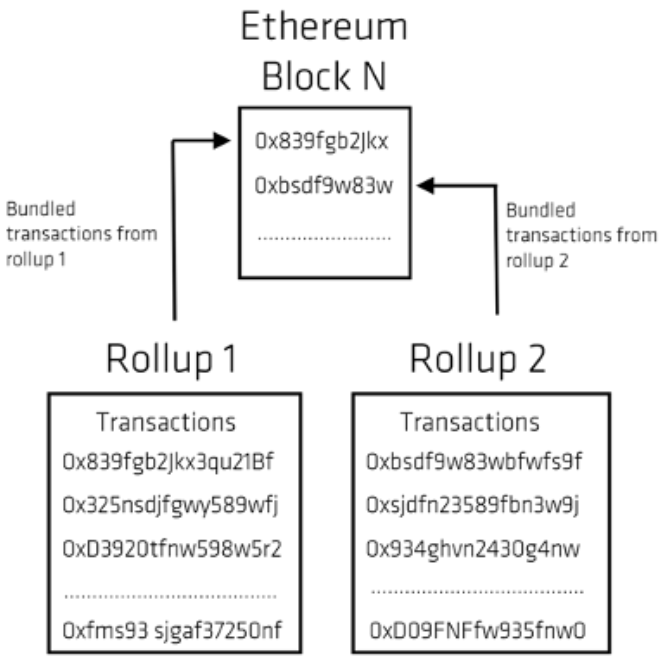


Figure 5: Rollups schema (Source: CoinShares)

Optimistic

By using fraud proofs[7], cases where transactions are not calculated properly are detected. Basically, all transactions are considered correct when submitted and there is a time window (challenge period) to raise disputes. If the fraud proof succeeds, rollup protocol is re-executed, and the state is updated accordingly in the mainnet. Because of economic incentives, i.e., the tokenomics of the protocol, fraudulent activities are not usual. However, auditing incentives need to be well incentivized to ensure that large-scale rollups (those that hold more than a few hundred TPS) are thoroughly done. That means that especially in this case of rollups, the tokenomics of the protocol need to be carefully balanced. Lastly, because of the challenge period, funds cannot be accessed until the state is updated and this implies that there can be a data availability problem (see Data availability problem section).

Nowadays, Optimistic rollups are the ones that rule the market with Optimism and Arbitrum as the current L2 solution leaders. Optimistic rollups tend to be Generalized L2s. However, the dispute resolution period problematic is causing that a rising number of Zero-Knowledge proof solutions - considered more common in Application Specific solutions [11] - are emerging, as ZK rollups' time to finality or state change is in the seconds magnitude spectrum.

[7] https://sonnino.com/papers/fraudproofs.pdf

The most notorious and widely used solutions in this category are Optimism and Arbitrum.

Zero-Knowledge proof

Validity or Zero-knowledge proof, first theorized in 1989 in "The Knowledge Complexity of Interactive Proof Systems"[8], is the underlying mechanism that allows to cryptographically proof that proposed changes to Ethereum's state are the result of all the transactions in the batch without revealing the information itself. Hence, ZK rollups provide validity proofs (ZK-SNARKs[9] or ZK-STARKs[10]) along with all transaction data. As this validity proofs are posted, the finality of each transaction is way faster than with Optimistic rollups.

ZK rollups are computationally intensive and hard to execute technically, making them less used by developers. However, as they have way faster finality, not long from now they will most probably dominate the rollups scene. In fact, Vitalik Buterin stated that [11]:

"…my own view is that in the short term, optimistic rollups are likely to win out for general-purpose EVM computation and ZK rollups are likely to win out for simple payments, exchange, and other application-specific use cases, but in the medium, to long term ZK rollups will win out in all use cases as ZK-SNARK technology improves."

The generation of ZK-SNARK proofs that are efficient with virtual machines (VM), which still has not been technically accomplished, will be the optimal solution when it comes to rollups, because it will allow for faster finality, better security and trustlessness while being optimal for a wide range of solutions.

Solutions like Loopring and zkSync are relevant in the space.

Property	**Optimistic rollups**	**ZK rollups**
Fixed gas cost per batch	~40,000	~500,000
Justification	a lightweight transaction that mainly just changes the value of the state root	verification of a ZK-SNARK is quite computationally intensive, hence, the hardware needs to be high-end
Per-transaction on-chain costs	Higher	Lower

[8] Paper available: here

[9] https://arxiv.org/abs/2202.06877

[10] https://eprint.iacr.org/2018/046

Justification		if data in a transaction is only used to verify, and not to cause state changes, then this data can be left out, whereas in an optimistic rollup it would need to be published in case it needs to be checked in a fraud proof
Off-chain computational costs	Lower	Higher
Justification	though there is more need for many full nodes to redo the computation	ZK-SNARK proving especially for general-purpose computation can be expensive, potentially many thousands of times more expensive than running the computation directly
Validity proof	Fraud proofs	ZK proofs as a validity proof
Transaction finality or withdrawal period	~7 days	Very fast
Justification	withdrawals need to be delayed because of challenge period	next batch takes seconds. Considered zero finality.
TPS capacity	2.000 – 4.000	9.000 – 100.000
Generalizability	Easier	Harder
Justification	general-purpose EVM rollups are already close to mainnet	ZK-SNARK proving general-purpose EVM execution is much harder than proving simple computations, though there are efforts working to improve on this
Complexity of technology	Low	High
Justification		complex cryptographic proofs
Trust	No need for a trusted set-up	Needs a trusted set-up to run
Live monitoring	Needed Verifiers	No need
Justification	Verifiers (rollup sequencers) must maintain live tracking of actual rollup state and the reference state in the state root	monitoring L2 chain for fraud detection is unnecessary

Security	Lower	Higher	
Justification	emphasizes on crypto incentives to users to ensure security	cryptographic proofs guarantee security	

Table 3: Optimistic vs ZK rollups (source: vitalik.ca & 101blockchains.com)

1.3.2. State channels

Presented by Jeff Coleman in 2015, State Channels are the generalization of payment channels[11], allowing for multiple transactions off-chain and just transferring two of those to the mainnet. As such, this solution can match or even exceed the TPS rollups can offer. Despite being useful in cases where users are going to be exchanging many state updates over long periods of time, if one of the participants is not available (nor is paying another third-party to maintain it on his/her behalf), the processing of the payment channel is ceased [11].

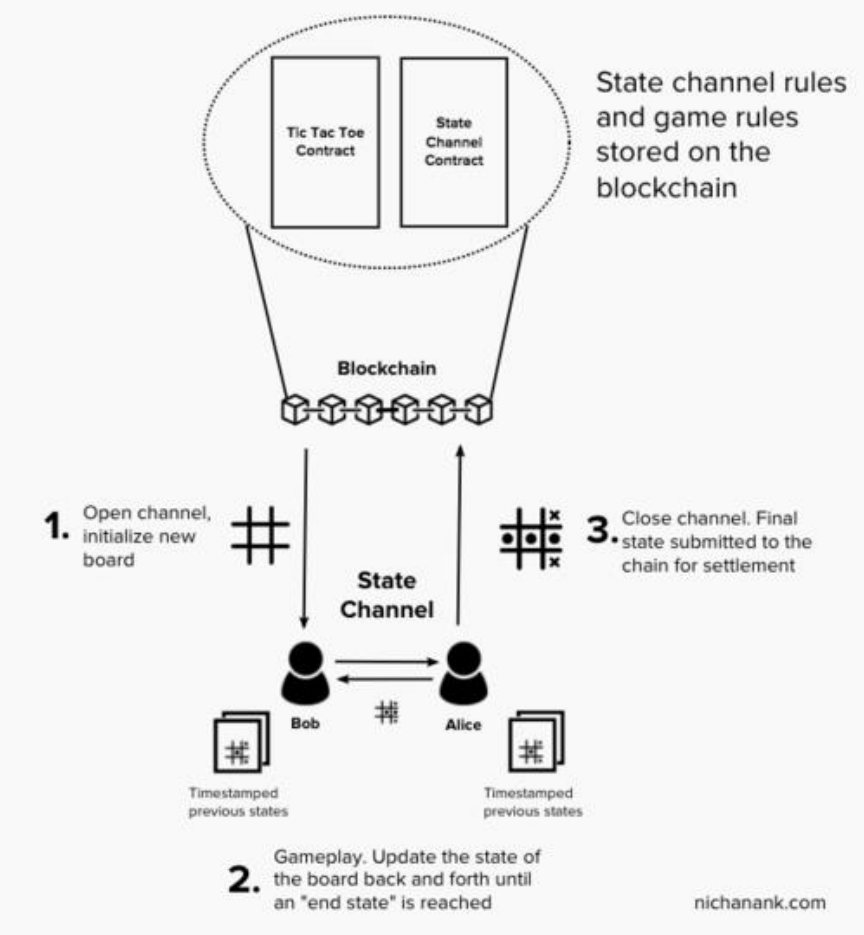


Figure 6: Representation of a simplified State Channel (Source: Nichanan Kesonpat personal blog, nichanank.com)

[11] The way in which merchants accept payments and get them verified by banks or other payment providers.

State channels are the earliest scaling solution [59] and, given that they do not support general-purpose solutions nor many DeFi applications, such as Automatic Market Makers (AMM) like Uniswap.

Nowadays, they are useful for applications designed to exchange and deposit ether and tokens, but we are already witnessing their downfall [58]. Nonetheless, as they offer instant finality, privacy, and trustless payments, this solution can be very interesting for applications like micropayments. The most well-known state channel is Bitcoin's Lightning Network.

1.4. Overall L2 performance

In Binance's *Full-Year Review 2022 & Themes for 2023* [20], Layer 2 solutions have a whole dedicated chapter where the key takeaways indicate that their TVL rose 119% this past 2022. Moreover, the TPS L2 solutions had this 2022 overtook Ethereum's TPS for a sustained period of time (see *figure 7*). Finally, comparing L2 solutions to alternative L1 solutions, L2 solutions have performed better both in terms of adoption as dApps like Trader Joe, who used to be in Avalanche, have migrated to L2 and also lightly in terms of assets' value (see *figure 8*).

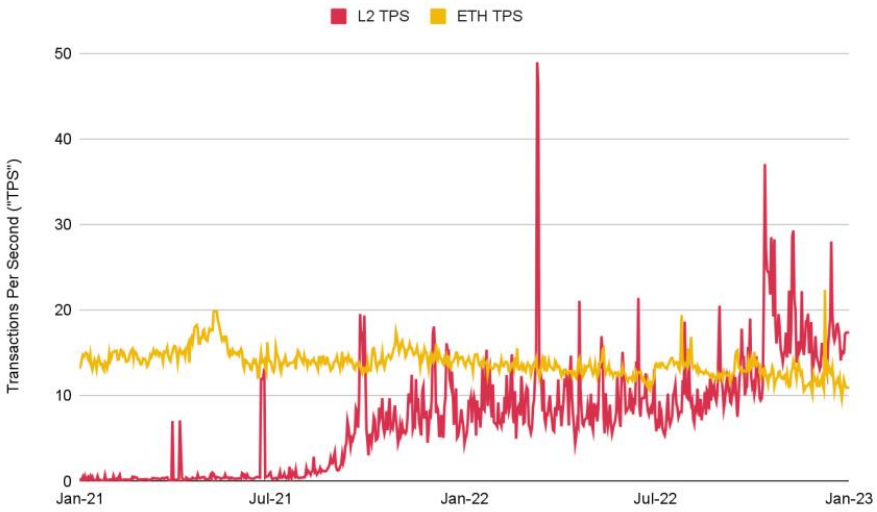


Figure 7: TPS comparison between Ethereum and Layer2 protocols (Source: Binance Research)

Figure 8: L2 performance in value (TVL) compared to alt-L1 (Source: Binance Research and DeFiLlama)

Having seen the overall intricacies of this Layer 2 scaling solutions, a list of all the established Layer 2 solutions and a brief description of them is presented.

1.5. List of L2 solutions

Nowadays, the current present L2 solutions, taking into account that by L2 only Rollups and State Channels are considered, can be seen in *Table 3*. In order to fetch this list, the protocols presented in L2Beat[12] as well as BlockchainComparison[13]. All the information on the brief description comes from either their website or open-source information.

Name	Type	Brief Description
Arbitrum One	Optimistic Rollup	Arbitrum was founded by former US White House Chief Technology Officer, Ed Felten, and a team of blockchain experts: OffChain Labs. The project is focused on building a Layer 2 scaling solution that can offer fast and cheap transactions while maintaining the security of the Ethereum mainnet.

[12] https://l2beat.com/scaling/tvl

[13] https://blockchain-comparison.com/layer-2-blockchain-protocols/

Arbitrum Nova	Optimistic Rollup	Built on the same technology as Arbitrum One, but is designed specifically for use by developers who want to build their own custom Layer 2 solutions. The project is also led by OffChain Labs.
Aztec Network	zkRollup	Aztec Network is led by a team of blockchain developers and experts, including co-founders Thomas Walton-Pock and Zachary Williamson. Integrated with several DeFi protocols, it is a private layer 2 payments protocol.
Boba Network	Optimistic Rollup	A hard fork of Optimism made by the OMG Network team, stablished in 2017 under the brand name OmiseGO, the rebranded OMG Network is a subsidiary of Genesis Block Ventures (GBV). It is integrated with several popular DeFi protocols, including Uniswap and Balancer.
Celer Network	State Channel	Celer Network was founded by Mo Dong and Junda Liu. The project is integrated with a few popular DeFi protocols, including Aave and Chainlink.
dYdX	Zk Rollup	dYdX, initially a decentralized trading platform, that was founded by blockchain developer Antonio Juliano. The project moved to L2 by using StarkEx technology. It is still essentially an exchange, but they have been able to reduce drastically their transaction fees with this implementation of zk-STARKs.
Fuel	Modular blockchain & Optimistic Rollup	Fuel was founded in 2019 by John Adler and Nick Dodson. The project has been adopted by various decentralized exchanges and has received backing from prominent investors such as Coinbase Ventures and Dragonfly Capital.
Hermez Network	Zk Rollup	Hermez Network lead by Jordi Baylina has been integrated with several popular DeFi protocols, including Uniswap and Balancer.
Lightning Network	State Channel	Lightning Network is a decentralized payment protocol that enables near-instant transactions with low fees on top of the Bitcoin blockchain. It allows users to make off-chain transactions without relying on third-party intermediaries, providing increased privacy and scalability. Lightning Network was developed by Joseph Poon and Thaddeus

		Dryja and has been adopted by various Bitcoin wallets and exchanges.
Loopring	Zk Rollup	Loopring is a Layer 2 scaling solution that was founded by blockchain developer Daniel Wang. The project is focused on offering fast and cheap transactions for decentralized exchanges (DEXs). It has been integrated with a number of popular DeFi protocols, including Aave and Curve.
Metis Andromeda	Optimistic Rollup	Metis is an EVM-equivalent Scaling Solution originally forked from Optimism. It provides support for multiple, interconnected L2 chains with main focus on supporting easy creation of DACs (Decentralized Autonomous Companies).
Optimism	Optimistic Rollup	Optimism is a Layer 2 scaling solution that was founded by a team of blockchain developers, including Jinglan Wang and Ben Jones. Optimistic Ethereum is an EVM-compatible Optimistic Rollup chain. It aims to be fast, simple, and secure.
RhinoFi	Zk Rollup	Formerly known as Diversify or Ethfinex was founded by blockchain developers Will Harborne and Ross Middleton. The project is focused on building a Layer 2 scaling solution that can offer fast and cheap transactions for trading on decentralized exchanges (DEXs).
StarkNet	Zk Rollup	Starkware is a Layer 2 scaling solution for Ethereum that uses was developed by a team of experienced mathematicians and cryptographers. The project has been adopted by various DEXs and has received backing from prominent investors such as Sequoia Capital and Paradigm.
Sorare	Zk Rollup	Sorare is a French solution that used SX Network to move to L2 to make the ecosystem cheaper. It is a global fantasy football game where you can play with officially licensed digital cards and earn prizes every week.
zkSpace	Zk Rollup	zkSpace was founded by blockchain developers Andre Cronje and Michael Kong. The project is integrated with popular DeFi protocols, including Uniswap and SushiSwap.

zkSync	Zk Rollup	zkSync is a Layer 2 scaling solution that was created by Matter Labs, founded by Alex Gluchowski. Curve and Aave are some of the dApps that are integrated on it.

Table 4: List of L2 solutions (sources: L2Beat and Blockchain Comparison)

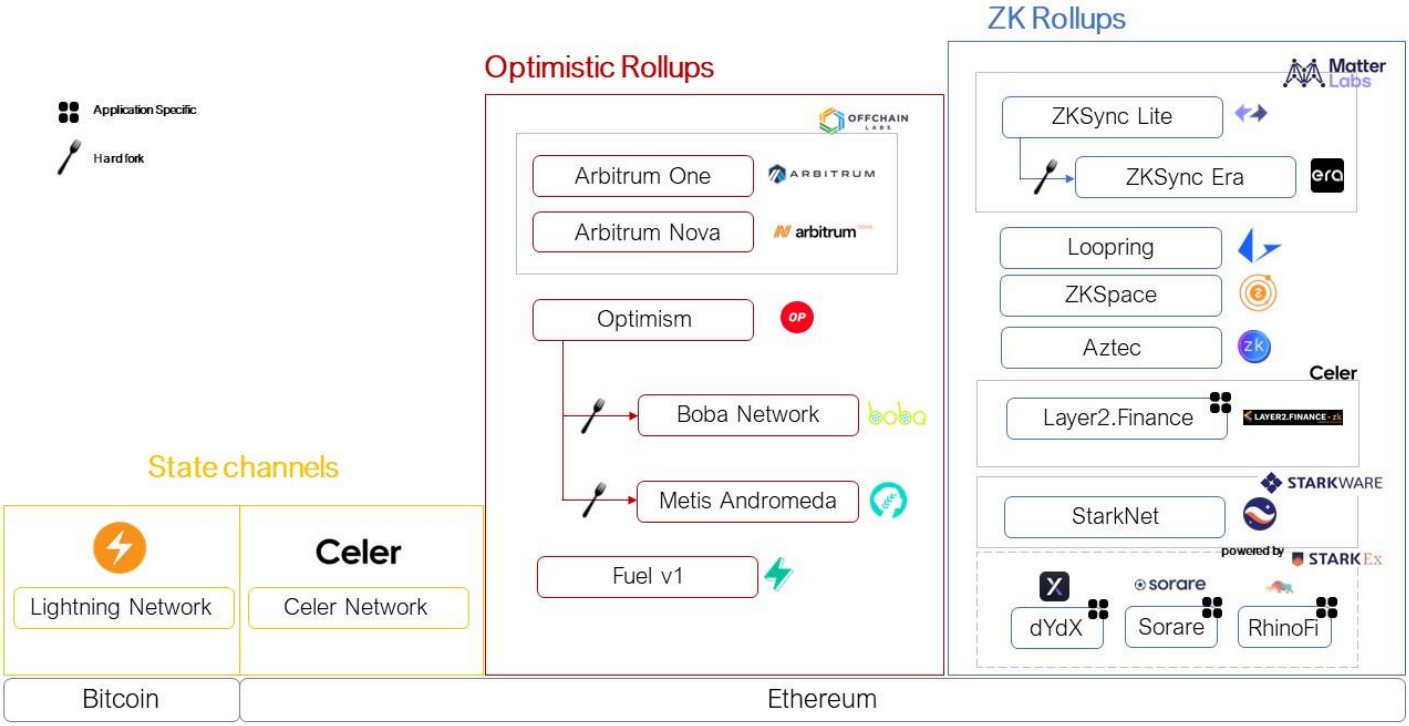


Figure 9: Visual representation of L2 ecosystem (Source: author's elaboration)

1.6. Assessment of blockchain protocols

Currently, there is no generalized accepted model to analyze blockchain protocols from their business feasibility side. Not even to assess protocols overall. However, there is thesis surrounding the idea of what a protocol is and how it can be defined. Moreover, there are few frameworks that asses them. On the one hand, a framework that assesses the business model of blockchain protocols, the VDBE framework, is presented. On the other hand, three comparatives that focus on the general assessment of Layer 2 protocols will also be presented.

1.6.1. Blockchain protocols

There has been a widespread theorization of what protocols are. This idea, the *fat protocols* [6] theory, was presented by Joel Monegro back in 2016. In his work, Monegro suggests that the shift from current web (web 2.0) to blockchain (or web 3.0) means that the value creation and value distribution will shift from the application layer (as

we have nowadays with the 6-top tech brands[1]) to the protocol layer. As the protocol layer grows, the application one shrinks, turning into *thin applications* [7]. It is important to strive that this value "capture" has more to do with the fact that the networks at protocol layer bear most of the costs of production than with investment returns. In other words, the application layer can also provide economic value but, as it will always cost less to operate, investment will always be lower demanding less of the market's value.

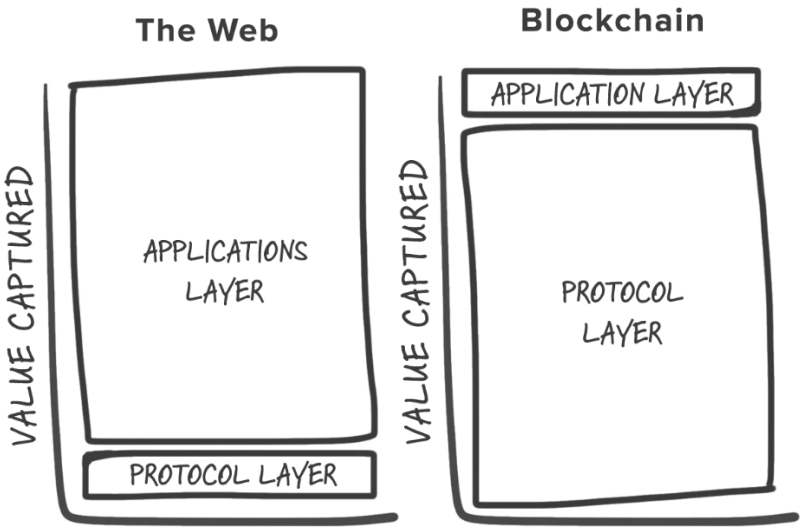


Figure 10: Depiction of the concept of blockchain's fat protocols (Source: usv.com)

This theory has been controversial these past years due to the fact that the definition of blockchain protocols is:

"Protocols are basic sets of rules that allow data to be shared between computers. For cryptocurrencies, they establish the structure of the blockchain — the distributed database that allows digital money to be securely exchanged on the internet."[16]

and if a protocol has no application on top that adds value, the protocol will just be deemed to be just that, sets of rules[14]. As a Blockworks[15] researcher, Westie Capital, stated: there has not been a single application reaching enough product-market fit to compete with web 2 applications [17]. Consequently, to this researcher, supporting protocol solutions has been the way to bet on the technology until a web 3 application thrives.

[14] The only exception in this case would be Bitcoin, since it is considered "digital gold" for large groups of individuals, deeming it to a higher status.

[15] https://www.blockworksresearch.com/

Bearing in mind these statements on what protocols are and their importance in the success of blockchain as a feasible and long-term solution, the different available frameworks to assess blockchain solutions are studied in the following sections, also analyzing different variables that are considered relevant when it comes to addressing various aspects of them.

1.6.2. Blockchain business model - VDBE Framework

The VDBE Framework [53] is a blockchain business model presented by Gennaro Cuofano in FourWeekMBA on September 2022. VDBE Framework, a blockchain business model presented by Gennaro Cuofano in FourWeekMBA. It has four verticals that will be detailed in the following sections.

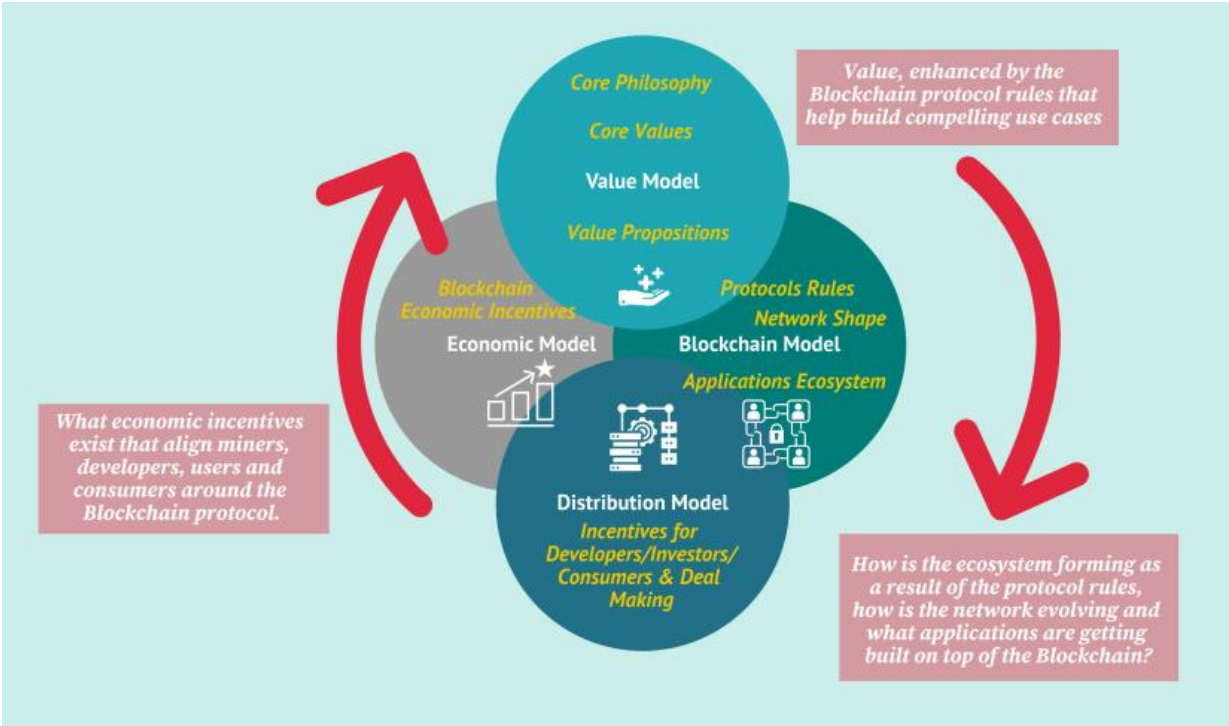


Figure 11: VDBE framework to analyze blockchain business models (Source: FourWeekMBA)

Value Model

The value model aims to define the how value is created. The basics presented in the VDBE are the following:

Core Philosophy: Presenting the long-term hard problem they aim to solve.

Core Values: Key values driving the protocol

Value Proposition: Set of values stakeholders (developers, investors, and users) get from the protocol

Blockchain Model

The blockchain model depicts the rules that shape the protocol and which applications can be built on top of it.

Protocol rules: Presenting the consensus rules of the protocol

Network shape: Which shape has the shared distributed ledger

Applications ecosystem: Which applications can be built on top of the protocol

Distribution Model

The distribution model aims to describe how the various pieces come together to make the underlying Blockchain ecosystem sustainable and keep growing it. Therefore, how, investors and developers are motivated to partake in the ecosystem. In the VBDE framework, the here below basics are presented:

Developer's community: Whether the developer community is engaged in developing apps on top of the Blockchain and the underlying mechanisms that allow it.

Investor Relationships: Underneath every project there is cryptocurrency that backs it up, and its value is key to investors.

Mining Incentives: Incentive system for miners.

Deal Making: Agreements to integrate the protocols that are in place.

Economic Model

This model describes how the underlying crypto asset gains value and how the key players are monetizing the applications built on top of it. The following metrics are detailed:

Underlying crypto asset: Determining which is the underlying crypto asset and how it allows players to monetize.

Monetization: how does the crypto asset gain value and how the key players monetize the applications on top of it.

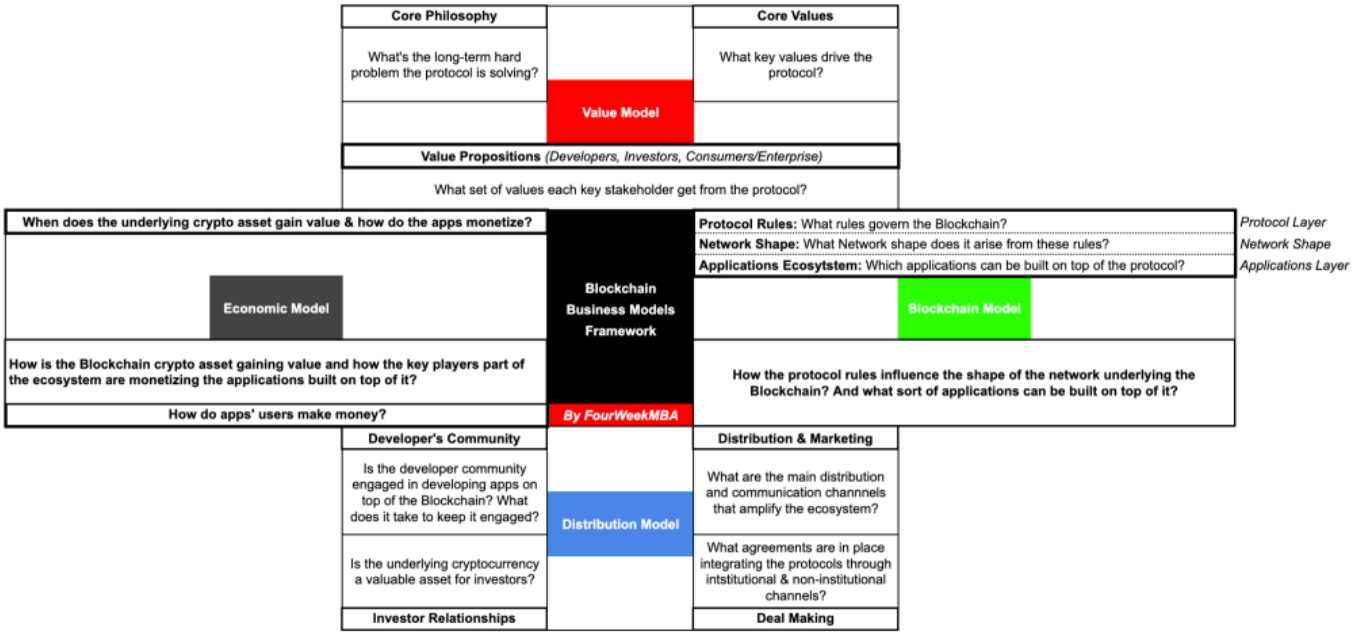


Figure 12: VDBE framework Model template (Source: FourWeekMBA)

All in all, this framework aims to study the possibility a protocol has to succeed as well as some basis of general analysis. However, there are other proposed frameworks or questions that should be posed, that are not that detailed that give further interesting points of study to evaluate the protocols. Before introducing them, from this framework we need to remark how they clearly state the relevance of the application layer of these solutions.

1.6.3. Matter Labs L2 comparison framework

The founder of Matter Labs, organism that created zkSync, provided a L2 comparison framework in order to understand the different scaling solutions in the market [18]. This comparative analysis is based in four verticals or categories from which a batch of questions to evaluate the solutions. The four verticals are presented here below, as well as detailing of which questions they aim to answer:

Technical considerations: Security

- **Liveness assumption:** Whether the users need to validate activity on mainnet or there are trusted validators in the protocol.
- **Mass exit assumption:** Assessing if the security assumptions of the scaling allow users to successfully perform exit transactions (withdrawals) to L1 within a short period of time.

- **Custody:** Studying if user funds can be seized or made inaccessible for illimited periods of time
- **Vulnerability to hot-wallet key exploits:** Does the security of the keys rely on internet connectivity (hot-wallets).
- **Vulnerability to crypto-economics attacks:** How vulnerable to attacks and whether the protocol relies on game-theoretic assumptions.
- **Cryptographic primitives:** The maturity of the cryptographic construction chosen for the protocol.

Economic Considerations: Performance / Economics

- **Max throughput:** maxim possible transactions per second of the solution both in Ethereum 1.0 and 2.0.
- **Capital Efficiency:** Capital efficiency is the ratio that compares the spending of a company on their growing revenue and how much they are receiving in return in the way of profits [30]. Therefore, in the case of these solutions, what is looked into is if they require a substantial amount of capital to be locked in order to operate.
- **Cost to open new account:** Is it required to do a L1 transaction to start using an account on the L2?

User Experience Considerations: Usability

- **Withdrawal time:** how long withdrawals to L1 take (dispute resolution time)
- **Time to subjective finality:** Transaction finality time, or number of confirmations needed to ensure finality
- **Client-side verifiability of subjective finality:** Possibility of the confirmation being verified by light clients. Light clients are either browser or mobile wallet verifiers.
- **Instant tx confirmations:** Depends totally on the scaling solution chosen. While apparent finality is given by all solutions, some, like optimistic rollups, can be reverted. In those cases, bonded instant transaction confirmation are the case.

Other

- **Smart contracts:** Does the L2 support arbitrarily programmable smart contracts (i.e. dApps) or only a limited subset that can be implemented?
- **EVM-bytecode portability:** Can the EVM bytecode of existing solutions be migrated without major changes?
- **Native privacy support:** Without shielded transactions by default, privacy protection is highly ineffective [28] [29].

In this case, the author has considered L2 solutions all the solutions built differently than L1, in other words, what is considered to be L2 in this study: rollups and state channels, and, additionally, Sidechains, Plasma and Validium. The result is the table present in *figure 13,* which was last updated in 18/02/21.

	State channels	Sidechains[0]	Plasma	Optimistic rollups	Validium	zkRollup
Security						
Liveness assumption (e.g. watch-towers)	Yes	Bonded	Yes	Bonded	No	No
The mass exit assumption	No	No	Yes	No	No	No
Quorum of validators can freeze funds	No	Yes	No	No	Yes	No
Quorum of validators can confiscate funds	No	Yes	No	No	Yes [1]	No
Vulnerability to hot-wallet key exploits	High	High	Moderate	Moderate	High	Immune
Vulnerability to crypto-economic attacks	Moderate	High	Moderate	Moderate	Moderate	Immune
Cryptographic primitives	Standard	Standard	Standard	Standard	New	New
Performance / economics						
Max throughput on ETH 1.0	1..∞ TPS [2]	10k+ TPS	1k..9k TPS [2]	2k TPS [3]	20k+ TPS	2k TPS
Max throughput on ETH 2.0	1..∞ TPS [2]	10k+ TPS	1k..9k TPS [2]	20k+ TPS	20k+ TPS	20k+ TPS
Capital-efficient	No	Yes	Yes	Yes	Yes	Yes
Separate onchain tx to open new account	Yes	No	No	No	No	No [5]
Cost of tx	Very low	Low	Very low	Low	Low	Low
Usability						
Withdrawal time	1 confirm.	1 confirm.	1 week [4] ([7])	1 week [4] ([7])	1..10 min [7]	1..10 min [7]
Time to subjective finality	Instant	N/A (trusted)	1 confirm.	1 confirm.	1..10 min	1..10 min
Client-side verification of subjective finality	Yes	N/A (trusted)	No	No	Yes	Yes
Instant tx confirmations	Full	Bonded	Bonded	Bonded	Bonded	Bonded
Other aspects						
Smart contracts	Limited	Flexible	Limited	Flexible	Flexible	Flexible
EVM-bytecode portable	No	Yes	No	Yes	Yes	Yes
Native privacy options	Limited	No	No	No	Full	Full

[0] Some researchers do not consider them to be part of L2 space at all, see https://twitter.com/gakonst/status/1146793685545304064

[1] Depends on the implementation of the upgrade mechanism, but usually applies.

[2] Complex limitations apply.

[3] To keep compatibility with EVM throughput must be capped at 300 TPS

[4] This parameter is configurable, but most researchers consider 1 or 2 weeks to be secure.

[5] Depends on the implementation. Not needed in zkSync but required in Loopring.

[7] Can be accelerated with liquidity providers but will make the solution capital-inefficient.

Matter Labs

Figure 13: Overview of the framework after analysis [Updated 2021–02–18] (Source: MatterLabs' Medium)

1.6.4. L2Beat Risk Analysis

As aforementioned, L2 solutions inherit security from mainnets, but that is in theory. The developed projects in L2 are young (being most of them firstly launched in 2021). Because of their low maturity and the fact that it is a new type of technology that is being implemented, they are somewhat experimental. Specially, trust assumptions are made as they try to decentralize properly their networks. The risks involved can affect drastically the course of the protocol and the dApps related to them and can be defined according to the following categories [13]:

State Validation

How the validity of the state is checked. It will depend on the type of L2 scaling solution and its subtype of implementation.

Data availability

Whether the data needed to reconstruct the state is available or not. This problematic is further detailed in the following section: Data availability problem.

Upgradeability

Ethereum's smart contracts upgradeability. Most L2 solutions are upgradable and until its upgradability mechanism is disabled or controlled by a sufficiently decentralized DAO, funds could be stolen by upgrading the constructions. It is important to monitor who holds the upgradability keys.

Sequencer failure

Consequences of sequencer being offline or sequencer censoring. Sequencers are the third parties responsible for storing and executing user-submitted transactions locally and ordering them. Currently, most L2 have centralized sequencers which centralizes and threatens their integrity.

Validator failure

Consequences of the block producer being offline or block producer censoring. Validators are virtual entities that participate in the consensus of L1, making the network more robust by storing data and adding new blocks to the mainnet.

Data availability problem

The data availability problem can be summed up with the following question: "how do we verify that the data for a newly produced block is available?"[14] In other words, what if the block producer has published a block where the header is present but some or all the block data is missing. This problematic is common to all blockchains but, for this project, we will focus on the implications it has on L2 solutions.

In order to withdraw coins from L2 in a trustless way, ownership of those coins on L1 needs to be proved. Therefore, not just the sequences of transactions but also their nature must be known. That is verified by analyzing the nature of the transactions done in the given L2 (i.e., analyzing its current state). Therefore, for trustlessness to be maintained, this historical record of transactions on L2 need to be stored somewhere: either on L1 (safest solution) or on some external provider that needs to guarantee this data availability. If the latter case is given but there is no guarantee, then the security is too low for this solution to be reliable.

Name	State Validation	Data Availability	Upgradeability	Sequencer Failure	Validator Failure
Arbitrum	Fraud Proofs (INT)	On chain	Yes	Transact using L1	Propose blocks
Optimism	In development	On chain	Yes	Transact using L1	No mechanism
dYdX	Zk proofs (ST)	On chain	Yes	Force trade to L1	Escape hatch (MP)
Metis	In development	Optimistc (MEMO)	Yes	Transact using L1	No mechanism
Loopring	ZK proofs (ST)	On chain	Yes	Force exit to L1	Escape hatch (MP)
zkSync	ZK proofs (SN)	On chain	21d or no delay	Force exit to L1	Escape hatch (ZK)
ZKSpace	ZK proofs (SN)	On chain	8d delay	Force exit to L1	Escape hatch (ZK)
ApeX	ZK proofs (ST)	External	Yes	Force trade to L1	Escape hatch (MP)
Sorare	ZK proofs (ST)	External (DAC)	14 days delay	Force exit to L1	Escape hatch (MP)
rhinofi	ZK proofs (ST)	External (DAC)	14 days delay	Force exit to L1	Escape hatch (MP)
Boba	In development	On chain	Yes	Transact using L1	No mechanism
StarkNet	ZK proofs (ST)	External (DAC)	Yes	No mechanism	No mechanism

Table 5: Security state of most prominent L2 solutions [1st March 2023] (source: L2Beat)

The security assessment for L2 solutions, known as Risk Analysis, is available and has been presented by L2Beat. In *table* 5, we can see the overall results of the different L2 solutions, where no highlight means secure (no threat), yellow highlighted cases are a medium threat and, finally, red highlighted items are a high threat to the solution.

All in all, these L2 solutions still have a long way to ensure full security as, as it is evident in *table 5*, there is not one solution that does not have any security issue, all presenting some kind of threat in more than one of the categories.

1.6.5. Polygon and The Block Research approach

Commissioned in 2022 to The Block Research by Polygon, Andrew Cahill as research director and Saurabh Deshpande as analyst presented mid-2022 a framework for comparison of L2 solutions [54].

This comparison framework for Layer 2 solutions offers, firstly, an overview of the state of Layer 2 solutions and, continuously, a selection of the most prominent projects is made, and relevant metrics are studied. In order to assess them, interviews to the founders and blockchain engineers of the selected L2 solutions were made, as well as a data analysis of the current state of the ecosystem. The projects selected for the study and the interviewed people are detailed here below:

Arbitrum (Offchain Labs, Inc.) - A.J. Warner, Steven Goldfeder

Boba Network (Enya Inc.) - Alan Chiu, Violet Abtahi

Optimistic Ethereum (Optimism PBC) - Ben Jones, Joshua Stein

Polygon Hermez (Polygon Technology) - David Schwartz, Bobbin Threadbare, Brendan Farmer

StarkNet, StarkEx (StarkWare Industries Ltd.) - Avihu Levy, Liron Hayman

zkSync (Matter Labs) - Tyler Perkins

Here below, the analyzed metrics are detailed and, the results obtained are presented in table format as a sum up. The study was done according to the four verticals that are reviewed in this section.

Project Overview

To assess these protocols, an analysis of the team and its key members is firstly done. This decision is clear and stems from the fact that in early stages, these key members have significant influence over major technical decisions. Moreover, the most prominent investors that have funded the protocol are presented and the total funding of the protocol is stated. Finally, the key historical events and the upcoming events per each project are enumerated.

Since these elements have been partially presented in the L2 solutions list and the analysis done by this study is very presentational and not detailed at all, the results obtained had not been included here.

Technical Design

To study the technicalities behind these L2 solutions, three metrics are observed. Firstly, the purpose of the protocol, i.e. whether they are general purpose, application specific or if they have a preferred or main purpose. Additionally, the scaling approach is determined: optimistic rollup or zk rollup (no State Channels were analyzed). Finally, the dispute resolution is detailed. In the case of L2, as presented in the **Error! Reference source not found.**, in the case of optimistic rollups the dispute resolution is always fraud proofs while in the case of zero-knowledge rollups it is that of validity proofs (that can be STARKS or SNARKs). This analysis can be seen in *figure 14*. It is important to note that, in this study, the idea that the scaling approach affects the use cases (the decentralized applications on top) is made. However, it is not proofed in the study.

To assess technical details, in addition, the different execution environments for each solution is detailed as well as the programming language used. This detailing is represented in *figure 15*.

Scaling Approaches Impact Layer-2 Use Cases

Technical Overview of Layer-2 Networks

Layer-2 Network	Purpose	Scaling Approach	Dispute Resolution
Arbitrum One	General Purpose	Optimistic Rollups	Fraud Proofs
Boba	General Purpose	Optimistic Rollups	Fraud Proofs
Optimistic Ethereum	General Purpose	Optimistic Rollups	Fraud Proofs
Polygon Hermez	Payments, General Purpose(1)	ZK Rollups	Validity Proofs (STARKS, SNARKs)
Polygon Zero	General Purpose(1)	ZK Rollups	Validity Proofs (STARKS, SNARKs)
Polygon Miden	General Purpose(1)	ZK Rollups	Validity Proofs (STARKS)
Polygon Nightfall(2)	Privacy	Optimistic & ZK Rollups	Fraud Proofs, Validity Proofs
StarkEx	Application Specific	ZK Rollups, Validium	Validity Proofs (STARKS)
StarkNet	General Purpose	ZK Rollups	Validity Proofs (STARKS)
zkSync	Payments, General Purpose(2)	ZK Rollups	Validity Proofs (SNARKS)

Notes: (1) Support for general purpose computation is under development for Polygon Zero, Polygon Miden and has been deployed in testnet for zkSync's zkEVM. (3) Polygon Nightfall is currently used as an application for transferring ERC20, ERC721 and ERC1155 applications under Zero Knowledge and does not have general purpose (smart contract) support.
Source: Development Organization Websites

THE BLOCK · Research

Figure 14: Scaling approaches pf L2 networks (Source: The Block Research)

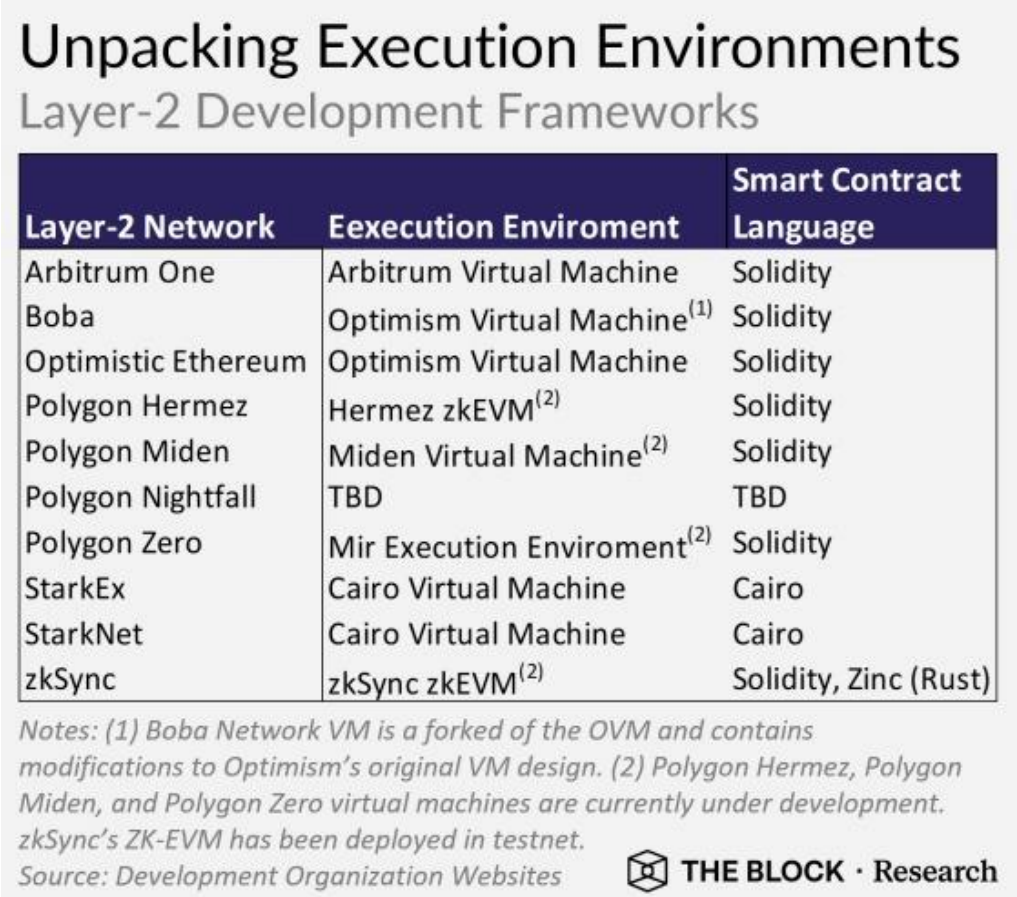


Figure 15: Analysis of the execution environments of the different L2 solutions (Source: The Block Research)

Throughput and Finality

As the ultimate goal of layer 2 solutions is to improve the scalability of the blockchain performance, both the throughput (TPS) and the finality are assessed. As presented earlier, the finality of optimistic rollups is way higher (7 days) than that of zero-knowledge ones (almost instantly).

On chain and Ecosystem Data

The creators of the framework state that, despite this protocols being in their early stages, analyzing their blockchain data can give insights to the solutions. The comparative statistics are given regarding:

- **TVL** – Total Value Locked
- **Transaction Counts** – Number of transactions per day
- **Active addresses** – Daily active addresses
- **Fee per transaction** – Cost per transaction
- **Ecosystem data** - Developer time measured in Discord Member count
- **Social Media Following** – Measure of growth of platform ecosystem measured in Twitter followers

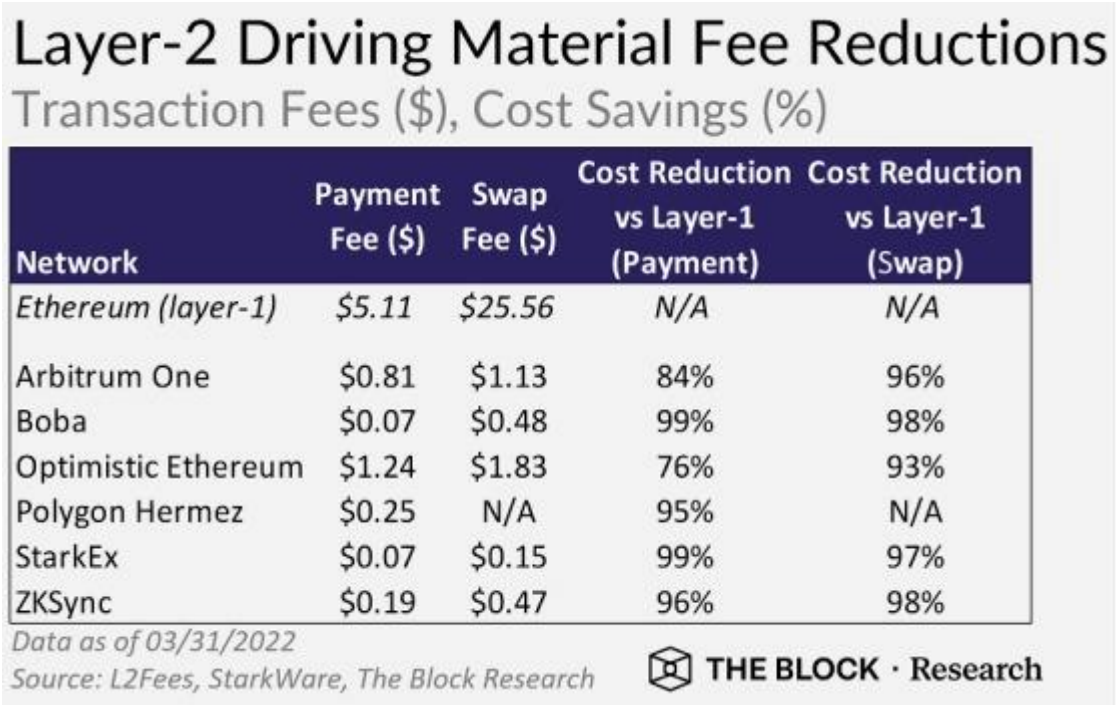


Figure 16: Fee reductions in the L2 ecosystem compared to the mainnet Ethereum (Source: The Block Research)

As it is evident in *figure 16*, there is a notable fees reduction in L2 solutions compare to the mainnets. Additionally, despite having variable fees amongst them, the adoption or consequences of that are not made clear.

On the other hand, as seen in *figures 17* and *18*, social media data is considered, despite this metric not being proofed of being indicative of the success of the protocol. In - Further metrics of study their relevance will be further analyzed.

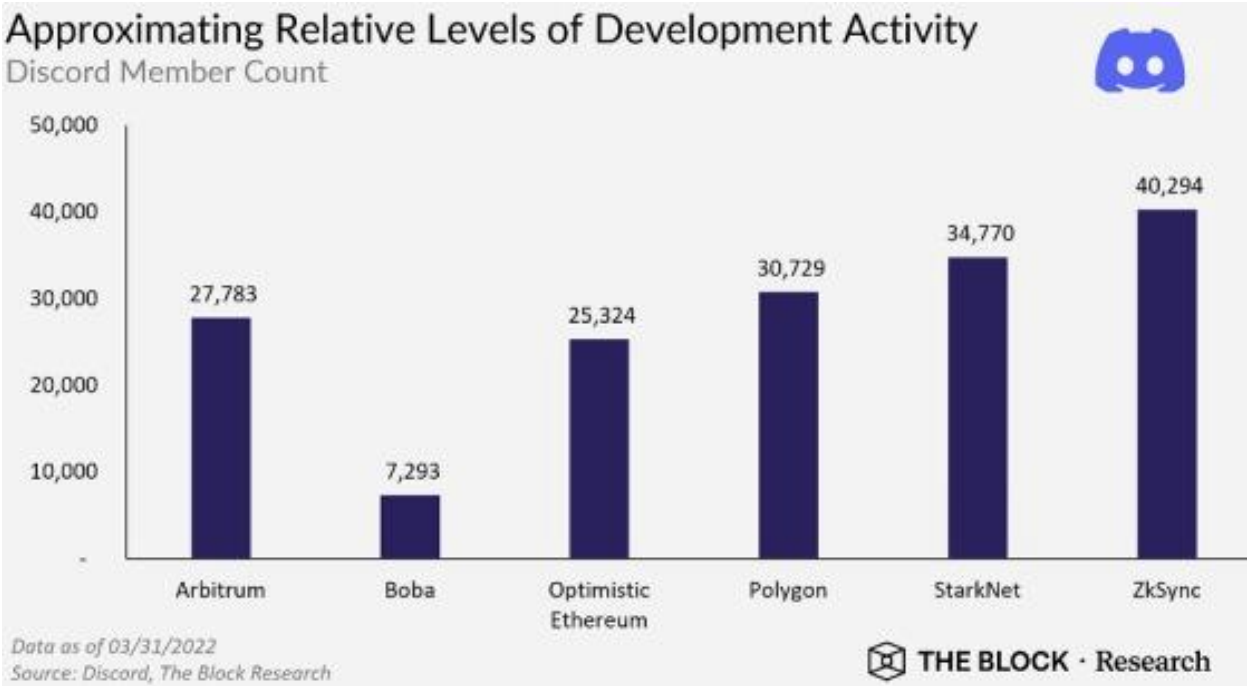


Figure 17: Discord members of each solution (Source: The Block Research)

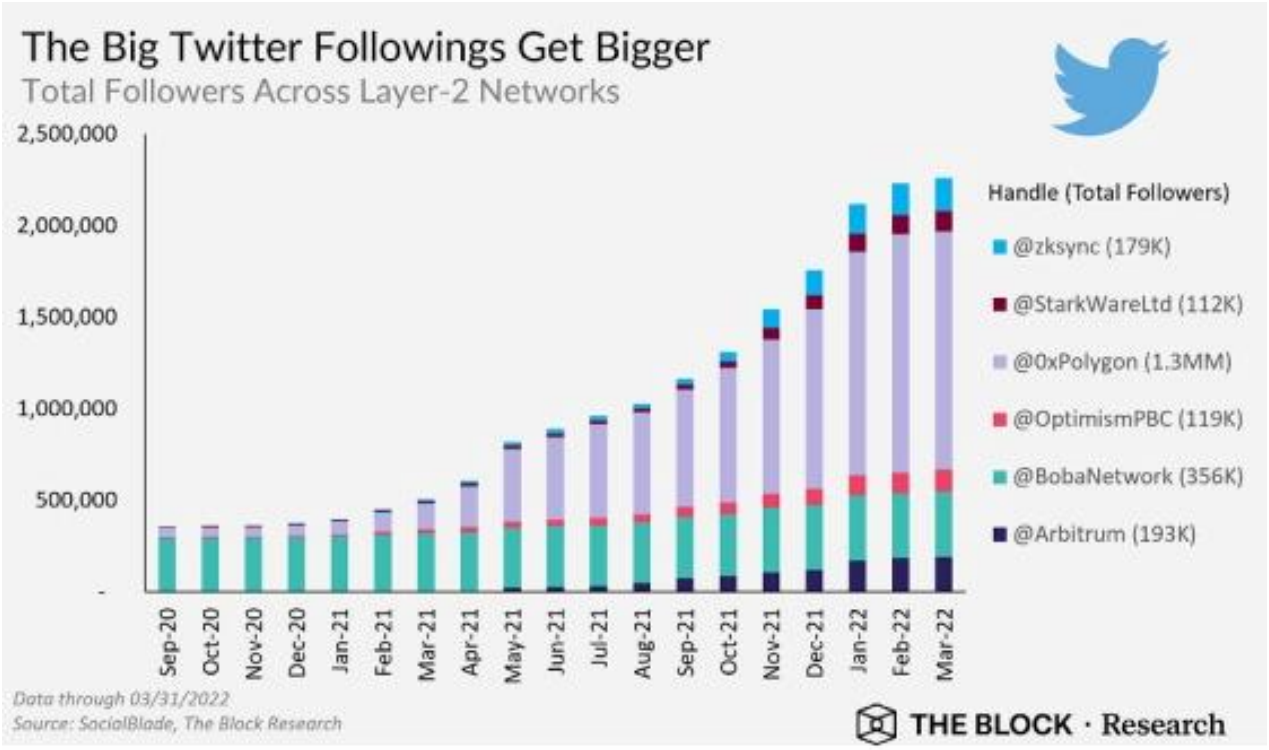


Figure 18: Followers on Twitter of the listed L2 solutions (Source: The Block Research)

Native Tokens

As previously seen, tokens are at the center of most blockchain-based solutions. In this report, only two of the protocols had tokens when the study was done, represented in *figure 19*. The metrics studied for each token are, respectively, its price, market capitalization, if they have a limited supply or not and the total circulating supply. As seen, also protocols also will be launching their token in the future. No further discussion on its relevance is done.

Figure 19: The only L2 tokens at the time of the study (Source: The Block Research)

Currently more protocols have token, so, as presented in *table 6*, and only taking into account the protocols that were considered for this study, as of March 2022 there is one more protocol that has an active token [60].

Name	Token name	Price ($)	Market Cap ($ M)	Capped Supply	Circulating Supply (% of Total)
Optimism	OP	2.62	827	Yes	7,3%
Boba Network	BOBA	0.241	49.5	Yes	65,5%
Polygon Hermez	MATIC	1.17	10600	Yes	90,8%
StarkNet	STRK	Not Yet Available	-	-	-

Table 6: Current state of tokens subject to The Block Research study (source: CoinGecko)

As we can see, Optimism has launched their token this past 2022 and StarkNet also yet only for private bidders. That is why no information about the token has been disclosed. Finally, in the case of Arbitrum and zkSync, there is a lot of speculation regarding their token launch, but no official statement has been done.

1.6.6. Further metrics of study

There are a few metrics relevant to blockchain protocols and these layer 2 solutions that have not been expressed, or have been done so in a vague way, in the previously presented frameworks, that will be presented onwards. These elements are expressed in the following sub-sections and give a broader view of the overall of blockchain solutions.

Whitepaper and team

Every blockchain project is determined and explained by their whitepaper, a document that helps outline the main features and technical specifications of a specific cryptocurrency or blockchain project [19]. Both the quality of their whitepaper and the team that backs a project up are essential to determine the success of a blockchain project [21]. However, in this whitepaper, all the technical aspects of the protocol are closely detailed, and those technical elements, as seen, have been widely studied.

Brand / Community

Beyond their inner qualities, it is also very important to reach well the market, i.e, to create demand. Demand generation, in other words, enabling people to identify with your brand [26]. For these solutions, to have a strong brand is especially important because blockchain projects are open-source and that means that at any time the blockchain can be forked and a new project (new brand, per se) with the same

availability can start running. Even so, the project can be even improved, making you lose your user base (demand). Then, it is having a strong brand what helps projects persist in the long run and give them value. Brands can also be defined as community flywheels [24], as presented in *figure 20.*

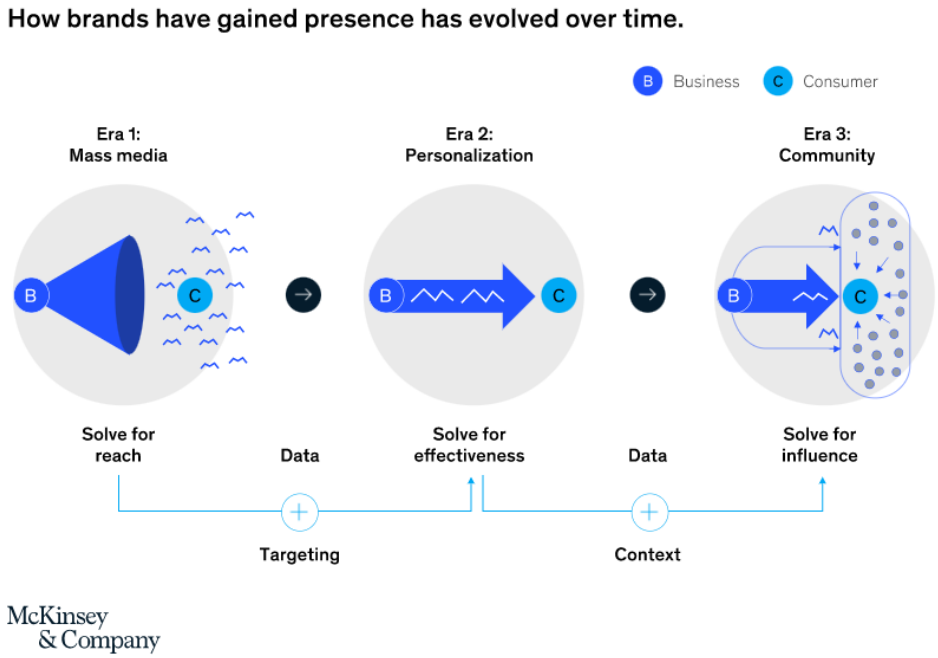


Figure 20: Brands evolution over time (Source: McKinsey)

Additionally, demand, in the current state of the layer 2 solutions, can be defined as their beachhead market [22], a small market of users with similar pain points fulfilled by their proposed solution. Building a strong web3 community is a very valuable resource, since this dedicated community members are the starting point for ideating around, testing, and iterating upon the product [23]. Therefore, there are strong points that interlink the idea of demand generation with brand identity and, in turn, building of a strong community around the solution.

Communities, in the blockchain space, are defined as: "a virtual community where a group of people with shared ownership can meet" [25] and, since there is no centralized platform for that purpose, these communities are only reflected on social media engagement. Despite this affirmation not having a strong back up, there are some platforms (like CoinGecko), that offer main metrics and information on blockchain projects, that have dedicated metrics for social media following under the tag *community*. In addition, in formal literature, it is evidenced that to study the success of a blockchain brand the social activity is a key factor [21]. Finally, the most relevant social networks that can depict this communities are considered to be: Twitter, Telegram, Discord and Reddit [27].

Even though this is a widely accepted metric, as also seen with The Block Research framework (despite them considering it a metric of growth and not brand nor community), there has not been a study backing up the fact that social media following is strongly correlated to the success of a protocol in terms of inherent value. In other words, whether the fact that having more social media presence means that the protocol's performance is enhanced. This fact should be reviewed since, as community or brand in blockchain could directly be related to demand generation, then this should translate into protocol success [52].

Developers' community

When it comes to L2 solutions, a parallelism with Venture Capitals can be done: the more start-ups a VC bets on, the higher the likelihood they will be betting for the next unicorn. In the same way, L2 solutions want dApps to join their scaling solution instead of another one and, therefore, it is essential that there is good documentation and a good community devoted to migrating their solutions to the given L2. In order to assess it, the whitepaper of the project can be evaluated as well as their Github's or Discord community, numerical inputs and documentation detailing [21].

Investor relationships - Funding in web3 solutions

Web3 is not blockchain. Web 3 is considered to be an extension of cryptocurrency, using blockchain in new ways to new ends [31]. Web3 enthusiast would define it as [33]:

Web3 is a decentralized version of the internet where platforms and apps are built and owned by users. Unlike web2 (the current web), which is dominated by centralized platforms such as Google, Apple, and Facebook, web3 will use blockchain, crypto, and NFTs to transfer power back to the internet community.

Blockchain solutions that allow for dApps and are trying to decentralize the Internet in various aspects are considered to be web3. Per se, Bitcoin would not be considered a web3 solutions because, regardless of their efforts to decentralize payments, there is no bigger purpose attached to it. However, all those solutions built on top of Ethereum, Polkadot or other blockchain protocols that aim to decentralize various services are considered to be, as they are trying to iterate on the World Wide Web paradigm. In this group, all the Layer 2 solutions that have been presented take a role by trying to scale the whole ecosystem to reach this web 3 state.

Nowadays the Web requires too much trust. That is, most of the Web that people know and use today relies on trusting a handful of private companies to act in the public's best interests [32]. However, web3 aims to change that by decentralizing the servers again. With that selfless purpose, a lot of focus has been put to these solutions and, with that, also a lot of criticism.

Jack Dorsey, founder and ex-CEO of Twitter said, it's big venture capital firms like Andreessen Horowitz (a16z), which has dedicated more than $3 billion to investments

in the space (and has made investments in several dozen crypto companies, including OpenSea and CryptoKitties), that will control these new web systems [34]. After these statements, a lot of researchers and alternative publishers have been discussing this decentralization claim.

Despite this idea of 'who owns the web3 ecosystem', which can also be relevant to visualize, there is a very interesting idea behind funding too. The idea that, in the end, these protocols need funding to succeed and that is may be a factor for their success. As stated in the VDBE framework, the relationship a protocol has with investors is an important metric, and, as such, who is investing on the protocol is also of special relevance. However, it is not stated whether there are just a specific subset of ventures that are the main investors in the space, or whether it is a more heterogeneous situation, i.e. a high number of different firms are betting on these solutions.

Finally, it is important to mention that not all blockchain projects get funding the traditional way, i.e. via private investors (investing firms or venture capitals) but by making a public coin offering, typically an Initial Coin Offering or ICO.

DApps in the blockchain scene

Decentralized applications (dApps) are digital applications or programs that exist and run on a blockchain or peer-to-peer (P2P) network of computers instead of a single computer. DApps (also called "dapps") are thus outside the purview and control of a single authority [38]. These applications started with Ethereum, when instead of single transactions, smart contracts could be run on the blockchain. The first dApp was released on April 22, 2016 [35]. However, it wasn't until the 28th November 2017 when these applications started having relevance and the NFT paradigm started booming. It was in this date when CriptoKitties, a decentralized gaming application created by Axiom Zen innovation studio, was launched. In CryptoKitties, players collect and breed oh-so-adorable creatures that are called CryptoKitties. Each kitty has a unique genome that defines its appearance and traits. Players can breed their kitties to create new furry friends and unlock rare cats and cattributes [36]. Within the first week after being released, there were about 60K registered players, with ~100K newborn kitties and over $10M USD in transactions had been processed. Their success came, specially, because of the seamless UX of the gaming, which, in turn, helped adoption amongst non-blockchain enthusiasts.

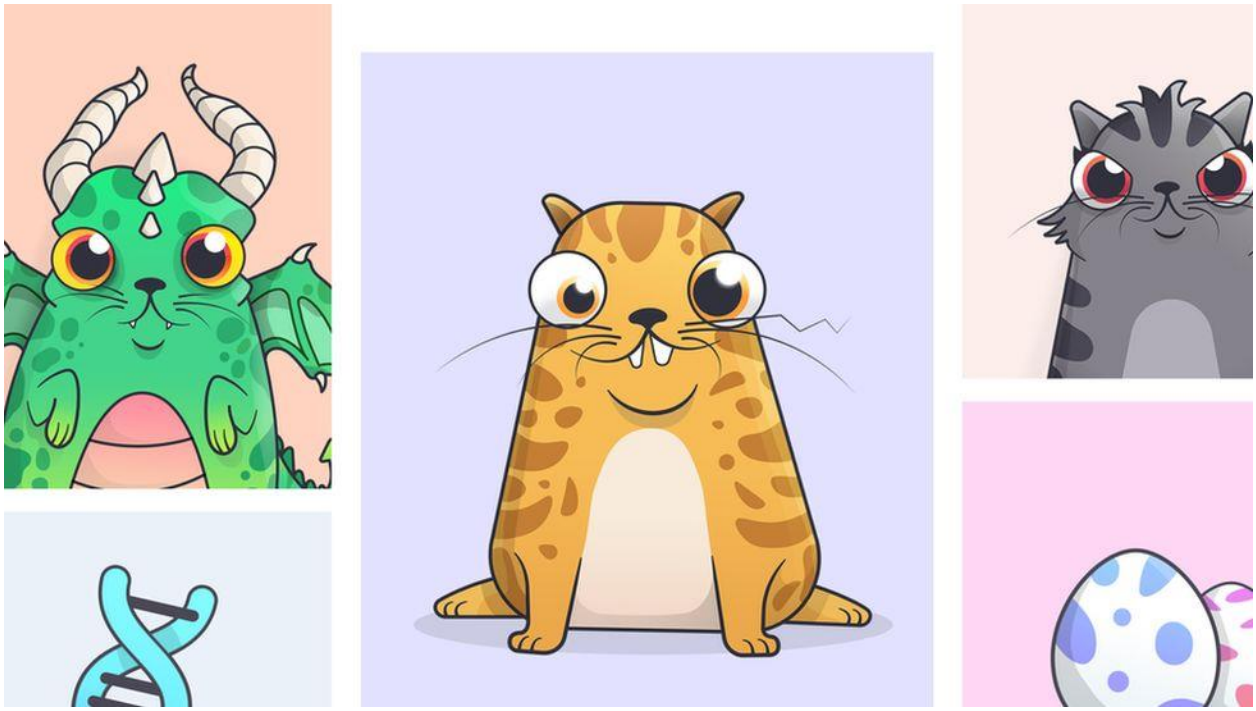


Figure 21: Cryptokitties UI (Source: cryptokitties.co)

Such a simple game, CrypoKitties, brought in 2017 the entire Ethereum blockchain to a near standstill [37]. Etherscan reported a sixfold increase in pending transactions on Ethereum since the game's release [39]. This problem has resulted in high transaction times and low transaction speeds. That was a problem with CryptoKitties, but back then (in 2017) Ethereum was not used for actual financial purposes [37]. It was then when the scalability issue was detected and then efforts on improving it arose. Parallelly, more and more dApps were created, leaving the ecosystem with thousands of them nowadays. These dApps, in face of this scalability problematics and high gas fees, have migrated over this 2022 to L2 solutions. A study by Messari shows that gas fees spent by layer 2 Ethereum scaling solutions to settle proofs on Ethereum clinched an all-time high as dApps native to layer 1 networks are increasing migration to L2s this 2022 [40].

Therefore, number and type or category of decentralized apps on top of these L2 protocols, could be a significant metric of study when assessing these protocols, however, it has not been studied yet. Additionally, the relevance they could have, if the fat protocols theory was starting to get obsolete, would be very high.

By type of category, it is meant that, all these dApps in the market have been built for multiple purposes, from financial to supply chain management solutions, but there are a few that are the most prominent ones, listed here below as the main dApps categories.

dApps main categories

In order to understand the different main categories of dApps, the glossaries of CoinTelegraph [63], CoinMarketCap [64], CoinGecko [65] and Academy Binance [66] have been consulted. Here below, the most common dApp categories are listed and explained.

Decentralised finance applications, commonly known as **DeFi**, are those applications that represent a new financial system built on blockchain technology. By far they are the dominant category in the space. However, since this categorization is merely the idea of making finance accessible to anyone, at anytime, anywhere, there are a lot of sub-categories that encapsulte it, like decentralized exchanges, lending platforms, stablecoins, and more.

The most common types of dApps considered in the decentralized finance category are the following:

- **DEX -** Decentralized exchanges (DEX) are cryptocurrency exchanges that operate on top of decentralized networks and allow for peer-to-peer trading. With the usage of smart contracts, the matching of buyers and sellers is automated as well as settling trades.
- **CEX -** Centralized exchanges (CEX) are cryptocurrency exchanges that operate through a centralized authority, that Is subject to regulatory oversight. Hence, users typically need to pass KYC to use the services.
- **Payments** - Platforms that enable to send and receive cryptocurrencies.
- **On-ramps/off-ramps -** Platforms that allow to convert fiat currency into cryptocurrency (on-ramp) or the other way around (off-ramp). They usually involve the use of CEX or other intermediaries.
- **AMMs -** Automated Market Makers (AMMs) are a type of DEX that use mathematical algorithms to determine the price of assets. Trading is peer-to peer and smart contracts allow automatic matching of buyers and sellers, as well as settling trades.
- **Liquidity providers:** Platform where users can provide liquidity to DEXs and other DeFi protocols in exchange for rewards. Users deposit cryptocurrency into a liquidity pool, which is then used to facilitate trades on DEXs. In return providing liquidity, the users receive a portion of the transaction's fees.
- **CDP** - Collateralized Debt Position (CDP) enable users to borrow cryptocurrency using their own holdings as collateral. Users who deposit collateral into a CDP can take a portion of the collateral value as a loan and a minimum collateralization ratio is required to ensure safety.

- **Yield –** Interest or rewards that users can earn by participating in lending, staking or liquidity provision activities. If a dApp is considered Yield, that means they compute in real-time which deals can get you highest yield and allow for those activities.
- **Algo Stables –** Algorithmic stablecoins are a type of cryptocurrency that aims to maintain a stable value, typically pegged to a fiat currency or other assets. They use complex algorithms and economic mechanisms to maintain their stability.

Besides from DeFi, which is the most common in the blockchain world of applications, there are other dApp types, such as GameFi. **GameFi** is a new category of blockchain-based games that incorporate DeFi elements in their games to incentive play. Players can earn cryptocurrency while playing and have strong community-driven governance and ownership models. Often, they also incorporate in-game NFTs. Non-Fungible Tokens, or **NFTs**, are also considered a big category across the dApp ecosystem. By definition, NFTs are a type of digital asset that represent the ownership of a unique digital item, normally artwork, music or videos. Since they have gained significant attention in the recent years, a lot of platforms of creation, exchange and other activities related to these digital assets have been created. The most remarkable one is OpenSea, a CEX of NFTs.

Additionally, there are decentralized applications that focus on the governance, as their core value. These are typically Decentralized Autonomous Organizations, or **DAOs**, a type of organization that is run entirely on the blockchain and governed by its members. These applications allow groups of individuals to make decentralized decision-making for a variety of purposes, like fundraising, investment and community-driven projects.

Moreover, since blockchain technology is available to everyone behind a cryptographical code, there is a new vertical that is booming: **Identity.** In the context of blockchain, identity refers to the ability to verify users' digital identity. Hence, these type of dApps provide secure and decentralized methods to verify one's identity.

In order to be able to store, secure and manage NFTs, cryptocurrencies and all these blockchain availabilities, wallets are essential. **Wallets,** considered another type of dApp, can either be hot (connected to the internet) or cold (disconnected from the internet).

Finally, there are two more relevant categories. On the one hand, **Bridges,** which enable interoperability between different blockchain protocols. Sometimes bridges are considered themselves protocols, however, in this study they will be treated as dApps, just like the L2 protocols of study do. On the other hand, the category of **Tools**, which refer to all those services that are designed to make it easier for developers or users to interact with the blockchain.

There are more categories and types of dApps, as many applications the blockchain technology can have, such as social media, e-commerce or supply chain applications. However, either they are still not numerous, or their applications are made for private blockchains.

#	Name	Category	Chain(s)	TVL (in $ M)
1	ETH2 Deposit Contract	DeFi	Ethereum	32.420
2	Polygon POS Bridge	Bridge	Ethereum	3.840
3	Curve	DeFi	Ethereum, Polygon, Avalanche, Fantom, Moonbeam, Aurora, Optimism	2.480
4	Uniswap V3	DeFi	Ethereum, Polygon, Celo, Optimism, Arbitrum, BNB Chain	2.410
5	Autoshark Finance	DeFi	BNB Chain, Polygon	1.170
6	Oasis.app	DeFi	Ethereum, BNB Chain, Optimism, Moonriver, Moonbeam, Cronos, Harmony, Avalanche, Aurora Fantom	1.150
7	Venus Protocol	DeFi	BNB Chain	894,84
8	Compound	DeFi	Ethereum	829,23
9	Axie Infinity	GameFi	Ronin, Ethereum	795,04
10	GMX	DeFi	Arbitrum, Avalanche	623,37

Table 7: Top 10 dApps by TVL [1st March 2023] (source: dApp Radar: Top Blockchain dApps)

In *table 7,* the top 10 dApps in terms of TVL that are presented. We can see that three of them have already migrated to Layer 2 solutions and almost all of them are DeFi solutions.

1.7. Valuation of L2 solutions

Value in blockchain solutions can be expressed in different ways and there is still no clear set of quantitative metrics that mirror the inherent value a protocol has. However, there are two key metrics that are widely considered representative of the current value of the protocol. On the one hand, the total value locked (TVL) that represents it in term of economical value. On the other hand, the transaction volume, commonly expressed as the number of transactions per second (TPS) a protocol has. These two metrics are expressed in both the MatterLabs framework and the Block Research one. Not just there, but on L2Beat, the reference website stated by Ethereum [47], these two metrics are the ones that are highlighted from L2 protocols. Additionally, if a protocol has an inherent token, the market capitalization is considered a metric that determines the value of the protocol [48]. Additionally, the number of active addresses is a determining factor for value [49]. In the following sub-sections, these different valuation metrics are presented and their relevance is stated.

1.7.1. Total Value Locked

The total value locked is the sum of all funds locked on the protocol expressed in either a fiat currency or a cryptocurrency. The more value locked up in a protocol, the greater the confidence in the protocol. The basic criteria for assets to be counted towards a protocol's TVL are [50]:

- cannot be minted by the protocol itself.
- is generating economic activity.
- is liquid.

As a result, TVL excludes assets that are minted by the protocol itself, assets not generating economic activity (such as tokens locked in liquidity mining or governance contracts), and illiquid assets.

1.7.2. Transaction volume

On-chain transactions that are happening in the protocol of study [51]. The transaction volume is, as already presented, as transactions per second (TPS) or total volume of transactions across time. Since not all protocols were created at the same time, the latter is not of interest and, hence, in order to address the transaction volume, the TPS (daily mean) will be the one of relevance. However, in some cases a window of a month is taken, and then the total amount of transactions in that window is accounted for (30D tx).

1.7.3. Market Capitalization

Market capitalization, or market cap, is the total dollar value of all the coins that have been minted (issued). Consequently, only those protocols with an underlying own cryptoasset can be subject to an analysis of their market cap. Since the L2 protocols are not fully developed and most still haven't launched a native token, this valuation metric will not be of crucial relevance in this study.

1.7.4. Active Addresses

This metric is measured by collecting and recording how many unique nodes are active during a predetermined time span, such as per day, per week or per month. In permissionless blockchains, the greater the number, the greater the indication that more nodes are using and trusting the blockchain application. The active nodes value is generally made available to all participating nodes. However, there are no official dashboards nor values of the daily active addresses in the case of L2 protocols. There are some unofficial data posted in Dune[16] but, as it is not from an official source and there is no validation, it won't be subject of study.

[16] https://dune.com/

1.8. Overview on literature review

After reviewing the current literature on the upcoming and the established Layer 2 solutions, it has been evidenced that there are some metrics that have not been yet sufficiently studied, especially in the L2 paradigm. Firstly, the relevance of community is clear yet, the fact that this community is directly enhancing value and whether it can be measured with social media following still has not been proved. Moreover, the investors behind these solutions – very risky solutions – are considered important but not really analyzed. Also, the money that backs the protocols (the investment they have had) is not presented. Finally, the dApps ecosystem is not analyzed in the big picture, and there is little research on them. Additionally, the fat protocols theory has not been yet tested in L2 solutions.

This study aims to present an assessment framework for Layer 2 solutions and insights on the overall solution ecosystem, that allows for comparison among them beyond technological intricacies. In order to do so, some metrics that will be present on the framework proposed need to be contrasted. Firstly, the conceptual metrics framework is presented, and the metrics that need to be contrasted, pinpointed. Continuously, the gaps in the literature that will be subject of study to determine the relevance of the metrics of interest are presented.

1.8.1. Conceptual metrics framework

In order to draft the conceptual framework, four verticals have been taken into account, just like in the VDBE framework [53]. Additionally, all the metrics of relevance mentioned in the Block Research framework [54] are taken into account as well as the technological intricacies that both the Matter Labs approach [18] and the L2Beat risk analysis [13] highlight in their frameworks. Finally, all the metrics studied in the Further metrics of study section (section 2.6.7) are also added in the framework, as they are, as seen, also of relevance. This conceptual metrics framework has been drafted by the author of this thesis by combining these aforementioned elements and existing frameworks.

Firstly, in the center of the framework, the name of the protocol, its type of scaling solution (optimistic rollup / zk rollup / state channel), the link to the protocol's whitepaper and the team behind or the CEO of the project needs to be evidenced. All these points and metrics are evidenced to be crucial to assess a protocol. The framework has four verticals, just like the VBDE one [53], but they have been changed for the following: Distribution Model, Protocol Valuation, Ecosystem, and Technical Design. Here below, each vertical is reviewed and the need of further scrutiny of each

subsection of each vertical will be presented. All these elements that need to be further analyzed, and which will be subject of study, have been written in italic.

Presenting the verticals of the conceptual framework, the one that has been maintained fully is the **Distribution Model**, where the incentives for consumers (users of the protocol), developers, and investors is presented. Regarding the investors, firstly the funding method is assessed: Regular funding / Coin offering. Regardless of the type, which can also be hybrid, the amount raised, as seen, is also a relevant metric. It could be the case with an initial coin offering (ICO) that the amount cannot be known, and, in such cases, it should be left blank. The relationship with investors, still needs to be reviewed as there needs to be a further analysis on how these protocols are funded and how many investing firms are backing them up. When it comes to the consumers community, Twitter following will be the quantitative way to evidence it. When it comes to the suitability for developers, the study will not focus in Github metrics but only on Discord ones. Moreover, other channels like Reddit and Telegram have also been ruled out. Hence, only those channels of interest in The Block Research study have been considered. Additionally, this distribution model is subject to further study because, if the community or brand, which is, as viewed, the demand generation, can also be associated with the value of the protocol, these metrics will account in the **Protocol Valuation** vertical. Moving to this Protocol Valuation vertical, it has been substituted by the Economical Model because in the VDBE framework it was a given that the protocol had an underlying cryptocurrency, which is not the norm in L2 solutions, as seen in *table 5.* As a result, the valuation is studied in the two main metrics mentioned, TVL and TPS. Additionally, if the protocol has an underlying token, then the market capitalization is studied as well as the percentage of circulating supply, in those cases where there is a capped supply, just like in The Block Research Framework. Finally, the number of active addresses, despite also depicting value, as mentioned in the previous section, due to the lack of public official data it has not been added in the framework.

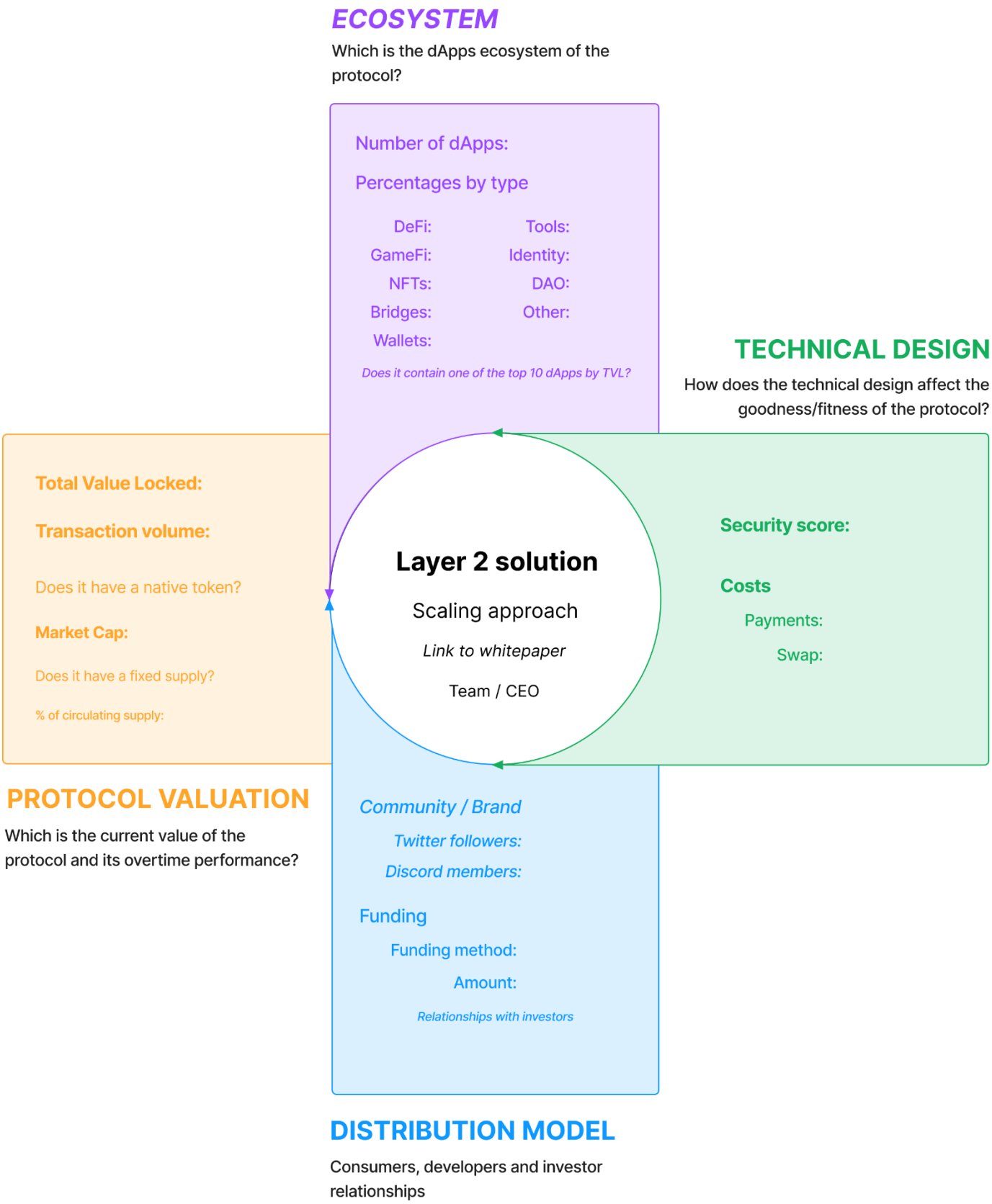
There has been a new vertical added, that was represented inside of the Blockchain Model in the VDBE framework which is the dApps **Ecosystem** vertical. By drafting this vertical the idea that the Fat Protocols [6] theory is no longer the norm is hypothesized. As such, it is subject of further study to see if the value of the protocol is, or not, that much greater of that of the dApps. If this theory that the protocols by themselves have most of the value, then the Ecosystem vertical would not be of special relevance. Additionally, the question of whether the apps with higher TVL are included in the protocol would not be relevant. In this Ecosytem section, the number of dApps is studied as well as which of the most prominent types of dApps the protocol has, based on the types previously presented: DeFi, GameFi, NFTs, Bridges, Wallets, Tools, Identity and Others. It is relevant to state that this study of types of dApps by percentages may not be necessary in the case of zk rollups if it is true that most of their applications are DeFi. This fact is also subject of study. Finally, if the

protocol is application specific, only the purpose and different applications it inherently has need to be disclosed.

The Value Model has been ruled out given that the value proposition of these L2 protocols is to improve the scalability of blockchain and allow for cheaper and higher-volume of transactions.

Finally, the Blockchain Model is too generic for this framework. The protocol rules and network shape is the same according the type of scaling solution in case (optimistic rollup / zk rollup / state channel). Because this framework is specific, the vertical has been renamed to **Technical Design.** In order to decide the metrics of interest, both the Matter Labs approach and the L2Beat Risk Analysis have been looked upon. In both cases, the security is a determining factor, and since L2Beats already has a very detailed study of the inherent security of these solutions segregated in three states, the combination of the 5 risks: State Validation, Data availability, Upgradeability, Sequencer failure and Validator failure is considered. So as to do so, a score is obtained by taking 0 as the riskiest (red), 1 as problematic (yellow) and 3, maximum score, as safe (white). The color reference has been presented in *table 5*. After scoring every one of the five risks, all of them are added giving, a minimum score of 0 (really unsafe protocol) and a maximum score of 15 (really secure and risk-free solution). In the Matter Labs framework, the performance and usability is also assessed and the only metric that is relevant for the L2 solutions that are under scrutiny is the cost of transactions. The reason is due to the fact that, the maximum throughput, the finality and the capital efficiency are inherent to the scaling approach taken, as seen in *table 3.* In other words, if the scaling approach is an optimistic rollup, the finality cannot be shorter than around a week whereas a zk rollup finality will always be seconds; it is inherent to the underlying technology, i.e. the scaling approach. In the presented framework, the costs taken into account are both the payments and the swap costs.

Finally, the shape of the protocol denotes that, in the end, the technical design is key aspect of these protocols both to attract dApps and to be able to have it easier to get funding and build a bigger community. So, the Technical Design has consequences on the Ecosystem and Distribution Model verticals. Also, these two affect each other because the more brand awareness more dApps will be on your protocols and viceversa, the more dApps unite you, the more people will be aware of your brand and join your community. Finally, the three mentioned verticals are the ones that result in a higher or lower valuation of the protocol.


ECOSYSTEM
Which is the dApps ecosystem of the protocol?
Number of dApps:
Percentages by type
DeFi:
Tools:
GameFi:
Identity:
NFTs:
DAO:
Bridges:
Other:
Wallets:
Does it contain one of the top 10 dApps by TVL?
TECHNICAL DESIGN
How does the technical design affect the goodness/fitness of the protocol?
Total Value Locked:
Transaction volume:
Does it have a native token?
Market Cap:
Does it have a fixed supply?
% of circulating supply:
Layer 2 solution
Scaling approach
Link to whitepaper
Team / CEO
Security score:
Costs
Payments:
Swap:
PROTOCOL VALUATION
Which is the current value of the protocol and its overtime performance?
Community / Brand
Twitter followers:
Discord members:
Funding
Funding method:
Amount:
Relationships with investors
DISTRIBUTION MODEL
Consumers, developers and investor relationships

1.8.2. Gaps in the literature

After presenting the literature, we can see that there are already frameworks that aim to study these L2 solutions and shed light on these type of solutions. However, not all metrics that can be of relevance are demonstrated to be impactful in the solutions and, also, other metrics are just overviewed and their actual relevance is unknown. In the literature review, these are presented in *Further metrics of study* and, besides the whitepaper and team section, which is a widely accepted metric, but very hard to quantify, the rest of the presented metrics need further assessment.

In the case of communities, these are considered to be of very high relevance in these protocols, because they can represent the brand of the protocol, very essential in these cases where all the code is open-source and blockchains can be forked. However, their relationship to the actual value of the solutions is unknown. Additionally, the investors behind solutions are often mentioned when analyzing the protocols (as seen in the VBDE framework [53], and in The Block Research [54] one) but their actual relationship with the protocols, and whether there are a few number of investors that control most of the ecosystem has been suggested [34], but never deeply studied. Additionally, whether the invested amount in a solution is translated directly into its value is also not reviewed.

Regarding the ecosystem of dApps, in the VBDE framework [53] there is a small subsection that mentions them, but, their relevance could be higher. There was no literature found on the ecosystem of dApps on the L2 paradigm and the only statement done regarding so is that zero-knowledge solutions are more suitable for DeFi solutions [11]. This has not been proved, and it could be that the space of other types of dApps are already migrating towards these solutions.

Finally, all these frameworks are based on the idea that the protocols are the ones that accrue the most value, and there has not been a study made to study if that applies to be true in the L2 space. If the value of the protocol is highly deemed by the ecosystem of dApps, then their relevance should be stated and a partial shift of focus should be done.

2 Methodology

The aim of this thesis is to provide a framework to assess L2 solutions, specifically for general purpose rollups. In order to assess the goodness of the framework presented in the Conceptual metrics Framework section, the different questions posed in the Subject of study section have to be answered. Then, the subset of L2 solutions subject to study is presented and detailed.

To answer the questions and draft the final framework, quantitative research has been done. Firstly, the data collection has been done with web scraping techniques and power searching, that will be further detailed in the following section. Once all the data was gathered, the data analysis was done, mainly with descriptive statistics and very simple inferential statistics in some cases.

2.1. Objective of the research

Given the relevance L2 solutions can have in the space, this study aims to define the general situation of the least studied relevant metrics and, also, shed light to metrics that might be (or not) relevant. Additionally, it aims to provide a framework suitable for the assessment of L2 solutions, especially for general-purpose rollups.

To do this, an empirical analysis has been conducted on the most valuable rollup solutions. startups operating on these technologies globally. The total value locked has been deemed as the most relevant valuation metric in order to determine the most important protocols in the space.

2.2. Subject of Study

In order to assess the correctness of the conceptual framework, as mentioned during its detailing, the following questions will be answered.

2.2.1. Research questions

Community relevance in terms of value

Community is considered to be one of the most relevant metrics, and also suggested as deeming the success or future success of protocols (demand generation), as presented in the literature review and, as such, a study on whether the success of the protocol in value (valuation metrics) and their social media engagement are related. Hence, should it be considered a measure of inherent value of the protocol or is it better to be studied as a separate metric (distribution value).

Main investors in the L2 ecosystem

Despite all these protocols being decentralized, behind them there are venture capitals that support their projects and, therefore, own a substantial part of the ecosystem. In those cases where there is a native token they own a big stake of it and in those cases where there is not, they own part of the protocol. A study of the most funding active venture capitals in the most prominent L2 solutions will be made and the total power or monetary value they accrue will be presented.

DApps ecosystem

Verifying if DeFi solutions are leaning towards zk rollups, and whether they make up most of their ecosystems (in the study, most will be considered 90%), as well as dApp categories choice of L2 protocol. In other words, proving whether the assumption that zk rollups are only deemed to financial purposes or other solutions are also betting on them. This analysis will also allow for an overview of the number of dApps each main protocol has.

Assessing Fat Protocols Theory

To decide whether or not the Fat Protocols [6] theory is obsolete or not, the top dApps in terms of TVL of every solution assessed will be analyzed. Comparing their success and the protocol's success as well as the overall TVL of the sum of dApps and the protocol the validity of the theory will be assessed.

2.2.2. L2 solutions for the study

For the scope of this project, only the L2 protocols who are built on top of Ethereum, i.e, their mainnet is Ethereum, will be considered. Having said that, only one solution, Lightning Network is discarded, as it is a L2 for Bitcoin. Moreover, the focus, since the market indicates that the most solutions are migrating there, only rollups will be considered. Hence, Celer Network will be out of the scope of the study.

Having stated that, the focus will be on rollups and, in each question of this subject of study, a different subset will be studied. In order to determine each subset, from these, only a specific subset will be of relevance. Each subset has been chosen considering two differentiated metrics. Firstly, their TVL value, the higher, the most prominent the solution. Therefore, in those cases where the valuation of the whole ecosystem is taken into account, only those with the highest TVL will be considered. Secondly, in some cases, whether they are application specific or general purpose will be another filtering method. The reason behind this choice is that those L2 solutions that only focus on a specific solution do not shed light on the protocols and landscape of L2 scaling itself but more on the solution. In other words, solutions like Sorare, who are now by themselves a L2 solution, only allow for their specific purpose (in this case, collecting digital football cards) and do not allow for other solutions to be built with them. As this study aims to build a framework to assess these L2 solutions in terms of usability

and success, it is imperative that their growth relies on ecosystem (dApps being built on top of these solutions).

In *table 8*, the different existing rollup solutions are presented, as well as the TVL they accrue in the L2 scene.

Solution	**TVL (M $)**	**Purpose**
Arbitrum One	3390	General-purpose
Optimism	1900	General-purpose
dYdX	360	Application-specific
Metis Andromeda	131	General-purpose
Loopring	111	General-purpose
zkSync	64.02	General-purpose
zkSpace	46.21	Application-specific
ApeX	21.67	Application-specific
Sorare	20.03	Application-specific
rhino.fi	17.96	Application-specific
Aztec	14.86	Application-specific
Boba Network	13.9	General-purpose
StarkNet	7.5	General-purpose
Polygon Hermez	0.326	General-purpose
Fuel v1	0.0004	Application-specific

Table 8: L2 protocols by TVL [1st March 2023] (source: L2Beat)

Seeing this, there are two further protocols that are ruled out. On the one hand, Arbitrum Nova, as it is created by the same group as Arbitrum One (OffChain Labs) and as they are both Optimistic Rollups, only Arbitrum One will be studied. This choice also stems from the fact that, provided that one day Arbitrum Nova outperformed Arbitrum One, the migration among them would be easy. On the other hand, zkSync Era, as the same logics apply to zkSync Era as zkSync is the main blockchain of Matter Labs.

Having ruled out state channels, and both Arbitrum Nova and zkSync Era, the resulting number of solutions are 15. The extensive list is the following:

- Arbitrum One
- Optimism
- Metis
- Loopring
- zkSync
- Boba Network
- zkSpace
- StarkNet
- Polygon Hermez
- Fuel v1
- dYdX
- ApeX
- Sorare
- rhino.fi
- Aztec

However, there is a subset that is of higher relevance, and it is that of those solutions that are general-purpose. From these solutions, zkSpace will also be ruled out as its concept, value proposition and applicability are almost the same as Loopring and, since Loopring has a higher TVL, it has been considered to be more prominent in the space. Additionally, all those solutions with a TVL lower than $500k are also discarded for this subset. Therefore, the general-purpose subset subject of study is made of 7 solutions, the following:

- Arbitrum One
- Optimism
- Metis
- Boba Network
- ZkSync

- Loopring
- Starknet

All in all, the chosen L2 solutions for this study are the ones shown in *figure 22*. The ones highlighted heavier will be the ones that will be subject to further scrutiny, the general-purpose subset, and the ones highlighted lighter will be studied in only the community relevance (the first subject of study), and are part of the bigger subset of chosen solutions.

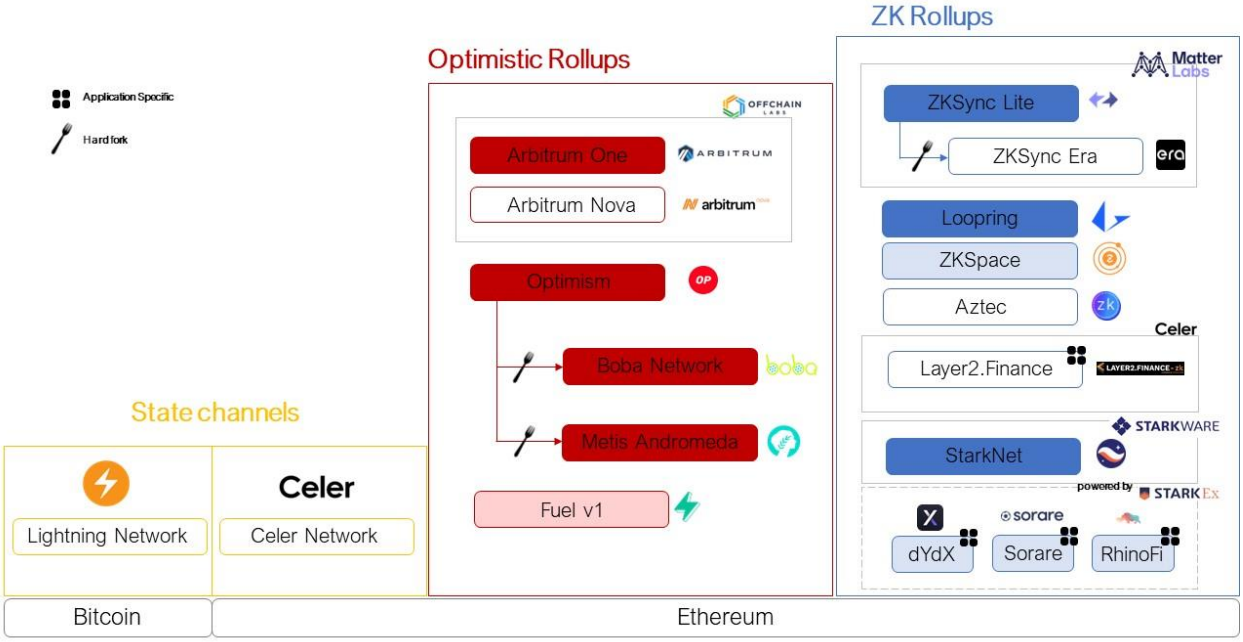


Figure 22: L2 ecosystem with the chosen solutions highlighted

2.3. Data Collection

All the numerical data provided as well as the state of the different Layer 2 solutions, are those of the 1st of March of 2023. In order to fetch the data, different sources have been consulted. To start with, the valuation metrics have been consulted in L2Beat, where, as seen previously, is an official source stated by Ethereum. Therefore, the total value locked values – daily, monthly and historical maximum – and the transaction volume values – 30D tx count, maximum historical TPS and TPS – have been obtained directly from their website. It is worth noting that all the transaction volume metrics were also contrasted with those of Etherscan to ensure their correctness and all the TVL values with websites like CoinGecko, OKX and Messari. In the case of TVL, between the different sources, there were some slight discrepancies, however, not big enough to discredit their values.

Additionally, in order to obtain the community following or membership of both Twitter and Discord, manually their values were found in the official profiles of the protocols and added to the worksheet of study.

With the aim of getting the investment rounds and the amount of money raised by the protocols, power searching was done, searching with keywords and logics operators. This way, newspaper, official twitter posts or technological blog posts were found where the information of each funding round and the amount were disclosed.

Finally, so as to assess the dApps ecosystem, webscrapping was done. Because there is no source where all the dApps are accounted in, only on the official websites of each protocol they have a dedicated tab with the different solutions. However, the dApps are displayed as JavaScript or HTML elements which complicated the retrieving of them all, especially because of the high number of dApps each of the chosen protocols have. So, with the help of a python script, the *requests* library and a the *BeautifulSoup* parser, the official websites of each protocol were scraped and all the dApps that are on their ecosystem were fetched as well as their type of dApp after a data formatting. It is worth noting that the data obtained is not copyrighted nor protected by terms of service, simply it was tedious to obtain it manually. Here below, the code used is presented for each solution, as well as the websites used.

In order to structure the code, the python script must import the following libraries:

```
import requests
from bs4 import BeautifulSoup
from selenium import webdriver
```

Once those are added, we need to access the website and configure the driver, in this case, the chrome driver:

```
chrome_options = webdriver.ChromeOptions()
chrome_options.add_argument('--headless')
chrome_options.add_argument('--disable-gpu')
chrome_options.add_argument('--no-sandbox')
chrome_options.add_argument('--disable-dev-shm-usage')
chrome_options.add_argument('--remote-debugging-port=9222')

driver = webdriver.Chrome('/path/to/chromedriver',
options=chrome_options)
url = 'URL'
driver.get(url)

html = driver.page_source
soup = BeautifulSoup(html, 'html.parser')
dapps=[]
```

From this second snippet of code, what must be changed is: `'/path/to/chromedriver'`, which should be the executable path of the chrome driver

used (if none, download here: https://chromedriver.chromium.org/downloads). Moreover, the URL of the studied protocol needs to be added. Since each website is different, for each, a different parsing has been done (note that, if the landing websites, i.e. how the content is displayed, were changed, this codes would not be of use and should be updated). Here below, the analyzed solutions with their URL and the parsing snippet of code are provided:

- Arbitrum: https://portal.arbitrum.io/

```
for card in soup.select('div.card'):
      dapp = {}
      dapp['name'] = card.select_one('div.card-body > h5.card-
      title').text.strip()
      dapp['category'] = card.select_one('div.card-body > p.card-
      text').text.strip()
      dapp['url'] = card.select_one('a.btn-primary')['href']
      dapps.append(dapp)
```

- Optimism: https://www.optimism.io/apps/all

```
for card in soup.select('div.app-card'):
      dapp = {}
      dapp['name'] = card.select_one('h5').text.strip()
      dapp['category'] = card.select_one('p').text.strip()
      dapp['url'] = card.select_one('a')['href']
      dapps.append(dapp)
```

- Boba Network: https://boba.network/dapps

```
for card in soup.select('div.app-card'):
      dapp = {}
      dapp['name'] = card.select_one('h4.card-title').text.strip()
      dapp['category'] = card.select_one('p.card-text').text.strip()
      dapp['url'] = card.select_one('a.btn-primary')['href']
      dapps.append(dapp)
```

- Metis: https://metis.io/ecosystem/

```
for card in soup.select('div.app-card'):
      dapp = {}
      dapp['name'] = card.select_one('h5.card-title a').text.strip()
      dapp['description'] = card.select_one('p.card-text').text.strip()
      dapp['url'] = card.select_one('h5.card-title a')['href']
      dapp['category'] = card.select_one('span.app-
      category').text.strip()
```

```
    dapp['platform'] = card.select_one('span.app-
    platform').text.strip()
    dapps.append(dapp)
```

- ZkSync: https://ecosystem.zksync.io/

```
for card in soup.select('div.project-card'):
    dapp = {}
    dapp['name'] = card.select_one('h3.card-title').text.strip()
    dapp['category'] = card.select_one('p.card-text').text.strip()
    dapp['url'] = card.select_one('a')['href']
    dapps.append(dapp)
```

- StarkNet: https://www.starknet-ecosystem.com/

```
for card in soup.select('div.project-card'):
    dapp = {}
    dapp['name'] = card.find('div', {'class': 'card-
title').text.strip()
    dapp['category'] = card.find('div' , {'class': 'card-
description').text.strip()
    dapp['url'] = card.find('a', ['class': 'card-link'})['href']
    dapps.append(dapp)
```

Finally, the results need to be saved and, in this case, in a csv document (where, `protocol_ecosystem` is the name of the file, which must be changed accordingly):

```
import csv
with open('protocol_ecosystem.csv', 'w', newline='', encoding='utf-8')
as f:
    writer = csv.DictWriter(f, fieldnames=dapps[0].keys())
    writer.writeheader()
    writer.writerows(dapps)
```

This code has been done by me, but it is the standard code for website scrapping, so not innovative in those lines. The differentiative snippets are the ones that are specific for each one of the solutions. It is also important that if having issues with the SSL/TLS certificate and not being able to parse the certificate, then an alternative, less automated but perfectly suitable, would be using the chrome extension Web Scrapping (https://webscraper.io/). In this case, manually the different desired variables for each website would have to be selected.

In addition, in this case, each protocol had different considerations in which are the different types of dApps, in other words, some, were very detailed and others, very

general. Additionally, the highest-TVL dApp of the protocols was found in dApp Radar and CryptoRank. However, it was only found for the chosen protocols that were optimistic rollups.

2.4. Empirical Analysis

Analyzing the data, in most cases, it has been a simple descriptive statistical exercise, and, in some others, a very simple inference has been done.

Starting with the community relevance, the two main valuation metrics, TVL and transaction volume have been contrasted with both their Twitter following and their Discord communities. This simple analysis aims to provide visual evidence of whether the social media following and the value of the studied protocols present any pattern or visual correlation. The valuation metrics taken will be daily, monthly and all-time high. In this case, to have enough data, all the solutions with a TVL higher than $500k were taken.

On the other hand, the investing rounds of all the protocols that account for +95% of the total TVL and +95% of the total transaction volume of the L2 ecosystem are presented and then gathered by venture capital. Only when the venture capital had led the funding round, it was considered to have invested in the company. From there, a table with all the investing firms that had funded L2 protocols and the amount they have invested is specified and also depicted visually. After that, in order to see which VCs have more stake in the overall L2 total TVL, a further study to see which ones accrue the highest value of TVL theoretically is done. Finally, a depiction of the chosen protocols in terms of funding amount is presented, to visually see the results.

Finally, to study the dApps ecosystem, two different analyses have been done. Firstly, all the scraped data was united with pivot tables and aggregated into the categories presented in the Literature Review: DeFi, GameFi, NFTs, Bridges, Wallets, Tools, Identity, DAO and Other (see dApps main categories). Once that manual aggregation is done, a depiction with pie charts in each case has been done to visually see which type of dApp is most prominent in every case.

Once that is done, then the assessment of fat protocols is presented. Despite value being defined as both TVL and transaction volume, in this case, only the TVL will be assessed. The reason stems from the fact that even if transactions can be studied, these jump from address to address, and the same transaction can have gone through multiple dApps and protocols and there is no method for filtering that nowadays. Moreover, if the transaction volume of dApps was studied, since they operate across multiple protocols, the specific volume dedicated to each protocol cannot be filtered either. As such, a study of the highest TVL apps and the TVL of the protocols is done. A comparative analysis to see if the protocol withholds much more value (in terms of TVL) or not is done, in other words, the sum of TVL accrued by the dApps is compared

to the total TVL of the protocol, to see the relevance of having – or not – highly used dApps on top. This study could only be done with the protocols where data from the highest TVL dApps of their ecosystem was found. As so, only the optimistic rollups of the chosen subset are subject of study, and not the full list of dApps of each protocol was found, the top 50 in some cases and just the top 20 in other cases. Since not all protocols have the same number of dApps on top, the overall represented dApps taken into account (whose data was found) range from 17% of the whole ecosystem to the 50% of the overall ecosystem. Regardless of the situation, a theoretical percentage is presented: the one that assumes the rest of the dApps TVL (the total remaining no information on could be found) is almost zero (tending asymptotically to zero). This approach has been named asymptotic approach and is the one that will be considered for the Fat Protocols assessment. If the dApps ecosystem represent more than a 50% of the total TVL, the fat protocols theory can be substantially questioned and, hence, the shift of focus should be put in the dApps instead of the protocols. However, if that is not the case, then, the theory cannot be ruled out and the obtained numbers will be analyzed, and a conclusion will be drawn.

2.4.1. Variables of study

All in all, the variables used for this study are:

- TVL – Total Value Locked
    - Max TVL – Maximum TVL of the protocol's history
    - TVL – The fetched TVL as of March 1st 2023
- Transaction Volume
    - TPS – Daily mean of transactions per second (as of March 1st 2023)
    - 30D tx – The number of transactions the last 30 days (those of February 2023)
    - Max TPS – Maximum TPS of the protocol's history (daily mean)
- Social media following
    - Twitter followers
    - Discord members
- Investment obtained
    - Investor firms behind each solution
    - Round of funding
    - Investing amount
    - Valuation given
- DApps ecosystem
    - Number of dApps per protocol
    - Types of dApps according to the following categories:

    - DeFi
    - GameFi
    - NFTs
    - Bridges
    - Wallets
    - Tools
    - Identity
    - DAO
    - Other
- Highest valued apps in terms of TVL

2.5. Limitations of the methodology

While this methodology can provide some insight, its limitations should be taken into consideration when interpreting the results. The lack of available data and the fact that valuation can only be studied with two metrics, really limits the study. Moreover, the techniques used for the data analysis are mostly graphical and the patterns identifications are merely visual. Additionally, some interviews with the teams behind these solutions could have been done, but, since it was done in The Block Research approach, they were not done in this study. Lastly, the current methodology could improve substantially if it was automated and the results could be studied over time, in which case, some patterns could be detected.

All in all, despite the methodology being limited, the results did provide clarification and the framework to assess L2 solutions – especially general-purpose rollups - is presented after the results.

3 Empirical analysis and results

In this section, the empirical analysis is presented and the most relevant results of the four research questions' results are described in detail. The analysis and results presentation are structured in the same order as they were presented in the subject of study.

3.1. Community relevance

In order to study whether the online community – measured in Twitter and Discord members – directly affects the valuation (the value) of the protocol, first, the study of the online communities in these two metrics compared to the total value locked (TVL) in millions of dollars is contrasted. Then, the same is done comparing them to the transaction activity. In all cases, the bigger subset, 15 protocols, both application specific and general-purpose ones are studied.

3.1.1. Community relevance in TVL terms

In *table 9* we can see the different values of TVL of all the 15 solutions as well as their online following and membership. The TVL is presented in 4 different manners: the maximum historical value, the value at September 2022, the TVL of the 1st of March 2023 and, finally, the growth during the last 6 months (from September 2022 to March 2023).

Solution	max historical TVL (M $)	TVL (M $) - September 2022	TVL (M $)	Growth in last 6 months (TVL)	Twitter Followers	Discord Members
Arbitrum One	4142	2662	3390	21%	548,800	325,710
Optimism	2038	1577	1900	17%	427,700	100,397
Metis	742					
Andromeda		135	131	-3%	143,800	12,630
Loopring	781	167.7	111	-51%	210,700	28,695
zkSync	176.25	59.5	64.02	7%	637,700	351,444
Boba Network	1375	31.2	13.9	-124%	363,600	18,723
zkSpace	87.57	42.7	46.21	8%	131,000	11,602
StarkNet	7.818	1.337	7.5	82%	187,000	55,730
Polygon	31.54					
Hermez		0.320	0.326	2%	26,900	287
Fuel v1	0.003	0.0004	0.0004	0%	169	41,698

dYdX	1,031	473	360	-31%	198,700	58,285
ApeX	21.7	4.48	21.67	79%	51,300	23,018
Sorare	39.47	25	20.03	-25%	167,800	1,919
rhino.fi	104.93	24.3	17.96	-35%	53,100	5,361
Aztec	14.75	6.6	14.86	56%	98,500	43,523

Table 9: L2 solutions and valuation in the form of TVL contrasted with online communities (Twitter and Discord)

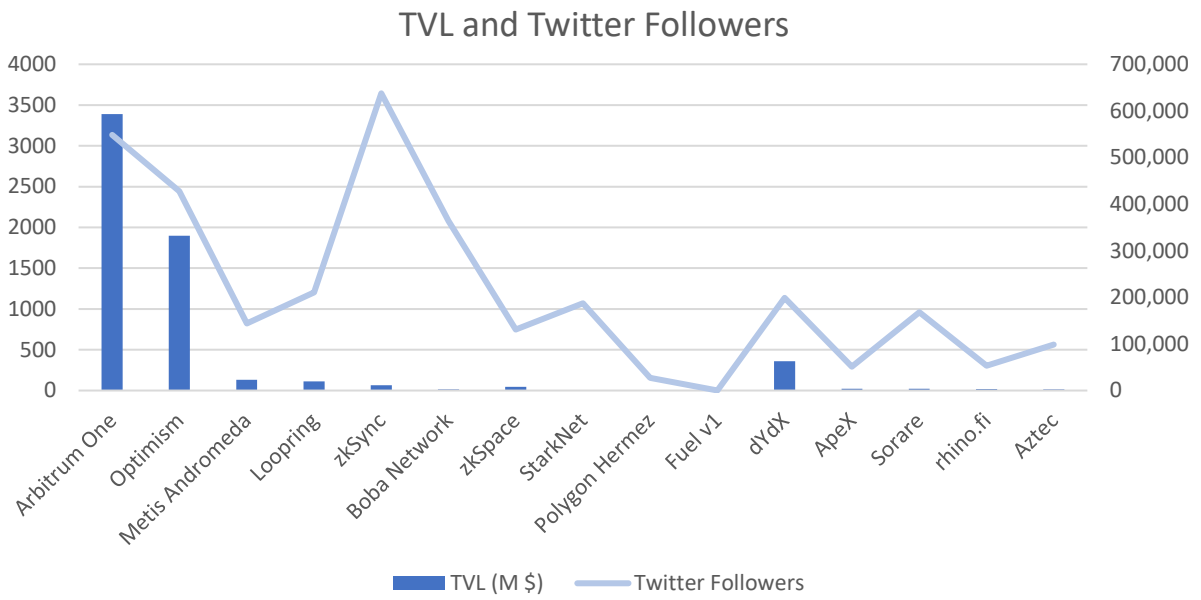


Figure 23: TVL of L2 protocols compared to their following on Twitter

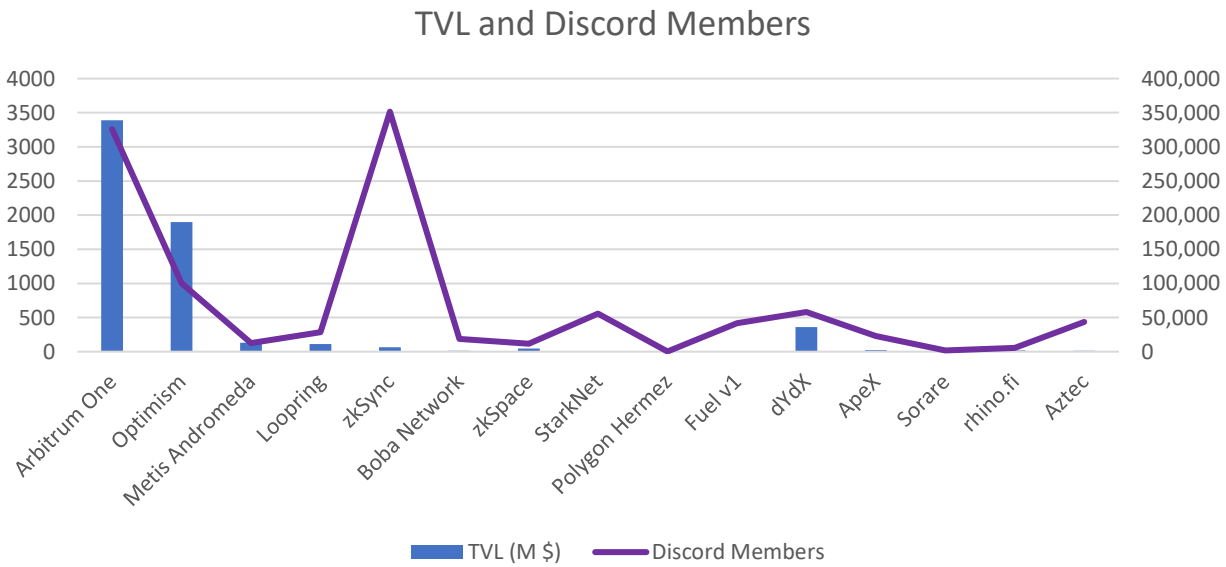


Figure 24: TVL of L2 protocols compared to their Discord communities

Because the TVL is not accumulative but the Twitter following, and the joining of a Discord community is (despite being a reversible action) it has been considered essential to contrast them with the maximum historical TVL value of each protocol, presented in *figure 25*.

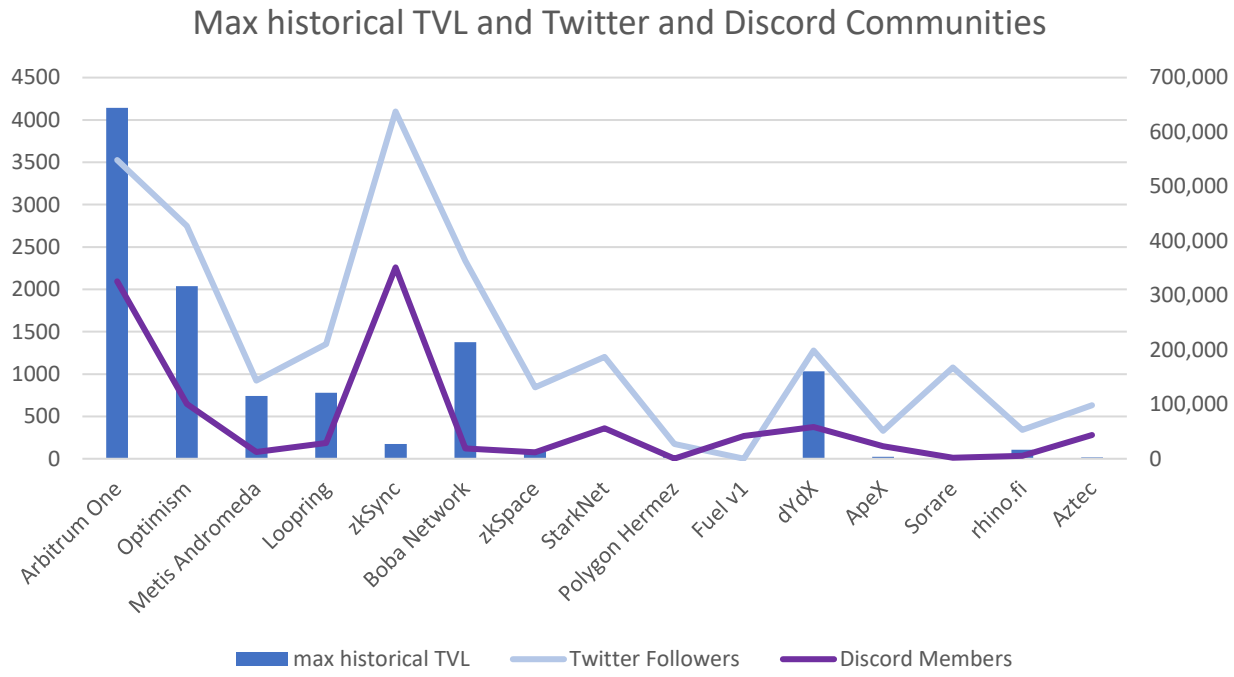


Figure 25: Maximum historical TVL of L2 protocols compared to their online communities: Twitter and Discord

Despite comparing it to this maximum value, we can observe that there is a trend where some solutions follow a pattern with their TVL and the social media communities but there are too many outliers like zkSync, StarkNet, Sorare and Aztec. Finally, logarithmic scale has been attempted but no logical pattern has been found either.

As such, the comparison with the transaction volume (usage of the solution) has been done.

3.1.2. Community relevance in transaction activity terms

As seen in *table 10*, the different ways to present transaction activity and the online communities expressed in Twitter followers and Discord members is presented. The transaction activity is presented in terms of the last transactions done in the last 30 days (30D tx count) in millions. These last 30 days, as the data was retrieved the 1st of March, is that of the month of February. Additionally, the maximum historical TPS is presented, and, finally, the value of the transactions per second of the 1st of March is

presented. It is important to note that the value of TPS is computed as the daily mean of all the TPS of a given day.

Solution	30D tx count (in M)	max historical TPS	TPS	Twitter Followers	Discord Members
Arbitrum One	19.13	12.77	6.43	548,800	325,710
Optimism	6.63	9.26	2.41	427,700	100,397
Metis Andromeda	0.329	1.25	0.09	143,800	12,630
Loopring	0.234	1.48	0.05	210,700	28,695
zkSync	1.24	1.99	0.4	637,700	351,444
Boba Network	0.018	0.29	0.01	363,600	18,723
StarkNet	0.382	0.6	0.15	187,000	55,730
dYdX	12.13	11.45	3.89	198,700	58,285
Sorare	1.28	2.31	0.52	167,800	1,919
rhino.fi	0.01	0.42	0.01	53,100	5,361
Aztec	0.0008	0.05	0.01	98,500	43,523

Table 10: L2 solutions and valuation in the form of transaction activity contrasted with online communities (Twitter and Discord)

Some L2 solutions have been removed in this transaction volume study due to the lack of transaction data on the protocols. The solutions previously presented and not considered in this table are: zkSpace, Polygon Hermez, Fuel v1 and ApeX.

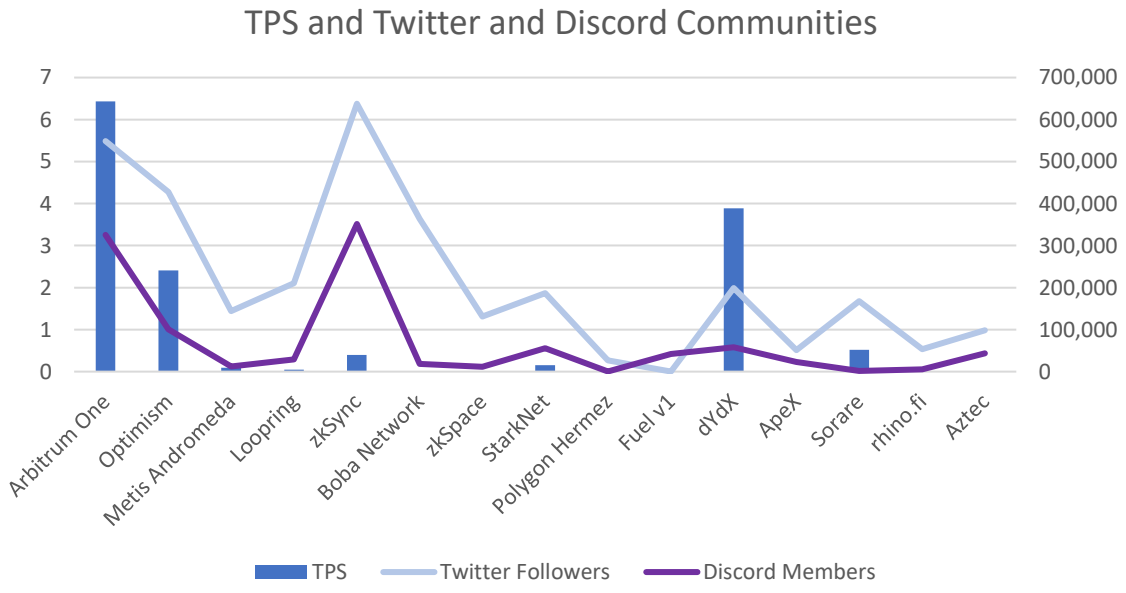


Figure 26: TPS of L2 protocols compared to their online communities: Twitter and Discord

As these daily mean TPS has not been stable in the past and, as mentioned earlier, both Twitter followers and Discord communities have past tracking, also the number of transactions of February 2023 in millions and the maximum historical TPS are assessed.

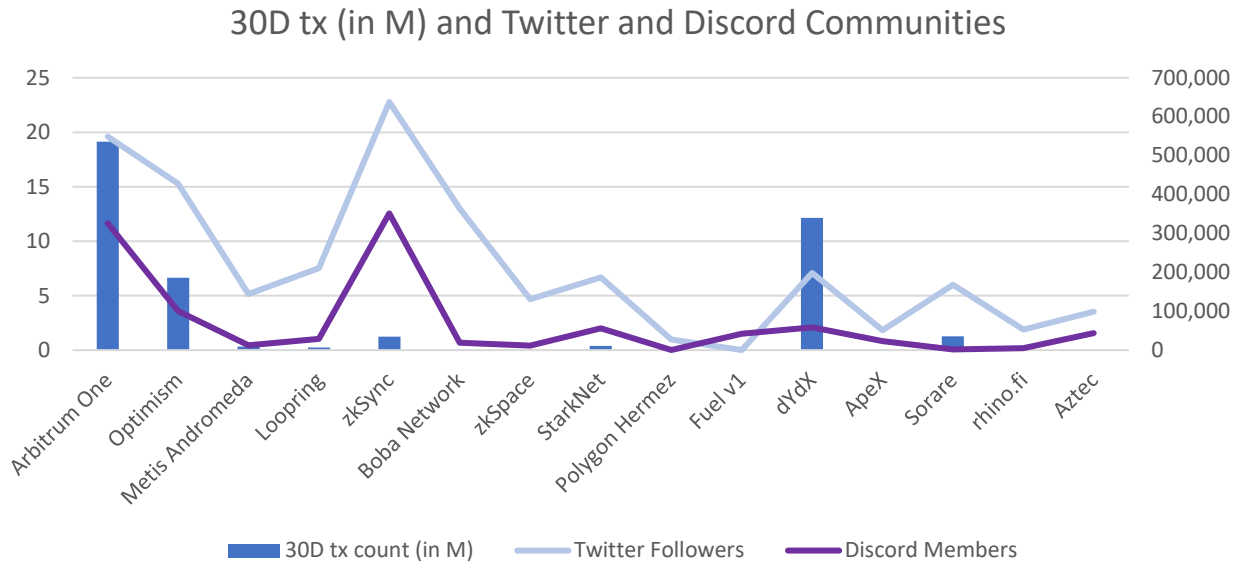


Figure 27: Previous month transaction volume (February 2023) of L2 protocols compared to their online communities: Twitter and Discord

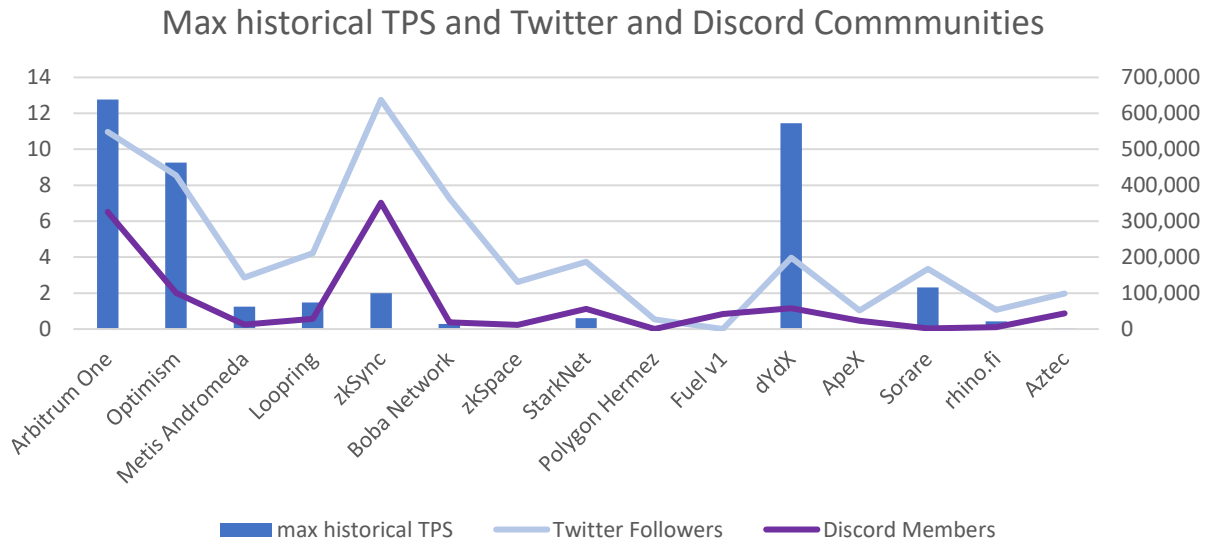


Figure 28: Maximum historical TPS of L2 protocols compared to their online communities: Twitter and Discord

Again, there are some that follow a trendline regarding the transaction volume and the social media following but there are too many exceptions like: zkSync, dYdX, Aztec and Boba Network and StarkNet on Twitter.

3.2. Main investors of the L2 ecosystem

Being the total TVL of the whole L2 ecosystem $5.6B, to study this, the subset of 7 protocols will be the ones considered, as they represent more than 90% of the whole ecosystem (only Arbitrum accounts for more than half and Optimism almost 30%). Additionally, if looked in transaction volume metrics, the solutions chosen also account for the 67% of the solutions. Because there is still a 30% underlooked, for this section the application specific solution dXdY is added. Hence, in terms of TVL, the solutions that will be subject to study account for the 98% of the total TVL of the L2 ecosystem, and the 97% of the overall transaction volume.

It is important to note that Loopring was funded by doing an initial coin offering, or ICO, and, despite having had a private sale, the buyers have not been disclosed. Moreover, Metis did the same thing but did have an initial Seed round. For this study, it will be considered that both who partook in the seed round partook in the token sale too. Therefore, Loopring will be overlooked and discarding this option mean that we will be analyzing the 96% of the total TVL and also the 96% of the total transaction volume. In *table 11*, the last funding round, the last valuation given and the total amount raised by each solution is stated.

Type	Last Funding round	Valuation ($)	Total funding ($)
Arbitrum One	Series B	1.200.000.000	124.000.000
Optimism	Series B	1.650.000.000	178.500.000
Metis Andromeda	Seed (with post ICO)	-	-
zkSync	Series C	not disclosed	458.000.000
Boba Network	Series A	1.500.000.000	45.000.000
StarkNet	Series D	8.000.000.000	261.000.000
dYdX	Series C	not disclosed	87.000.000

Table 11: L2 chosen solutions with funding round, valuation and total funding

The total amount invested in this L2 space is of $1.15B, lower that the TVL of the space.

In *table 12* presented here below, the funding rounds and the investors behind them are disclosed, and the leads in every round are remarked.

ARBITRUM ONE		**Series B**	120.000.000		
	Lead	LightSpeed VP			
		Pantera			
		RedPoint			
		Alameda Research			
		Polychain Capital			
		Ribbit Capital			
		Series A	25.000.000		
		a16z			
		Ideo Colab Ventures			
		Paradigm			
		Seed	3.700.000		
		Paradigm			
		Ideo Colab Ventures			
		Compound VC			
OPTIMISM		**Series B**	150.000.000		
	Lead	a16z			
		Paradigm			
		Series A	25.000.000		
	Lead	a16z			
		Ideo Colab Ventures			
		Paradigm			
		Seed	3.500.000		
		Paradigm			
		Ideo Colab Ventures			
METIS ANDROMEDA		**Seed**	5.000.000		
	Lead	OKX BlockDream Fund			
	Lead	DFG			
	Lead	Master Ventures			
		Genblock Capital			
		Autonomy Capital			
		Waterdrip Capital			
ZKSYNC		**Series C**	200.000.000	**Extra Series**	200.000.000
	Lead	Blockchain Capital		BitDao	
		DragonFly Capital			

		a16z	
		Lightspeed VP	
		Series B	50.000.000
	Lead	a16z	
		DragonFly Capital	
		Placeholder Ventures	
		Union Square Ventures	
		ConsenSys	
		Alchemy	
		OKX Blockdream Ventures	
		Series A	6.000.000
	Lead	a16z	
		DragonFly Capital	
		Placeholder Ventures	
		Union Square Ventures	
		1kx	
		Seed	2.000.000
	Lead	Placeholder Ventures	
		DragonFly Capital	
		1kx	
		Dekrypt Capital	
Boba Network		**Series A**	45.000.000
		Parachain Ventures	
		Crypto.com	
		GBV Capital	
		LD Capital	
		Kosmos Ventures	
		Huobi Capital	
		Rok Capital	
		(31 in total)	
STARKNET		**Series D**	100.000.000
	Lead	Greenoaks Capital	
	Lead	Coatue	
		Three arrows capital	
		Paradigm Capital	
		Sequoia Capital	
		Tiger Global	
		Series C	50.000.000

	Lead	Sequoia Capital	
		Series B	75.000.000
	Lead	Paradigm	
		Wing venture capital	
	Lead	Sequoia Capital	
		Alameda Research	
		Series A	30.000.000
		Pantera Capital	
		Consensys	
		Multicoin Capital	
		Seed	6.000.000
	Lead	Pantera Capital	
		Polychain Capital	
dYdX		**Series C**	65.000.000
	Lead	Paradigm	
		Polychain Capital	
		a16z	
		Electric Capital	
		Series B	10.000.000
	Lead	DeFiance Capital	
	Lead	Three Arrows Capital	
		Polychain Capital	
		Scalar Capital	
		Series A	10.000.000
	Lead	a16z	
	Lead	Polychain Capital	
		DragonFly Capital	
		Abstract Ventures	
		1confirmation	
		Seed	2.000.000
	Lead	Polychain Capital	
	Lead	a16z	
		1confirmation	

Table 12: Detailing of every L2 solution investment round and amount with investment firms behind them

As such and taking as the relevant investment firms the ones that have led the funding rounds, the chart by volume of investment is presented in *figure 29*. Note that, if no lead disclosed, then an equal division amongst all the ones that partook in the round has been done. The total amount can also be seen in *table 13*, it differs from the seen before because of the case of Boba.

VC	Investment (M $)
a16z	245.33
BitDao	200
Blockchain Capital	200
LightSpeed VP	120
Paradigm	113.82
Sequoia Capital	87.5
Greenoaks Capital	50
Coatue	50
Pantera Capital	16
Ideo Colab Ventures	11.32
Consensys	10
Multicoin Capital	10
Polychain Capital	6
DeFinance Capital	5
Three Arrows Capital	5
Placeholder Ventures	2
Compound VC	1.23
	1133.2

Table 13: Major VCs that have invested in L2 protocols with the respective amount in millions of dollars

In *figure 30,* all the main venture firms that have invested most in the space are presented, as seen in *figure 29*, but this time taking into account the overall TVL they "own" from L2 solutions. In order to assess this, each percentage of TVL accrued by each solution (the division of the TVL of the protocol over the total TVL of the L2 solutinos) has been multiplied by the total investment amount on that specific protocol by the given investing firm. In this case, the total TVL is considered to be the added TVL of the presented solutions, that, as discussed previously, it accounts for the 96% of the total TVL.

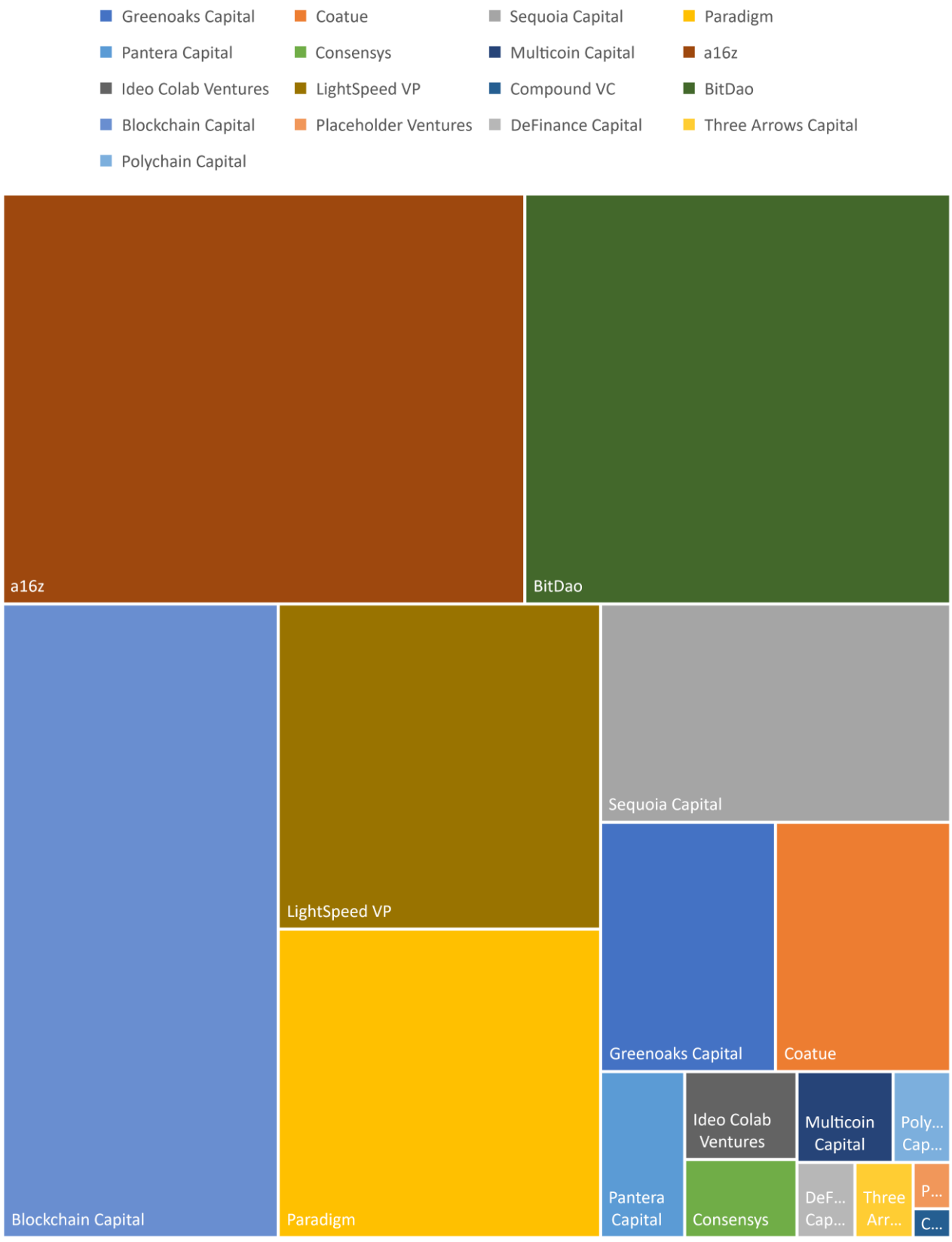


Figure 29: Representation of all the investing firms that has invested in L2 solutions, by investing amount

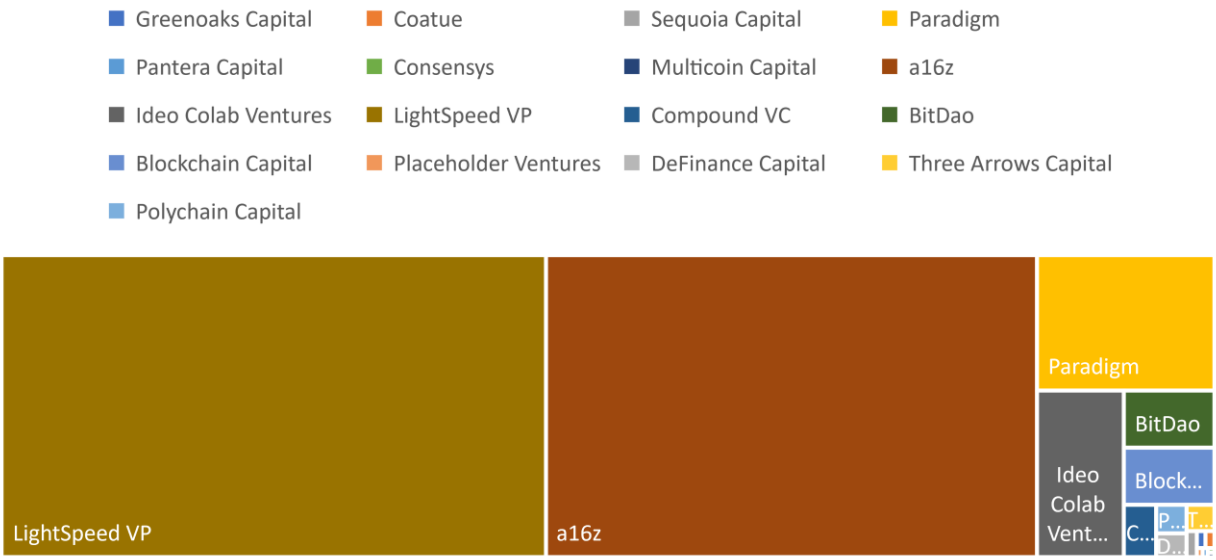


Figure 30: Representation of all the investing firms that has invested in L2 solutions, by TVL accrued

We can see that the most prominent investment firms are both LightSpeed VP and Anderssen Horrowitz (a16z). Finally, Paradigm is also notoriously big in the space.

Finally, a comparison of the presented projects as in funding amount is presented in *figure 31*.

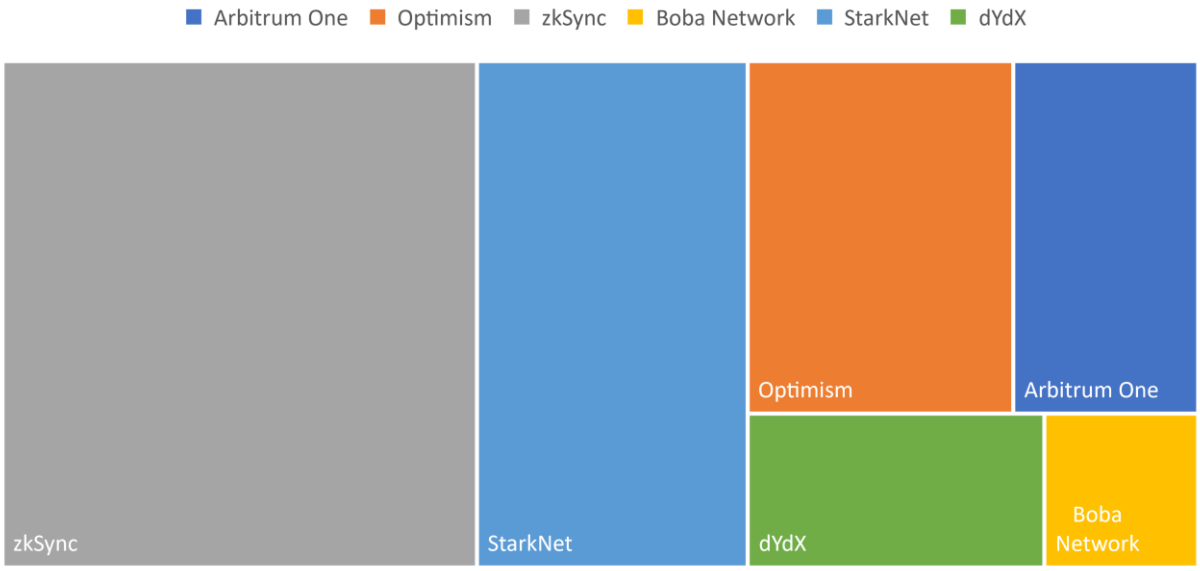


Figure 31: Representation of L2 solutions by investing amount obtained

3.3. DApps ecosystem

In order to assess the different dApps across all the chosen L2 solutions, firstly, the optimistic rollups will be presented and, then, the zk rollups. Finally, a comparison across the two different categories will also be presented. Only the subset of 7 solutions (general-purpose solutions) is studied.

To present all the dApp ecosystem, firstly, the segregation among types of dApps presented by each protocol will be stated. However, for the study, an aggregation of these categories into the categories presented in the literature review subsection DApps in the blockchain scene is done.

3.3.1. Optimistic Rollups

Arbitrum One

type	count
Bridges	30
Centralized Exchanges	10
Crypto Taxes	2
DAO Tools	10
Directories	2
Fiat On-Ramp	10
Growth	2
Lending	17
Liquidity Management	4
NFT Marketplaces	6
NFT Tools	3
NFTs	22
Node Providers	11
Options	8
Payments	5
Perpetuals	13
Stablecoins	10
Swapping	22
Tools	42
Wallets	36
Yield Optimization	11
	276

Table 14: Aggregation of the dApp ecosystem of Arbitrum One, by the categories they considered on their website

That translates, in the studied categories, to:

type	count	%
Defi	112	41
GameFi	0	0
NFT	31	11
Bridges	30	11
Wallets	36	13
Tools	42	15
Identity	0	0
DAO	10	4
Other	15	5
	276	100%

Table 15: Arbitrum's ecosystem by chosen dApp types

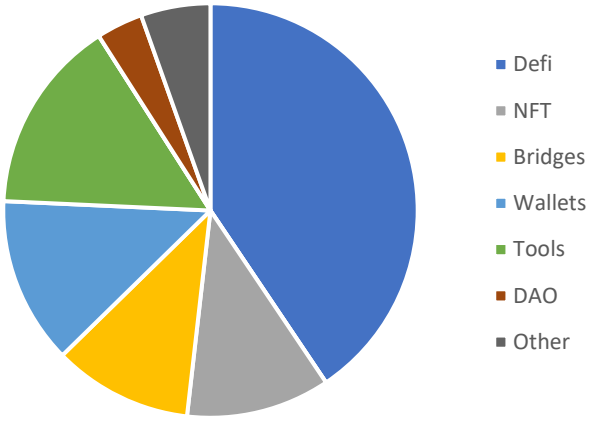


Figure 32: Arbitrum One ecosystem, by defined types

The most dominant is DeFi with almost half of the dApp ecosystem (41%).

Optimism

type	count
Bridges	20
DAOs	11
DeFi	78
Fiat on Ramp	12
NFTs	31
NFTs / Collectibles	1
NFTs / Gaming	1
Op Summer Innovations	17
Tools	42
Wallets	20
	233

Table 16: Aggregation of the dApp ecosystem of Optimism, by the categories they considered on their website

type	count	%
Defi	90	38,63
GameFi	0	0
NFT	33	14,16
Bridges	20	8,58
Wallets	20	8,58
Tools	42	18,03
Identity	0	0
DAO	11	4,72
Other	17	7,3
	233	100%

Table 17: Optimism's ecosystem by chosen dApp types

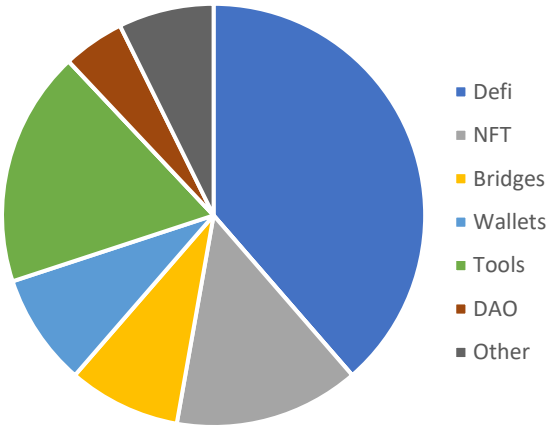


Figure 33: Optimism's ecosystem, by defined types

Again, the most prominent in the dApp scene in Optimism is DeFi (38.6%).

Metis

type	count
Bridge	7
DAC	1
DEX	6
AMM	3
Yield	3
GameFi	1
Identity	1
E-commerce	1
Platform	2
Stable Coin	1
NFT	5
Metaverse	3
Wallet	5
Infrastructure	11
	50

Table 18: Aggregation of the dApp ecosystem of Metis, by the categories they considered on their website

That translates, in the studied categories, to:

type	count	%
Defi	13	26
GameFi	1	2
NFT	5	10
Bridges	7	14
Wallets	5	10
Tools	13	26
Identity	1	2
DAO	1	2
Other	4	8
	50	100%

Table 19: Metis' ecosystem by chosen dApp types

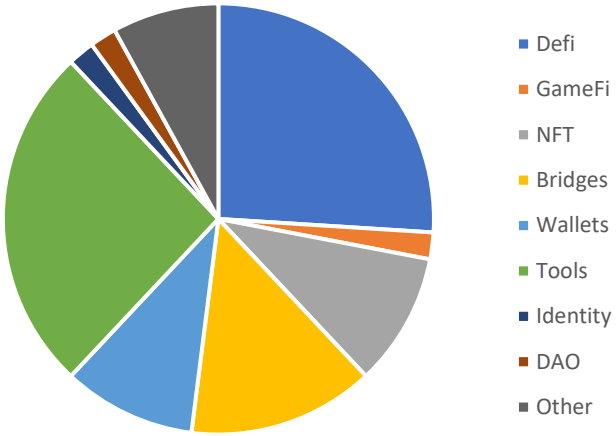


Figure 34: Metis ecosystem, by defined types

In this case, Metis supports, again, DeFi dApp on top but not as remarkably much as the other two reviewed. In this case, the two most prominent solutions are both Tools and DeFi. Moreover, it is important to note that Metis also holds interesting more heterogeneous solutions like Metaverse, and e-commerce. Finally, it is important to note that we can see some solutions like GameFi and Identity are already migrating to the L2 space.

Boba Network

In the case of Boba Network, their categorization was already the one subject to study, hence:

type	**count**	**%**
Defi	18	42,86
GameFi	0	0
NFT	4	9,52
Bridges	4	9,52
Wallets	11	26,19
Tools	5	11,90
Identity	0	0
DAO	0	0
Other	0	0
	42	100%

Table 20: Boba's ecosystem aggregate

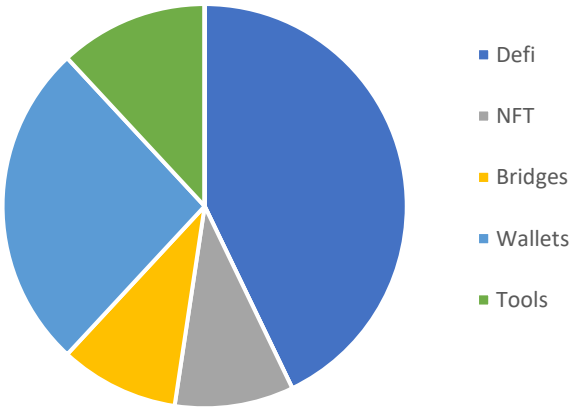


Figure 35: Boba Network ecosystem, by defined types

In the case of Boba Network, once again, most of the applications on top are focused on decentralized finance and wallets, in the end, also a vehicle for holding digital assets.

3.3.2. Zero-knowledge Rollups

ZKSync

Type	count
BRIDGES	11
DAO	9
DEFI	47
DIGITAL ID	3
GAMES	4
GATEWAYS/CEX	6
GOVERNANCE	2
INFRASTRUCTURE	36
NFT	14
PAYMENTS	1
PRIVACY	1
SOCIAL	1
WALLET	14
	149

Table 21: Aggregation of the dApp ecosystem of ZkSync, by the categories they considered on their website

That translates, in the studied categories, to:

type	count	%
Defi	48	32,21
GameFi	4	2,68
NFT	14	9,40
Bridges	11	7,38
Wallets	14	9,40
Tools	36	24,16
Identity	3	2,01
DAO	11	7,38
Other	8	5,37
	149	100%

Table 22: ZkSync's ecosystem by chosen dApp types

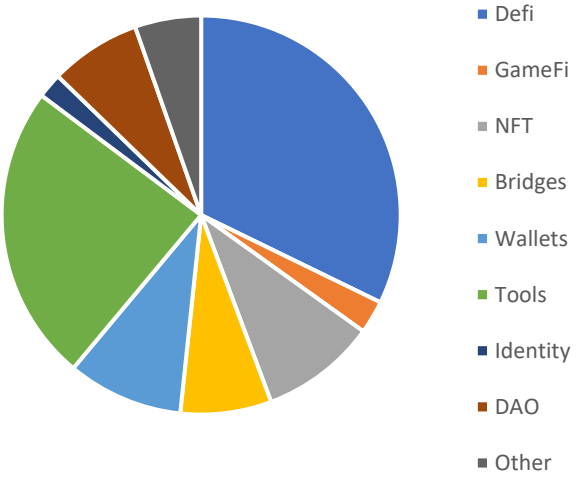


Figure 36: ZKSync ecosystem, by defined types

Loopring

In the case of Loopring, their aim is to bring decentralized exchanges on top of it and, hence, their sole focus in in DeFi, both payments and trading. All the solutions that are on top currently are built in house, in other words, have been presented by Loopring.

Finally, we cannot state that it is a 100% DeFi since they have added an availability to trade NFTs. However, much of the volume of both availabilities and transaction volume comes from the DeFi verticals they have.

StarkNet

In the case of StarkNet, dApps are categorized with various tags that point to different categories. If we look at all the categorization the first column is presented and, if taken into account just the most relevant purpose of the dApp, then we obtain the second column. For the study, the second one will be taken into account as it also represents the actual number of dApps built on top of the protocol.

In *table 23*, the fact that that the dApps where tagged in more than one category is defined as multitagging.

type	multitagging count	single count
Bridges	4	4
DeFi	19	15
NFTs	14	5
Social	5	1
Infrastructure	10	8
DAOs	9	2
Games	14	13
Wallets	2	2
Identity	0	1
		50

Table 23: Aggregation of the dApp ecosystem of StarkNet, by the multitagging considered on their website and the manual single count

Therefore, within the categories of the study, we obtain *table 24*.

type	count	%
Defi	15	30,00
GameFi	13	26,00
NFT	5	10,00
Bridges	4	8,00
Wallets	2	4,00
Tools	8	16,00
Identity	1	2,00
DAO	2	4,00
Other	0	0,00
	50	100

Table 24: StarkNet's ecosystem by chosen dApp types

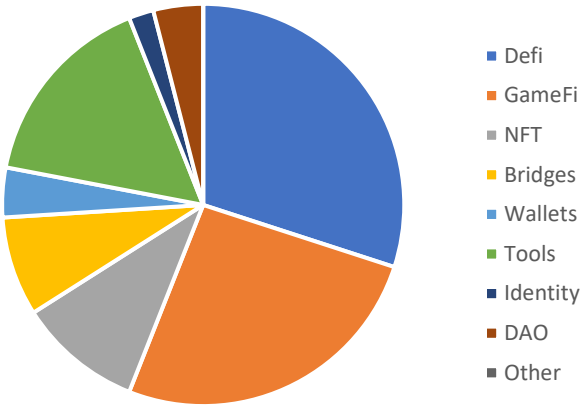


Figure 37: StarkNet ecosystem, by defined types

3.4. Assessing Fat Protocols Theory

In order to proof or disproof the idea that the value stays in the protocol, the highest value dApps compared to the value of the protocols is compared. Despite value being defined as both TVL and transaction volume, in this case, only the TVL will be assessed. The reason stems from the fact that even if transactions ca be studied, these jump from address to address, and the same transaction can have gone through multiple dApps and protocols and there is no method for filtering that. Moreover, if the transaction volume of dApps was studied, still they operate across multiple protocols and the specific volume dedicated to each cannot be filtered either.

As such, a study of the highest TVL apps and the TVL of the protocols will be studied. A comparative analysis to see if the protocol withholds much more value or not is done. For this, firstly, Loopring is out of the study since all their dApps are built in house and the value stays in the same hands. Moreover, both StarkNet and zkSync dApps are not as mature and there is not documented evidence of the TVL of most solutions. Therefore, the Fat Protocols Theory will only be assessed with Optimistic Rollups solutions. Bearing in mind the figures presented in table 25, firstly the 10 dApps with the highest TVL of the ecosystem of each solution is presented and then a comparison with the protocol's TVL is done.

Type	TVL (M $)	number of dApps
Arbitrum One	3390	276
Optimism	1900	233
Metis Andromeda	131	50
Boba Network	13,9	42

Table 25: Chosen solutions' TVL in millions of dollars and their number of dApps

The first protocol studied is Arbitrum One, firstly assessing the top 10 dApps in terms of TVL.

ARBITRUM ONE top 10 dApps	TVL ($)
GMX	525.264.576,78
Uniswap V3	160.774.485,25
Radiant Capital	127.255.026,55
SushiSwap	116.004.275,35
Synapse	85.525.871,17
Camelot	76.000.455,51
Curve	74.620.638,01
AAVE V3	67.780.177,71
Zyberswap	62.545.762,55
Stargate	55.793.786,11
	1.351.565.054,99

Table 26: Arbitrum One's top 10 dApps by TVL and respective TVL in dollars

We can see that the top 10 dApps in terms of TVL account for the 40% of the TVL of the protocol. In relation to the number of dApps, this 10 top account for the 3.6% of the total ecosystem of Arbitrum One. If the same study is done with the top 50 dApps in terms of TVL, the total TVL is that of $2.016.750.975,01, accounting for the 60% of the total TVL and accounting only for the 18.2% of the ecosystem.

	TVL ($)	% of ecosystem	% of TVL	number of apps
top 10	1.351.565.055	4%	40%	10
top 15	1.610.706.305	5%	48%	15
top 25	1.881.703.372	9%	56%	25
top 50	2.016.750.975	18%	59%	50
Arbitrum Ecosystem	3.390.000.000	100%	100%	276
Asymptotic approach	2.016.750.975	hyp 100%	59%	276

Table 27: Arbitrum One's TVL assessment according to its ecosystem, with asymptotic approach

Hence, the accrued TVL by the dApps ecosystem in the Arbitrum One protocol is considered at 59%.

In the case of Optimism, in *table 28*, the ten highest TVL dApps are presented and the same study is done.

Optimism top 10 dApps	**TVL ($)**
Velodrome	308.277.312,57
Synthetix	156.793.951,26
Curve	90.025.952,74
AAVE V3	86.848.849,83
Beefy Finance	79.108.558,07
OKX	76.739.016,19
Multichain	52.739.767,18
Uniswap V3	51.236.770,23
PoolTogether	40.050.785,15
Sonne Finance	39.361.650,56
	981.182.613,78

Table 28: Optimism's top 10 dApps by TVL and respective TVL in dollars

In this case, the top 10 dApps account for the 51.6% of the total TVL of the protocol, and the applications only represent a 4.3% of the total ecosystem of Optimism. Looking at the top 50 apps, the total TVL is of $1.346.962.007, accounting for the 70.9% of the protocols' TVL.

	TVL ($)	**% of ecosystem**	**% of TVL**	**number of apps**
top 10	981.182.614	4%	52%	10
top 15	1.185.083.866	6%	62%	15
top 25	1.303.654.052	11%	69%	25
top 50	1.346.962.008	21%	71%	50
Optimism Ecosystem	1.900.000.000	100%	100%	233
Asymptotic approach	1.346.962.008	hyp 100%	71%	233

Table 29: Optimism's TVL assessment according to its ecosystem, with asymptotic approach

For Optimism, the percentage observed is that of: 71% .

In the case of Metis, in table 30 the highest TVL solutions are presented, and, as seen, they account for a total of a 43.5% of the overall protocol's TVL, yet in this case, as the ecosystem is smaller, the top 10 represents the 20% of the ecosystem.

Metis Andromeda top 10 dApps	**TVL ($)**
Hummus	14.992.253,36
Hermes Protocol	10.433.461,87
Stargate	7.839.654,56
NetSwap	6.254.572,80
Maia	5.503.280,16
Synapse	4.654.870,63
QiDao	2.412.949,14
Beefy Finance	2.407.272,31
Tethys Finance	1.405.335,78
The Granary	1.031.306,71
	56.934.957,32

Table 30: Metis' top 10 dApps by TVL and respective TVL in dollars

In this case, only the top 25 dApps with higher TVL has been retrieved because of availability issues, but it is very representative bearing in mind the total of the ecosystem (50 dApps).

	TVL ($)	**% of ecosystem**	**% of TVL**	**number of apps**
top 10	56.934.957	20%	43%	10
top 15	58.816.740	30%	45%	15
top 25	59.277.641	50%	45%	25
Metis Ecosystem	131.000.000	100%	100%	50
Asymptotic approach	59.277.641	hyp 100%	45%	50

Table 31: Metis' TVL assessment according to its ecosystem, with asymptotic approach

In Metis case, the accountability of the total TVL is not as high as in the two previously presented cases, being the percentage observed: 45%.

Finally, in the case of Boba Network, the top 10 dApps with higher TVL are presented in *table 32* and, in Boba's case, 10 apps represent almost the 25% of the ecosystem. This quarter of the ecosystem account for the 30% of the total TVL of the protocol.

Boba Network top dApps	TVL ($)
SushiSwap	1.526.474,59
OolongSwap	1.487.176,44
Gin Finance	330.198,43
UMA Protocol	232.517,76
Symbiosis Finance	135.707,95
Thetanuts Finance	101.543,66
Bodh Finance	99.702,78
Zencha Finance	85.771,36
Poly Network	67.891,99
cBridge	64.835,22
	4.131.820,18

Table 32: Boba Network's top 10 dApps by TVL and respective TVL in dollars

In the case of Boba, again, due to data availability problems, only the top 20 with highest TVL values have been found. In this case, these 20 applications represent almost the 50% of the ecosystem.

In *table 33,* we can see that in the case of Boba, the protocol accrues way more value than the ecosystem built on top of it.

	TVL ($)	% of ecosystem	% of TVL	number of apps
top 10	4.131.820	24%	30%	10
top 15	4.259.310	36%	31%	15
top 20	4.269.124	48%	31%	20
Metis Ecosystem	13.900.000	100%	100%	42
Asymptotic approach	4.269.124	hyp 100%	31%	42

Table 33: Boba Network's TVL assessment according to its ecosystem, with asymptotic approach

In this case, in the protocol almost 70% of the TVL resides just in the protocol, being the obtained value: 31%.

Finally, the sum up of all the results obtained are expressed in *table 34*.

L2 solution	Assumed % (asymptotic approach) of TVL accrued by dApps ecosystem	Number of dApps
Arbitrum One	59%	276
Optimism	71%	233
Metis	45%	50
Boba Network	31%	42

Table 34: Summary of of the observed TVL percentages of the four different studied solutions as well as the number of dApps

4 Discussion and final framework

In this concluding chapter, the main findings of the empirical analysis are presented, and then further discussed. After this analysis, the final L2 Framework for comparison is presented with the amendments accordingly explained. Additionally, the limitations of the results are stated, and future research is suggested. Finally, the conclusion of the thesis is presented, clearly stating the main findings and the answers to the research questions.

4.1. Discussion and main findings

4.1.1. Main findings

From the obtained results, firstly, we can see that the social media metrics both in Twitter followers and Discord communities cannot be directly translated into value. Therefore, their qualitative values need to be assessed in the Distribution Model vertical of the framework.

Regarding the investors behind these solutions, we can see that the top 5 investing firms in the layer 2 space, account for more than 77% of the overall investment. These firms are: Andersen Horrowitz (a16z), BitDao, Blockchain Capital, Lightspeed VP and Paradigm. Moreover, we can see that there are two main investing firms that are behind most of the L2 TVL are Andersen Horowitz (a16z), and LightSpeed VP, "owning" more than the 85% of TVL of the space. On top of that, we can see that the solutions that are obtaining by far more funding are zk rollups, while the solutions that have the highest TVL and transaction volumes are optimistic rollups. Finally, regarding the framework, seeing the data, and seeing that there are few investing firms that invest heavily in these types of solutions, a follow-up question regarding which top 5 investing firms are behind the solution will be added.

On the other hand, concerning the dApp ecosystem, we can see that regardless of being optimistic or zero-knowledge rollups, if they are general purpose solutions, they have all kinds of types of solutions. In all cases, DeFi applications are the most relevant. Therefore, in the framework there will be no distinction whether it is an optimistic or zero knowledge scaling solution.

Last but foremost, despite not having empirical proof of the exact values, and, hence, not being able to rule out the theory of fat protocols, we can see that the TVL dApps accrue within the total protocol's TVLs is not negligible and, in some cases, very remarkable, and, hence, the ecosystem has enough relevance. Consequently, the Ecosystem vertical is kept, will be considered relevant and, also, the question of whether they contain one of the top 10 dApps by TVL will be maintained. It is

important to note, though, that with the results obtained, this latter question is not a positive nor negative one. In other words, having the highest TVL app adds a lot of value to the overall protocol's TVL but that also means that if that dApp decides to migrate to another protocol, the protocol will face a very noticeable downturn in TVL. That's why, in the case of the answer being positive, the number of highest TVL apps that are on top of the protocol will also be added.

4.1.2. Discussion of the results

Community relevance

Firstly, when studying the following on Twitter and the number of Discord members compared to the first metric of value, TVL, we can see that neither looking at the punctual value of TVL nor the historical maximum we can't see any pattern. In other words, there are too many outliers to think that the more followers or members of the online community, the higher the TVL they have. We can see that in the case of zkSync, StarkNet, Sorare and Aztec their online communities are in high disparity compared to the actual total value locked. In the clearest case, zkSync, we can see their following in Twitter is the highest of them all, 637.700 followers, while their TVL is 23.5 times lower than the most successful solution, Arbitrum One, which has 548.800 followers. In addition, when looking at table 9, we can see that the growth in TVL in the last 6 months, which is negative in the cases of Metis, Loopring, Boba, dYdX, Sorare and, rhino.fi, is not related to lower values in online communities. It is important to note that, probably, it would be interesting to study the increase (or decrease) of Twitter followers and Discord members overtime because it could shed some light of whether they are related. However, it is also true that the number of followers and members is normally growing unless there is a massive unfollowing of a specific account, which is not common.

Continuously, when assessing the same for the second valuation metric, the volume of transactions both by TPS and by 30D tx, we obtain similar results, where again, we can see that the online communities do not directly represent more activity on the network. In this case, the study is less representative as not all solutions could be studied, zkSpace, Polygon Hermez, Fuel v1 and ApeX had to be removed from the study due to data unavailability. In this case, we can see that zkSync is again a notorious outlier and, this time, also dYdX, a protocol with high transaction volume compared to their online communities. Finally, the only visible pattern is that the number of Discord members is normally proportional to those of Twitter followers, as all the lines that depict those online communities are mostly parallel (except for the case of Fuel v1).

The outliers can be attributed to bought bots to gain followers and members and create hype on the protocols or, also - and that is why a study over time would be interesting - maybe it is indicative of future success.

For this first subject of study, the empirical work is as wide as it could be, however, it would be interesting to study the following on social media over time and whether that reflect patterns on changes on TVL, TPS and, also, market capitalization and active addresses.

Main investors of the L2 ecosystem

The second subject of study, the investing firms behind all these solutions, firstly, on table 11 we can see the maturity in terms of investment obtained of the different solutions chosen. The chosen solutions are representative of the space as they account for the 98% of the total TVL of the L2 ecosystem, and the 97% of the overall transaction volume.

In this same table, *table 11*, it is made clear that that the last funding round depends on the solution, but those more advanced (Series C and D) are those that are zk rollups. However, not in all cases, that means they have had the highest investment amount - we can see that in the case of dYdX, the only application specific solution, despite having gotten to Series C, they have gotten far less investment than most of the other solutions.

In *table 12*, where all the solutions with all the funding rounds and amount gotten are disclosed, we can see that it is normally augmenting from round to round, even though we can see that in the case of StarkNet, the amount raised in the Series C ($50M) was substantially lower than that of the Series B ($75M). Moreover, we can see that there are many ventures have invested in more than one solution. As such, in *figure 29* we can see that there are clearly 5 firms that have ruled the investments done in the space, which account for more than the 77% of all the investments: a16z, BitDao, Blockchain Capital, LightSpeed VP and Paradigm. However, as seen in figure 30, there are two that really rule the ecosystem: a16z and Paradigm, as they are the major investors of the solutions with the highest TVL solutions. These two, Andersen Horrowitz and Paradigm, accrue the 85.6% of the TVL of the space (noting that the TVL of the space considered is the 98% of the total TVL).

Finally, in in *figure 31* we can see that the solutions that have gotten the higher investment are, by far, zero-knowledge rollups, as StarkNet and ZkSync have been invested in more than half of the total amount of funding the ecosystem has received. Actually, of the total amount raised in the space ($1.15B), they have gotten the 62.3% and, taking into account all the zk rollups, it is almost the 70% of the total amount raised. Therefore, we can see that the investment efforts are clearly heavier on zk rollups than on optimistic ones.

Regarding this second subject of study, it is important to mention that it is inaccurate the decision taken of only taking the leads as the total amount of investment and, in case of missing information of who led it, dividing it all equally. Therefore, the accuracy in that sense of the results is not optimal.

DApps ecosystems

In this subject of study, the empirical work is the widest it could be, as all the protocols that are generalized L2 solutions have been taken into account to see their ecosystems of dApps. Therefore, the whole subset of the 7 solutions with a TVL higher than $500k and that are general-purpose are studied. We can see that, overall, the solutions that accrue most dApps are Arbitrum One and Optimism with 278 and 233 respectively, as seen in in *tables 14-17*.

Regarding the optimistic rollup solutions, in all cases DeFi is the most prominent solution, with percentages from 26% up to almost the 43% of the protocols, visible in *tables 15, 17, 19* and *20*. However, in the case of Metis, also the number of dApps that are Tools are also on a tie with the DeFi solutions. Additionally, only in the case of Metis we can see the first GameFi solutions that have migrated to optimistic rollup protocols. Remarkably, all the protocols have more than 40 dApps in their ecosystems - being Boba Network the one with the fewest solutions, 42 followed by Metis, 50 dApps and finally Arbitrum and Optimism with more than 250 dApps on their ecosystem each. Finally, while in the case of Arbitrum, Optimism and Metis, there are a wide range of different solutions, Boba's solutions are way more limited, mostly being all the ecosystem based on Defi and Wallets.

On the other hand, zk rollups' ecosystems are also ruled by DeFi solutions ranging from 30% of their ecosystem, in the case of StarkNet up to almost a 100% of their ecosystems, in the case of Loopring. This case, Loopring's is a peculiar one given that the solutions they offer are merely built in house, focused on DeFi while also allowing for NFT trading. Therefore, in this case, it is more complicated to study this protocol (with the analysis proposed). In the case of ZkSync, DeFi represents 32% of the ecosystem, as seen in *table 22*. Both cases, zkSync and StarkNet have all the different types of dApps represented in their ecosystems, and, remarkably, GameFi solutions are present in both of them. In the case of zkSync, doubling that of Metis and, in the case of StarkNet, there are 13 GameFi solutions, an outstanding number. Additionally, zkSync's ecosystem is highly dense, with almost 150 dApps (still far from the ecosystems of Arbitrum and Optimism but still a very high number of solutions). Finally, in the case of StarkNet, the total amount of dApps is 50, as seen in *table 23*. It is important to note that, in this last case, the multitagging of the dApps on their official website has made the categorization a little bit more complicated and probably biased due to the fact that it was necessary to choose which of the tagged types was the more

relevant and suitable one for each solution. Therefore, there could be different interpretations when computing the third column of *table 23.*

Finally, as an overall assessment, regarding the percentages of DeFi, we can see that the protocol with the highest percentage of this category is not a zk rollup but an optimistic one, Boba Network, with almost 43% of their ecosystem being based on DeFi dApps. Therefore, the theory that zk rollups are the ones mostly fit for DeFi solutions has been overruled and, also, as seen in *tables 20-22* other types of dApps - and very varied ones - also trust these protocols.

In this subject of study, the only discrepance could be in some of the manual categorization from what each protocol has considered to the categories expressed in this thesis. However, it should be minimal, because, as seen in the literature review, the categories are sufficiently bounded. As mentioned, the one that could possibly be a considered more biased is that of StarkNet due to the multitagging of some solutions.

Fat protocols assessment

Lastly, when assessing the fat protocols theory, the empirical work here is quite limited as only the subset of optimistic rollups, that are general-purpose, has been considered due to not enough data on the other protocol's ecosystems. Even with these, since not all the data was available, the numbers obtained could only be an approach: the minimum percentage possible (asymptotic approach). This approach, depending on the observed results, will be considered the minimum or, actually, an approximation of the real value.

The four solutions studied are one of the most remarkable solutions in the space and for each, the top 10 dApps for each protocol has been presented (tables 26, 28, 30 and 32). In these tables, we can firstly see that the highest dApp in terms of TVL of Arbitrum One and Optimism accrue more value than the sum of the top 10 dApps by TVL of both Boba Network and Metis (even combining those two values). Even so, that the highest value dApp of Arbitrum One, GMX, has a TVL of more than $525M and the total TVL of Metis is $131 and that of Boba is $13.9. The same thing can be observed in the case of Optimism, whose top valued dApp, Velodrome, has a TVL of $308M. Only these two mentioned dApps, represent a very high percentage of the protocol's TVL - just the top 1 dApp. In the case of Arbitrum One, GMX represents the 15% of the protocol's TVL and, in the case of Optimism, Velodrome represents the 16% of the total TVL of the protocol. What this inherently means is that, if this top solution decided to migrate to other protocols, the total TVL of the protocol would be highly affected.

Extrapolating this idea looking at all the data available, we can see that, in the case of Arbitrum, and only having the data of the top 50 dApps in terms of TVL (which represent a 18.2% of the ecosystem), the 59% of the protocol's TVL is due to these dApp

solutions. Again, as mentioned, this percentage is considered to be, then, the hypothesized 100% of the ecosystem of dApps. This supposition is, actually, not far from the truth beacuse, as presented in table 27, from top 25% to top 50%, only a 3% of TVL is due to these added 25 dApps. Applying the same logics to the case of Optimism, we can see, in table 29, that the top 50 dApps with highest TVL (the only available data), represent the 21% of the ecosystem and account for the 71% of total TVL of the protocol. Even higher than in the case of Arbitrum One. The same supposition can be considered true as, from top 25 to top 50 solutions, these 25 added dApp solutions only account for a 2% of added TVL value (contrasted with the total of the protocol). Therefore, the asymptotical supposition, the fact that all the ecosystem accrues around the 71% of the total TVL of the protocol, is considered, again, close to the actual value.

By applying the same logics to Metis and Boba, we can see that the results differ. In the case of Metis, the total number of dApps found was the top 25 dApps by TVL, which represent the 50% of the total ecosystem (more significant than in the two foreseen cases). However, the 50% of the ecosystem represents, in this case 45% of the total TVL of the ecosystem a value lower than in the two previous cases, bearing in mind that the supposition of asymptotical nature is applied. In this case, it is even more clear, because the percentage of TVL that is represented by the top 15 dApps is the same of that of the top 25 dApps (45%). As this asymptotical behavior is evident, we can assume that the hypothesis, that the 100% of the ecosystem, represents the 45% of the total TVL of the protocol, is very close to the actual data. Finally, in the case of Boba, only the top 20 dApps by highest TVL were found, which represent almost the 50% of the total ecosystem (the 47.8%). Assuming, again, the asymptotical nature, which is once again confirmed - the top 15 dApps represent the same percentage as that of the top 25, 31% - we can see that the ecosystem of Boba Network represents only the 31% of the total TVL of the protocol.

All in all, the highest percentage accrued by the ecosystem is that of Optimism, as seen in table 29 where the ecosystem represents at least the 71% of the total TVL. On the other hand, the lowest is attributed to Boba Network, where the dApps account for the 31% of the overall TVL. Due to the limited scope and the very disparate results among the protocols, the fat protocols theory is not demonstrated nor refused but, from these numbers and the assessment presented, the relevance dApps also have in terms of value is explicitly showcased. Therefore, the ecosystem of dApps will be considered as a relevant metric when assessing these protocols. The reason is that, if the top 1 app in terms of TVL migrates to another protocol, the given protocol can lose (even in the case of Boba) more than a 10% (as we can observe from table 33).

From this conclusion, it is also important to remark that it is not super positive to have just one very prominent solution, because, if this one decides to migrate to other solutions, it can impinge drastically on the valuation in terms of TVL of the protocol. In accordance with this idea, if another dApp like Cryptokitties were to hit the L2

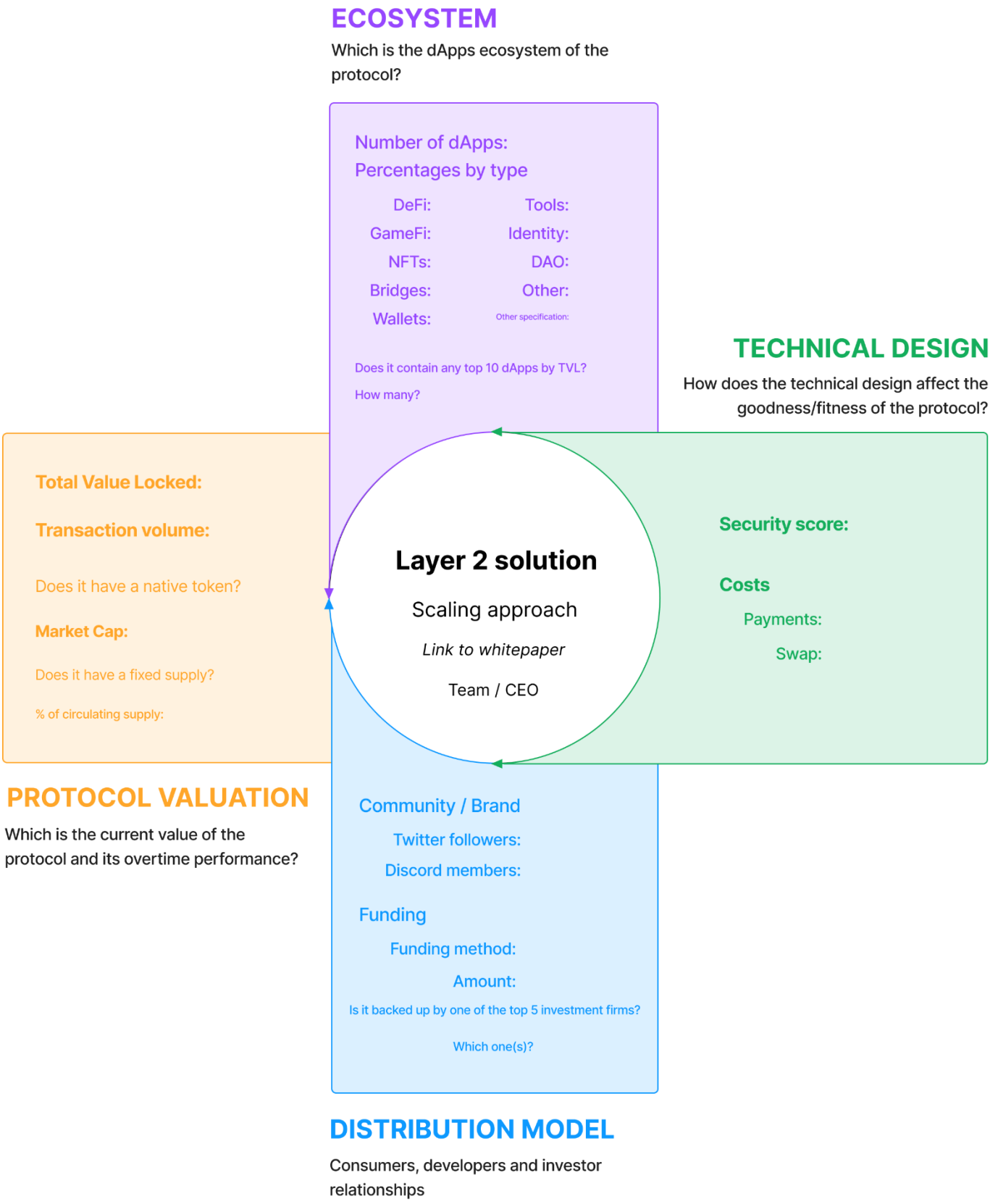
space, the protocol such a decentralized application chose would drastically impact the valuation of the given protocol.

Lastly, the results obtained are quite robust, as seen with the quite correct assumption on the asymptotical nature of the TVL of the ecosystems, but, the study and the results would be way more accurate if all the data was studied (the actual sum of all the dApps TVL). Additionally, since only the general-purpose optimistic rollups could be studied, not great conclusions can be extracted due to the unknown nature of the ecosystems of zk rollups. Consequently, once data is made available, it would be very interesting to do the same study with solutions like zkSync and StarkNet. However, since it has not been possible to fetch the zk rollups' ecosystem of dApps' TVL data, the same conclusions drawn from the optimistic rollups observations will be considered for general-purpose zk rollups.

4.1.3. L2 Framework

With the results obtained and the conclusions from those already presented the final framework is drafted with the necessary amendments. Starting with the Distribution Model, the online communities are kept in this vertical, as no direct relationship to value could be proofed. Additionally, a question has been added: Is it backed up by one of the top 5 investment firms? As well as a follow up question: Which one(s). As seen, there are 5 investing firms that dominate the space and, as in other reviewed frameworks, it is important to visualize which. Moving to the Valuation Model, as previously seen, no metrics were under scrutiny, so it has been maintained the same. The exact same applies for the Technical Design vertical. For what concerns the Ecosystem vertical, with the results obtained we can see that it is a relevant metric, and, hence, it has been kept in the framework. A little note has been added, as the Others category is more prominent than previously expected, the specific dApps in that category will need to be disclosed. Furthermore, as having one of the most relevant apps in terms of TVL (top 10), as previously presented, can be positive or negative at the same time, a follow-up question has been added: How many?

The final framework is presented here below. Additionally, the framework has been evaluated through the seven chosen solutions previously presented: Arbitrum One, Optimism, ZkSync, Metis, Boba, Loopring and StarkNet. Each respective framework can be found in the **Error! Reference source not found.** section.


ECOSYSTEM
Which is the dApps ecosystem of the protocol?
Number of dApps:
Percentages by type
DeFi:
Tools:
GameFi:
Identity:
NFTs:
DAO:
Bridges:
Other:
Wallets:
Other specification:
Does it contain any top 10 dApps by TVL?
How many?
TECHNICAL DESIGN
How does the technical design affect the goodness/fitness of the protocol?
Total Value Locked:
Transaction volume:
Does it have a native token?
Market Cap:
Does it have a fixed supply?
% of circulating supply:
Layer 2 solution
Scaling approach
Link to whitepaper
Team / CEO
Security score:
Costs
Payments:
Swap:
PROTOCOL VALUATION
Which is the current value of the protocol and its overtime performance?
Community / Brand
Twitter followers:
Discord members:
Funding
Funding method:
Amount:
Is it backed up by one of the top 5 investment firms?
Which one(s)?
DISTRIBUTION MODEL
Consumers, developers and investor relationships

Variables of the L2 framework

So as to fill the framework presented, the values need to be fetched and correctly placed within the framework. Here below, the different sources and methods where and how the data can be obtained are detailed.

Firstly, the layer 2 solution title needs to be changed for the name of the protocol of study. Below it, the type of scalability solution needs to be placed (Optimistic or Zero-knowledge Rollup). Then, the link to the whitepaper of the protocol, which can be found in the official website of the protocol (for the ones in the Appendix, the websites provided in the Methodology section) and, finally, either the group of engineers or the CEO of the protocol is provided. If providing the name of the CEO, that needs to be made clear.

Concerning the four verticals of the protocol, here below each vertical and each variable or metric within each vertical is explained and how its value can be added is also explained.

Distribution model

Community/brand

Twitter followers: followers of each protocol on www.twitter.com.

Discord members: number of members of each protocol on www.discord.com

The official pages can be found on L2Beat:
https://l2beat.com/scaling/projects/name_of_the_protocol, in *information*, under the *social* tag.

Funding

Funding method: can be "Regular funding" or "Coin offering"

Amount: the total invested amount on the protocol. Can be found by power searching as provided in the Empirical Analysis and Results section (see *table 13*)

Is it backed up by one of the top 5 investment firms? can be "Yes" or "No"

As seen, the top 5 investment firms are: a16z, BitDao, Blockchain Capital, LightSpeed VP and Paradigm.

If the answer is positive:

Which one(s)? Here, the ones that are behind the protocol need to be made explicit.

Protocol valuation

Total value locked: the total value locked of the protocol. It can be found on l2beat.com/scaling/tvl

Transaction volume: it can be expressed as TPS or 30D tx. The choice needs to be explicited and the value added. Both values can be found on l2beat.com/scaling/activity

Does it have a native token? Can be "Yes" or "No". In order to know so, it needs to be checked in Coingecko [60]. If the answer is positive, then all the following questions can be answered consulting this same source [60]:

Market cap: the market capitalization of the protocol

Does it have a fixed supply? Can be “Yes” or “No”. If the Max Supply is infinite (or not determined) then the token has an infinite supply and the answer should be “No”. If the Max Supply is determined, and the answer is positive:

% of circulating supply: This percentage is computed by dividing the Circulating Supply / Total Supply and multiplied by 100.

Ecosystem

To fetch the data for this whole vertical, the webscrapping techniques already detailed and presented, and the process presented in the Empirical Analysis and Results section needs to be done. As such, the following variables can be computed:

Number of dApps: the number of dApps the protocol has

Percentages by type: after uniting the different protocols in the groups presented – DeFi, GameFi, NFTs, Bridges, Wallets, Tools, Identity, DAO and Other – each respective percentage needs to be made explicit.

(Other specification): If the percentage of Other is not zero, then the types of dApps that are not represented in the explicited groups need to be detailed.

Does it contain one of the top 10 dApps by TVL? Can be “Yes” or “No”. The top 10 dApps by TVL can be found in: https://dappradar.com/rankings (also seen in *table 7* in this thesis). If the answer is positive, then the following question should be answered.

How many? The number of dApps from the previous list that are built on top of the protocol.

Finally, if the protocol is application-specific, in this section only the type of application needs to be disclosed (which will be one of the dApps groups presented).

Technical Design

Security score: This score is computed by analyzing the L2Beat risk analysis [13] and doing the following computation: for each risk - state validation, data availability, upgradeability, sequencer failure and validator failure – a 0 is assigned if the risk is in red, a 1 is assigned if the risk is in yellow and a 3 is assigned if the risk is in white (there is no risk). In this case, the lowest score can be 0 (very risky scalability solution) and the highest score can be 15 (very safe solution).

Costs

Both values of the costs of L2 solutions can be found in: l2fees.info/

Payments: value in dollars of the payment cost. It is the *Send ETH* value on l2fees.

Swap: value in dollars of the swapping costs. It is the *Swap tokens* value on l2fees.

As such, the different frameworks presented in the Appendix section were made.

4.1.4. Limitations and future research

The results obtained have been representative enough to oversee the metrics that wanted to be studied and see their relevance for the resulting framework. However, in some cases, the empirical work has not been as wide as it should be due to problems finding the data. For example, the results related to valuation could be more robust if the number of active addresses was available. Additionally, the TVL of dApps is still not totally made public and only the highest TVL solutions of general-purpose optimistic rollups is made available. Therefore, the conclusions of the fat protocols assessment, can only be done with the assumed asymptotic behavior approach and, therefore, the results are not as accurate as they could be. Once these data are disclosed, it would be interesting to repeat the study with these new inputs of data, i.e. with the TVL of all the dApps of the ecosystem. Also, because it has only been done with optimistic rollups, once the data on the TVL of the ecosystems of zk rollups is disclosed, the same study should be done to make sure the same behavior is observed.

Moreover, the fact that most of the protocols still don't have a native token impinges on the economical valuation, which now it can only be done by assessing the TVL. As more protocols launch their native token, the study according to market capitalization as well as price of the token, type of token and the supply of it would be essential.

In addition, due to the low maturity of most of the projects, there is still big differences between protocols. These results could be more accurate with better data and, especially, with a study of the same metrics over time, to see if there are more intricacies when it comes to timely evolution. It would be interesting, also, to replicate the framework and automate it, to fetch real-time data, as the metrics studied are changing and growing fast in time. As an example, Arbitrum launched a token (ARB) on March 23rd 2023, which was not taken into account as the data of all this thesis was fetched by March 1st.

5 Conclusion and future developments

As blockchain technology continues to face scalability problems, the most feasible and secure solutions seem to be layer 2 solutions. Despite these solutions being quite novel and not mature in the space, the ecosystem keeps on growing and the investments and usage of these protocols are on the rise. As such, there is a need for more understanding of the solutions that are out there and a way to standardize and understand the whole space.

Presenting the four main verticals that are relevant for these layer 2 protocols: technological design, distribution model, valuation metrics, and ecosystem of dApps, a framework that depicts metrics of interest within these has been drafted. In order to prove the importance of the ecosystem of dApps, and the inherent metrics of these verticals, a study has been done.

The results obtained, after power searching and web scraping to obtain the data, has been crucial to determine the last framework proposed. In such, it has been observed that social media communities do not have a direct impact on the value of a protocol in terms of total value locked nor transaction activity. Furthermore, it has been seen that there are a limited number of investment firms behind all these layer 2 solutions and there are five that have invested mostly (in terms of amount). Finally, the ecosystem of dApps of each protocol is not related to the type of scaling solution (Optimistic or zk rollup) and that which and how many dApps a protocol has in their ecosystem directly affects their value in terms of TVL.

The results obtained are robust but still a lot of data is yet unavailable and the same study could be done with better insights of all the different protocols. Therefore, despite providing insight of the L2 paradigm, the study is inherently limited due to the lack of available data, and low maturity of the studied protocols and the space.

Additionally, it would be interesting to continue the study by monitoring the same metrics over time. Also, once most of the protocols launch a native token, the study taking into account market capitalization as a value vertical would be essential. Moreover, other tokenomics metrics should be regarded. Finally, an automation of the protocol could be interesting to get automated data, as this technological field – blockchain – is in constant change.

All in all, this thesis proofs the importance of the ecosystem of dApps in the success of general-purpose layer 2 protocols, the state of investment behind the protocols, the

fact that community – in terms of social media following – does not impact directly on value, as well as providing a framework for assessment of these solutions.

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A Appendix

ECOSYSTEM

Which is the dApps ecosystem of the protocol?

Number of dApps: 276

Percentages by type

DeFi:	41%	Tools:	15%
GameFi:	0%	Identity:	0%
NFTs:	11%	DAO:	4%
Bridges:	11%	Other:	5%
Wallets:	13%	Other specification:	Directories Growth Node Providers

Does it contain any top 10 dApps by TVL? Yes

How many? 1

TECHNICAL DESIGN

How does the technical design affect the goodness/fitness of the protocol?

Total Value Locked: $3390 M

Transaction volume: 19.13 M
30D tx

Does it have a native token? No

Market Cap:

Does it have a fixed supply?

% of circulating supply:

ARBITRUM

Arbitrum One

Optimistic rollup

Whitepaper

OffChain Labs

Security score: 10

Costs

Payments: $0.10

Swap: $0.28

PROTOCOL VALUATION

Which is the current value of the protocol and its overtime performance?

Community / Brand

Twitter followers: 548.800

Discord members: 325.710

Funding

Funding method: Regular funding

Amount: $ 124M

Is it backed up by one of the top 5 investment firms?
Yes

Which one(s)?
LightSpeed VP, Paradigm and a16z

DISTRIBUTION MODEL

Consumers, developers and investor relationships

ECOSYSTEM

Which is the dApps ecosystem of the protocol?

Number of dApps: 233

Percentages by type

DeFi:	38.63%	Tools:	18.03%
GameFi:	0%	Identity:	0%
NFTs:	14.16%	DAO:	4.72%
Bridges:	8.58%	Other:	7.30%
Wallets:	8.58%	Other specification:	OP Summer Innovation

Does it contain any top 10 dApps by TVL? Yes

How many? 2

TECHNICAL DESIGN

How does the technical design affect the goodness/fitness of the protocol?

Security score: 6

Costs

Payments: $0.23

Swap: $0.33

Optimism

Optimistic rollup

Whitepaper

CEO: Jinglan Wang

PROTOCOL VALUATION

Which is the current value of the protocol and its overtime performance?

Total Value Locked: $1900 M

Transaction volume: 6.63 M

30D tx

Does it have a native token? Yes

Market Cap: 827 M

Does it have a fixed supply? Yes

% of circulating supply: 7.3%

Community / Brand

Twitter followers: 427.700

Discord members: 100.397

Funding

Funding method: Regular funding

Amount: $ 175.8M

Is it backed up by one of the top 5 investment firms? Yes

Which one(s)? Paradigm and a16z

DISTRIBUTION MODEL

Consumers, developers and investor relationships

ECOSYSTEM

Which is the dApps ecosystem of the protocol?

Number of dApps: 149

Percentages by type

DeFi:	32.21%	Tools:	24.16%
GameFi:	2.68%	Identity:	2.01%
NFTs:	9.40%	DAO:	7.38%
Bridges:	7.38%	Other:	5.37%
Wallets:	9.40%	Other specification:	Gateway Privacy Social

Does it contain any top 10 dApps by TVL? No

How many?

TECHNICAL DESIGN

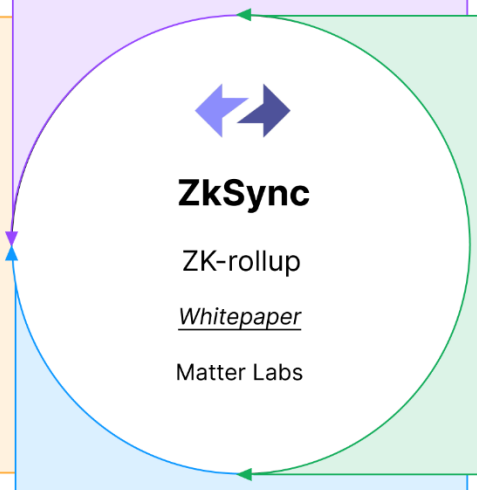
How does the technical design affect the goodness/fitness of the protocol?

Security score: 11

Costs

Payments: $0.08

Swap: $0.19



Total Value Locked: $64.02 M

Transaction volume: 1.24 M
30D tx

Does it have a native token? No

Market Cap:

Does it have a fixed supply?

% of circulating supply:

PROTOCOL VALUATION

Which is the current value of the protocol and its overtime performance?

Community / Brand

Twitter followers: 637.700

Discord members: 351.444

Funding

Funding method: Regular funding

Amount: $ 458M

Is it backed up by one of the top 5 investment firms?
Yes
Which one(s)?
LightSpeed VP, Blockchain Capital and a16z

DISTRIBUTION MODEL

Consumers, developers and investor relationships

ECOSYSTEM

Which is the dApps ecosystem of the protocol?

Number of dApps: 50

Percentages by type

DeFi:	26%	Tools:	26%
GameFi:	2%	Identity:	2%
NFTs:	10%	DAO:	2%
Bridges:	14%	Other:	8%
Wallets:	10%	Other specification:	E-commerce SocialFi

Does it contain any top 10 dApps by TVL? No

How many?

TECHNICAL DESIGN

How does the technical design affect the goodness/fitness of the protocol?

Total Value Locked: $131 M

Transaction volume: 0.329 M
30D tx

Does it have a native token? Yes

Market Cap: $120 M

Does it have a fixed supply? Yes

% of circulating supply: 44%

Metis

Optimistic rollup

Whitepaper

CEO: Elena Sinelnikova

Security score: 6

Costs

Payments: MD

Swap: MD

PROTOCOL VALUATION

Which is the current value of the protocol and its overtime performance?

Community / Brand

Twitter followers: 143.800

Discord members: 12.630

Funding

Funding method: Coin Offering

Amount: -

Is it backed up by one of the top 5 investment firms?

No

Which one(s)?

DISTRIBUTION MODEL

Consumers, developers and investor relationships

ECOSYSTEM

Which is the dApps ecosystem of the protocol?

Number of dApps: 42

Percentages by type

DeFi:	42.86%	Tools:	11.90%
GameFi:	0%	Identity:	0%
NFTs:	9.52%	DAO:	0%
Bridges:	9.52%	Other:	0%
Wallets:	26.19%	Other specification:	-

Does it contain any top 10 dApps by TVL? No

How many?

TECHNICAL DESIGN

How does the technical design affect the goodness/fitness of the protocol?

Security score: 6

Costs

Payments: $0.20

Swap: $0.38

Boba Network

Optimistic rollup

Whitepaper

Enya Labs

Total Value Locked: $13.9 M

Transaction volume: 0.018 M
30D tx

Does it have a native token? Yes

Market Cap: $49.5 M

Does it have a fixed supply? Yes

% of circulating supply: 34%

PROTOCOL VALUATION

Which is the current value of the protocol and its overtime performance?

Community / Brand

Twitter followers: 363.600

Discord members: 18.723

Funding

Funding method: Regular Funding

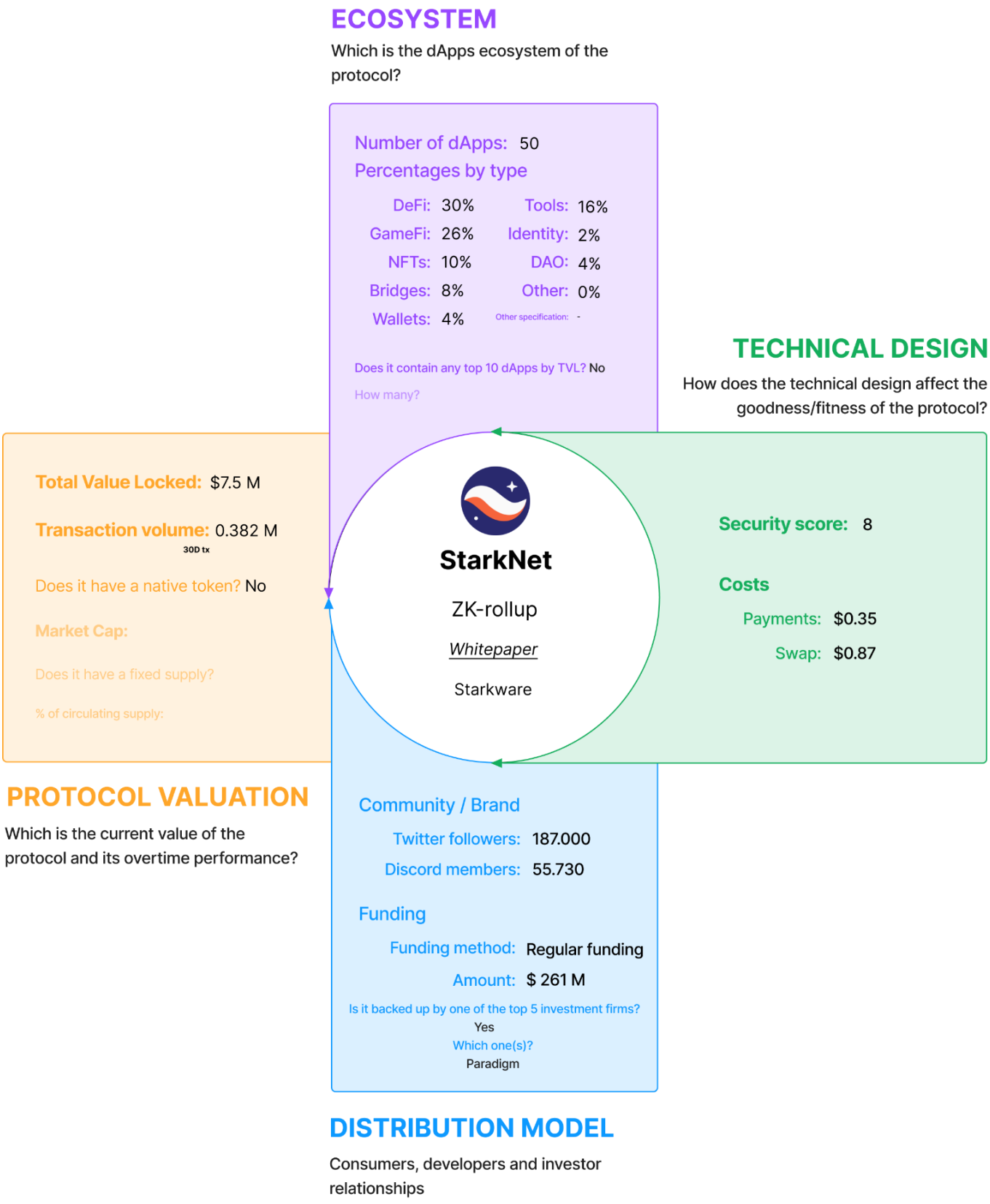
Amount: $45 M

Is it backed up by one of the top 5 investment firms?
No

Which one(s)?

DISTRIBUTION MODEL

Consumers, developers and investor relationships


ECOSYSTEM
Which is the dApps ecosystem of the protocol?
Number of dApps: 50
Percentages by type
DeFi: 30%
Tools: 16%
GameFi: 26%
Identity: 2%
NFTs: 10%
DAO: 4%
Bridges: 8%
Other: 0%
Wallets: 4%
Other specification: -
Does it contain any top 10 dApps by TVL? No
How many?
TECHNICAL DESIGN
How does the technical design affect the goodness/fitness of the protocol?
Total Value Locked: $7.5 M
Transaction volume: 0.382 M
30D tx
Does it have a native token? No
Market Cap:
Does it have a fixed supply?
% of circulating supply:
StarkNet
ZK-rollup
Whitepaper
Starkware
Security score: 8
Costs
Payments: $0.35
Swap: $0.87
PROTOCOL VALUATION
Which is the current value of the protocol and its overtime performance?
Community / Brand
Twitter followers: 187.000
Discord members: 55.730
Funding
Funding method: Regular funding
Amount: $ 261 M
Is it backed up by one of the top 5 investment firms?
Yes
Which one(s)?
Paradigm
DISTRIBUTION MODEL
Consumers, developers and investor relationships

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