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In February 2022 a framework for rollup economicswas proposed by Barnabé to think about resource pricing and value flows in an L1-dependent economy. It introduced key concepts to think about MEV at L2, interaction of L1 and L2 fees, operator revenues and costs. It was a simple framework for a simple world: centralized rollups on training wheels operating in silos. A lot has changed in the past 18 months: shared sequencing, decentralization, proof/data aggregation, rollup federations, governance.

We propose a new framework that will help make sense of the new world in which rollups get ready to scale. There is a lot of experimentation still going on, but several patterns are emerging. We will analyze key patterns and hopefully provide a tool that helps to understand where things might be headed and helps frame/answer current open questions. This is the first in a series of posts called “Rollups are Real”. Following posts in the series will go deeper on Aggregation and Interoperability, Decentralization and MEV Resiliency, Governance and Resource Allocation.

Back to Basics: Revisiting Rollup Economics 1.0

The original rollup economics framework has three entities: users, rollup operators, and base layer. It also has a similar simplified view on value flows: L2 fees and MEV, operator costs, and data publication costs. It’s a simple framework but it is useful to start from here to anchor to, because things will soon get more interesting and complex.

Rollup economics flows in the original framework.

From this basic flows one can measure rollup protocol surplus and reason about related concepts such as MEV extraction and allocation, L2 issuance, L2 congestion fee allocation, and the time horizon for a rollup to maintain a budget balance or run a budget surplus (L2 ecosystems are growing economies that may find it useful to run a surplus, to be allocated by the community to public goods funding, development, and growth).

rollup protocol surplus = L2 fees - operational cost - data cost

The rollup protocol has control on its L2 fees, including congestion pricing and MEV, and its operational costs , including issuance and rewards for operators. Whether the protocol decides to target a balance or a surplus goal, L2 operations require the orchestration of technologies that allow to (1) optimally set the L2 congestion fee , (2) extract and reallocate MEV , and (3) reduce the data cost via optimizations and strategic posting. These are the major economic design choices that different L2 ecosystems are experimenting with today. In the future, it is possible that protocols will want to reduce the uncertainty in data cost, for example using blockspace derivatives.

In the past 18 months, one major thing has changed. Similar to what happened to block building for L1, we are seeing an unbundling of the rollup operator role in more specialized roles. As the economy grows it naturally specializes, this is a good thing as separation of concerns leads to more resilient systems if we are able to design our way around it. But the design space is much larger now, so we need a new map to guide us through the process.

Rollups are Growing Up

As rollups mature and start taking off training wheels, sophistication is increasing both within each rollup and between rollups of the same type, which we call rollup federations . Shared rollup architectures between rollups of the same type are being designed to increase security (via shared governance and community alignment), efficiency (via shared functions and economies of scale), and user experience (via better interoperability and less fragmentation). At the same time, independent providers are developing infrastructure to deliver one or more of the above benefits to any rollup that decides to opt into their services, no matter their type. We call these rollup coops . We go into these models below, starting from the updates to individual rollup economics.

An Ethereum rollup successfully taking off training wheels.

Indy Rollups

Single rollups are taking off training wheels, increasing security and decentralizing. From an operations/economics perspective the main cost areas include:

Sequencing : this imposes an operational cost and (when decentralized) an economic cost to incentivize sequencers.

Data availability (DA) : rollups have to post data on the base layer and thus incur data cost , this is the main cost item that was discussed in the original framework.

State validation (SV) : this directly increases the operational cost of zk rollups via proving cost.

In all these cost areas, single rollups face important trade-offs between security and efficiency. For example they may choose to use a less secure data availability layer at lower cost. Data publishing cost (we simply call it data cost even though it includes some L1 computation cost associated with publishing) has historically been the highest line item. This will decrease significantly after EIP-4844 goes live soon on Ethereum and later with full Danksharding, thus giving rollups the cost efficiency they need to scale and enable new use cases. In the longer term, efficiency in data costs and related services is likely going to come via offchain innovation on aggregation to unlock economies of scale.

The road to scaling Ethereum is paved with (recursive) aggregations.

Concrete examples of aggregation include: shared sequencing services ; for optimistic rollups, an interesting idea is shared batch posting that can deliver batch compression gains significantly faster, especially for smaller players, offering both lower cost and higher security via quicker data posting; for zk rollups, shared provers that aggregate many SNARKs into a single bigger proof before posting to L1are one of the most exciting scaling unlocks, especially because they can do these aggregations recursively, offering big gains in efficient utilization of the L1 data market, at the cost of more offchain computation. One thing that seems clear is that, sooner or later, rollups will choose to adopt shared services, either as part of a federation or of an economic union.

A direction that the rollup ecosystem could take is to have more independent rollups that are closely aligned to the L1. We have not seen many implementations yet but there are at least two interesting architecture. One is the based rollupthat delegates sequencing its blocks to the L1, thus leveraging the L1 transaction supply networkfor MEV extraction but retaining the agency to set L2 congestion fees. A more extreme one is rollups that are enshrined in the Ethereum protocolitself. We will dive deeper into the economics of these model when we discuss rollup MEV resiliency and decentralization.

Rollup Cooperatives

The first type of integration between two rollups is a purely economic one, such as an economic cooperative.

“A cooperative is a group of entities that share or work together to achieve a common objective, such as an economic benefit or saving.” — Wikipedia

In its simplest form the rollups have a joint purchase agreement of some service. Imagine that there is a shared batch posting service that rollups can subscribe to and get lower costs for data posting. There can also be deeper economic integration, for example shared sequencing services deliver both cost efficiency and also make it easier for transactions to settle atomically between rollups, thus decreasing the barriers to trade across them. The mental model is that of an economic association such as the European Economic Community(i.e., the European Union before it became political) or other similar common market associations.

Economic flows in rollup communities that adopt shared services (ShS).

We can augment the simple model of independent rollup economics with an intermediate service provider, such as a shared sequencer, poster, or even prover service (when it does not operate on a shared bridge, see next section). In this case, there are two new economic effects on the rollup ecosystem.

Rollup cost structure : the rollup operator cost now include operational costs, service costs, and data publication costs.

Shared service economics : the new entity needs to achieve budget balance.

shared service surplus = service cost rollup A + service cost rollup B - operational cost ShS - data cost ShS

Examples of such services include the Espresso sequencer, which is a shared service for sequencing and posting, shared batch posting only, or shared proving. In all these cases, shared services present two important economic problems.

Service cost-sharingfor L2s : the total service cost needs to be split between the rollups that adopt the shared service in an economic and fair way.

Decentralization for ShS : achieve level of decentralization that, depending on the service, strikes the right balance between performance and robustness. The bar is lower than the base layer, but it includes managing incentives and MEV.

We will dive into these and related open problems in the following posts.

Rollup Federations

Rollup federations are distinct from economic cooperatives in that they have both economic and some form of political integration. The mental model is that of a federation of states.

“ A federation is a group of states that give part of their sovereignty to a central governing authority that enforces certain laws and regulations.” — Wikipedia

Technically, political integration is enabled by a shared bridge but it also requires a system of shared governance (the central governing authority for the federation). We will largely put aside political and governance considerations here, we will assume the existence of a shared bridge and focus on the economic relationships that it implies. This rollup federation architecture is emerging on all the major rollup systems, which are becoming platforms for deploying interoperable peer rollups (as opposed to subordinate rollups, see RaaS and L3s in the next section).

The emergent architecture of major L2 ecosystems.

For example Optimism Superchain, Polygon 2.0, StarkWare SHARP, zkSync Hyperchains, and other related projects share similar patterns in their architecture. We distill it in the following figure, to isolate the effects we make the realistic assumption that federated rollups automatically opt into shared services and do not incur direct data publication costs.

Rollup federations share both services and a bridge to the base layer.

The presence of a shared bridge introduces additional economic variables. In particular, native L2 tokens such as OP for the optimism ecosystem offer important decision powers to allocate resources, roles, and economic flows within the ecosystem via governance (for example, the OP governanceis an experiment in hybrid token-identity based governance). Once rollups tech stack matures and the first-order security concernsare solved, the next-order concern is robustness, which is likely going to involve some level of decentralization.

When rollups think about setting up decentralized services (for sequencing, proving, or validation) they will need to run a consensus protocol. Here is when ecosystems that have enough scale see the opportunity to “upgrade” their native token to a productive asset, which is what Polygon 2.0 plans to do with POL. This is not the only way to decentralize L2 services, as Ethereum L1 can be leveraged for this with arguably better security properties. However, using the native token can be an appealing direction for larger ecosystems, which want to retain more internal control/governance of their services and the associated reward/incentive mechanisms.

native token value change = demand change - net emissions

The native token is an important economic tool to help bootstrap an L2 ecosystem/economy. Emissions can be used to reward service operators and fund ecosystem support projects or public goods. However, when the native token is used to support decentralization via some native proof-of-stake protocol, security may degrade with more dilution. Even when the native token is only used for governance, excessive dilution may cause more budget constrained holders to sell, thus potentially leading to ownership concentration. So it seems important to have a token emission schedule which is calibrated with its demand growth. Finally, another important consideration is that making the L2 economy more dependent on the native token (vs. ETH) also makes it less robust to certain failure modes, as exiting to L1 may not be an option. In the limit the L2 is still secured by Ethereum but loses the security provided by ETH as outside money.

More Layers

Another area of active development is around application-specific or tailor-made execution environments that settle, ultimately if not directly, on a base layer. These generally target applications that require low execution costs plus easy deployment and are willing to trade-off security. Think games, social media, NFT products that do not need to bootstrap their own economy of services or attract/secure large amounts of liquidity.

There are different flavorsof these that include L3s, validiums, and rollup-as-a-service (RaaS) platforms. For example,

Arbitrum Orbitis a platform that enables L3s chains that settle on Arbitrum L2 (One or Nova), and has some configurability, such as selecting an Arbitrum-authorized Data Availability Committee (DAC) versus Ethereum L1 as the data availability layer. StarkNet and other zk rollups projects have also been experimenting with enabling L3s. An extreme example on the ease-of-deployment direction are AltLayeror Calderathat have no-code solutions to deploy “customizable” rollups and give agency to the user to make their own security-efficiency trade-off.

Economic flows with L3 systems.

We focus on L3 systems. This is essentially an added layer on top of L2s. From the L2 rollup perspective it is an additional source of L2 fees. While the L3 is a new entity in the rollup ecosystem with its own budget balance constraint:

L3 revenue may come from fees, subscription in the case of games, or other mechanisms such as revenue sharing in the case of NFTs.

L3 costs include operational cost of the system plus L2 fees for compute/data. These may be borne directly by the L3, or in the case of managed services, paid by the RaaS platform. Another service provider that has to budget balance.

This is another example of economic specialization in the rollup ecosystem. In the next posts, we’ll go through the details of how these solutions actually deliver economic efficiency and ease of use that contribute to scaling Ethereum.