INFRASTRUCTURE

Layer 2s: Scaling Explained

Why blockchains are slow by design, and how Layer 2s solve the problem while preserving what matters.

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9 min

Bitcoin processes about 7 transactions per second. Ethereum manages 15-30. Visa handles 65,000. If you think this is a bug that engineers simply haven't gotten around to fixing, you've misunderstood the fundamental trade-off at the heart of blockchain design. Blockchains are slow on purpose. The slowness is the feature.

The Trilemma Nobody Can Escape

In 2017, Vitalik Buterin articulated what's now called the "blockchain trilemma": you can optimise for any two of three properties, but not all three simultaneously.

Security: How resistant is the network to attacks? Can someone with sufficient resources rewrite history, censor transactions, or steal funds?

Decentralisation: How many independent parties verify the network? Could a government, corporation, or cartel shut it down or control it?

Scalability: How many transactions can the network process? Can it handle global-scale usage?

Visa achieves massive scale by sacrificing decentralisation — a single company controls the network. A centralised database can process transactions infinitely faster than a distributed consensus mechanism. But that centralisation means Visa can freeze accounts, reverse transactions, and exclude participants at will.

Bitcoin and Ethereum chose differently. They prioritise security and decentralisation, accepting limited throughput as the cost. Every transaction must be validated by thousands of independent nodes worldwide. This redundancy is computationally expensive and time-consuming. It's also what makes these networks resistant to censorship, seizure, and manipulation.

> *"Blockchains aren't slow because engineers are incompetent. They're slow because making them faster would make them pointless. The slowness is the security."*

The Layer 2 Insight

For years, the scaling debate focused on changing how base-layer blockchains work — bigger blocks, faster block times, different consensus mechanisms. These changes inevitably sacrificed either security or decentralisation. The blockchain trilemma seemed inescapable.

Layer 2 solutions approach the problem differently: what if we don't change the base layer at all? What if we build a second layer that inherits the base layer's security while adding speed on top?

Think of it like the court system. The Supreme Court is slow, expensive, and handles relatively few cases. But its rulings set precedents that local courts follow. Most disputes never reach the Supreme Court — they're resolved at lower levels, with the implicit backing of the higher authority.

Layer 2s work similarly. Most transactions happen "off-chain" on the Layer 2, which is fast and cheap. But periodically, a summary of those transactions is "settled" on the Layer 1, which provides the ultimate security guarantee. You get the speed of

local courts with the finality of the Supreme Court.

> **KEY INSIGHT**
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> Layer 2s don't compete with Ethereum — they make Ethereum useful. By handling routine transactions off-chain and using Ethereum only for final settlement, L2s can process thousands of transactions per second while inheriting Ethereum's security. The base layer becomes the foundation, not the whole building.

How They Actually Work

There are two main approaches to Layer 2 scaling, each with different trade-offs:

Optimistic Rollups (Arbitrum, Optimism, Base) take an "innocent until proven guilty" approach. Transactions are assumed valid by default and processed immediately. There's a challenge window — typically seven days — during which anyone can submit a "fraud proof" if they detect an invalid transaction. If fraud is proven, the invalid transaction is reversed and the fraudster penalised.

The advantage: optimistic rollups are relatively simple and compatible with existing Ethereum tools. The disadvantage: withdrawing funds to Layer 1 requires waiting out the challenge period, typically seven days.

ZK Rollups (zkSync, Starknet, Polygon zkEVM) use cryptographic proofs to verify transaction validity mathematically. Instead of assuming transactions are valid and waiting for challenges, ZK rollups generate a proof that the transactions are valid. This proof can be verified by anyone instantly.

The advantage: withdrawals can be nearly instant since validity is proven rather than assumed. The disadvantage: ZK proof technology is more complex and computationally intensive. Full compatibility with existing Ethereum applications is challenging.

The User Experience

What does this mean in practice? Let's compare sending tokens on Ethereum Layer 1 versus a Layer 2 like Arbitrum:

Ethereum Layer 1: You initiate a transfer. Gas fees might be $5-50 depending on network congestion. The transaction confirms in 12 seconds to a few minutes. Your tokens move.

Arbitrum Layer 2: You initiate a transfer. Gas fees are typically $0.01-0.10. The transaction confirms almost instantly on Arbitrum. Your tokens move. Behind the scenes, the transaction will eventually be settled on Ethereum, but you don't need to wait for that.

The experience is nearly identical. The cost is 100x lower. The speed is faster. The security ultimately derives from Ethereum. This is why Layer 2 adoption has exploded — it's strictly better for most use cases.

The Trade-offs to Understand

Layer 2s aren't magic. They involve real trade-offs:

Different security assumptions: While L2s inherit Ethereum's security for settlement, they have their own operational requirements. Most L2s currently rely on a centralised "sequencer" that orders transactions. If the sequencer goes down, the L2 stops processing (though funds remain secure and eventually recoverable on L1).

Fragmented liquidity: Assets on Arbitrum aren't automatically usable on Optimism. Moving between L2s requires bridging, which takes time and costs fees. The ecosystem is fragmented in ways that traditional finance isn't.

Developing technology: L2s are still maturing. Decentralising sequencers, improving cross-L2 communication, and achieving full EVM equivalence are active areas of development. Early adopters accept some risk.

Exit complexity: Getting funds back to L1 from an optimistic rollup takes a week. ZK rollups are faster but may have withdrawal limits. In a crisis, you might not be

able to exit instantly.

Bitcoin's Different Approach

Bitcoin has its own Layer 2 scaling solution: the Lightning Network. Lightning works differently from Ethereum L2s — it uses payment channels rather than rollups — but the philosophy is similar: handle routine transactions off-chain, settle periodically on-chain.

Lightning enables instant, nearly-free Bitcoin payments. A coffee purchase that would be impractical on Layer 1 (slow, expensive) becomes viable on Lightning. Adoption is growing, particularly in countries with unstable currencies.

> **THE PRACTICAL VIEW**
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> For most users, Layer 2s are simply where you should be operating. The fees are lower, the speed is higher, and the security is sufficient for nearly all purposes. Using Ethereum Layer 1 directly is like using the Supreme Court to settle a parking dispute — technically possible but wildly inappropriate for the situation.

The Road Ahead

The Layer 2 ecosystem is evolving rapidly. Arbitrum and Optimism have established themselves as the leading optimistic rollups. ZK rollups are reaching maturity after years of development. Base, built by Coinbase, is bringing L2s to a more mainstream audience.

The endgame is a world where most users never interact with Ethereum Layer 1 directly. They'll use applications on various L2s, just as most internet users never think about TCP/IP. The base layer becomes infrastructure — essential, but invisible.

This isn't a defeat for Ethereum; it's the intended design. Ethereum becomes the settlement layer for a constellation of faster, cheaper execution environments. The base layer's "slowness" remains a feature — it's the security foundation that makes everything above it trustworthy.

The blockchain trilemma hasn't been solved. But Layer 2s demonstrate it can be worked around. By separating execution from settlement, speed from security, the ecosystem achieves something that once seemed impossible: scale without sacrifice.

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