Layer 2 Scaling Solutions: A Visual Introduction

Standalone Mini-Lecture

"Rollups are the only trustless scaling solution for Ethereum" – Vitalik Buterin

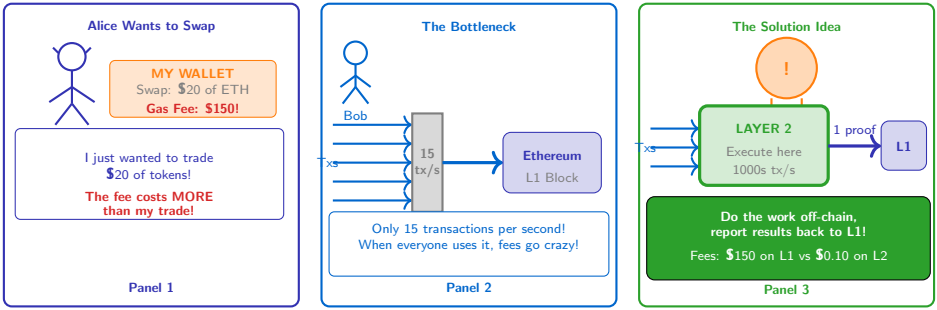
Prof. Dr. Joerg Osterrieder

University Lecture Series

February 26, 2026

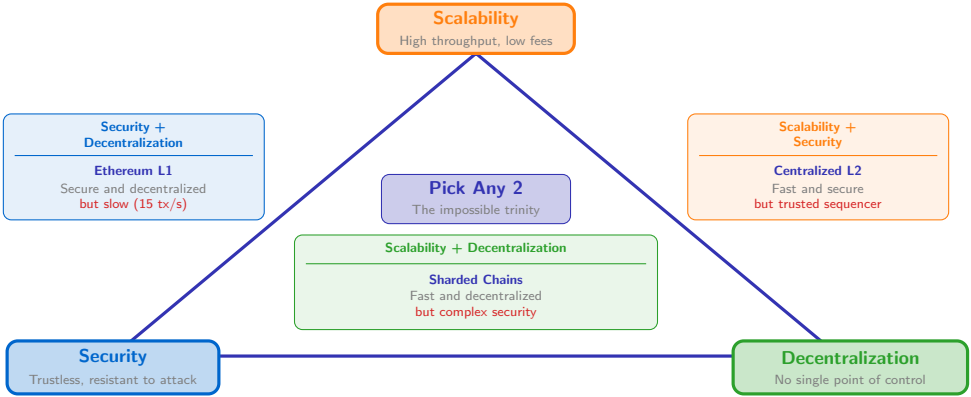
This mini-lecture covers Layer 2 scaling: the blockchain trilemma, rollup types, how rollups work, bridge risks, and the current L2 ecosystem.

The Scaling Problem



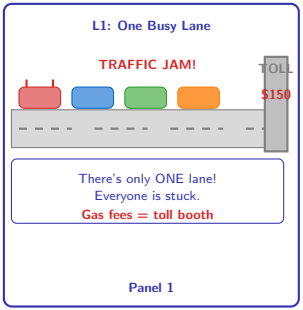
Ethereum L1 processes only 15 tx/s. High demand causes gas fee spikes, making small transactions uneconomical. Layer 2 solutions execute transactions off-chain and settle on L1.

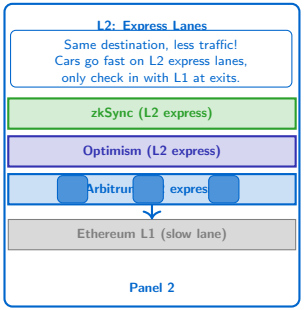
The Blockchain Trilemma

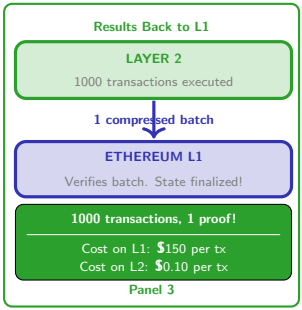


The blockchain trilemma: no system can simultaneously achieve scalability, security, and decentralization. Every blockchain design makes tradeoffs. L2 solutions help by inheriting L1 security.

What is Layer 2?

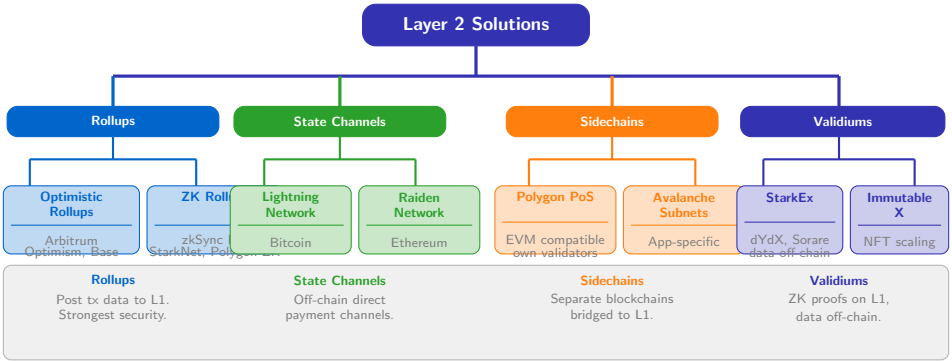






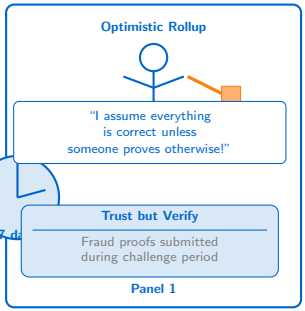
Layer 2 is a secondary protocol built on top of L1. It executes transactions off-chain at high speed and low cost, then posts compressed results back to L1 for security and finality.

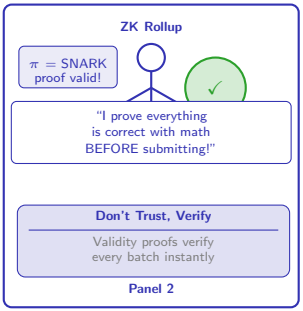
Types of Layer 2 Solutions

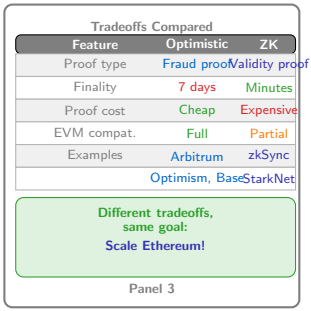


Four main L2 categories: Rollups (strongest security, data on L1), State Channels (peer-to-peer, for repeated interactions), Sidechains (own consensus, bridged to L1), Validiums (ZK proofs on L1, data off-chain).

Optimistic vs. ZK Rollups

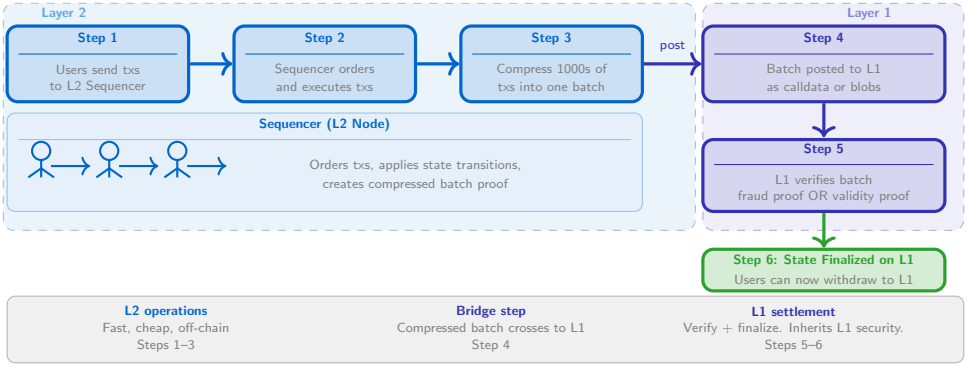






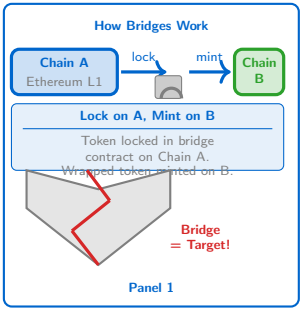
Optimistic rollups assume validity and use fraud proofs (7-day withdrawal delay). ZK rollups prove validity cryptographically with SNARKs/STARKs (instant finality, higher proving cost).

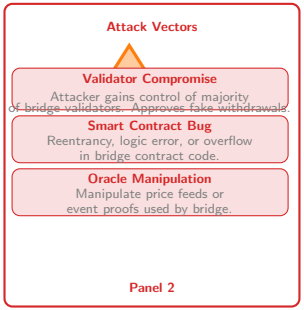
How Rollups Work: Step by Step



Rollup flow: users submit txs to L2 sequencer (fast, cheap) → sequencer batches and compresses → batch posted to L1 → L1 verifies via fraud proof (Optimistic) or validity proof (ZK) → state finalized.

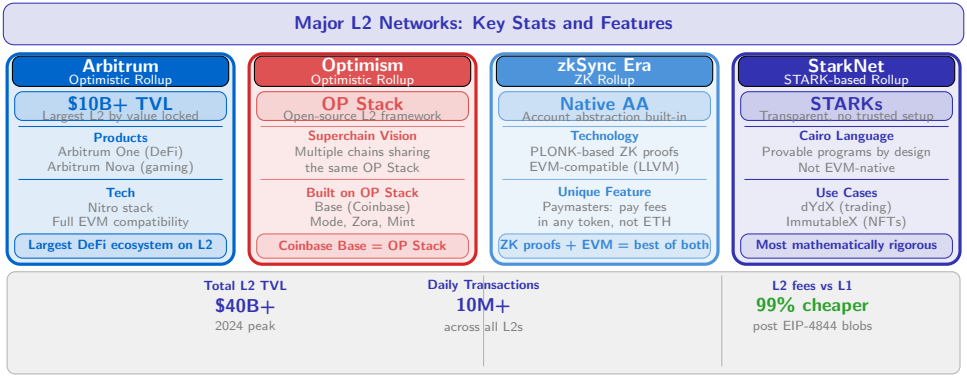
Bridge Security Risks





Bridges are the most dangerous part of the L2 ecosystem. Cross-chain value transfer requires trust in validators, oracles, or smart contracts – each is an attack surface. Over $1B was stolen in bridge hacks in 2022.

The L2 Ecosystem Today



The L2 ecosystem has matured rapidly. Arbitrum and Optimism dominate by TVL; zkSync and StarkNet lead in ZK technology. Total L2 activity now regularly exceeds Ethereum L1 transaction volume.

Key Takeaways

1 **Ethereum L1 cannot scale alone** — The blockchain trilemma forces tradeoffs between scalability, security, and decentralization.

15 tx/s is not enough for global adoption.

2 **L2 executes off-chain, settles on L1** — Thousands of transactions per second, $0.10 fees,

while inheriting Ethereum's security through periodic on-chain settlement.

3 **Two rollup flavors: Optimistic vs. ZK** — Optimistic: cheap proofs, 7-day delay. ZK: expensive proofs, instant finality.

Both compress transactions and post to L1 for verification.

4 **Bridges = biggest risk**

$1B+ hacked. Use with caution.

5 **Rollup-centric future**

Ethereum as settlement, L2s as execution.

Coming Next: DeFi Protocols – Uniswap, Aave, and the Automated Market Maker Revolution

How decentralized exchanges and lending protocols changed finance forever

Layer 2 is not a workaround – it is the roadmap. Ethereum's future is a settlement layer secured by cryptographic proofs, with diverse L2 networks handling execution at scale.