L09: Layer 2 & Scaling

Extended Slides – BSc Blockchain Course

Digital Finance

2026

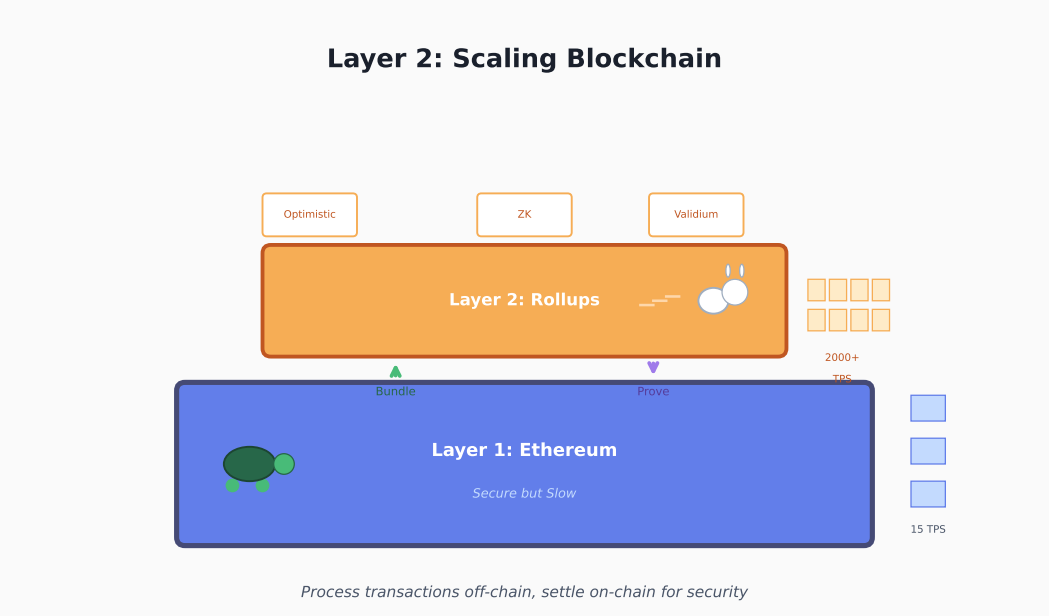
Learning Objectives

By the end of this lesson, you will be able to:

1. Explain the blockchain scaling trilemma
2. Compare optimistic and ZK rollups
3. Understand data availability and its importance
4. Analyze L2 cost and performance tradeoffs
5. Evaluate bridge security and risks

Prerequisites: L05 Ethereum, L06 Solidity.

Scaling the Blockchain



Purpose: Layer 2 solutions address blockchain's scalability limits. Understanding rollups is essential as most future activity will happen on L2s.

How to process thousands of transactions per second while inheriting L1 security.

Why Scaling Matters

Ethereum L1 Limitations:

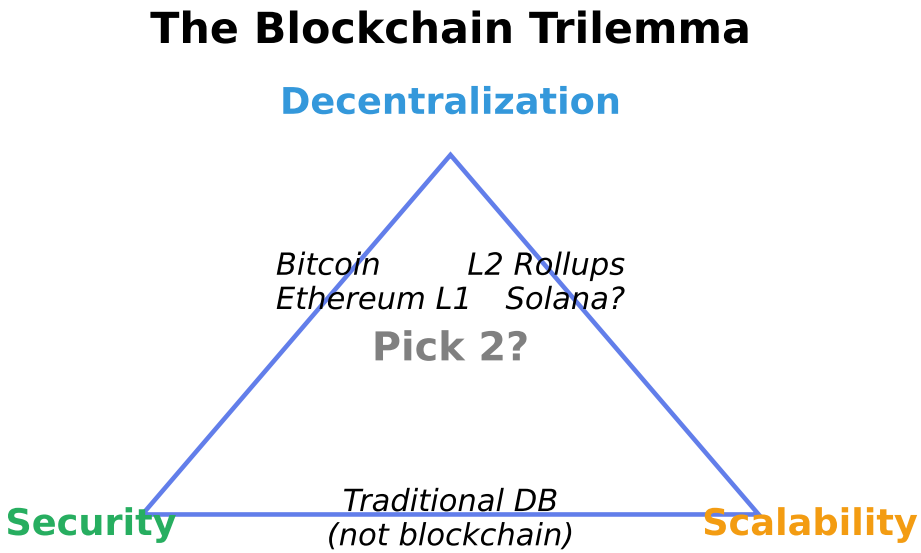
- $\sim$30 TPS for L1 execution (blobs add L2 DA capacity)
- High gas fees during congestion
- Poor user experience

Scaling Solutions:

- Layer 2: Rollups, State Channels
- Data Availability: Blobs, Alt-DA
- Future: Full Danksharding

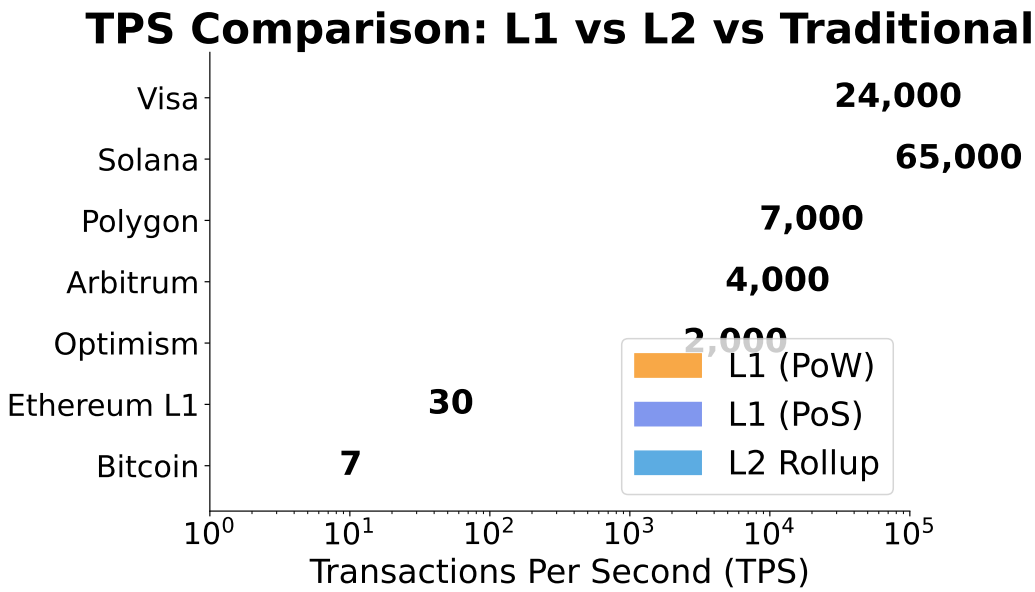
Goal: 100,000+ TPS while maintaining decentralization.

Scaling Trilemma



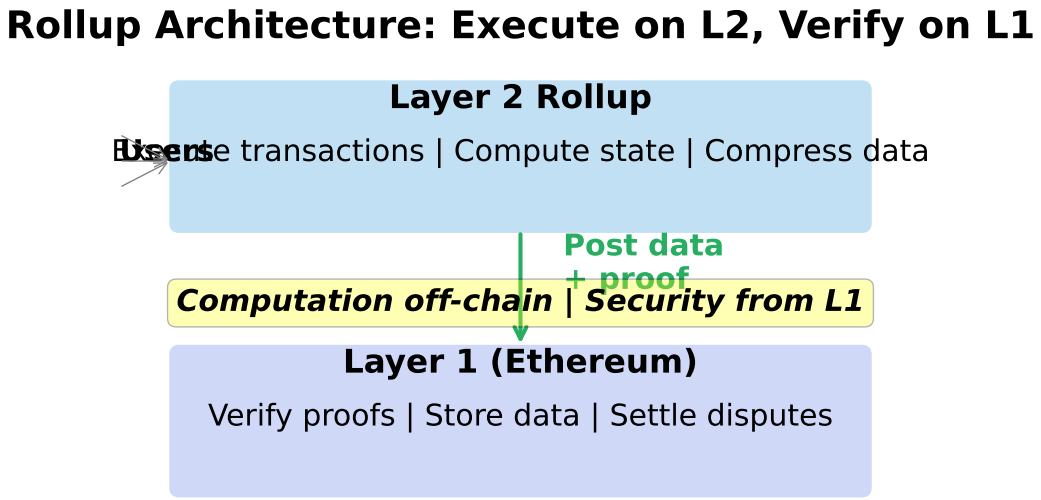
Vitalik's trilemma: traditional blockchains can only achieve 2 of 3.

TPS Comparison



L2s approach traditional payment system throughput.

Rollup Architecture



Rollups "roll up" many transactions into one L1 submission.

How Rollups Work

Key Components:

- Sequencer: orders and executes transactions
- Prover: generates validity/fraud proofs
- Bridge: locks/unlocks assets

Security Model:

- Data posted to L1 (calldata or blobs)
- Anyone can verify state transitions
- Inherits L1 security guarantees

Users can force-exit to L1 if sequencer misbehaves.

Optimistic vs ZK Rollups

Optimistic vs ZK Rollups

Feature	Optimistic Rollup	ZK Rollup
Proof Type	Fraud proofs	Validity proofs
Finality	~7 days dispute	Minutes
Withdrawal	7-day wait	Fast (~hours)
Complexity	Simpler	Complex (ZK math)
Examples	Optimism, Arbitrum	zkSync, StarkNet

Optimistic: assume valid, prove fraud | ZK: prove validity mathematically

Both approaches secure; different tradeoffs.

Optimistic Rollups

How They Work:

- Assume transactions are valid
- Challenge period (typically 7 days)
- Fraud proof if invalid state posted

Examples:

- Optimism (OP Stack)
- Arbitrum (Nitro)
- Base (built on OP Stack)

Simpler to build; EVM-equivalent.

ZK Rollups

How They Work:

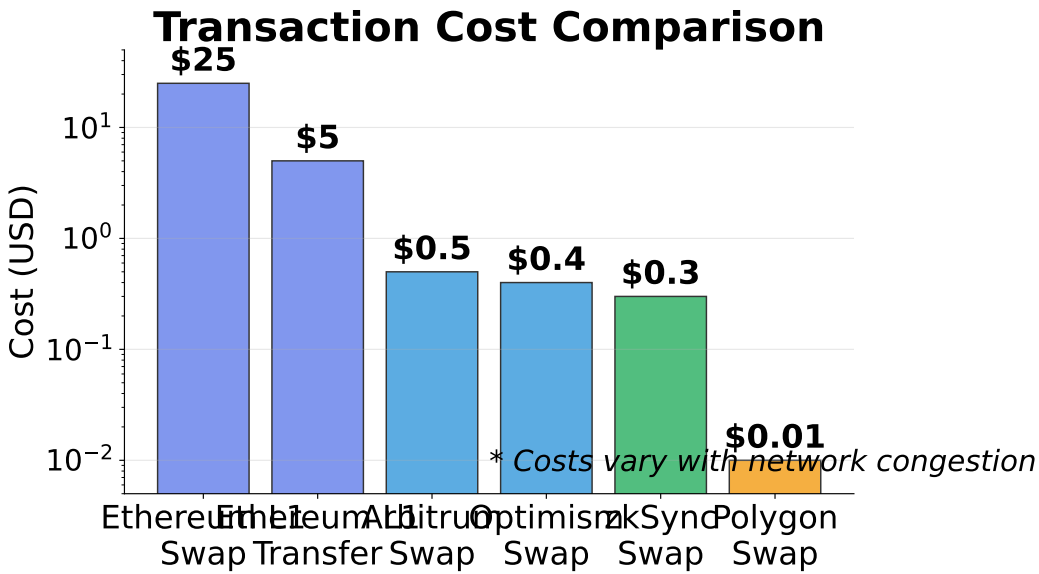
- Generate validity proof (SNARK/STARK)
- Proof verifies correct execution
- No challenge period needed

Examples:

- zkSync Era
- StarkNet
- Polygon zkEVM

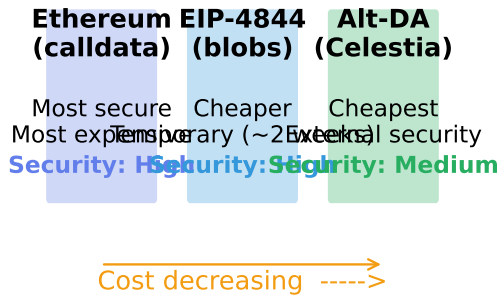
Complex to build; fast withdrawals; future-proof.

Cost Comparison



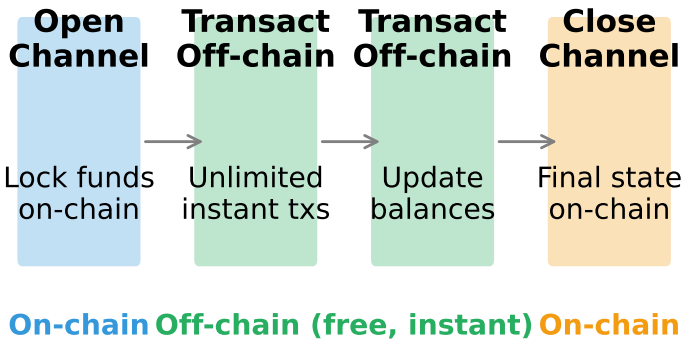
EIP-4844 reduced L2 costs further.

Data Availability



DA is critical: without data, can't verify state.

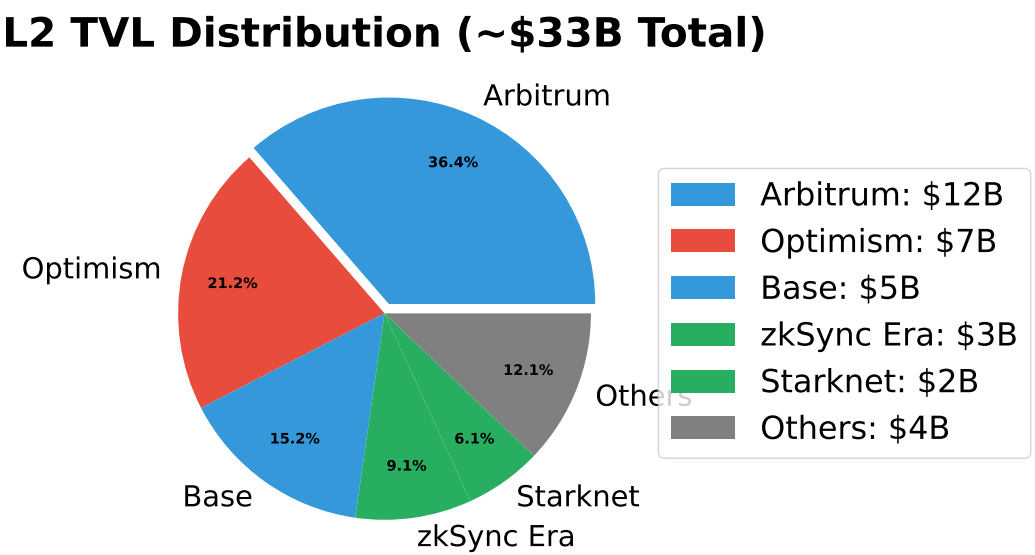
State Channels: Pay as You Go, Settle Once



Examples: Lightning Network (Bitcoin), Raiden (Ethereum)

Best for: frequent payments between known parties.

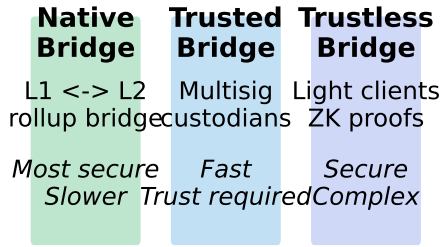
L2 TVL Distribution



Arbitrum leads; ZK rollups growing rapidly.

Bridge Types

Bridge Types: Moving Assets Between Chains



Bridge Risk: Billions lost to bridge hacks (Ronin, Wormhole, Nomad)

Native rollup bridges inherit L1 security; cross-chain bridges add risk

Billions lost to bridge hacks – bridges remain a major attack vector.

Scaling Roadmap

Ethereum's modular future: execution on L2, DA on L1.

Key Takeaways

Remember These Points

1. Trilemma: security, scalability, decentralization
2. Rollups execute off-chain, verify on-chain
3. Optimistic: fraud proofs, 7-day challenge
4. ZK: validity proofs, fast finality
5. DA critical for security; EIP-4844 reduces costs
6. Bridges are significant risk vectors

Next Lesson: Privacy Technologies.