ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

# OmniLedger: A Secure, Scale-Out, Decentralized Ledger via Sharding


Lefteris Kokoris-Kogias (@LefKok)

Decentralized and Distributed Systems Lab (DEDIS)

EPFL, IBM PhD Fellow, IC3



Scaling Bitcoin

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# Acknowledgements


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(EPFL, CH)

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(Trinity College, USA)

Bryan Ford
(EPFL, CH)

# Talk Outline

- Motivation
- OmniLedger
- Evaluation
- Conclusion

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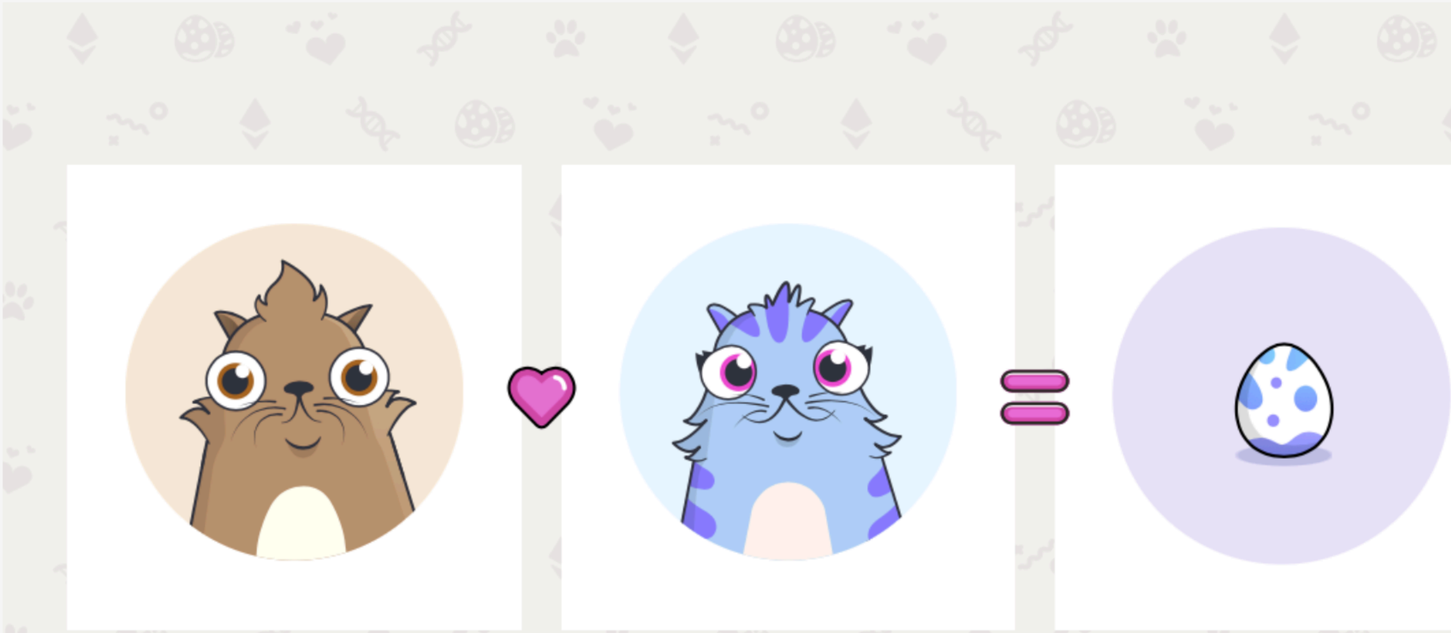
# Scaling Blockchains is More Important Than Ever …

CATS RULE THE BLOCKCHAIN, TOO

**The ethereum network is getting jammed up because people are rushing to buy cartoon cats on its blockchain**



# Bitcoin vs OmniLedger

| | Bitcoin | OmniLedger* |
|---|---|---|
| **Throughput** | ~4 TPS | ~20.000 TPS |
| **1-st Confirmation** | ~10 minutes | ~1 second |
| **Full Security** | ~60 minutes | ~42 second |
| **More Available Resources** | No performance Gain | Linear Increase in Throughput |

** Configuration with 1120 validators against a 12.5% adversary*

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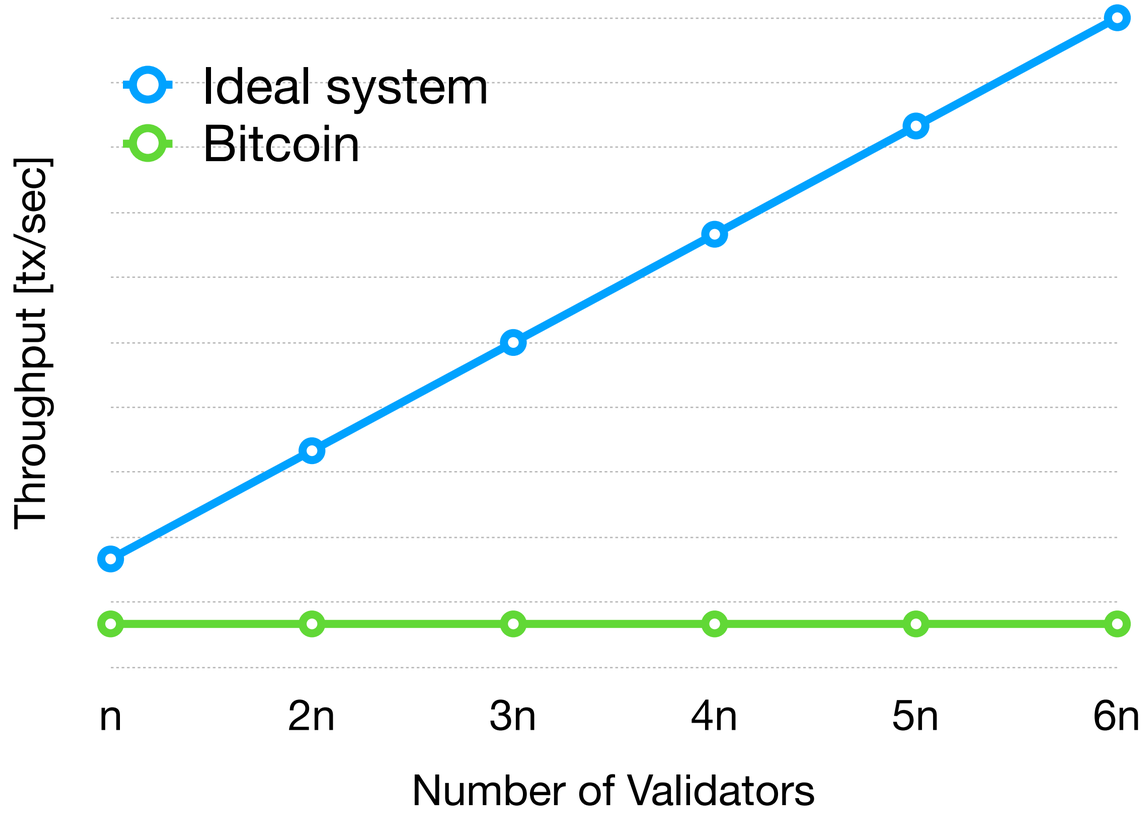
Scale-Out

# What we Want: Scale-Out Performance

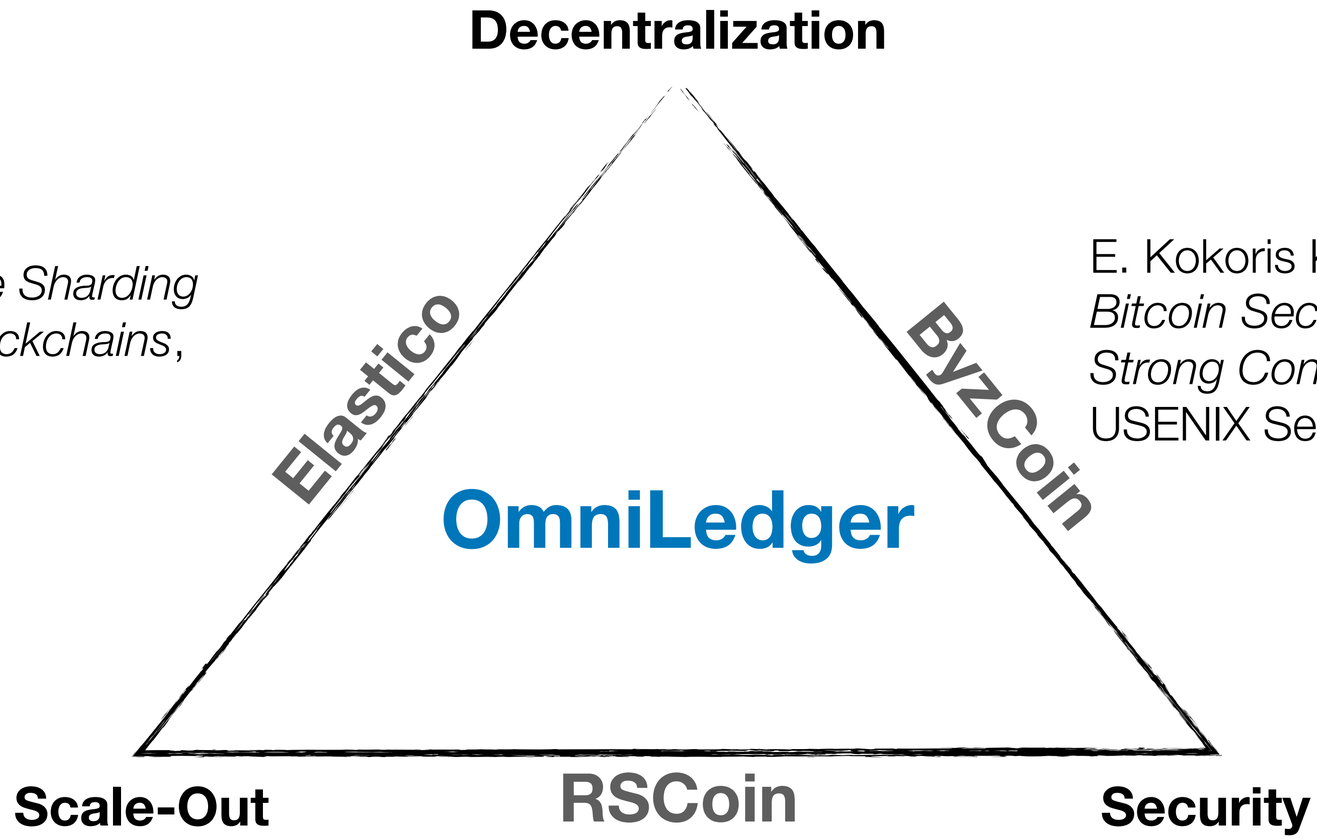



**Scale-out**: Throughput increases *linearly* with the available resources.

# … But Scaling Blockchains is Not Easy

# Distributed Ledger Landscape

L. Luu et al., *A Secure Sharding Protocol for Open Blockchains*, CCS 2016



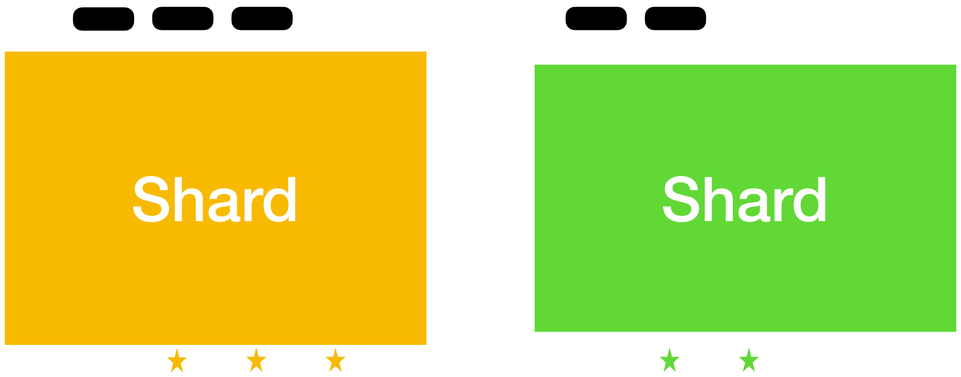

E. Kokoris Kogias et al., *Enhancing Bitcoin Security and Performance with Strong Consistency via Collective Signing*, USENIX Security 2016

G. Danezis and S. Meiklejohn, *Centrally Banked Cryptocurrencies*, NDSS 2016

# No Scale-Out (Bitcoin)

# Scale-Out (OmniLedger)

- How do validators choose which blockchain to work on?
- How can I pay a yellow vendor with greencoins?

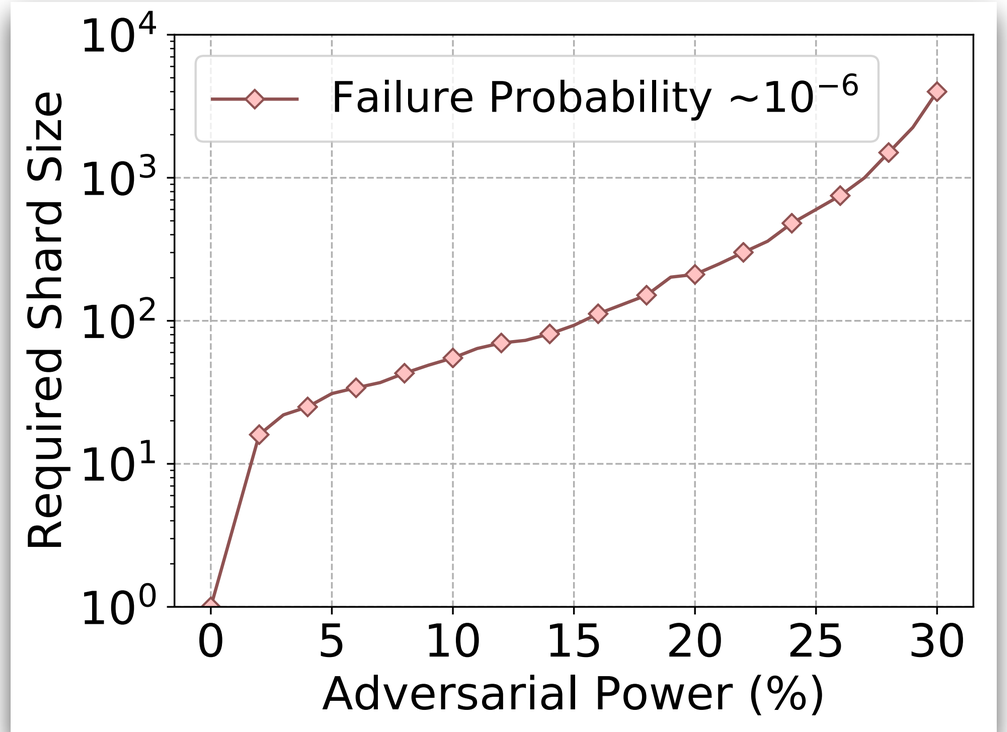



**Double Throughput**

# Random Validator Assignment

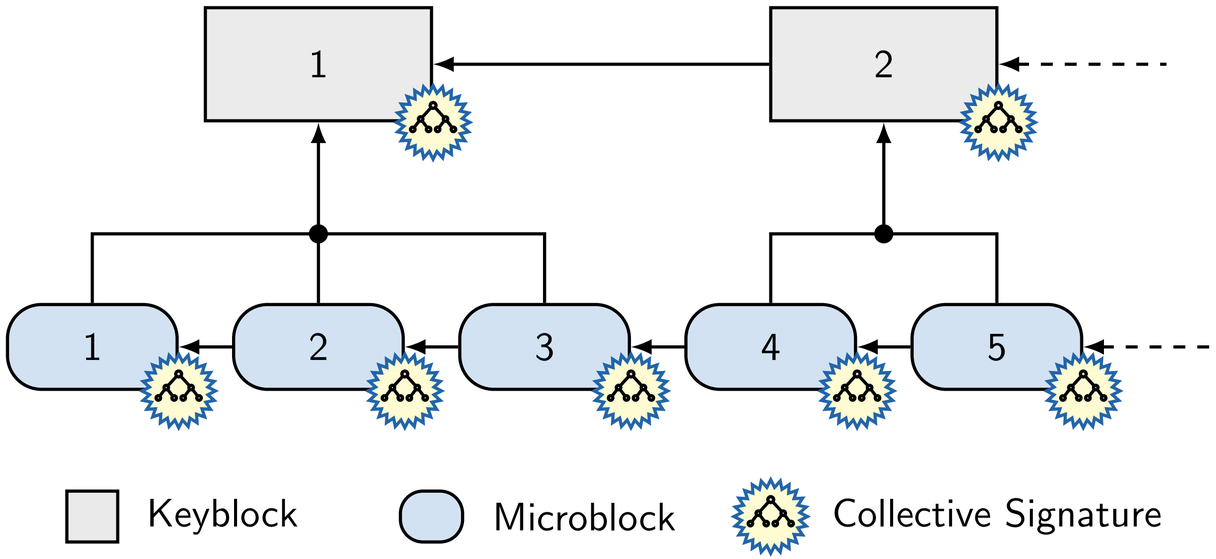
- Let validators choose? —> All malicious validators can choose the same chain

- Randomly assign validators? —> Preserve security for adequately large shard size



# Bootstraping Identies

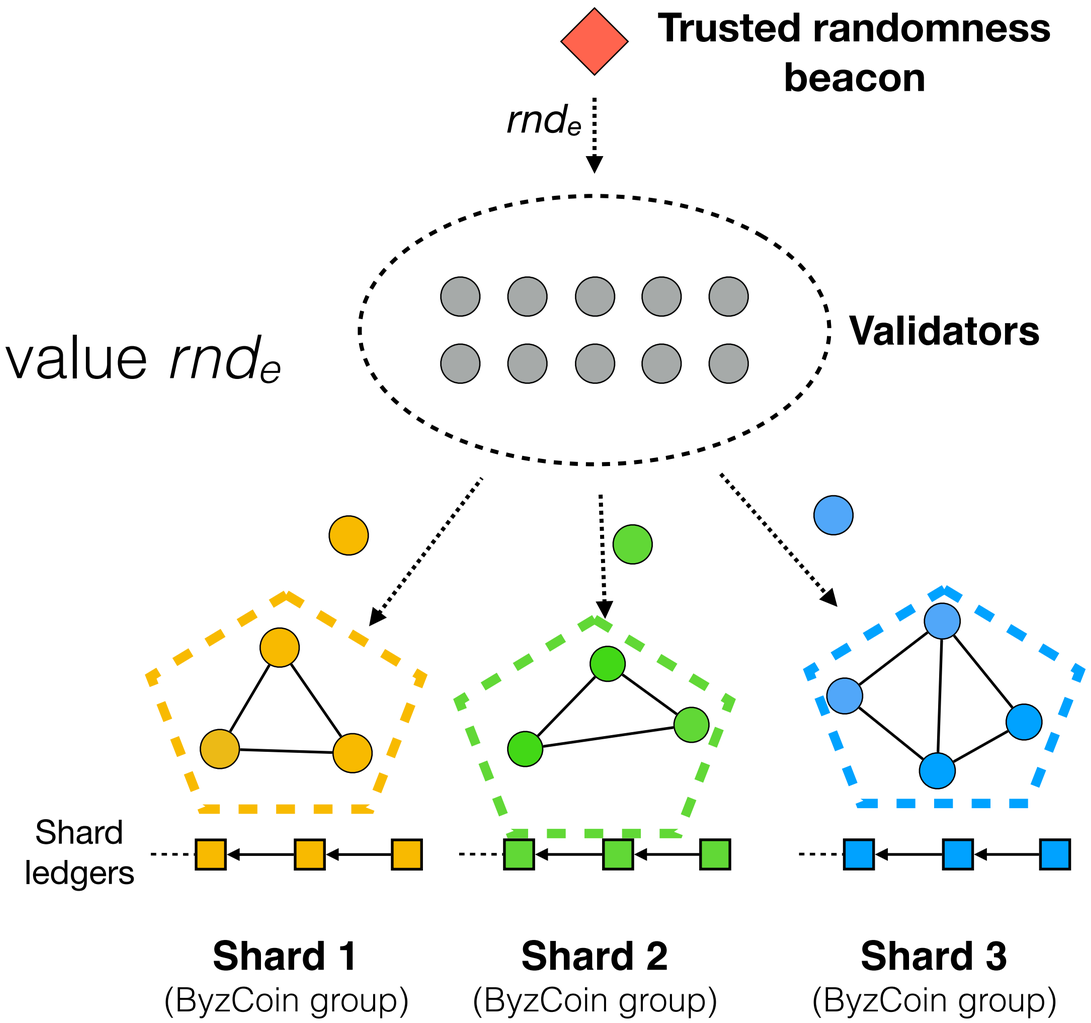
- **Key blocks:**
  - **PoW & share value**
  - **Leader election**
- **Microblocks:**
  - **Validating client transactions**
  - **Issued by the leader**



# Strawman: SimpleLedger

**Overview**

- Evolves in epochs *e*
- Trusted randomness beacon emits random value $rnd_e$
- Validators:
  - Use $rnd_e$ to compute shard assignment (ensures shard security)
  - Process tx using consensus within one shard (ByzCoin)



# Strawman: SimpleLedger

**Security Drawbacks**

- Randomness beacon: trusted third party
- No tx processing during validator re-assignment
- No cross-shard tx support

**Performance Drawbacks**

- ByzCoin failure mode
- High storage and bootstrapping cost
- Throughput vs. latency trade-off

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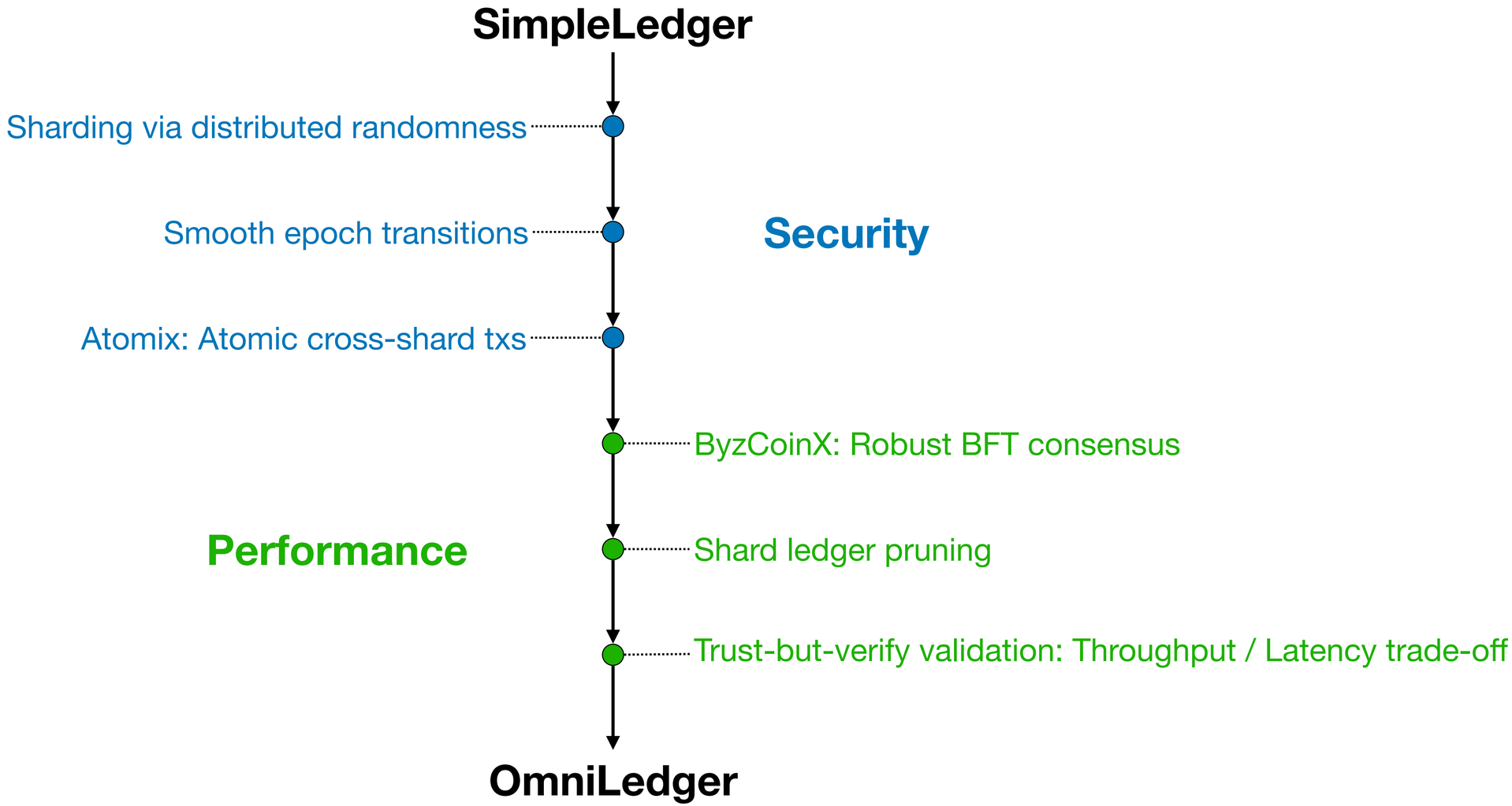
# Roadmap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Sharding via distributed randomness
Smooth epoch transitions
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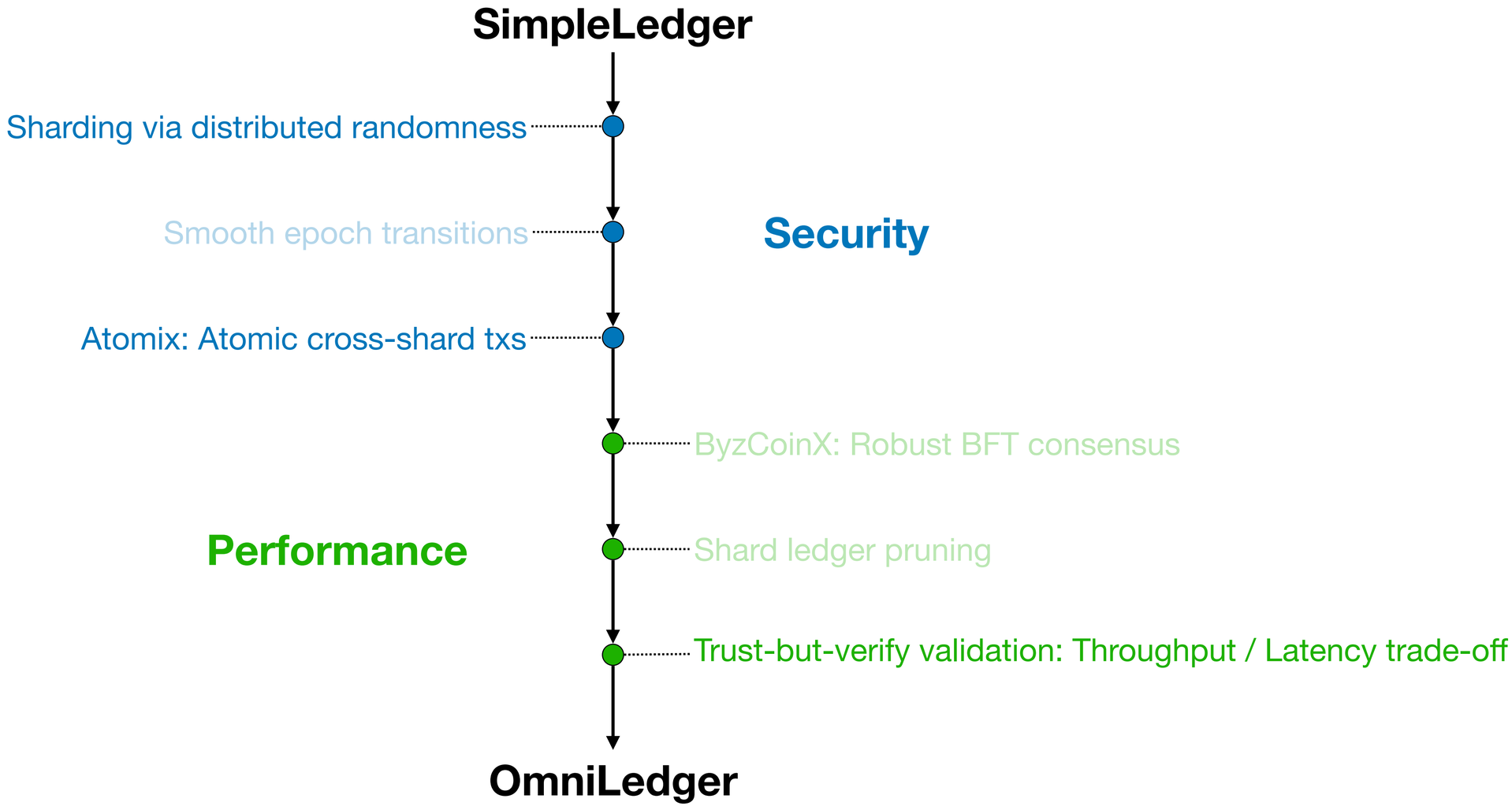
Atomix: Atomic cross-shard txs
ByzCoinX: Robust BFT consensus
Performance
Shard ledger pruning
Trust-but-verify validation: Throughput / Latency trade-off
OmniLedger

# Roadmap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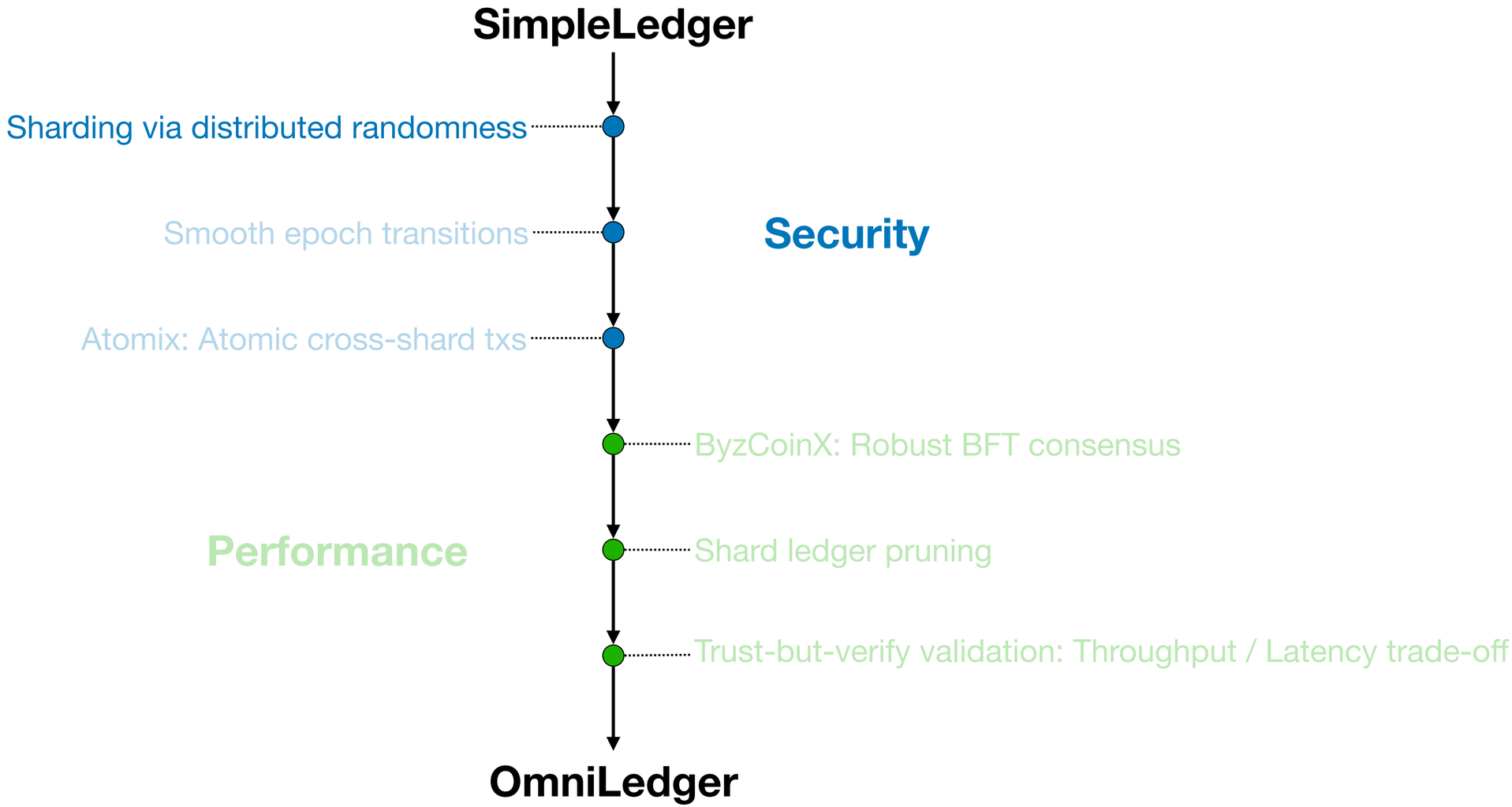
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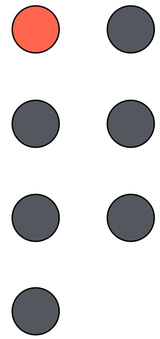
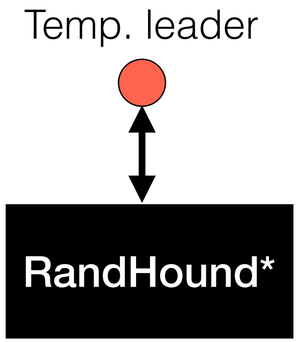
# Shard Validator Assignment

1. Temp. leader election
(Can be biased)



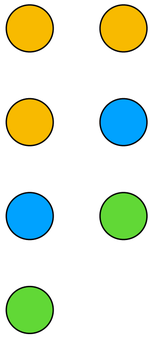
Validators

2. Randomness generation
(Output is unbiasable)




Verifiable
randomness $rnd_e$

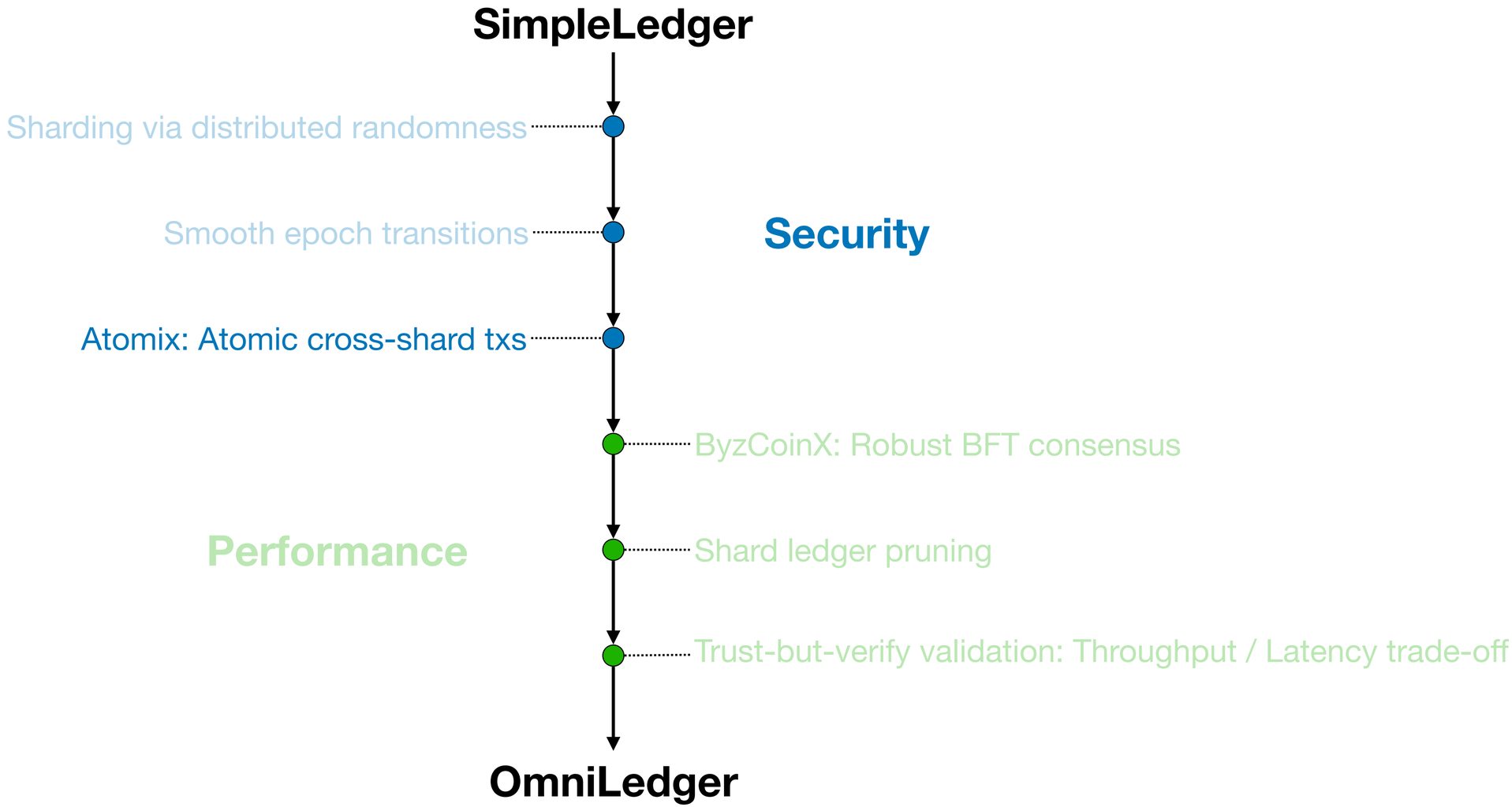
3. Shard assignment
(using $rnd_e$)



Validators
(sharded)

* Syta, Ewa, et al. "Scalable bias-resistant distributed randomness." Oakland ‘17

# Roadmap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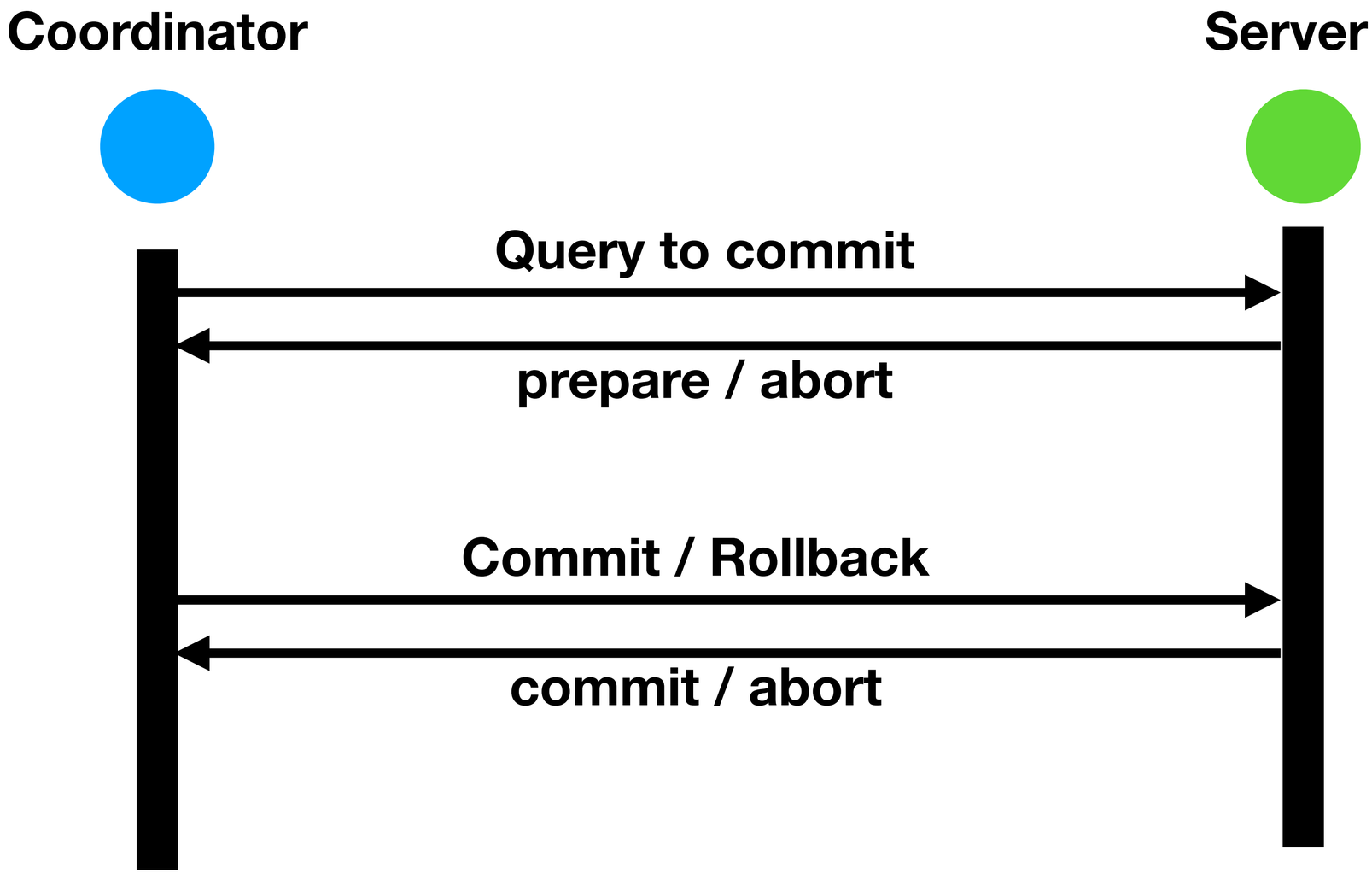
# Two-Phase Commit



# Atomix: Cross-Shard Transactions

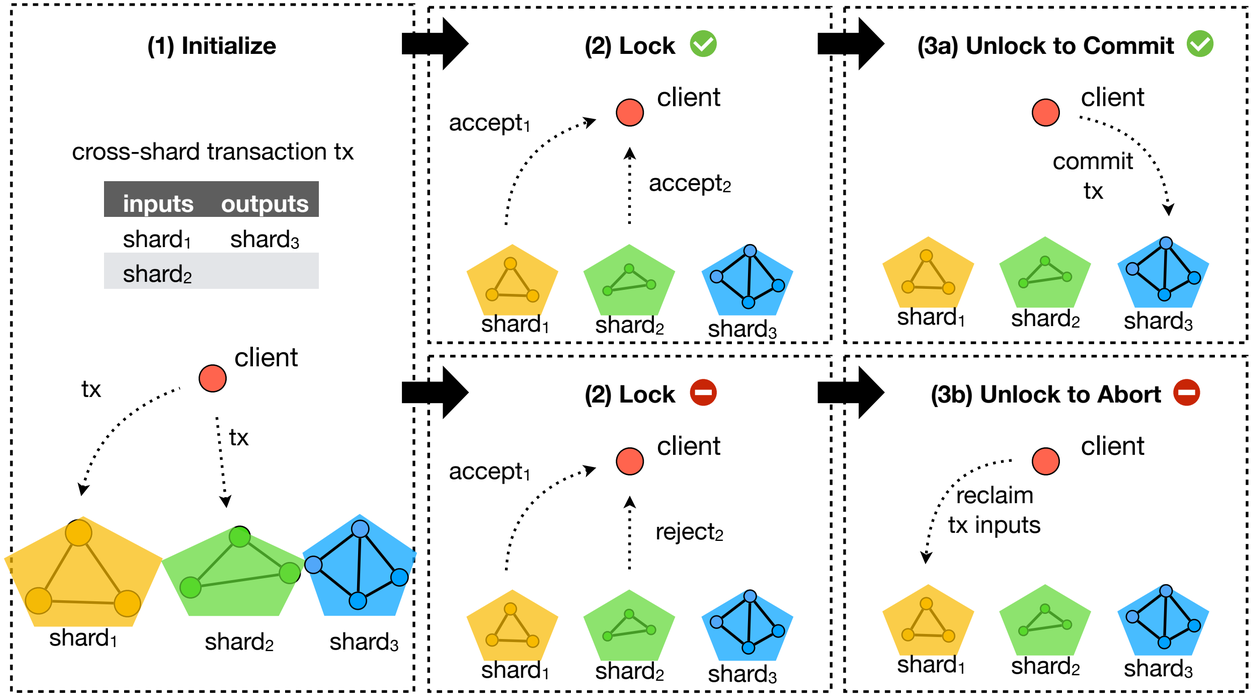
**Challenge:**

- Cross-shard tx commit atomically or abort eventually

**Solution:** Atomix

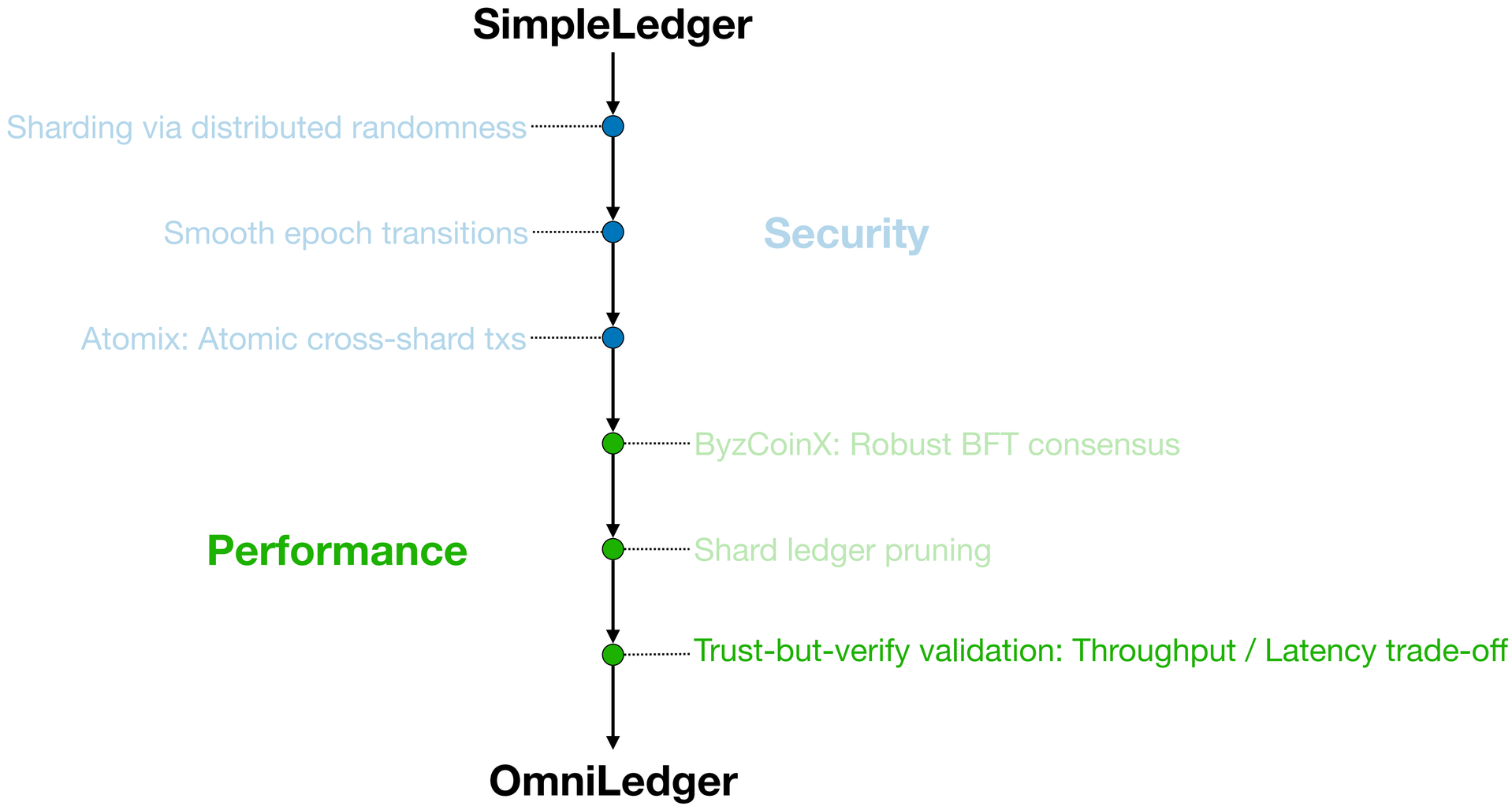
- Client-managed protocol
  1. Client sends cross-shard tx to input shards
  2. Collect ACK/ERR proofs from input shards

(a) If all input shards accept, commit to output shard, otherwise
(b) abort and reclaim input funds




The Atomix protocol for secure cross-shard transactions

# Roadmap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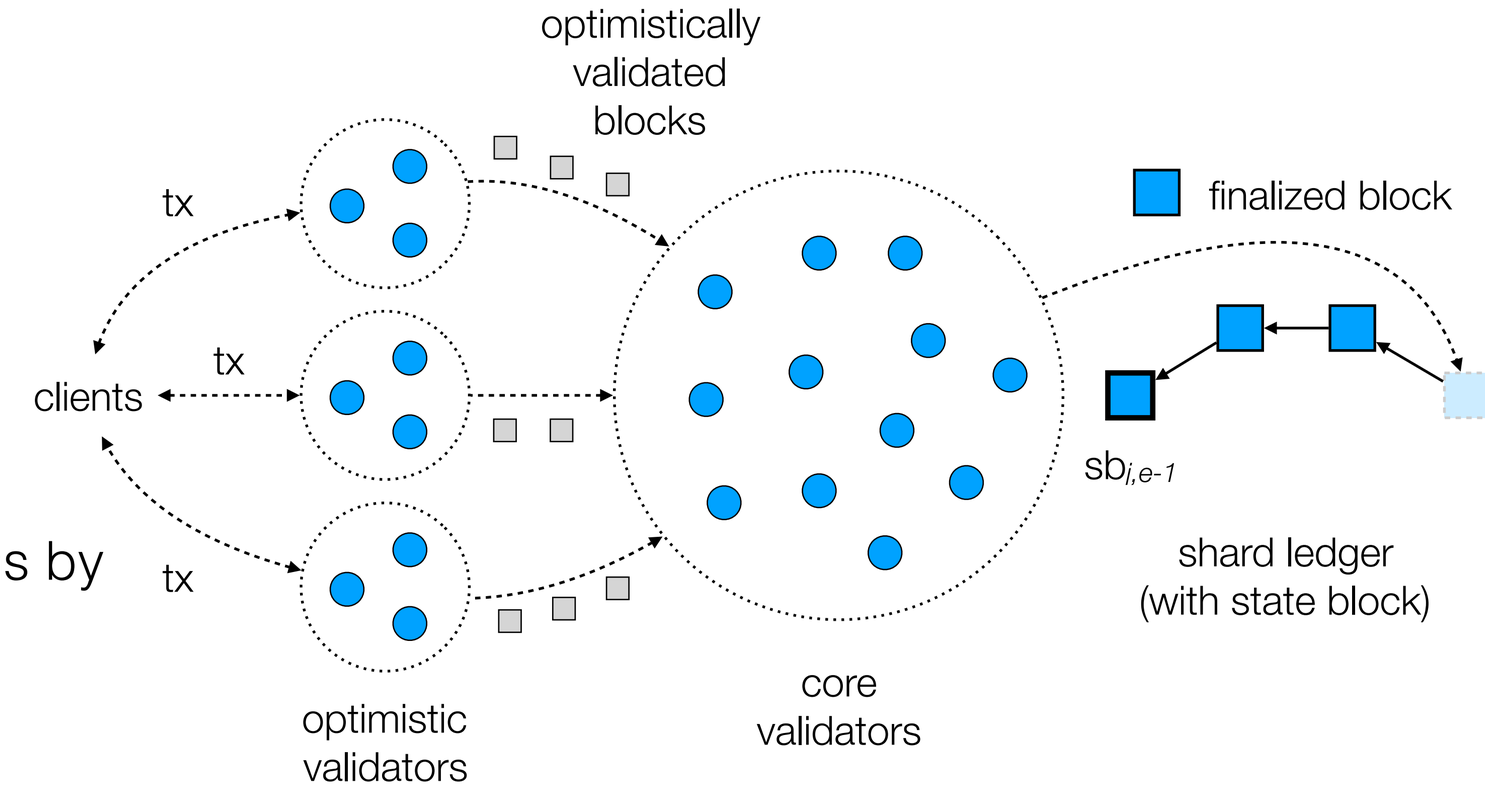
# Trust-but-Verify Transaction Validation

**Challenge:**

- Latency vs. throughput trade-off

**Solution:**

- Two-level “trust-but-verify” validation
- Low latency:
  - Optimistically validate transactions by “insecure” shards
- High throughput:
  - Batch optimistically validated blocks and audit by “secure” shards



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# Implementation & Experimental Setup

## Implementation

- OmniLedger and its subprotocols (ByzCoinX, Atomix, etc.) implemented in Go
- Based on DEDIS code
  - Kyber crypto library
  - Onet network library
  - Cothority framework
- https://github.com/dedis

## DeterLab Setup

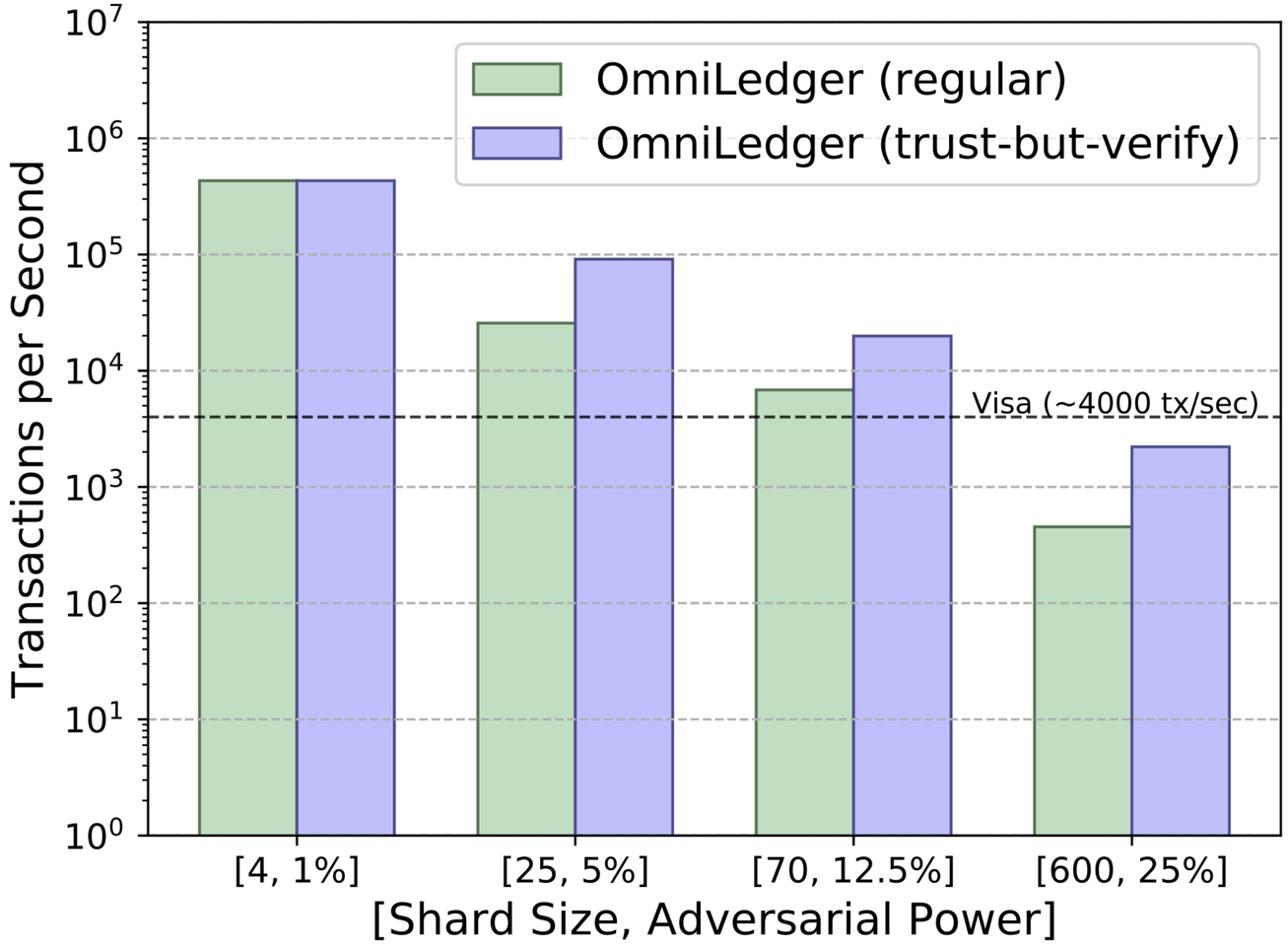
- **48 physical machines up to 1800 clients**
  - Intel Xeon E5-2420 v2 (6 cores @ 2.2 GHz)
  - 24 GB RAM
  - 10 Gbps network link
- **Network restrictions (per client)**
  - 20 Mbps bandwidth
  - 200 ms round-trip latency

# Evaluation: **Scale-Out**

| **#validators (#shards)** | **70 (1)** | **140 (2)** | **280 (4)** | **560 (8)** | **1120 (16)** |
|---|---|---|---|---|---|
| OmniLedger (tx/sec) | 439 | 869 | 1674 | 3240 | 5850 |
| Bitcoin (tx/sec) | ~4 | ~4 | ~4 | ~4 | ~4 |

**Scale-out** throughput for 12.5%-adversary
and **shard size 70** and 1200 validators

# Evaluation: **Throughput**




Results for 1800 validators

# Evaluation: **Latency**

Transaction confirmation latency in seconds for regular and mutli-level validation

| #shards, adversary | 4, 1% | 25, 5% | 70, 12.5% | 600, 25% | |
|---|---|---|---|---|---|
| **regular validation** | 1.38 | 5.99 | 8.04 | 14.52 | 1 MB blocks |
| **1st lvl. validation** | 1.38 | 1.38 | 1.38 | 4.48 | 500 KB blocks |
| **2nd lvl. validation** | 1.38 | 55.89 | 41.89 | 62.96 | 16 MB blocks |
| **Bitcoin** | 600 | 600 | 600 | 600 | |

latency increase since optimistically validated blocks are batched into larger blocks for final validation to get better throughput

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# Conclusion

- **OmniLedger – Secure scale-out distributed ledger framework**
  - Atomix: Client-managed cross-shard tx
  - ByzCoinX: Robust intra-shard BFT consensus
  - Sharding: Visa-level throughput and beyond
  - Trust-but-verify validation: No latency vs. throughput tradeoff
  - For PoW, PoS, permissioned, etc.
- **Code:** https://github.com/dedis
- **Contact**: eleftherios.kokoriskogias@epfl.ch , @LefKok