# Chainspace:
# A Sharded Smart Contract Platform

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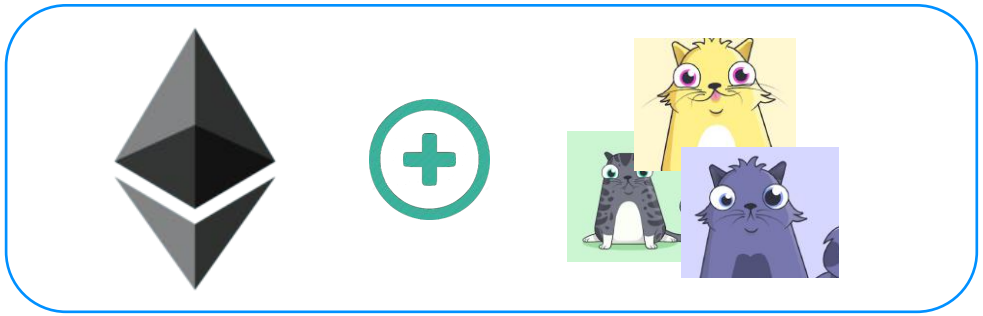
# Motivation

- Blockchains are cool — but scale badly



- Hard to operate on secret inputs


# Motivation

- Related works

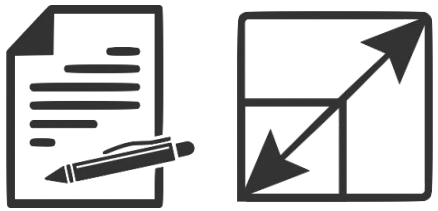
| | Smart Contract | Scalable | Privacy |
|---|---|---|---|
| Ethereum | ✓ | ✗ | ✗ |
| Hawk | ✓ | ✗ | ✓ |
| ZCash | ✗ | ✗ | ✓ |
| Omniledger | ✗ | ✓ | ✗ |
| RSCoin | ✗ | ✓ | ✗ |

# Introduction

- **What is chainspace?**

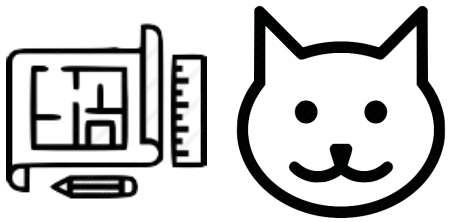
**contribution I**

**Scalable smart contract platform**

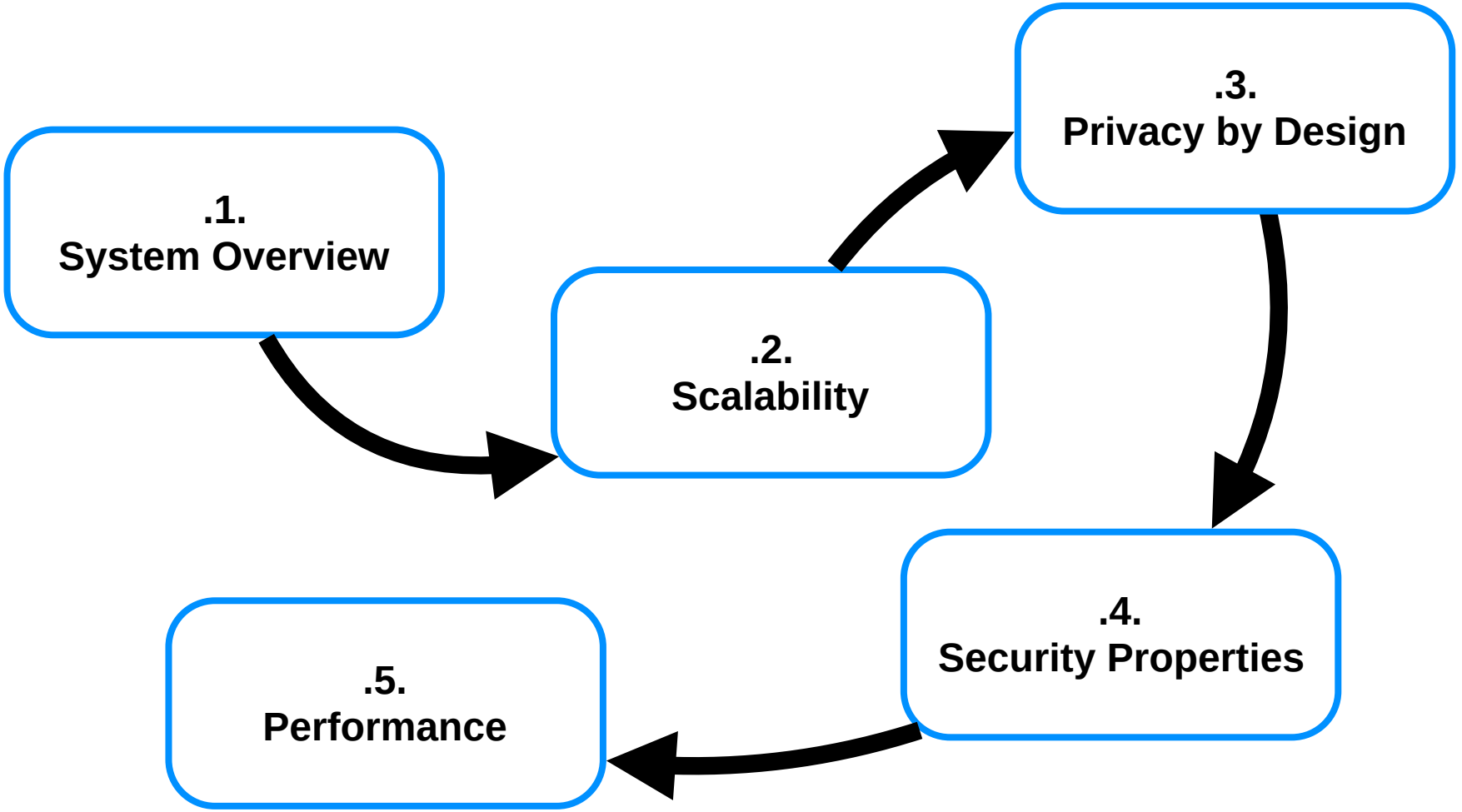


**contribution II**

**Supporting privacy**

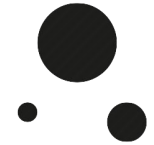


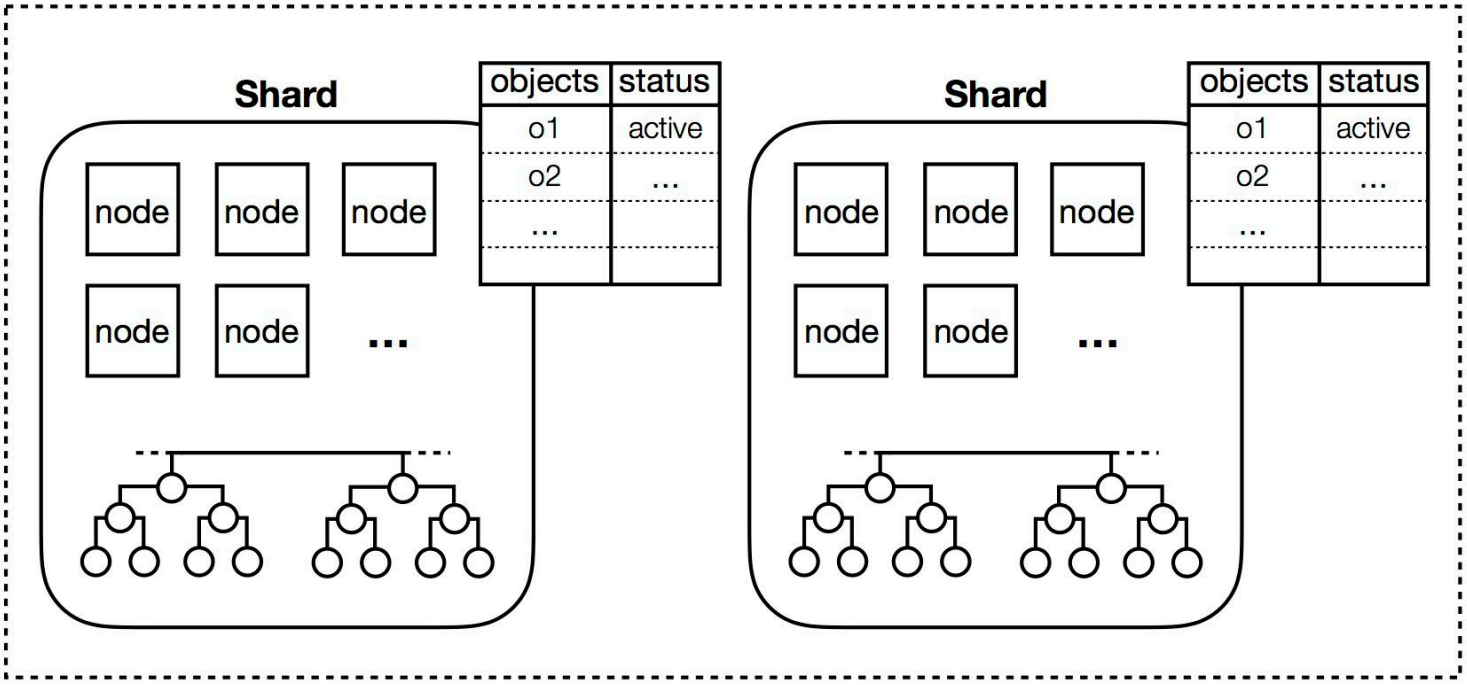
# Contents


.1.
System Overview
.2.
Scalability
.3.
Privacy by Design
.4.
Security Properties
.5.
Performance

# System Overview

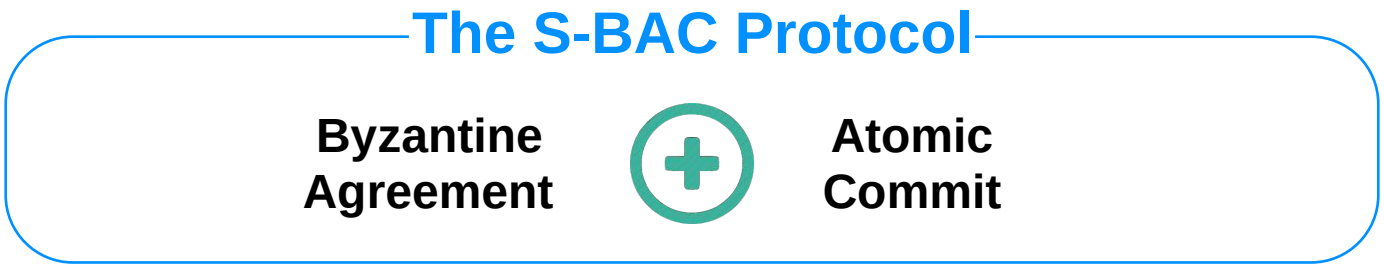
- How Chainspace works?
  - Nodes are organised into **shards**
  - Shards manage **objects**
  - Objects can be used only once

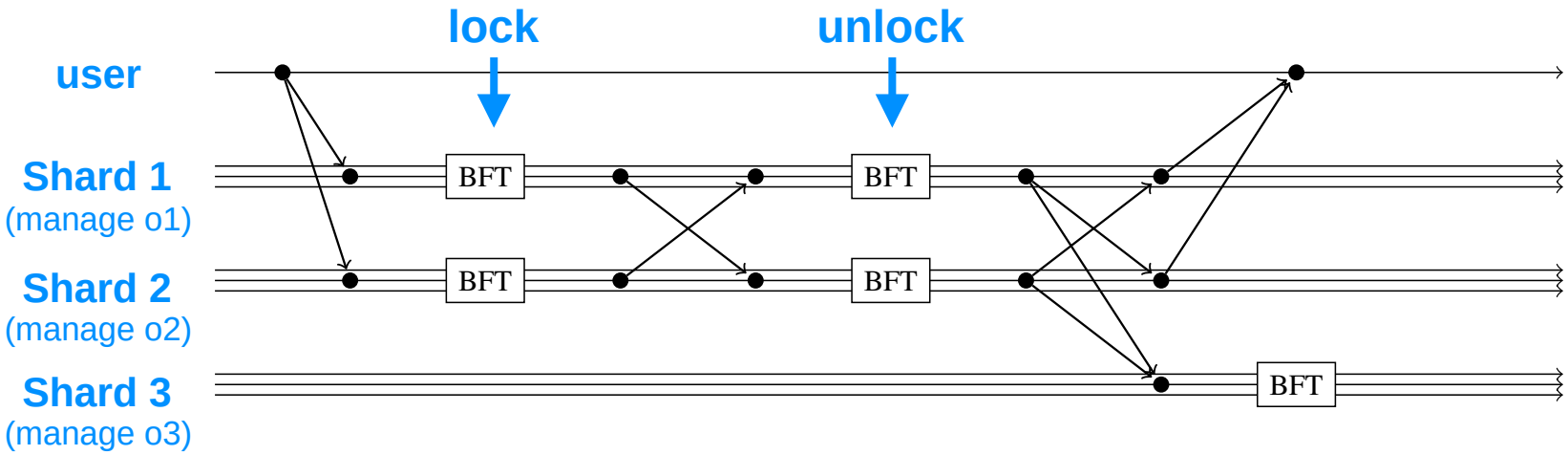


# Scalability

- How nodes reach consensus?



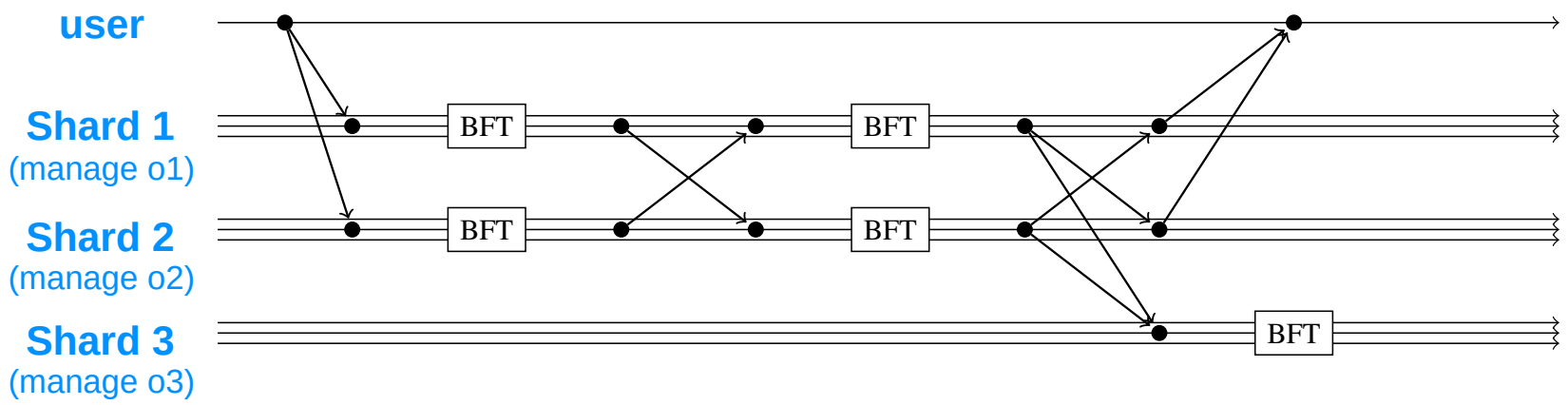



# Scalability

- The Wisdom behind S-BAC

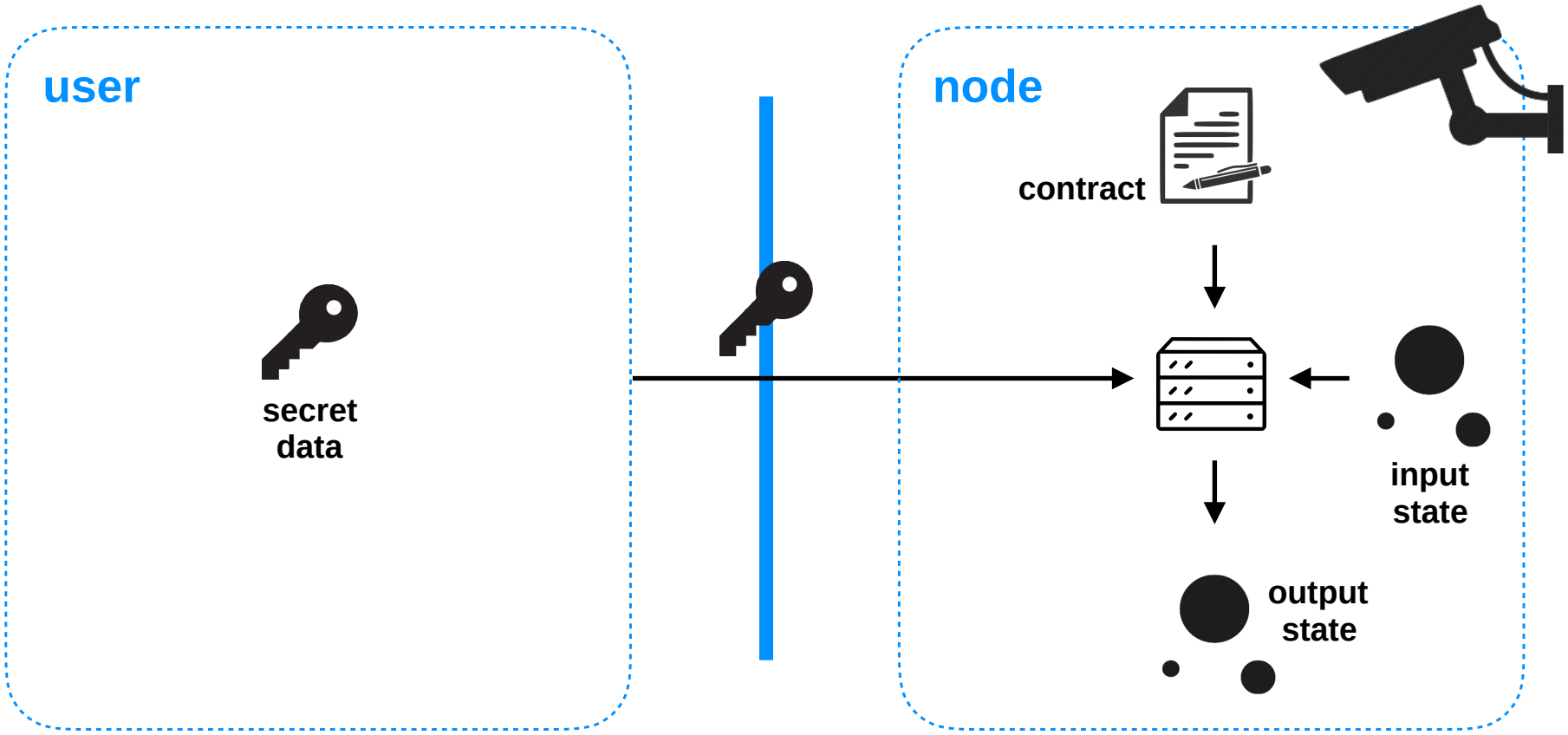
**Only shards managing *o1* and *o2* are reaching consensus**

**Shard 1 and shard 2 can work in parallel**



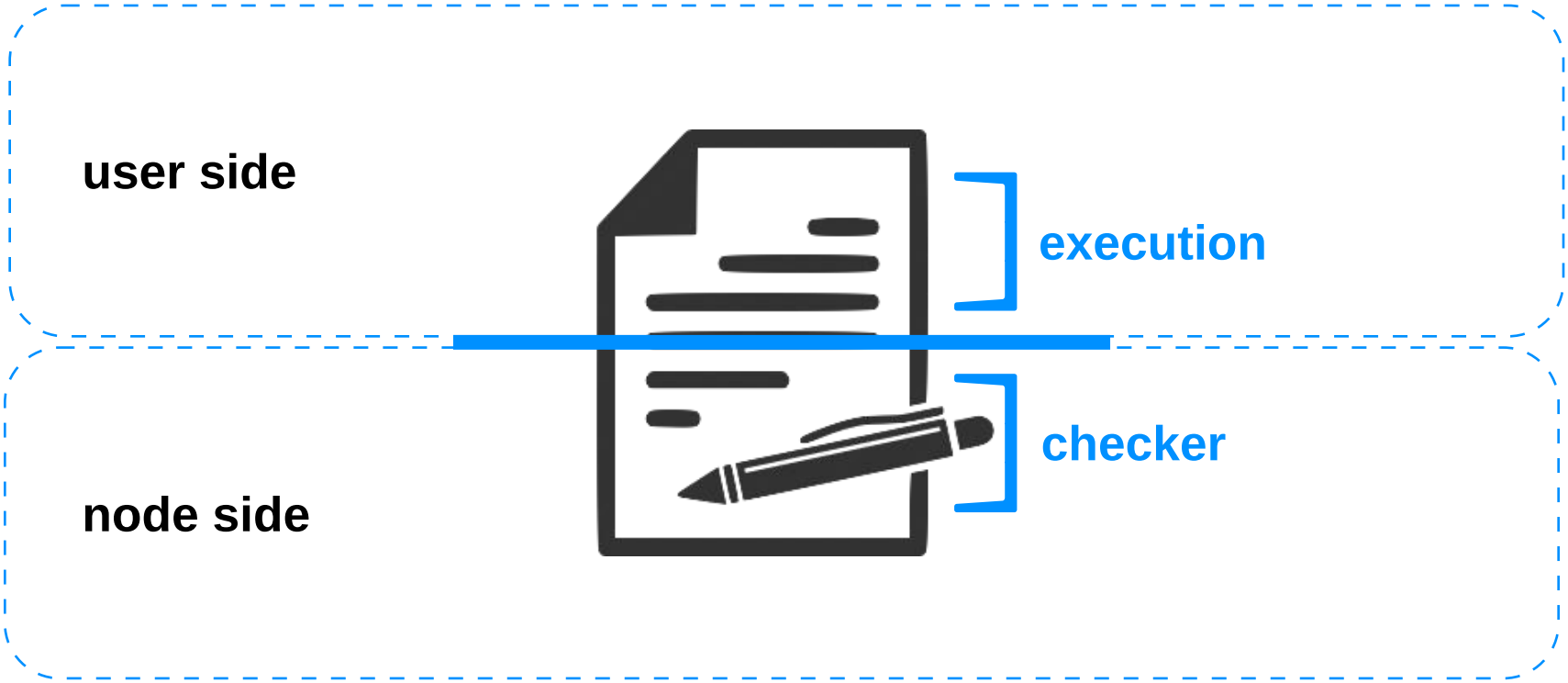
# Privacy by Design

- Transaction in classic blockchains



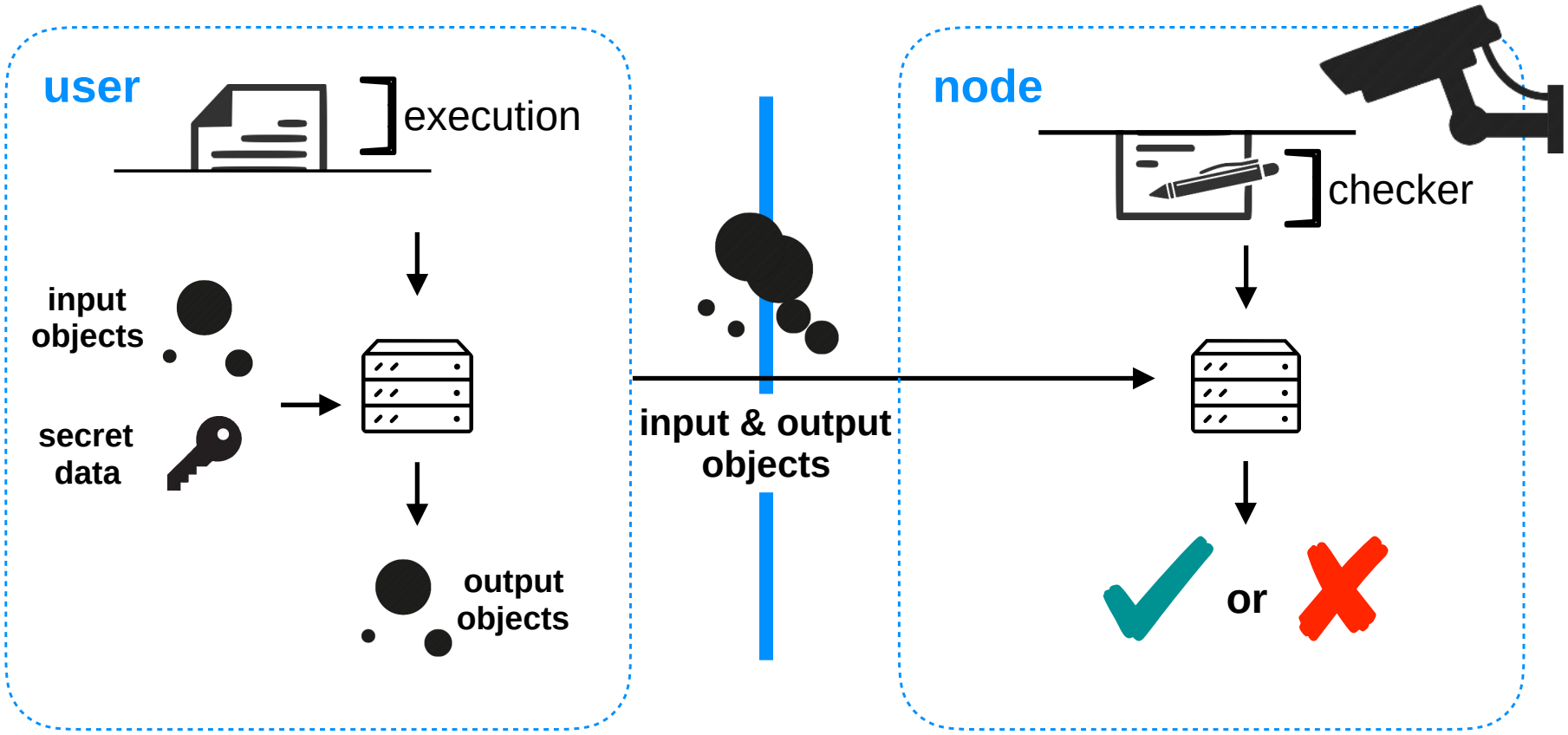
# Privacy by Design

- What are Chainspace Smart Contracts?



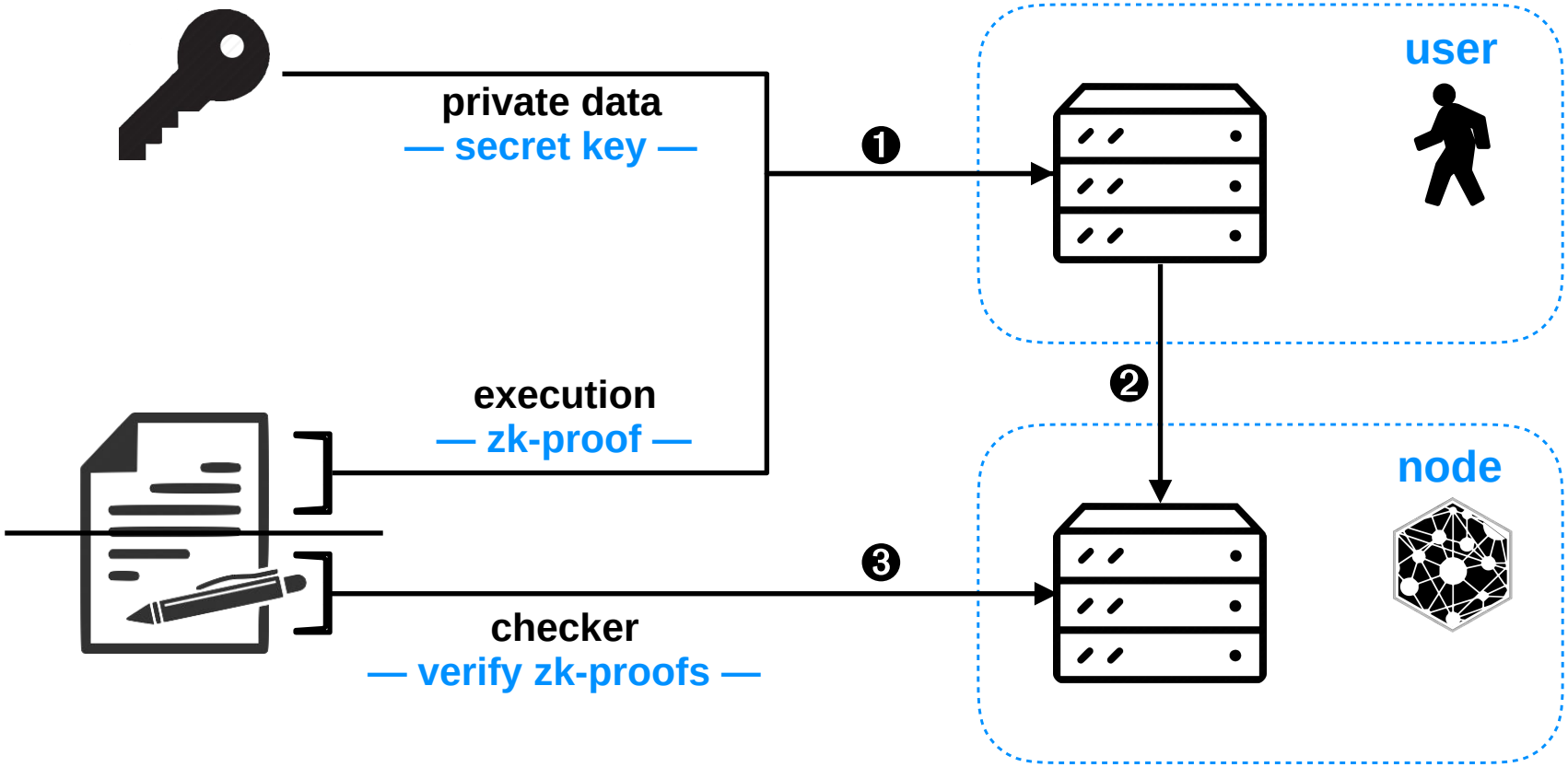
# Privacy by Design

- Chainspace transaction



# Privacy by Design

- Private data never leave the client !



# Security Properties

- What does Chainspace guarantee?
  - **Honest Shard:** among ***3f+1*** nodes, at most ***f*** are malicious.
  - **Malicious Shard:** over ***f*** dishonest nodes.
  - Chainspace properties:

**Transparency**

*Anyone can authenticate the history of transactions and objects that led to the creation of an object.*

**Encapsulation**

*A smart contract cannot interfere with objects created by another contract (except if defined by that contract).*

**Integrity**
**(Honest Shard)**

*Only valid & non-conflicting transactions will be executed.*

**Non-Repudiation**

*Misbehaviour is detectable: there are evidences of misbehaviour pointing to the faulty parties or shards.*

# Performance

- What did we implement?

**Measured and tested on Amazon AWS**


**S-BAC protocol implemented in Java**

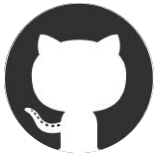
**Based on BFT-SMaRt**

**Python contract simulator**

Helps developers
Simulation of the checker
No need for full deployment

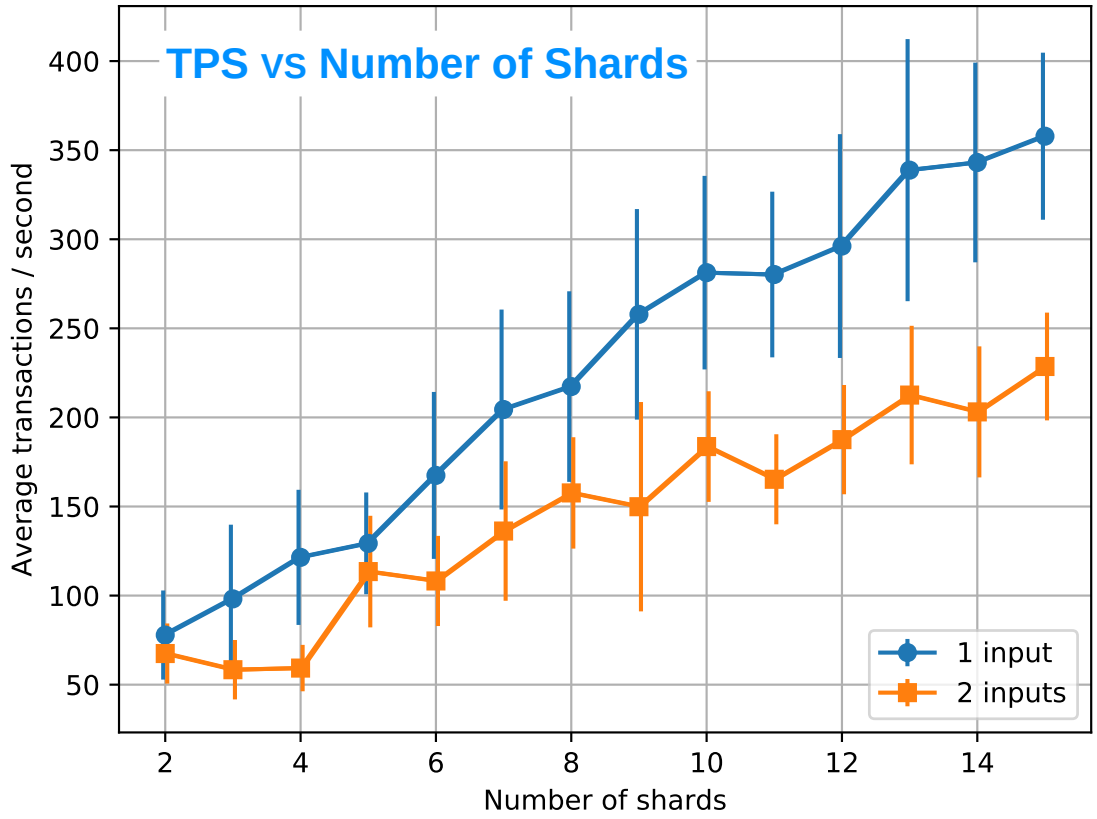
**Everything is released as open source software**

`https://github.com/chainspace`



# Performance

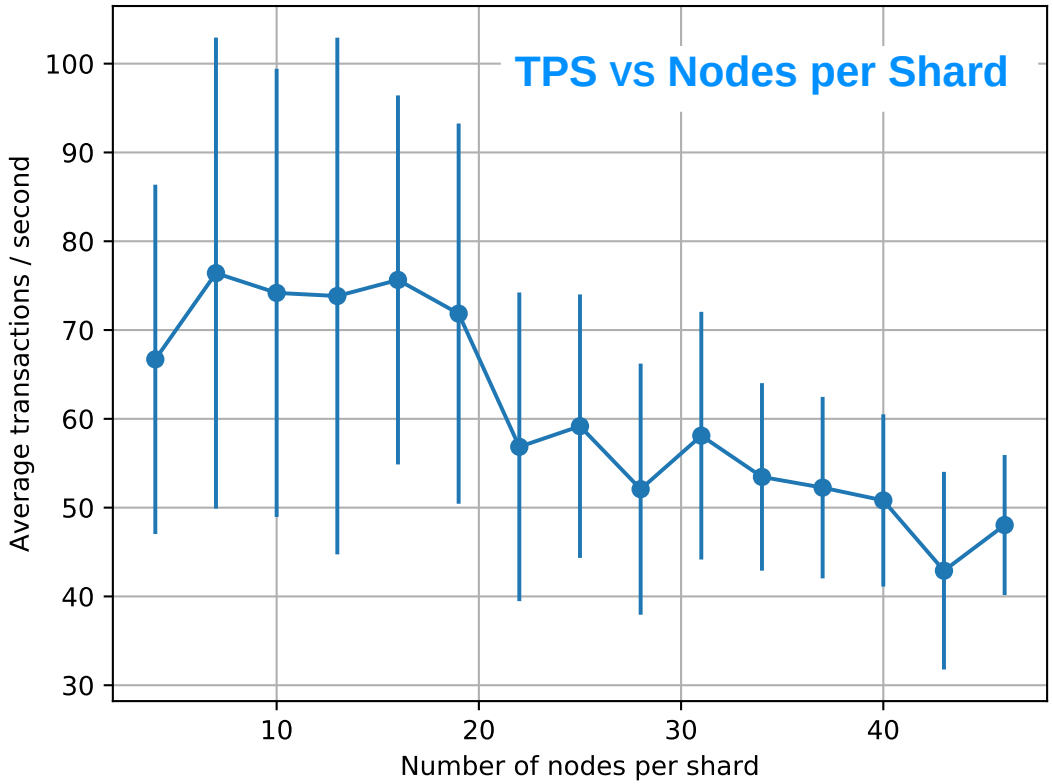
- How the number of shards influences the TPS?




**TPS scales linearly with the number of shards**

# Performance

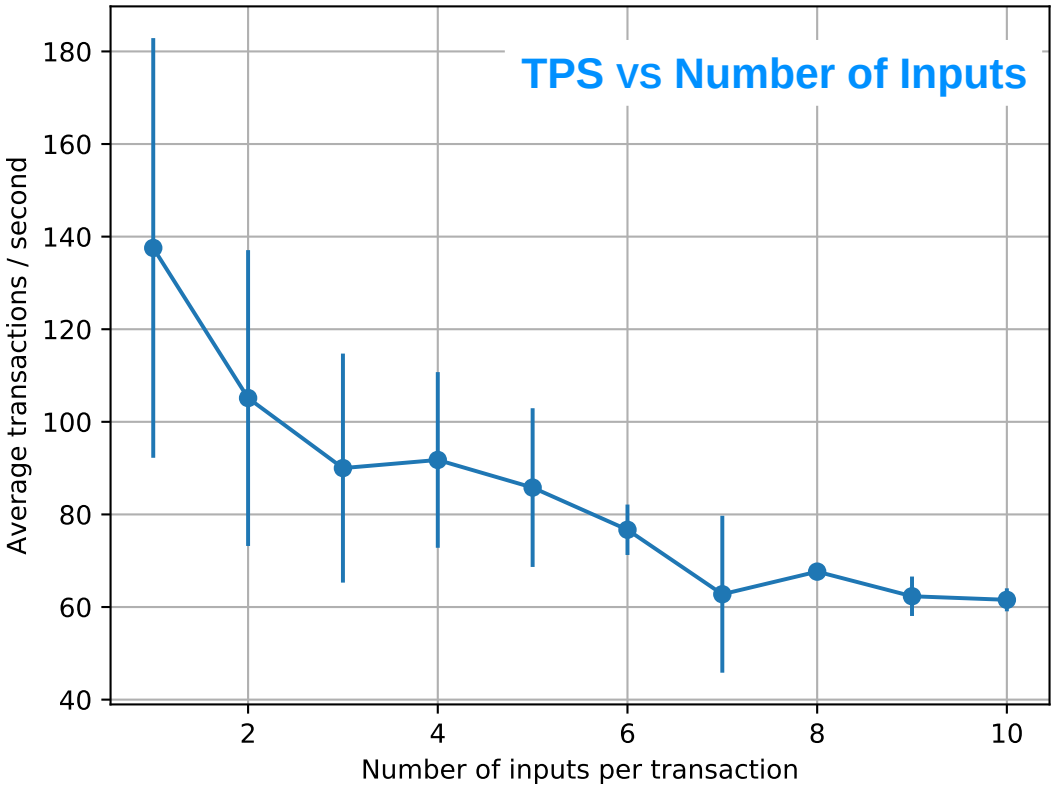
- How does the size of the shard influence the TPS?




**TPS decreases slowly**

# Performance

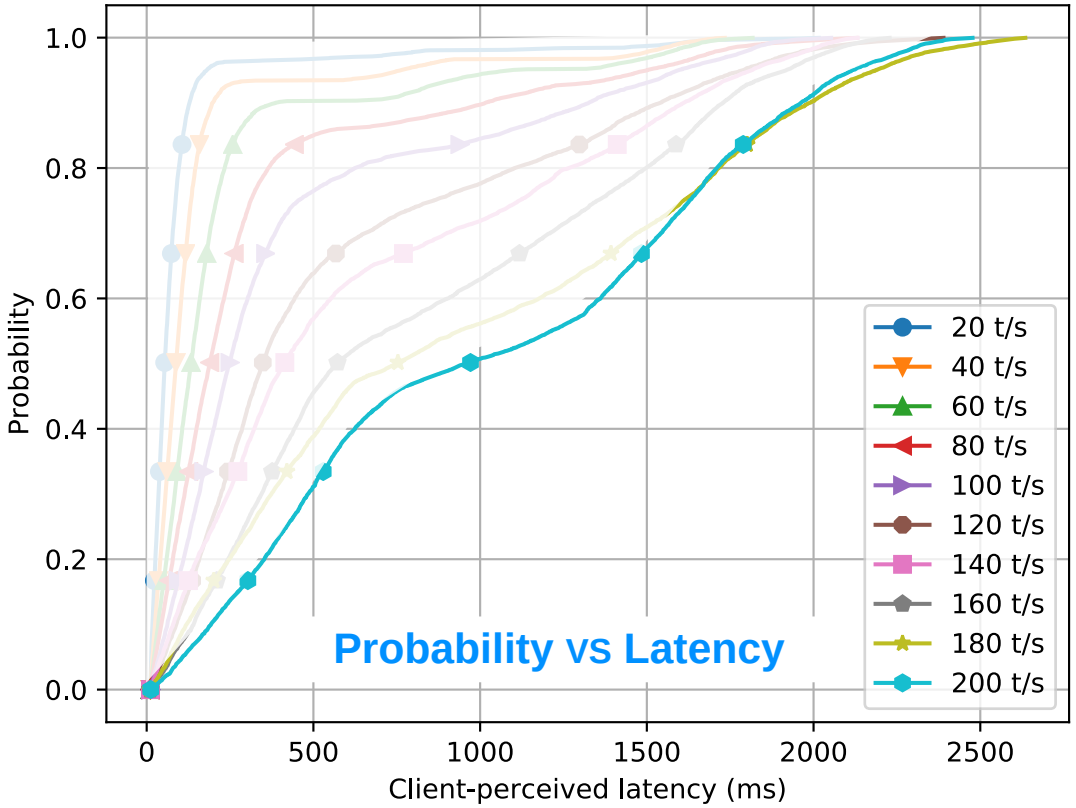
- How the number of inputs influence the TPS?




**TPS decreases slowly and then flattens out**

# Performance

- How is the trade off between TPS and latency?




**Low latency even when the system is heavy loaded**

# What else is in the paper?

***Cross shard transactions***

***Smart metering contract***

***Platform for decision making***

***contracts benchmarking and evaluation***

Chainspace: A Sharded Smart Contracts Platform

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* University College London, United Kingdom
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***Abstract*—Chainspace is a decentralized infrastructure, known as a distributed ledger, that supports user defined smart contracts and executes user-supplied transactions on their objects. The correct execution of smart contract transactions is verifiable by all. The system is scalable, by sharding state and the execution of transactions, and using *S*-BAC, a distributed commit protocol, to guarantee consistency. Chainspace is secure against subsets of nodes trying to compromise its integrity or availability properties through Byzantine Fault Tolerance (BFT), and extremely high-auditability, non-repudiation and 'blockchain' techniques. Even when BFT fails, auditing mechanisms are in place to trace malicious participants. We present the design, rationale, and details of Chainspace; we argue through evaluating an implementation of the system about its scaling and other features; we illustrate a number of privacy-friendly smart contracts for smart metering, polling and banking and measure their performance.**

## I. Introduction

Chainspace is a distributed ledger platform for high-integrity and transparent processing of transactions within a decentralized system. Unlike application specific distributed ledgers, such as Bitcoin [Nak08] for a currency, or certificate transparency [LLK13] for certificate verification, Chainspace offers extensibility though smart contracts, like Ethereum [Woo14]. However, users expose to Chainspace enough information about contracts and transaction semantics, to provide higher scalability through sharding across infrastructure nodes: our modest testbed of 60 cores achieves 350 transactions per second, as compared with a peak rate of less than 7 transactions per second for Bitcoin over 6K full nodes. Etherium currently processes 4 transactions per second, out of theoretical maximum of 25. Furthermore, our platform is agnostic as to the smart contract language, or identity infrastructure, and supports privacy features through modern zero-knowledge techniques [BCCG16, DGFK14].

Unlike other scalable but 'permissioned' smart contract platforms, such as Hyperledger Fabric [Cac16] or BigchainDB [MMM+16], Chainspace aims to be an 'open' system: it allows anyone to author a smart contract, anyone to provide infrastructure on which smart contract code and state runs, and any user to access calls to smart contracts. Further, it provides ecosystem features, by allowing composition of smart contracts from different authors. We integrate a value system, named CSCoin, as a system smart contract to allow for accounting between those parties.

However, the security model of Chainspace, is different from traditional unpermissioned blockchains, that rely on proof-of-work and global replication of state, such as Ethereum. In Chainspace smart contract authors designate the parts of the infrastructure that are trusted to maintain the integrity of their contract—and only depend on their correctness, as well as the correctness of contract sub-calls. This provides fine grained control of which part of the infrastructure need to be trusted on a per-contract basis, and also allows for horizontal scalability.

This paper makes the following contributions:

- It presents Chainspace, a system that can scale arbitrarily as the number of nodes increase, tolerates byzantine failures, and can be fully and publicly audited.
- It presents a novel distributed atomic commit protocol, called *S*-BAC, for sharding generic smart contract transactions across multiple byzantine nodes, and correctly coordinating those nodes to ensure safety, liveness and security properties.
- It introduces a distinction between parts of the smart contract that execute a computation, and those that check the computation and discusses how that distinction is key to supporting privacy-friendly smart-contracts.
- It provides a full implementation and evaluates the performance of the byzantine distributed commit protocol, *S*-BAC, on a real distributed set of nodes and under varying transaction loads.
- It presents a number of key system and application smart contracts and evaluates their performance. The contracts for privacy-friendly smart-metering and privacy-friendly polls illustrate and validate support for high-integrity and high-privacy applications.

**Outline:** Section II presents an overview of Chainspace; Section III presents the client-facing application interface; Section IV presents the design of internal data structures guaranteeing integrity, the distributed architecture, the byzantine commit protocols, and smart contract definition and composition. Section V argues the correctness and security; specific smart contracts and their evaluations are presented in Section VI; Section VII presents an evaluation of the core protocols and smart contract performance; Section VIII presents limitation and Section IX a comparison with related work; and Section X concludes.

# Future Works

1. How to recover from malicious shards?

2. How can a smart contract creator avoid dishonest shards ?

3. How to configure shards?

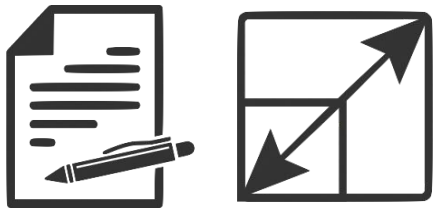
4. How to incentivise nodes?

# Conclusions

- What did we talked about ?

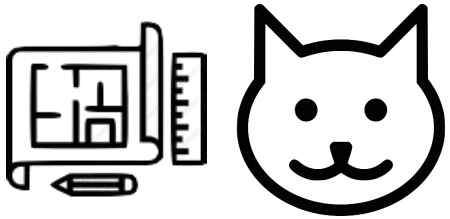
**contribution I**

**Scalable smart contract platform**



**contribution II**

**Supporting privacy**



# Conclusions

- **Main take-aways**

**sharding**  **scalability**

**execution / checker**  **privacy by design**

**Thank you for your attention**

**Questions?**

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`https://github.com/chainspace`

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