Practical zk with Summa

Napoli - 25/5/2023

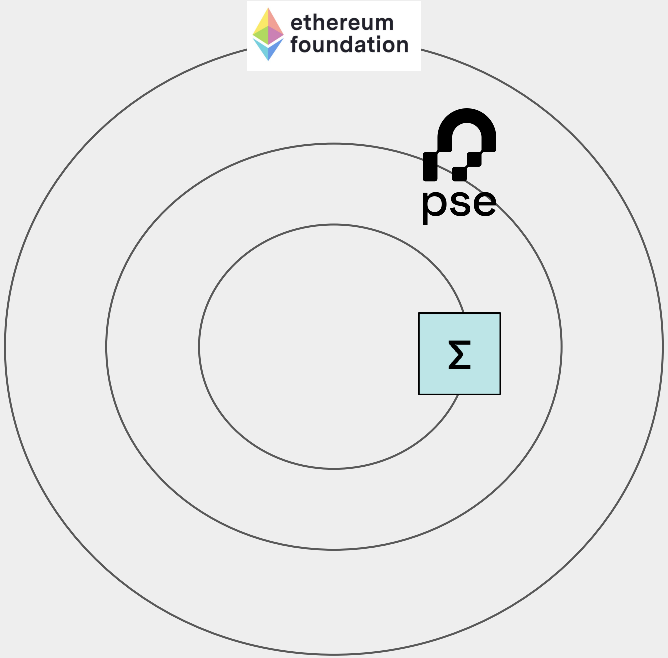
enrico.eth

Me

- Zero knowledge circuit engineer at Summa
- Previously at Polygon Hermez

Summa

- zk Proof of Solvency for CEXes



Goal : Understand zk in practice

#1 Context on ZK

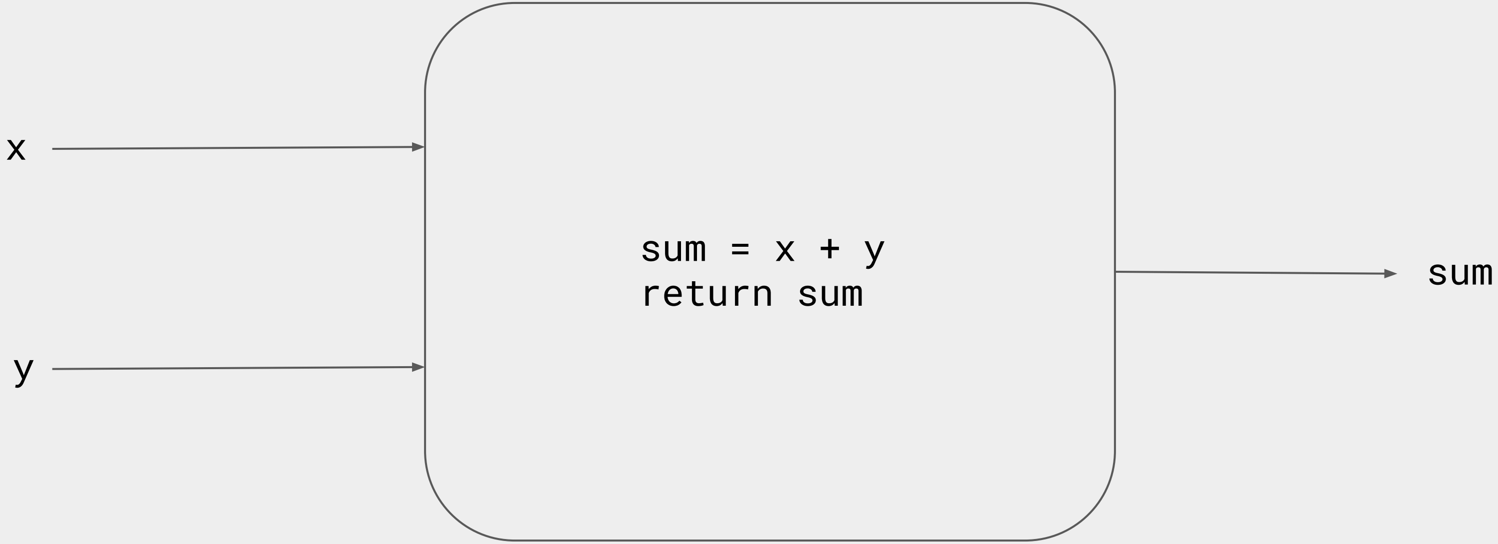
#2 Context on something practical

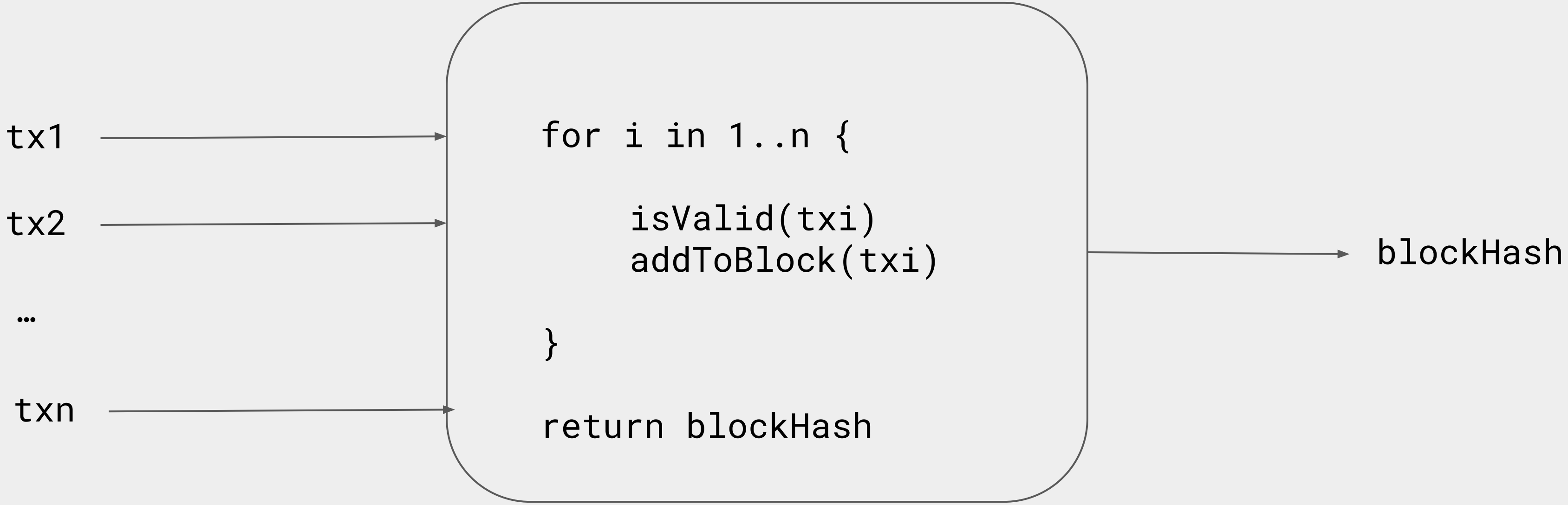
#3 Apply zk to something practical

#1 Context on ZK

Computation = set of rules

```
// Function that computes the sum of two numbers
function computeSum(x: number, y: number): number {
  // Rule 1: Compute the sum of 'x' and 'y' and return the result.
  const sum: number = x + y;
  return sum;
}
```

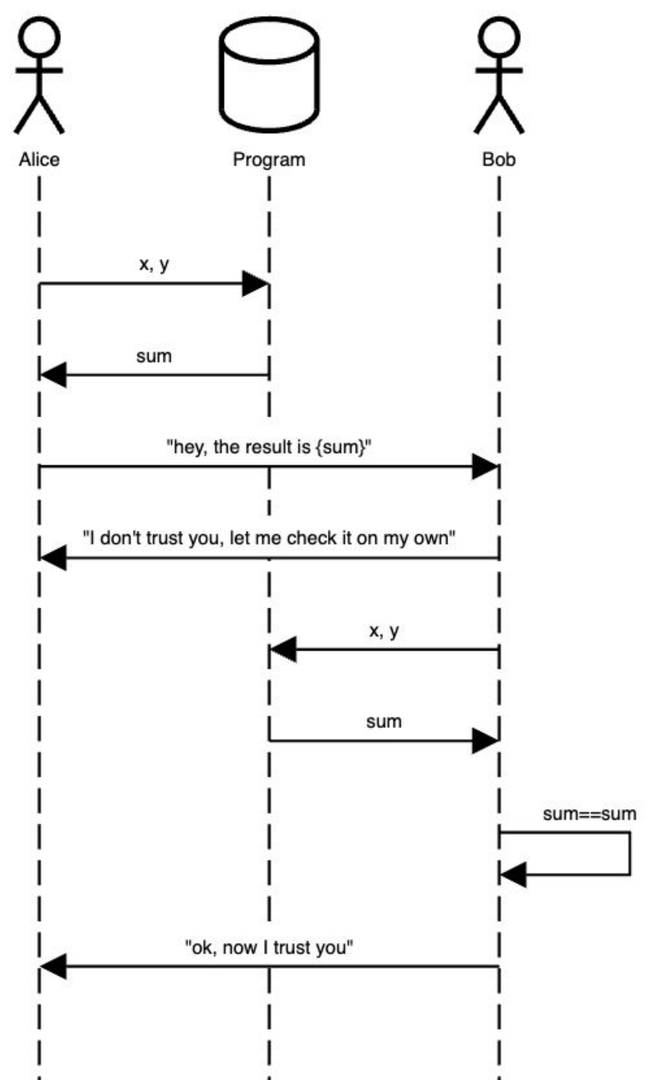

x
y
sum = x + y
return sum
sum


tx1
tx2
…
txn
for i in 1..n {
isValid(txi)
addToBlock(txi)
}
return blockHash
blockHash

Computational Integrity Guarantee

Given a computation which rules are known by everyone, a **prover** wants to prove that the output is the result of running the computation on certain inputs

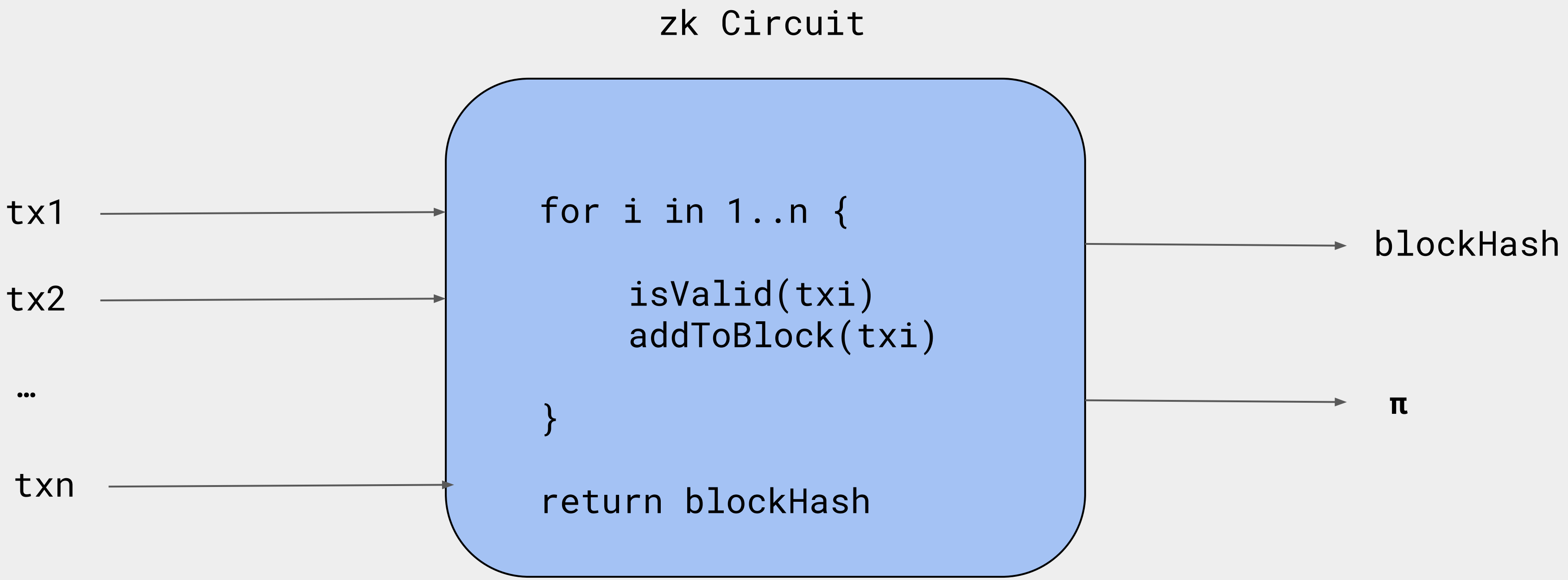
Traditional Prover Verifier dynamic

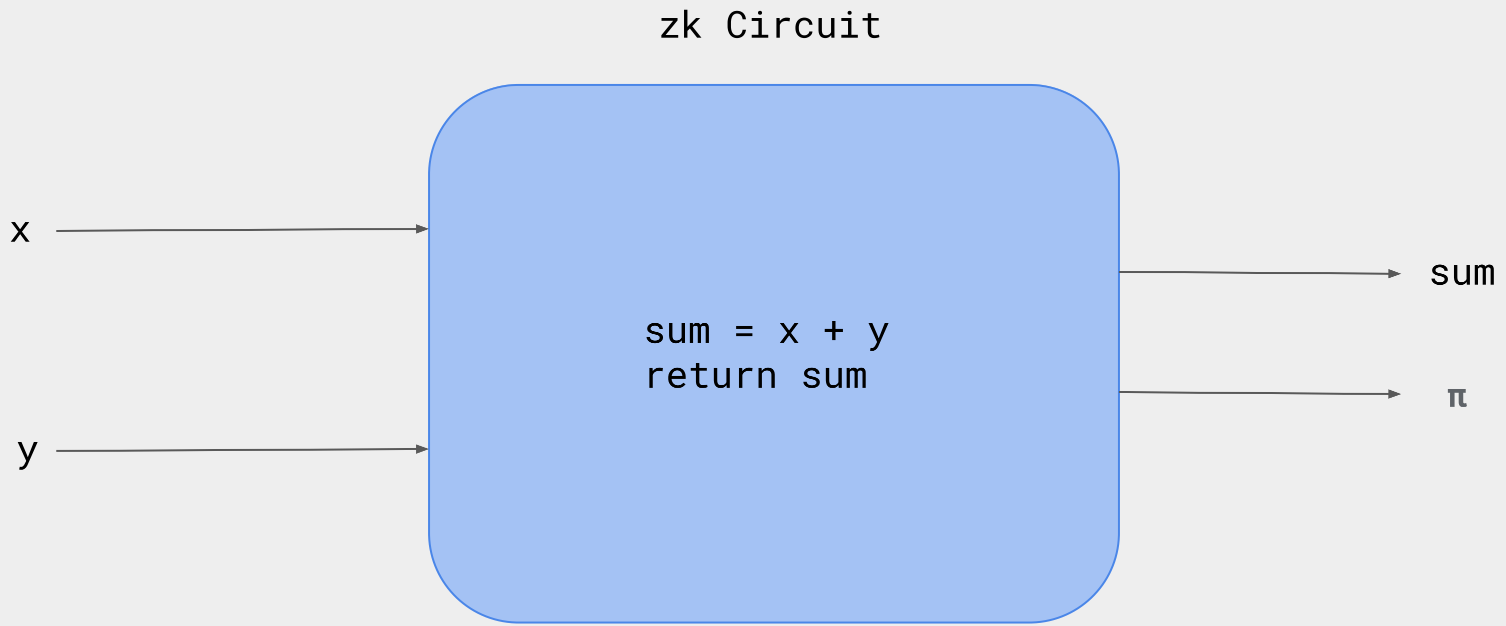


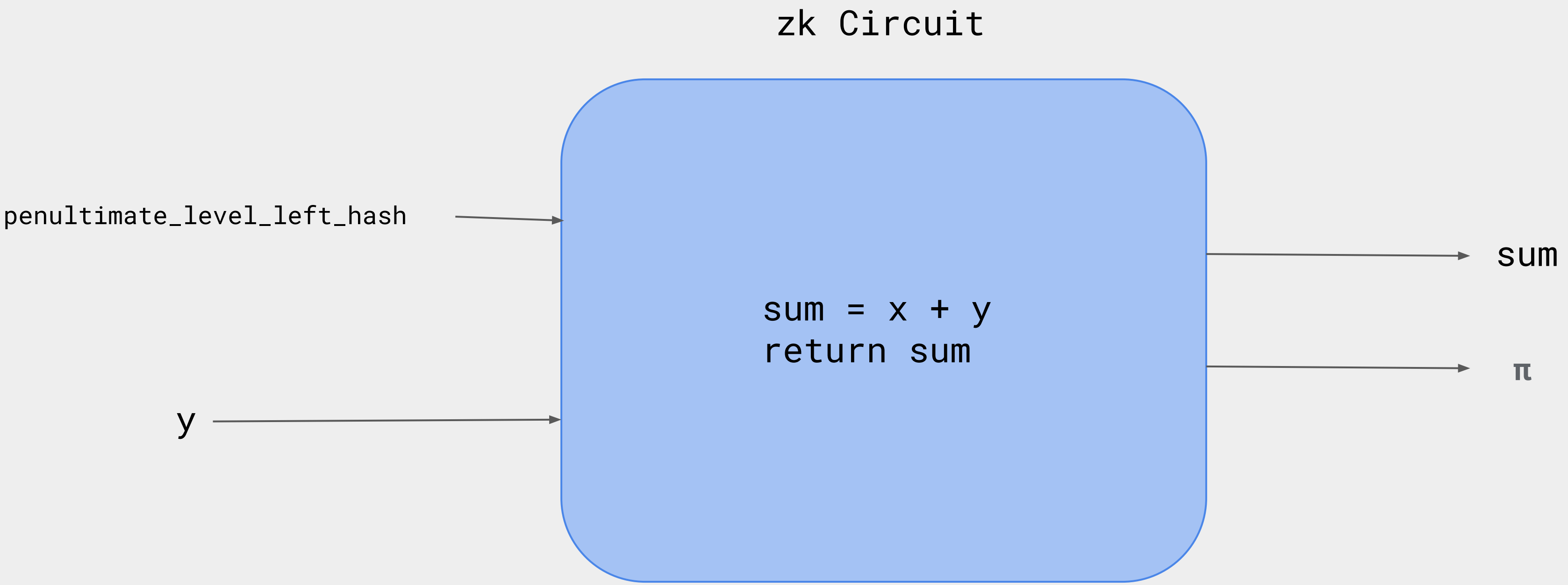
How to achieve Computational Integrity Guarantee?

- ➔ Verifier needs to rerun the computation with the same input and check that the output matches
- ➔ Issue #1: verification time is linear to the computation
- ➔ Issue #2: everything is public!

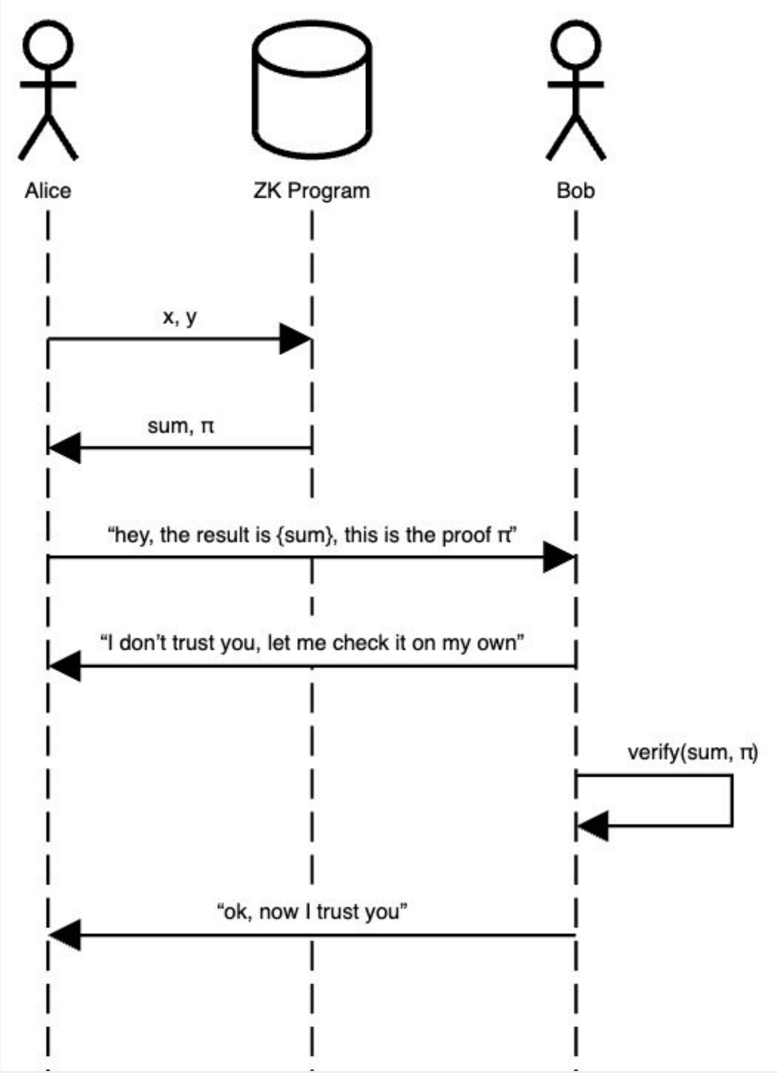
Enters ZK


zk Circuit
tx1
tx2
…
txn
for i in 1..n {
isValid(txi)
addToBlock(txi)
}
return blockHash
blockHash
π


zk Circuit
x
y
sum = x + y
return sum
sum
π


zk Circuit
penultimate_level_left_hash
y
sum = x + y
return sum
sum
π

ZK Prover Verifier dynamic

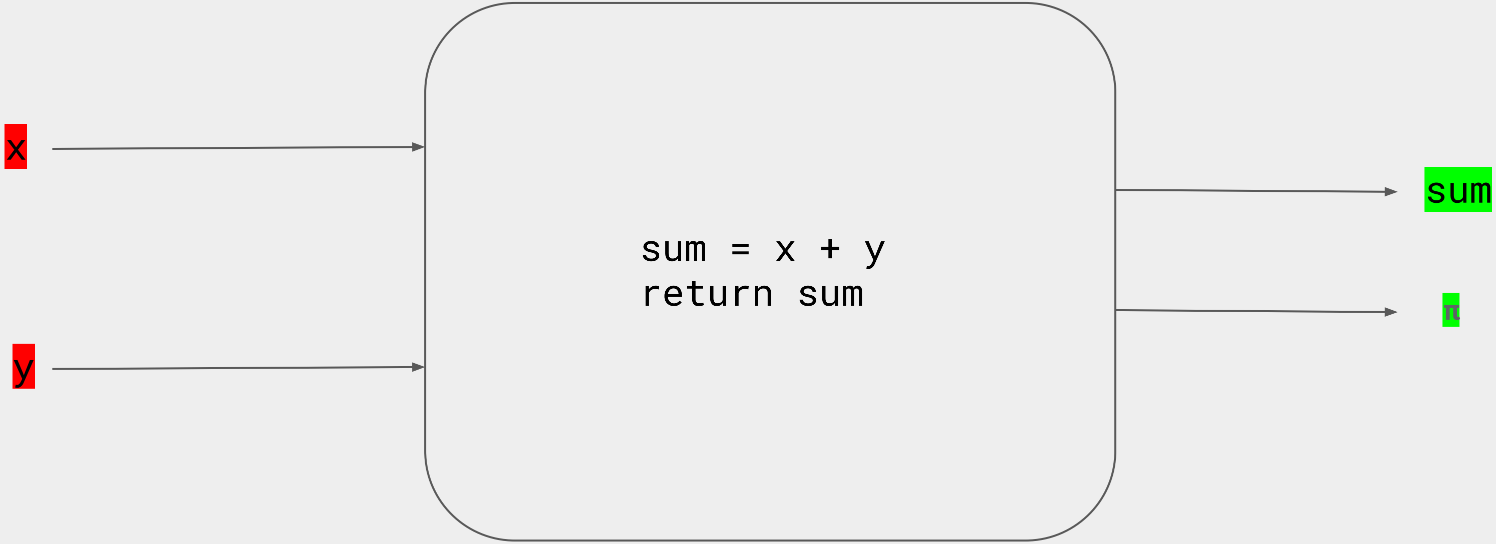


How to achieve Computational Integrity Guarantee?

- ➔ Verifier needs to run a verification algorithm on the proof π
- ➔ Solved Issue #1: verification time is constant no matter the time it took to run the computation
- ➔ Solved Issue #2: the prover can selectively decide what to keep private and what to keep public

How to achieve Computational Integrity Guarantee?

- Verifier needs to run a verification algorithm on the proof π
- Solved Issue #1: verification time is constant no matter the time it took to run the computation
- Solved Issue #2: the prover can selectively decide what to keep private and what to keep public
- New issue #1: Generating a proof for a computation is way slower than just running the computation
- New issue #2: Writing zk program is not as easy as writing a normal program


x
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#2 Context on Something Practical

Proof of Solvency

- Cryptographic proof that a CEX is solvent at a specific moment in time

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- Cryptographic proof that a CEX is solvent at a specific moment in time

Assets >= Liabilities

LIABILITIES

- Deposits of the users
- Denominated in ETH, BTC, USDC …
- Do not live on-chain, live in the CEX’s DB

ASSETS

- Cryptographic assets (ETH, BTC, USDC…) controlled by the CEX
- Live on-chain
- Should map (at least) 1:1 the deposits of the users

LIABILITIES

- Deposits of the users
- Denominated in ETH, BTC, USDC …
- Do not live on-chain, live in the CEX’s DB

Proof Of Solvency

- Cryptographic proof that a CEX is solvent at a specific moment in time

Assets >= Liabilities

Users are confident that they can withdraw at any time

#3 Apply ZK to something practical

Summa: ZK Proof of Solvency

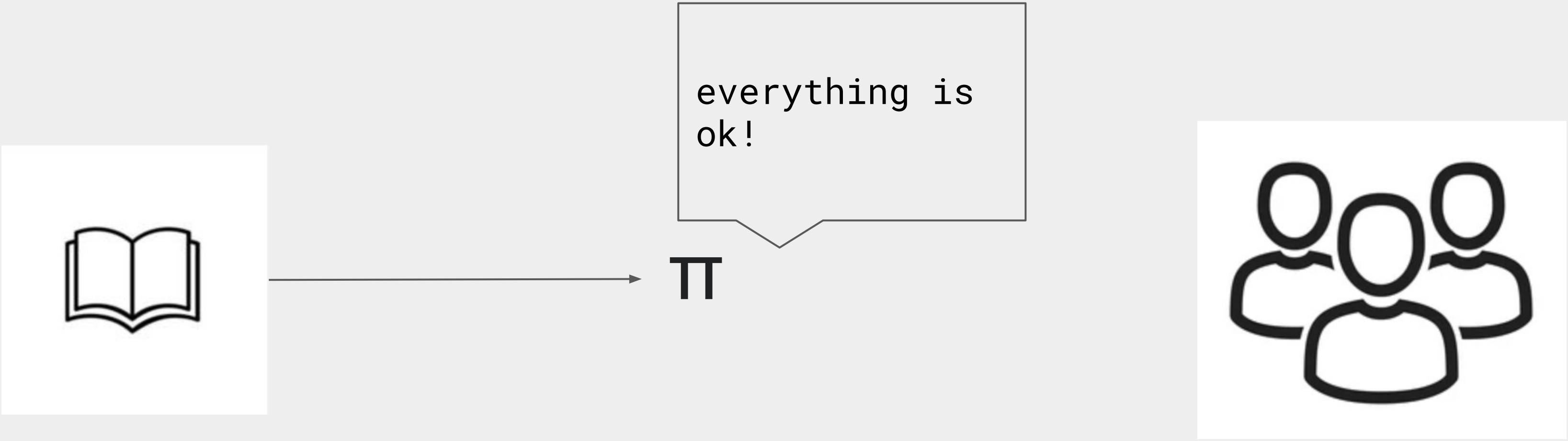
auditor-based proof of solvency

everything is ok!

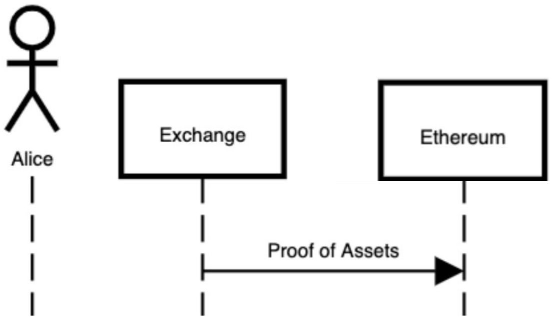
auditorless proof of solvency (naive approach)

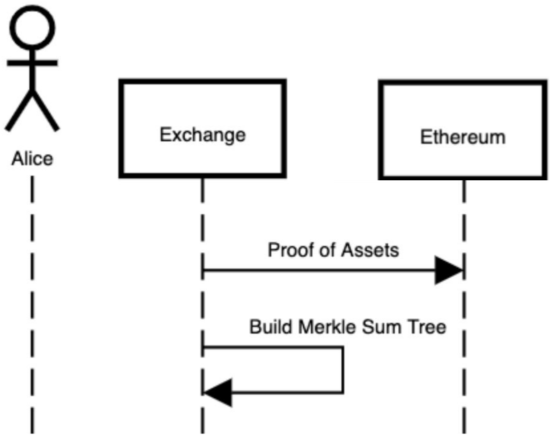
everything is ok!

auditorless proof of solvency
(ZK approach)



How?


Alice
Exchange
Ethereum
Proof of Assets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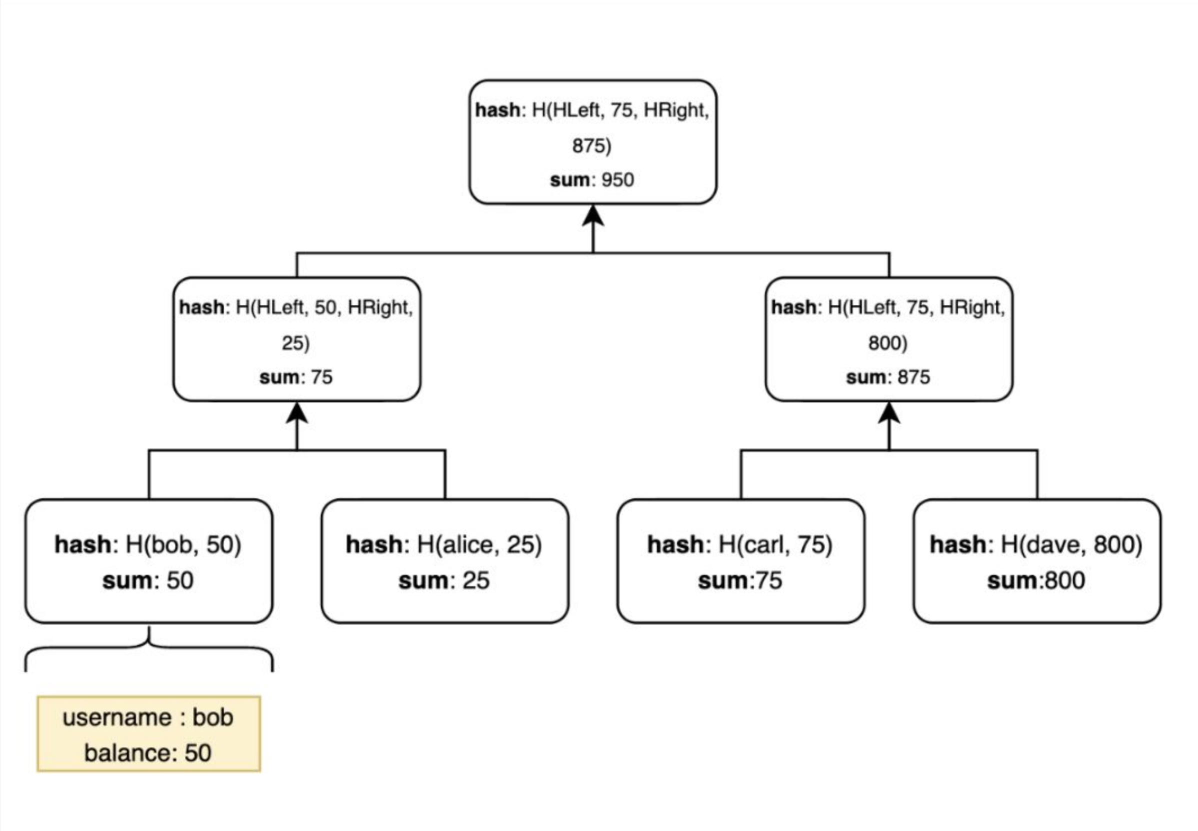
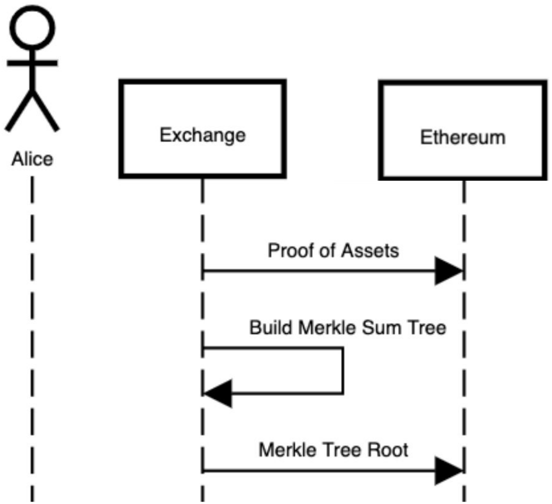
Proof of Assets
Build Merkle Sum Tree

Merkle Sum Tree



- The entries are the users' data (= liabilities)
- Lives off-chain
- Only the root-hash gets published on-chain



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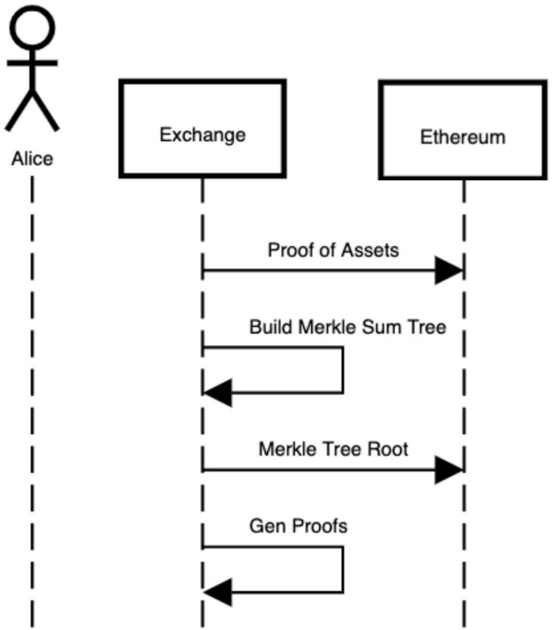
Proof of Assets
Build Merkle Sum Tree
Merkle Tree Root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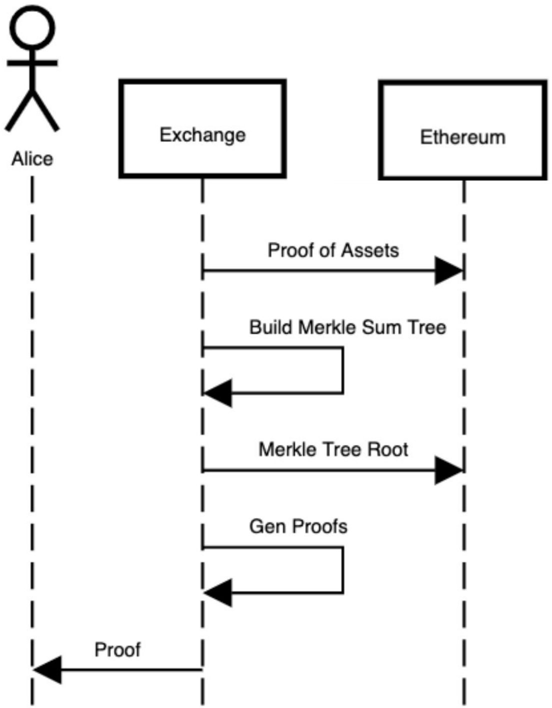
Build Merkle Sum Tree
Merkle Tree Root
Gen Proofs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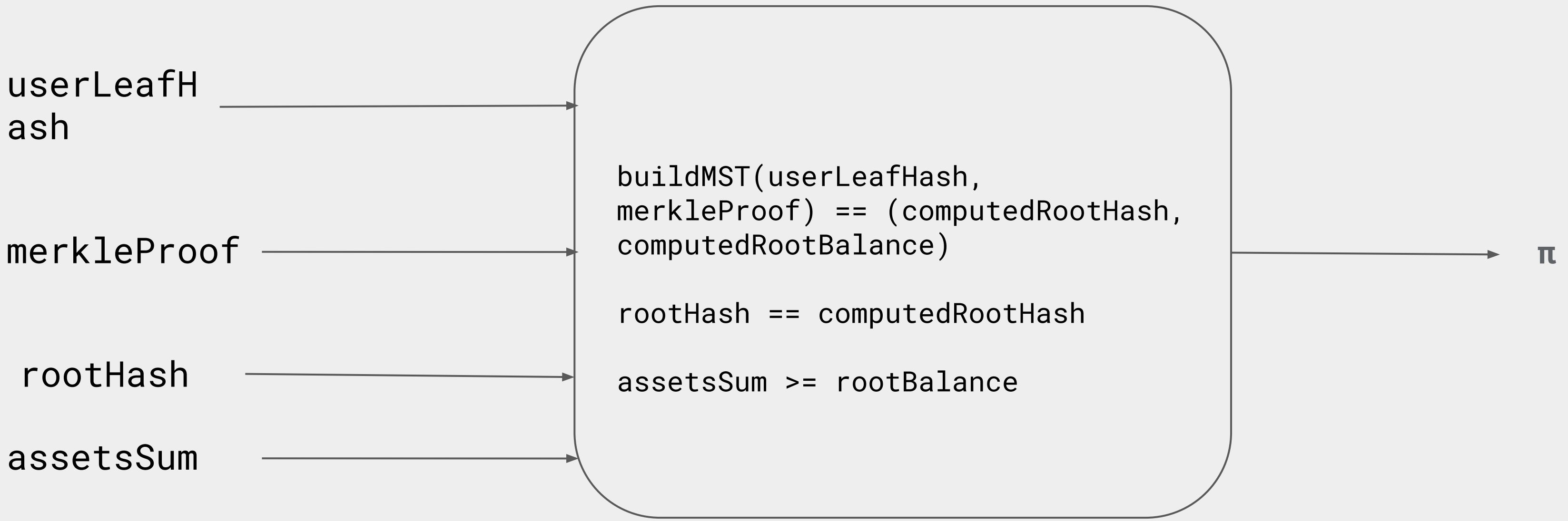
Gen Proofs
Proof

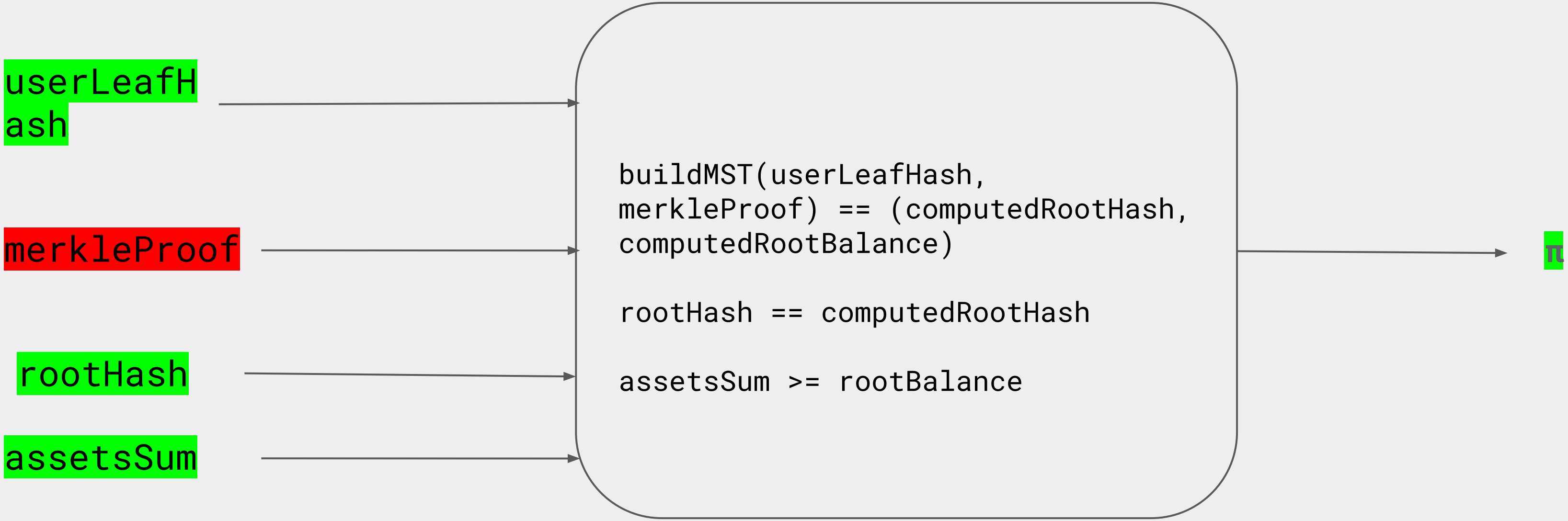
Zk Proofs - Program Rules

- ➔ Rule#1: The user (identified by its username) is included in the Merkle Sum Tree with the correct balance
- ➔ Rule#2: The hash of the Merkle Sum Tree matches the one committed on chain
- ➔ Rule#3: The sum of liabilities is Less Than the assets of the exchange (as committed in step 1)
- ➔ Rule#4: No sum overflow happened in the merkle sum tree computation


userLeafH
ash
merkleProof
rootHash
assetsSum
buildMST(userLeafHash,
merkleProof) == (computedRootHash,
computedRootBalance)
rootHash == computedRootHash
assetsSum >= rootBalance
π

Zk Proofs - secrecy

- Other users information such as their balances and usernames
- Total number of users
- Total amount of liabilities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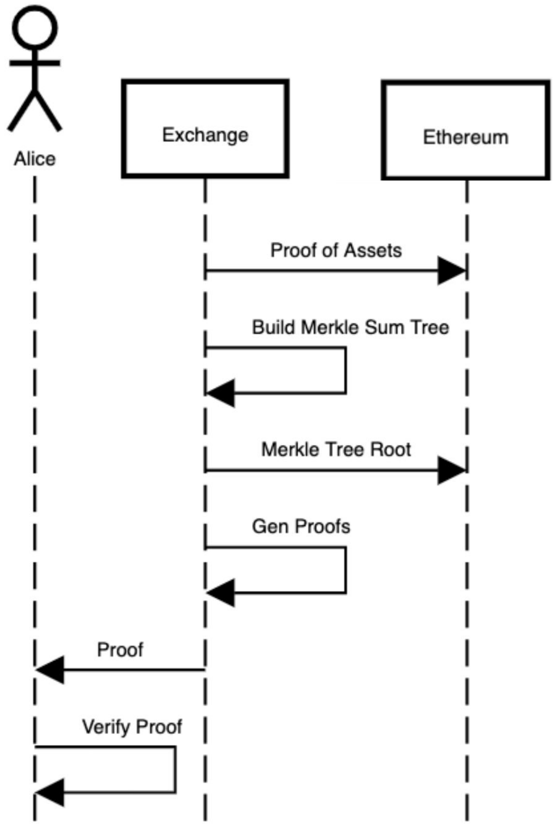
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Proof of Assets
Build Merkle Sum Tree
Merkle Tree Root
Gen Proofs
Proof
Verify Proof

Proof Verification

$F(\pi, username, balance, assetsSum, rootHash) = yes/no$

Conclusions

- How to think of zk apps: the mental model
  - Given a computation which rules are known by everyone, a prover wants to prove that the output is the result of running the computation on certain inputs, without revealing (part of) the input of such computation
- How to build zk apps
  - Building zk apps means writing circuits. Circom is the best tool to get started

Thank you!

me on github