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December 05, 2024

Distributed Lab

zkdl-camp.github.io

github.com/ZKDL-Camp

Plan

Introduction

Why do we need ZK?

Option

Solution to privacy

Example

1. *I know the private key that corresponds to this public key*
2. *I know a private key that corresponds to a public key from this list*

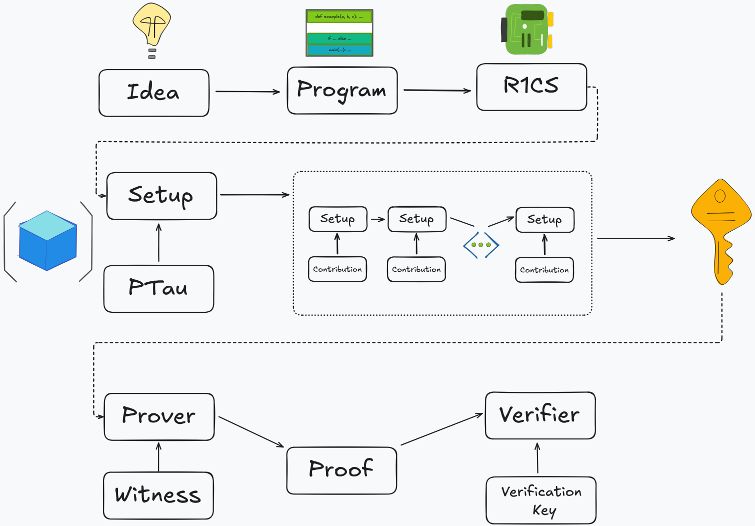
Option

Solution to scalability

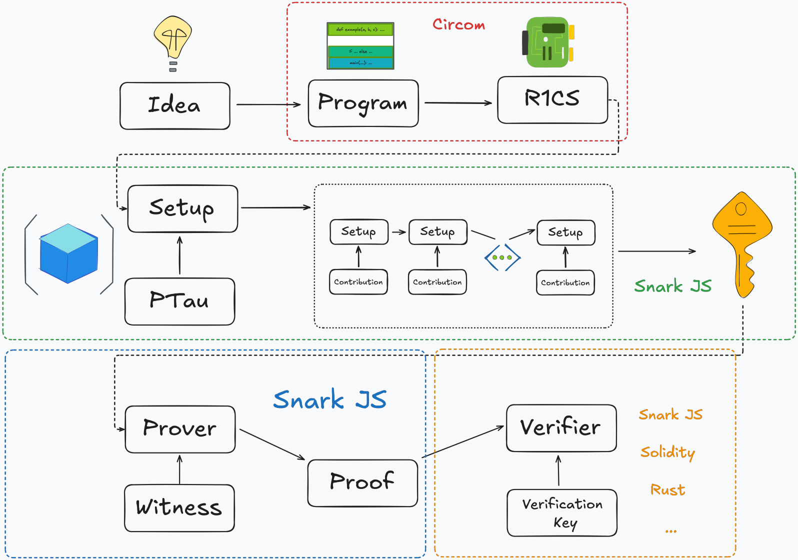
Example

This is the hash of a blockchain block that does not produce negative balances

Using ZKP


Idea
Program
R1CS
Setup
PTau
Setup
Setup
Setup
Contribution
Contribution
Contribution
Prover
Witness
Proof
Verifier
Verification Key

Toolchain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def example(a, b, c): ....
if ... else ...
main(...): ...
Idea
Program
R1CS
Setup
PTau
Setup
Setup
Setup
Contribution
Contribution
Contribution
Snark JS
Snark JS
Prover
Witness
Proof
Verifier
Verification Key
Snark JS
Solidity
Rust
...

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Probably you can recall the function

```
def r(x1: F, x2: F, x3: F) -> F:
    return x2 * x3 if x1 else x2 + x3
```

That can be expressed as:

$$r = x_1 \times (x_2 \times x_3) + (1 - x_1) \times (x_2 + x_3)$$

We need a boolean restriction for x_1:

$$x_1 \times (1 - x_1) = 0$$

Thus, the next constraints can be build:

$$x_1 \times x_1 = x_1 \quad \text{(binary check)} \tag{1}$$

$$x_2 \times x_3 = \text{mult} \tag{2}$$

$$x_1 \times \text{mult} = \text{selectMult} \tag{3}$$

$$(1 - x_1) \times (x_2 + x_3) = r - \text{selectMult} \tag{4}$$

Previously on ZKDL Camp

The witness vector: $\boldsymbol{w} = (1, r, x_1, x_2, x_3, \text{mult}, \text{selectMult})$. The coefficients vectors:

$$\begin{aligned}
\boldsymbol{a}_1 &= (0,0,1,0,0,0,0), & \boldsymbol{b}_1 &= (0,0,1,0,0,0,0), & \boldsymbol{c}_1 &= (0,0,1,0,0,0,0) \\
\boldsymbol{a}_2 &= (0,0,0,1,0,0,0), & \boldsymbol{b}_2 &= (0,0,0,0,1,0,0), & \boldsymbol{c}_2 &= (0,0,0,0,0,1,0) \\
\boldsymbol{a}_3 &= (0,0,1,0,0,0,0), & \boldsymbol{b}_3 &= (0,0,0,0,0,1,0), & \boldsymbol{c}_3 &= (0,0,0,0,0,0,1) \\
\boldsymbol{a}_4 &= (1,0,-1,0,0,0,0), & \boldsymbol{b}_4 &= (0,0,0,1,1,0,0), & \boldsymbol{c}_4 &= (0,1,0,0,0,0,-1)
\end{aligned}$$

Using the arithmetic in a large $\mathbb{F}_p$, consider the following values:

$$x_1 = 1, \quad x_2 = 3, \quad x_3 = 4$$

Verifying the constraints:

1. $x_1 \times x_1 = x_1 \quad (1 \times 1 = 1)$
2. $x_2 \times x_3 = \text{mult} \quad (3 \times 4 = 12)$
3. $x_1 \times \text{mult} = \text{selectMult} \quad (1 \times 12 = 12)$
4. $(1 - x_1) \times (x_2 + x_3) = r - \text{selectMult} \quad (0 \times 7 = 12 - 12)$

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By Groth16 Protocol the verifier should check the following condition:

$$e(\pi_L, \pi_R) = e(g_1^{\alpha}, g_2^{\beta}) e(\pi_{\text{io}}, g_2^{\gamma}) e(\pi_O, g_2^{\delta})$$

Recall

For BN254 (BN128), we have:

- Left inputs to e is of form $(x, y) \in \mathbb{G}_1$ — regular curve.
- Right inputs to e is of form $((x_1, y_1), (x_2, y_2)) \in \mathbb{G}_2$ — "complex" curve, consisting of two $\mathbb{F}_{p^2}$ coordinates.
- $e(g_1^{\alpha}, g_2^{\beta})$ is of form $(x_1, \dots, x_{12}) \in \mathbb{F}_{p^{12}}$

Thank you for your attention

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