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[Don‘t] share your data.

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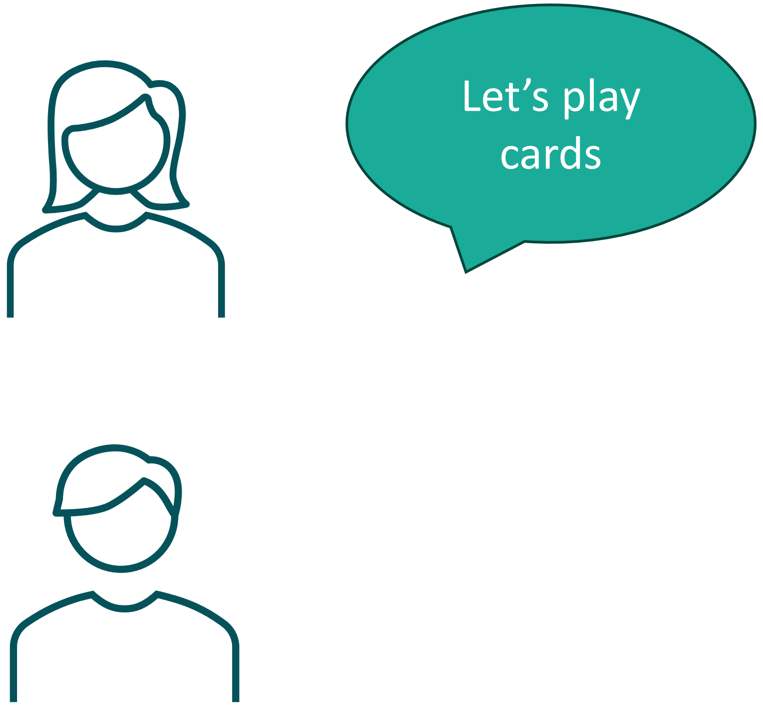
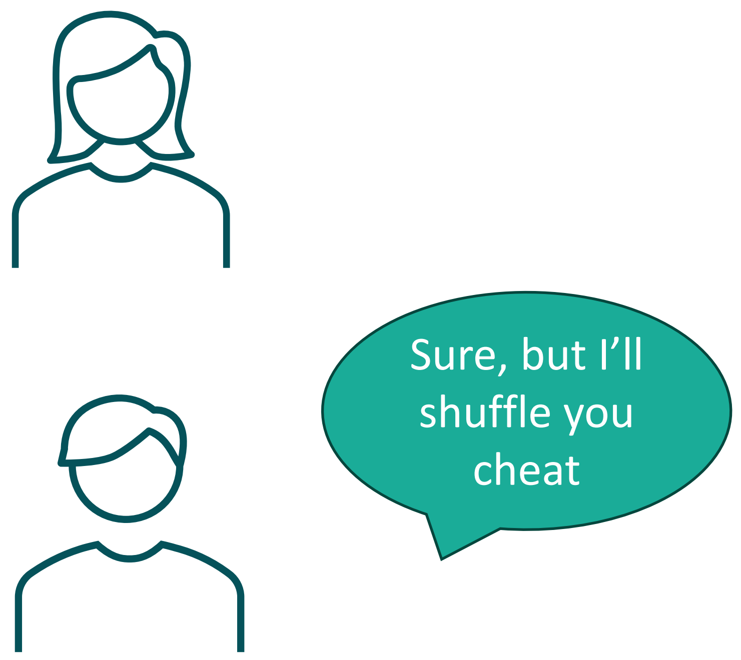
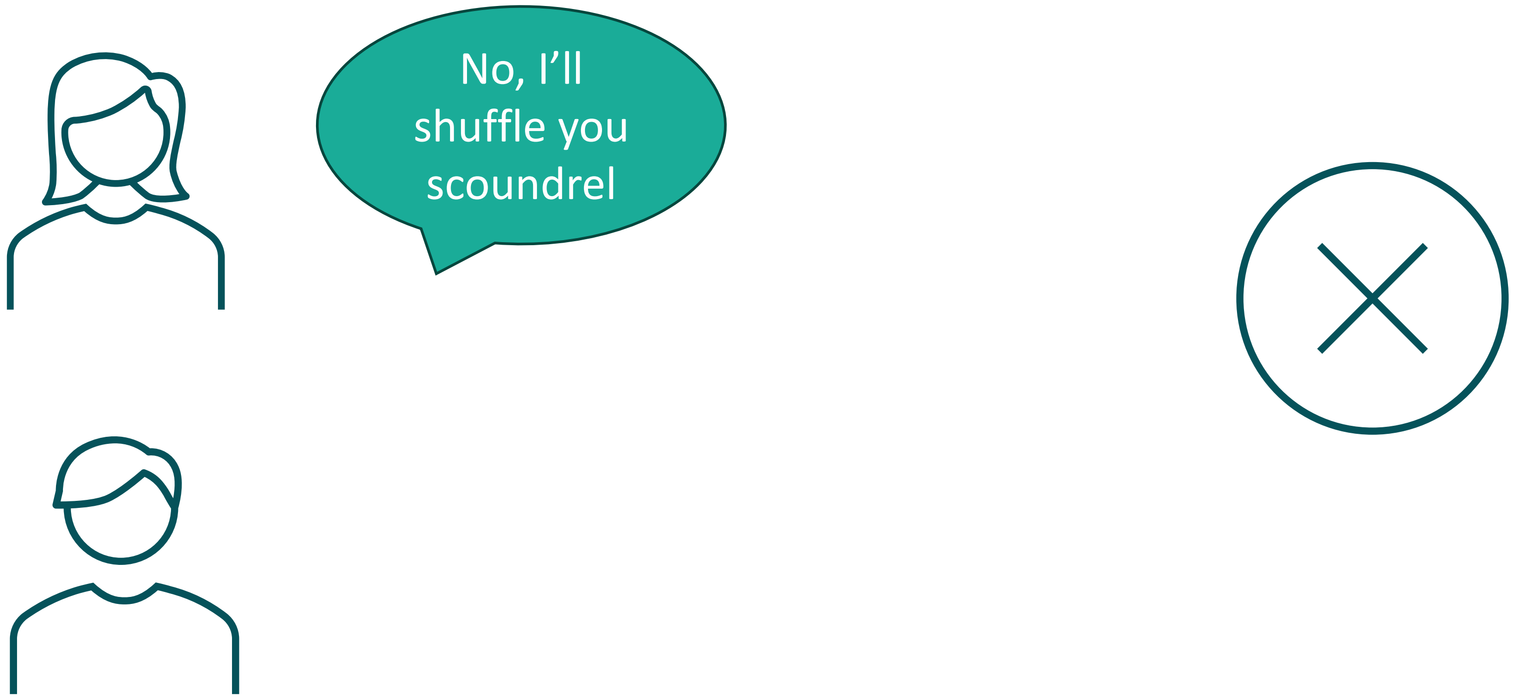
github.com/TaceoLabs/noir_workshop_0625/

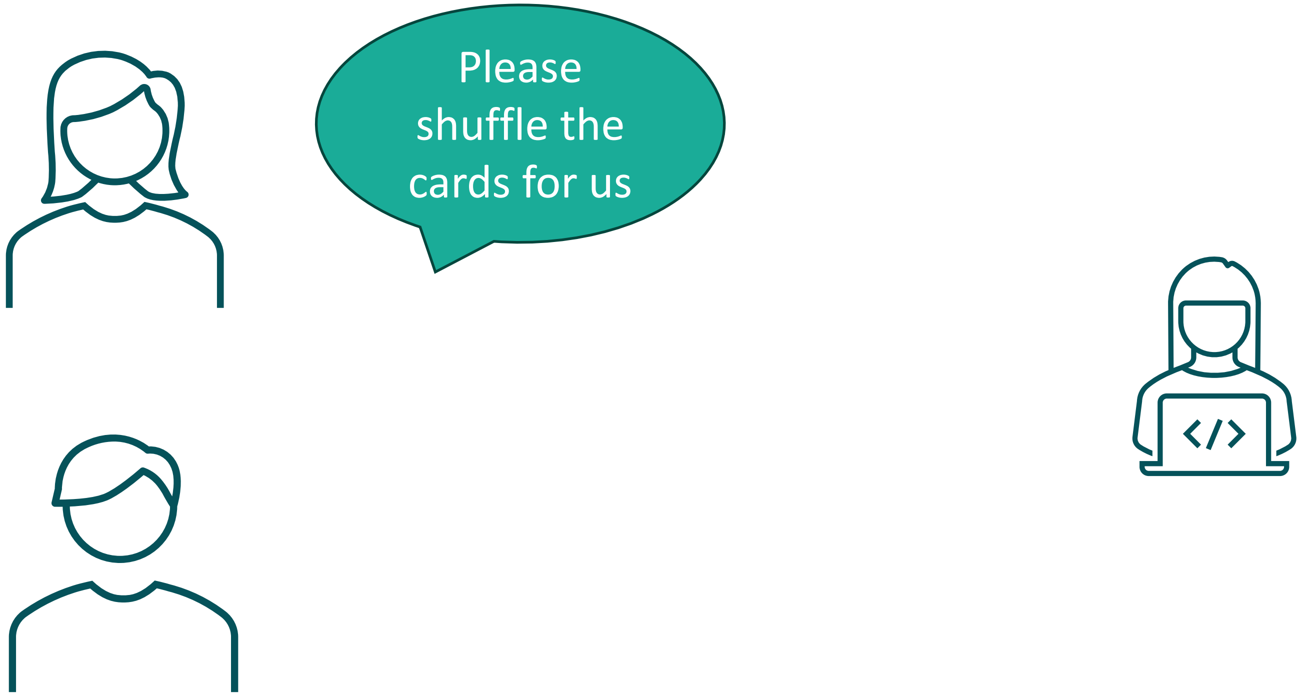
Building a coSNARK-powered DApp with coNoir

Shuffling Cards with MPC


Let’s play cards


Sure, but I’ll shuffle you cheat


No, I'll shuffle you scoundrel


Please shuffle the cards for us

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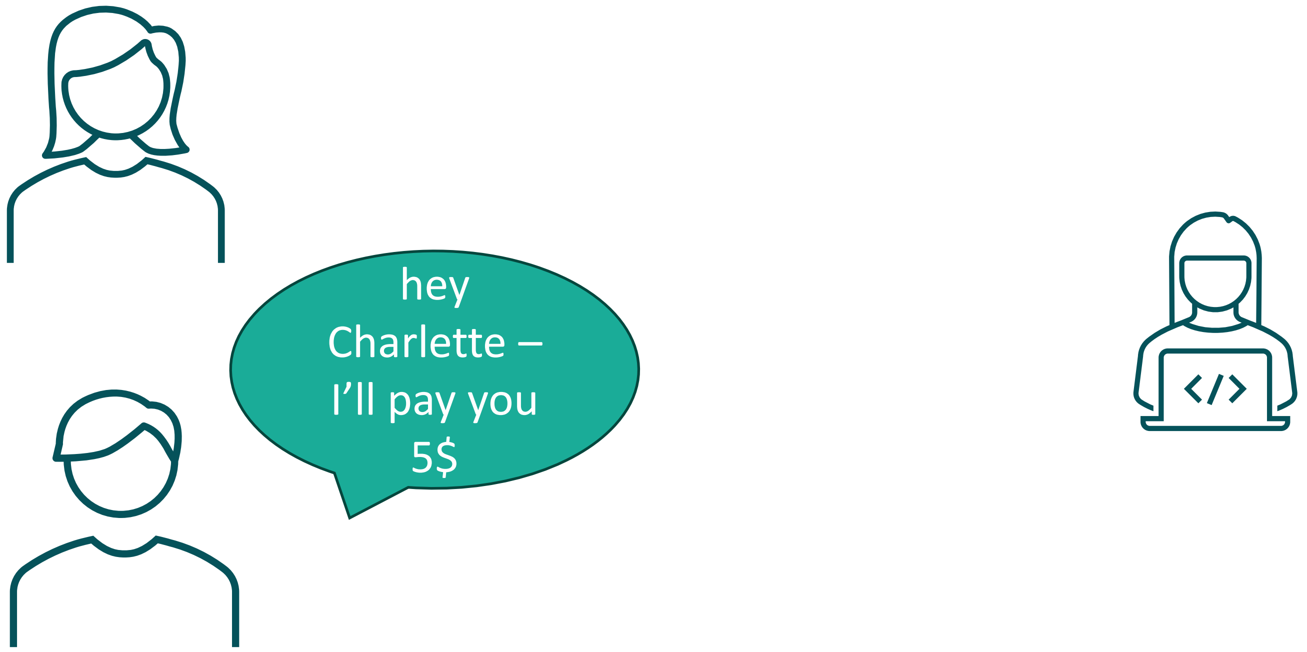
hey Charlette – I'll pay you 5$

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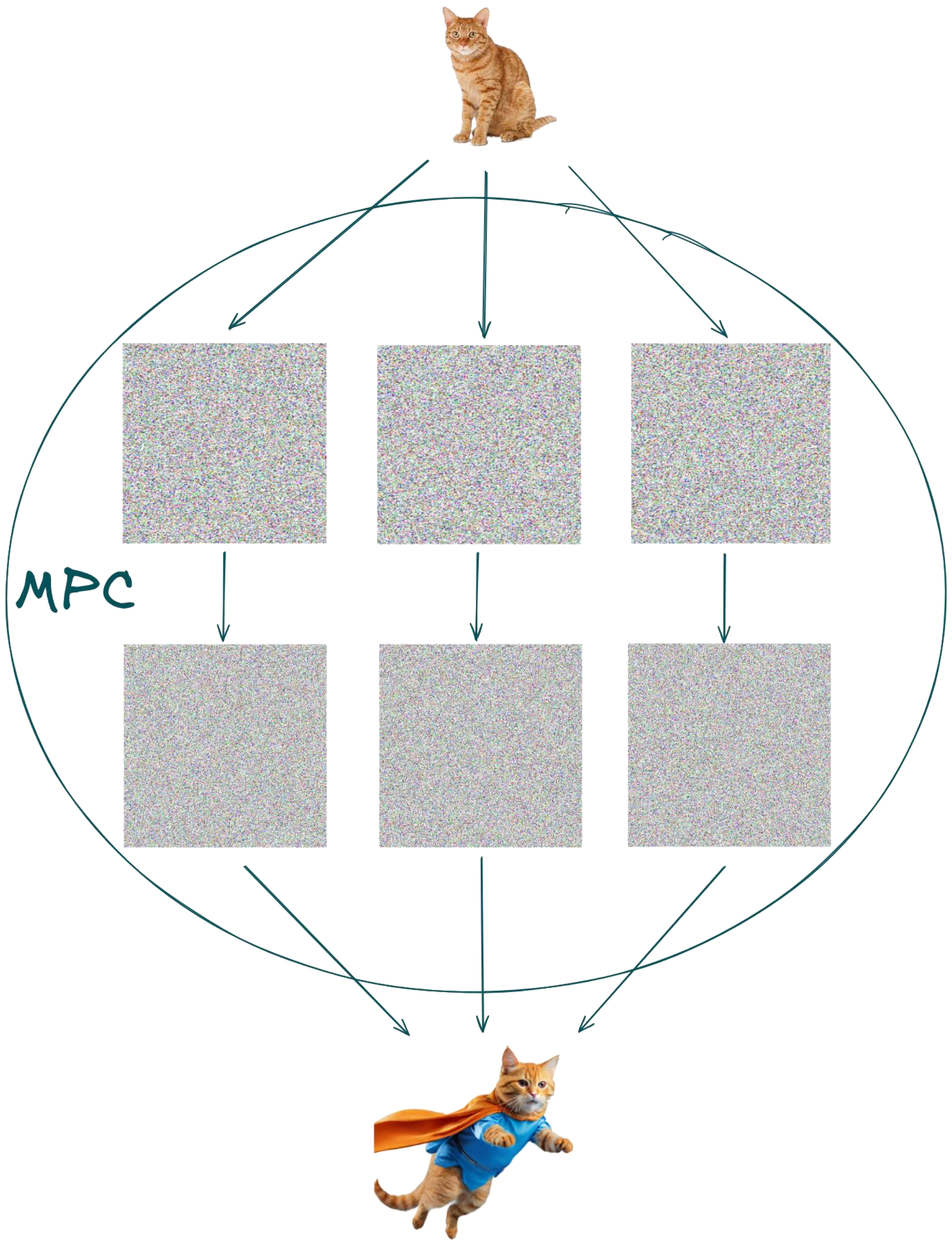
What now?

Private State only gets you that far


MPC

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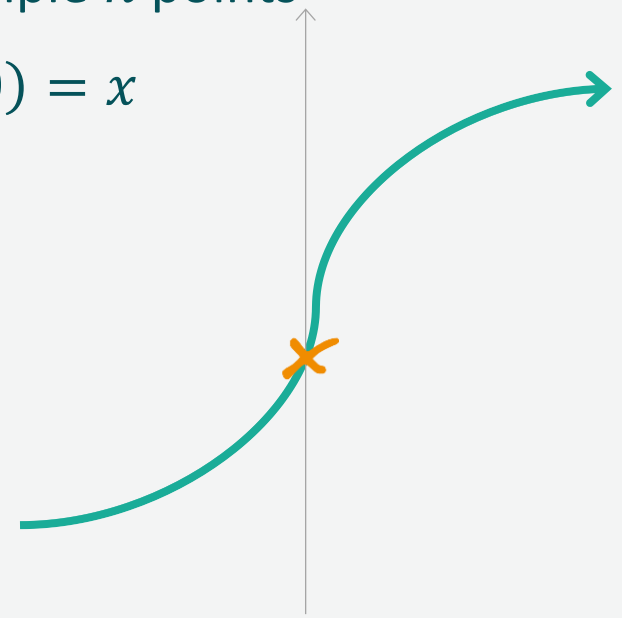
How to share a secret?

Shamir Secret Sharing

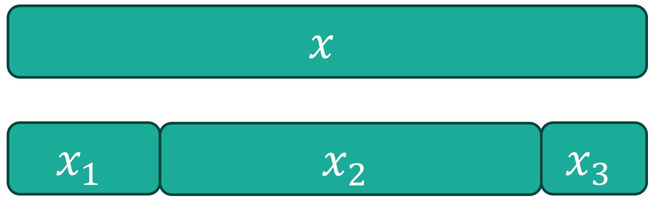
- Polynomial $f(X)$ of degree d
- Sample n points
- $f(0) = x$



Additive Secret Sharing

- Split x in n parts

$$\sum_{n} x_i = x$$



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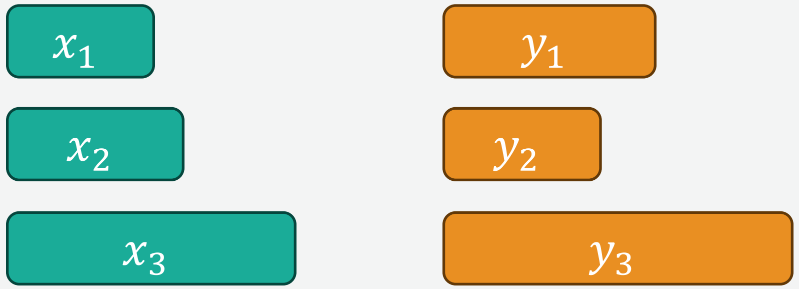
Computing on secrets

Addition

Two secrets x and y



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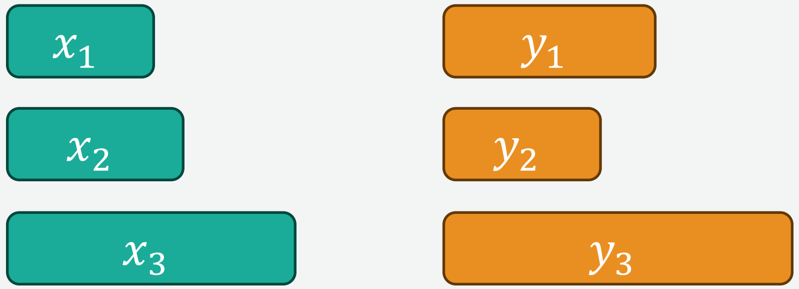
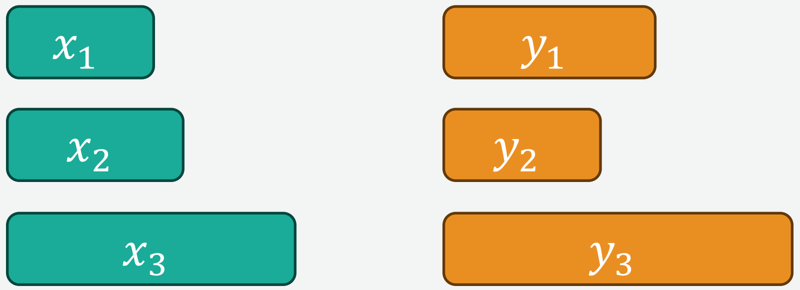


$$\begin{matrix} x_1 + y_1 \\ x_2 + y_2 \\ x_3 + y_3 \end{matrix} \quad = x + y$$

Computing on secrets

Addition

Two secrets x and y



$$\begin{matrix} x_1 + y_1 \\ x_2 + y_2 \\ x_3 + y_3 \end{matrix} \quad = x + y$$

Multiplication

?

Non-linear Operations

- Beaver triples
  - Generate helper triples $([\mathrm{a}], [\mathrm{b}], [c])$ and $ab = c$
  - Open $[a + x] = A$ and $[b + y] = B$
  - Compute $A[y] - B\,[a] + [c] = [xy]$

Non-linear Operations

- Beaver triples
  - Generate helper triples $([\mathrm{a}], [\mathrm{b}], [c])$ and $ab = c$
  - Open $[a + x] = A$ and $[b + y] = B$
  - Compute $A[y] - B\ [a] + [c] = [xy]$
- Replicated Secret Sharing (2 out of 3 sharing)
  - Parties hold two shares instead of one
  - Every party computes $x_a y_a + x_a y_b + x_b y_a + m$, where $m = [0]$
  - Reshare result

Great – what now?

zkSNARKs 101

Succinct proof for computational integrity

Keeping secret input hidden (potentially)

MPC 101

Mutually untrusting parties jointly compute a function

Inputs and intermediate values private (secret-shared)

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What are coSNARKs?

Zero-Knowledge

MPC

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What are coSNARKs?

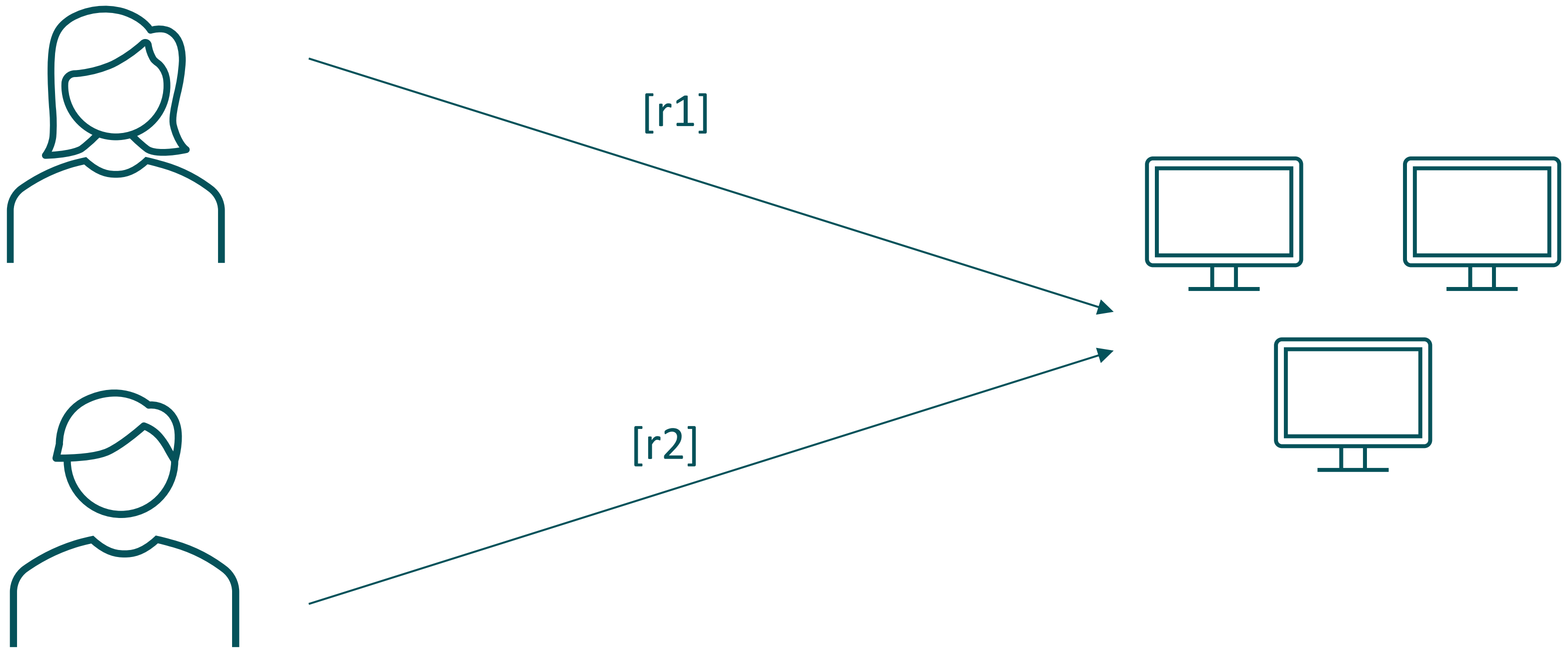
Zero-Knowledge + MPC = co-SNARKs

Co-SNARK 101

Mutually untrusting parties jointly compute a function

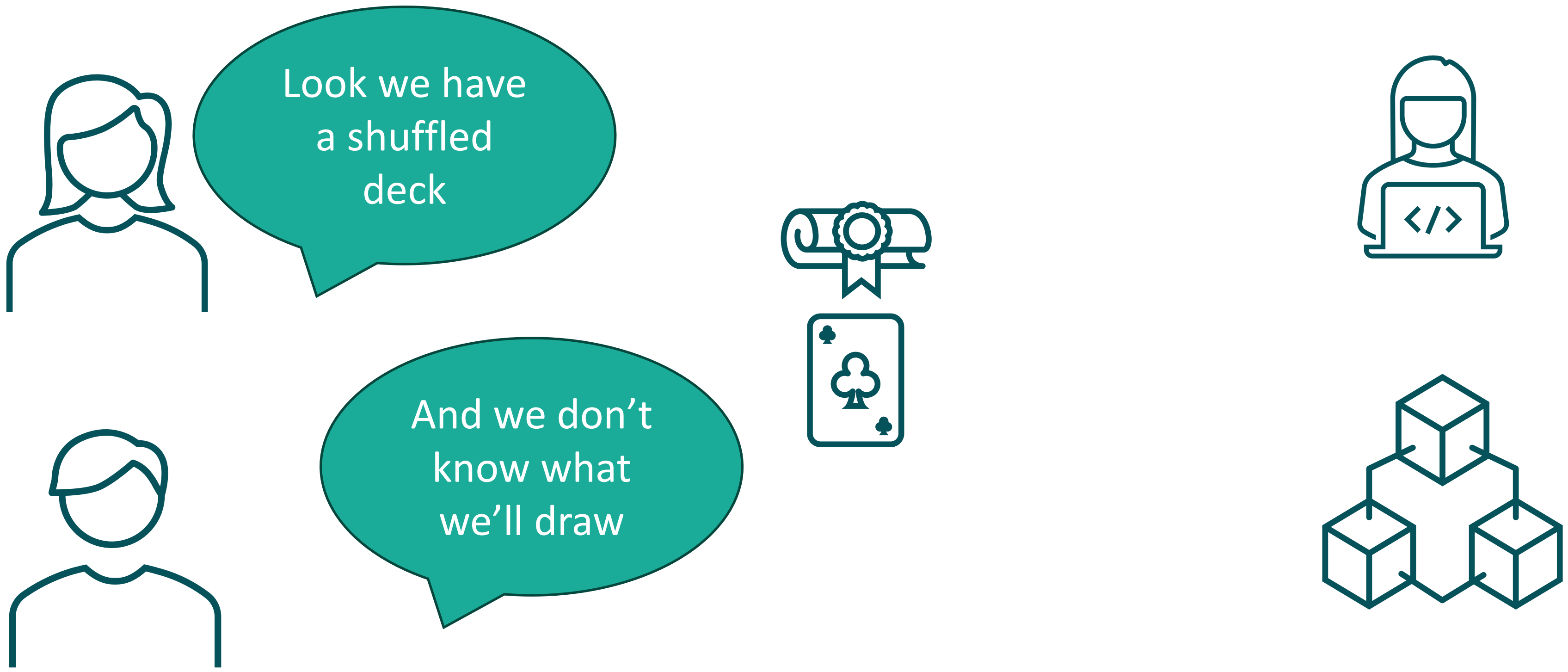
Succinct proof for computational integrity

Keeping secret inputs and intermediate values hidden


[r1]
[r2]

Here is a shuffled deck and a proof

Look we have a shuffled deck
And we don't know what we'll draw


Look we have a shuffled deck
And we don't know what we'll draw

We are done, right?

Let’s think this through

Let’s think this through

Playing a game of cards

- Shuffled the deck

Let’s think this through

Playing a game of cards

- Shuffled the deck
- Only distribute cards to respective players (verifiable encryption)

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Let’s think this through

Playing a game of cards

- Shuffled the deck
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→ No one knows the structure of deck!

Let’s think this through

Playing a game of cards

- Shuffled the deck
- Only distribute cards to respective players (verifiable encryption)

→ No one knows the structure of deck!

Private Shared State

- Not simply composing Alice and Bobs private state
- We generate new private state that nobody knows
- But: No input verification so far!

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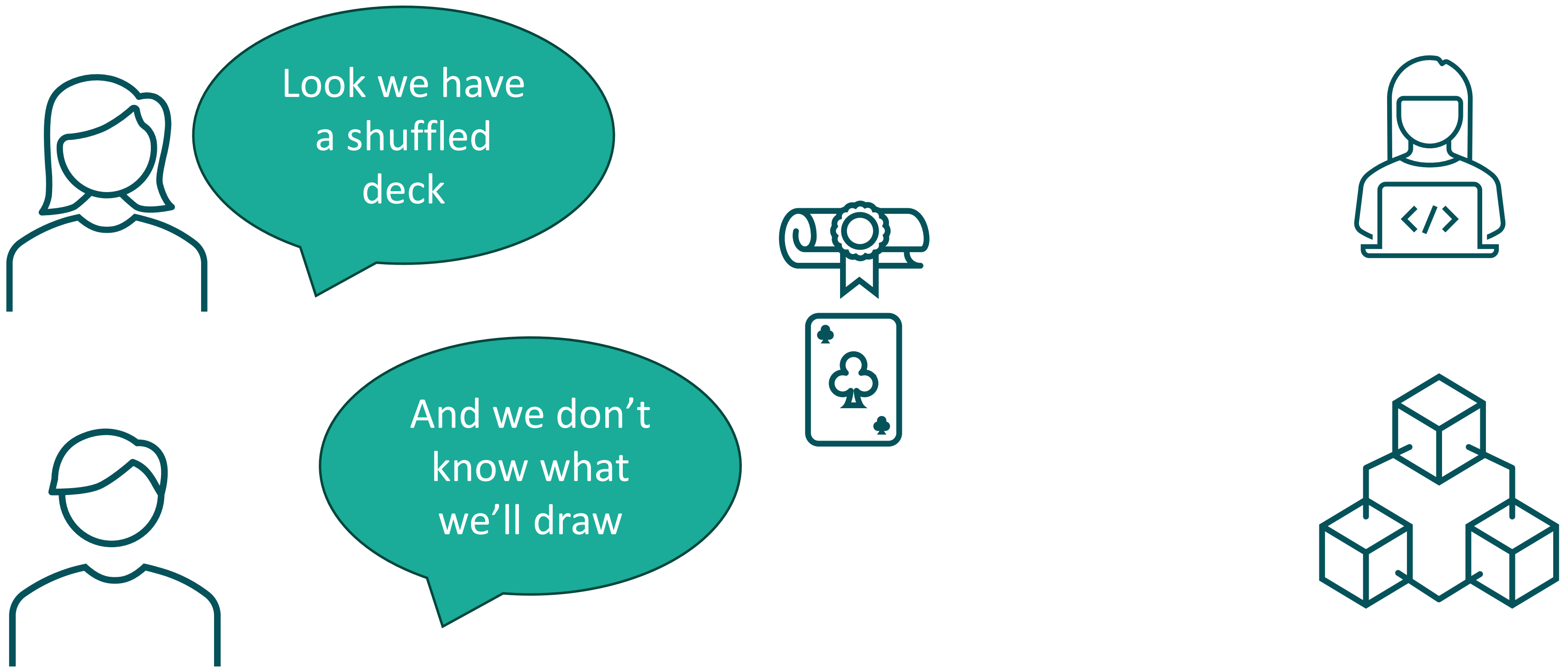
Look we have a shuffled deck
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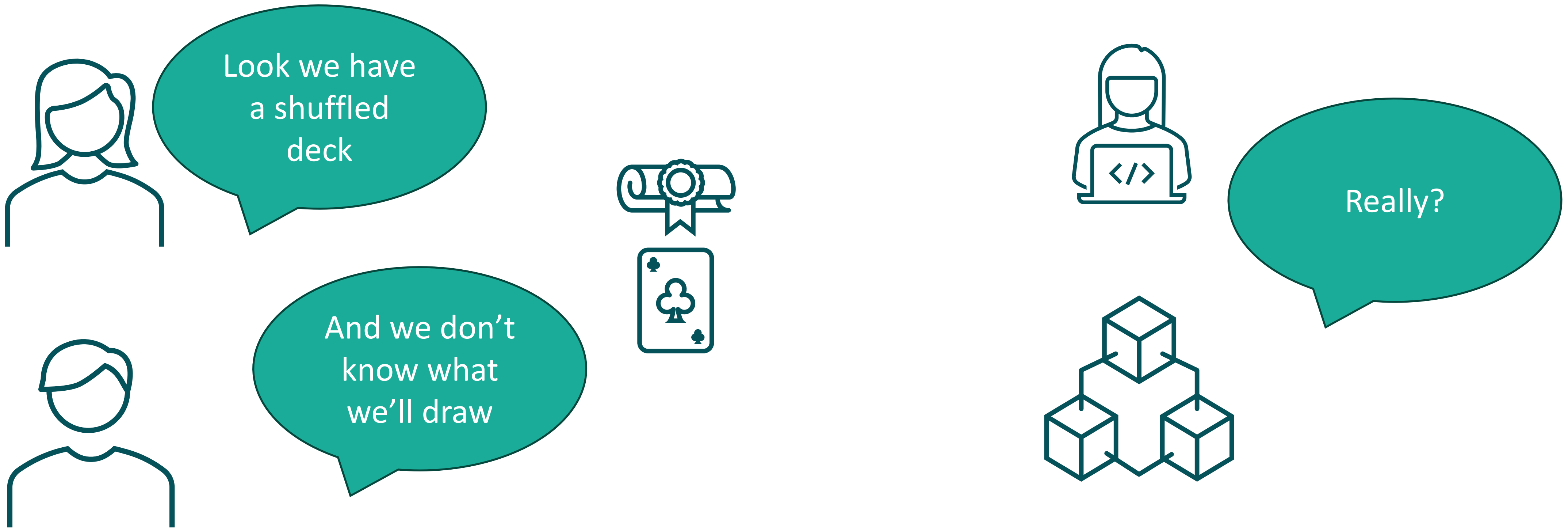
Look we have a shuffled deck
And we don't know what we'll draw
Really?

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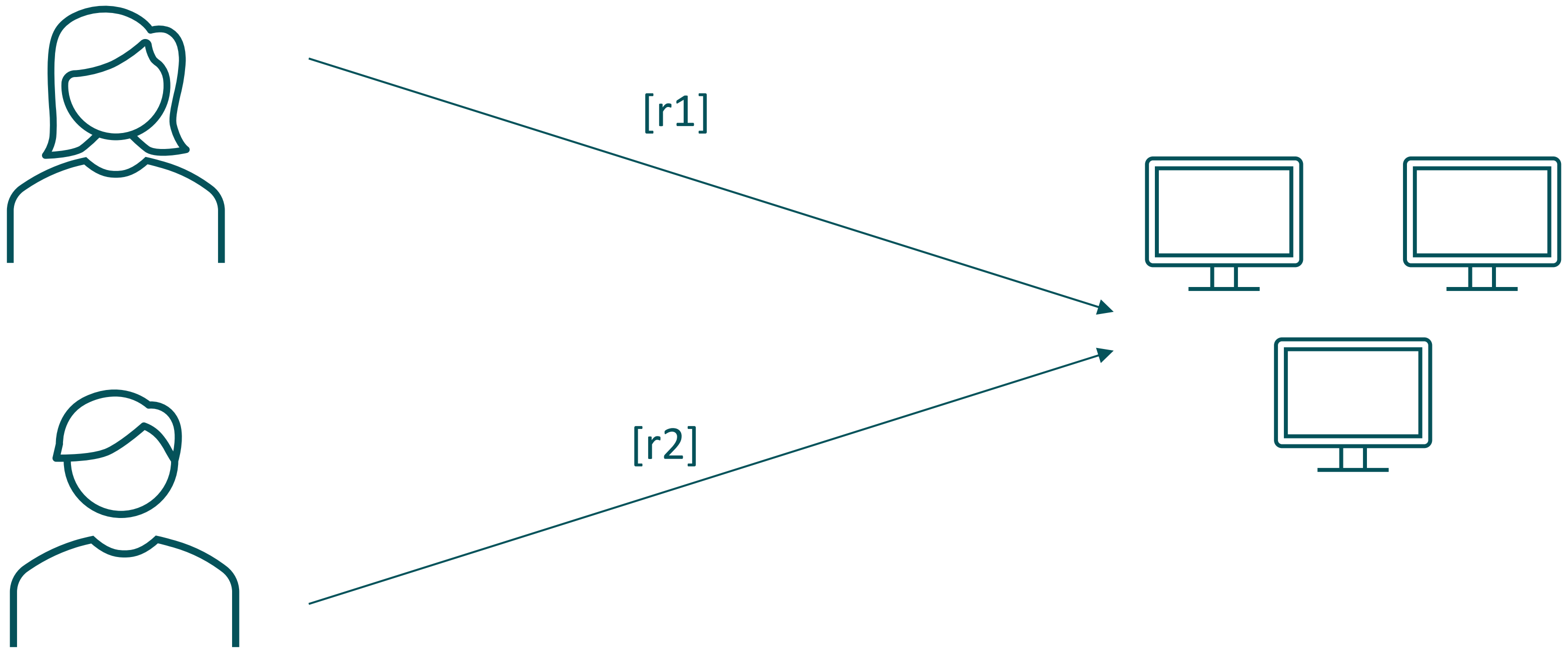
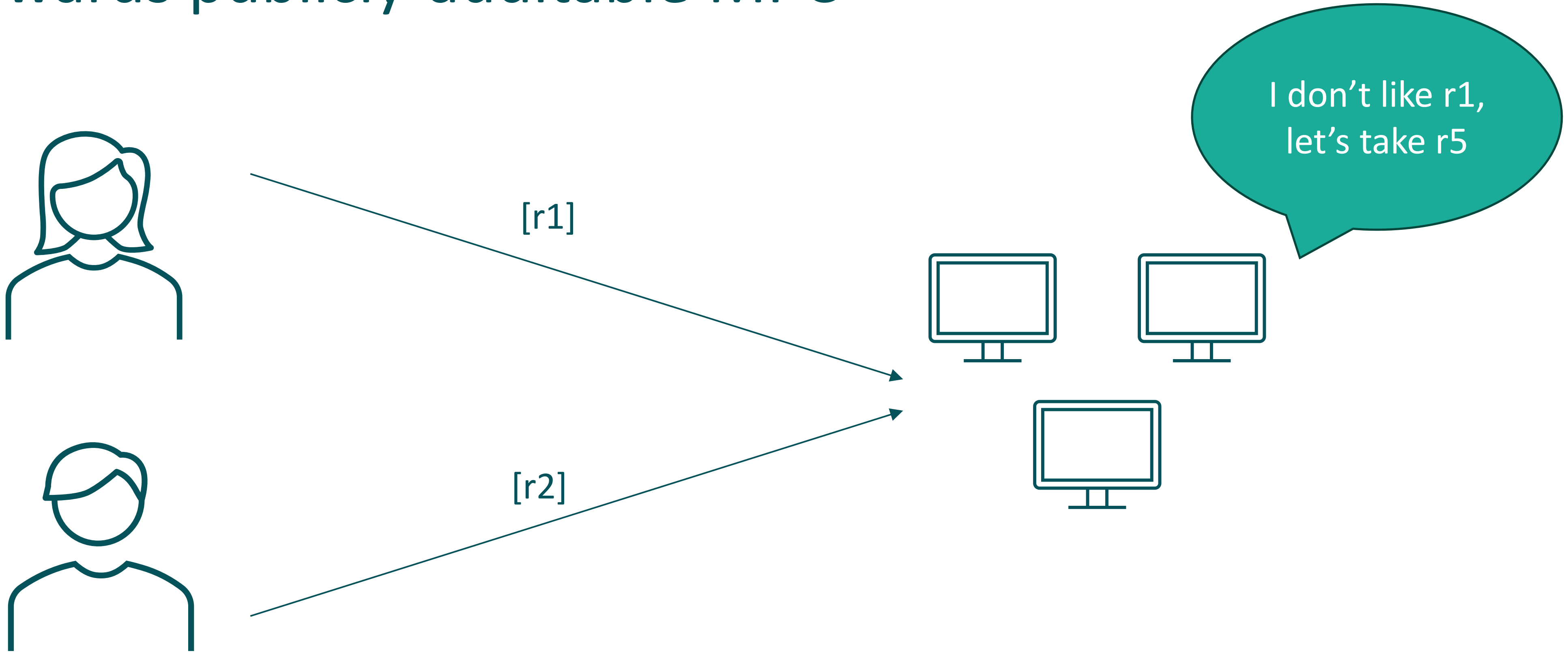
Towards publicly-auditable MPC



Towards publicly-auditable MPC



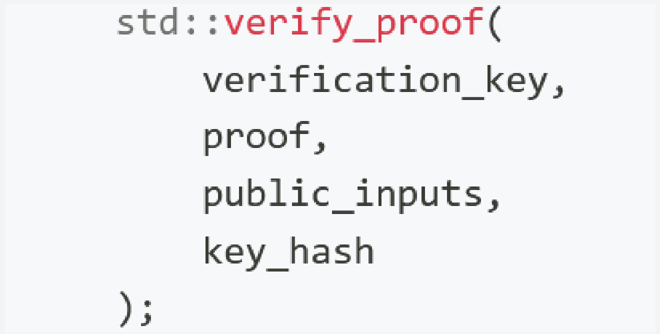
=> Solution: Always bind data to public commitments

Towards publicly-auditable MPC

Interop with Aztec

UltraHonk Proof System

- Currently supported by coNoir
- Recurse into smart contract



```
    std::verify_proof(
        verification_key,
        proof,
        public_inputs,
        key_hash
    );
```

Full Client-IVC Proof System

- Prove whole Aztec transactions in MPC
- Create Aztec keys that are secret-shared and own Private State

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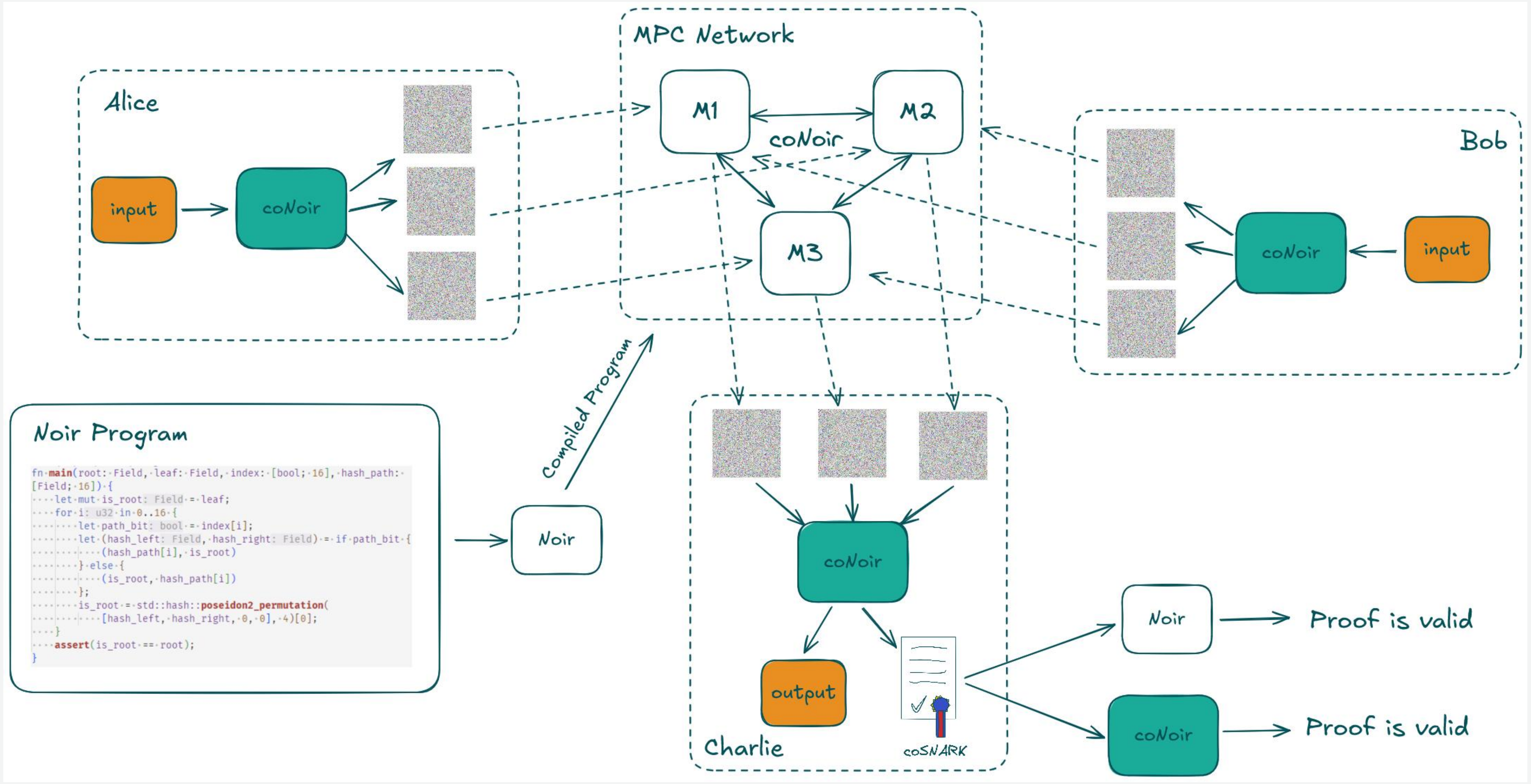

```
fn main(root: Field, leaf: Field, index: [bool; 16], hash_path:
[Field; 16]) {
    let mut is_root: Field = leaf;
    for i: u32 in 0..16 {
        let path_bit: bool = index[i];
        let (hash_left: Field, hash_right: Field) = if path_bit {
            (hash_path[i], is_root)
        } else {
            (is_root, hash_path[i])
        };
        is_root = std::hash::poseidon2_permutation(
            [hash_left, hash_right, 0, 0], 4)[0];
    }
    assert(is_root == root);
}
```

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