ZK-SecreC: A Domain-specific Language for Zero-Knowledge Proofs

Raul-Martin Rebane

Why a DSL?

- Bring ZK to new problem domains
- Simplify preparation of large statements
- Allow complex proofs
- Interface with many proof systems

The information flow types

Domain

A value may be

- known only to *P*, or
- known to *P* and *V*, or
- known at compile-time

Stage

A value may be

- local to parties, or
- also present at circuit

The information flow types

Domain

A value may be

- known only to *P*, or — @prover
- known to *P* and *V*, or — @verifier
- known at compile-time — @public

Stage

A value may be

- local to parties, or — $pre
- also present at circuit — $post

x : **int** $pre @prover

The information flow types

Domain

A value may be

- known only to P, or — @prover
- known to P and V, or — @verifier
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Stage

A value may be

- local to parties, or — $pre
- also present at circuit — $post

x : **int** $pre @prover

Allowed classification

@public → @verifier → @prover
$post → $pre

No declassification on domains!

The information flow types

Domain

A value may be

- known only to P, or @prover
- known to P and V, or @verifier
- known at compile-time @public

Allowed classification

@public → @verifier → @prover
$post → $pre

No declassification on domains!

Stage

A value may be

- local to parties, or $pre
- also present at circuit $post

x : **int** $pre @prover

$pre → $post

- Creates an input for the circuit
- There is an operation for this

wire { x } : **int** $post @prover

Other similar languages..

- conflate @prover and @verifier
  - Loses information, which checks are necessary in the circuit
  - Note that $pre @prover and $pre @verifier have different integrity properties

  or
- conflate @verifier and @public
  - Cannot separate the inputs defining the circuit from the verifier's inputs to the circuit

ZK Programming is hard

- Writing proofs is non-trivial
- Underconstrained circuits are dangerous
- Optimizing is required

$\Longrightarrow$ Don’t need to shy away from ZK mechanics

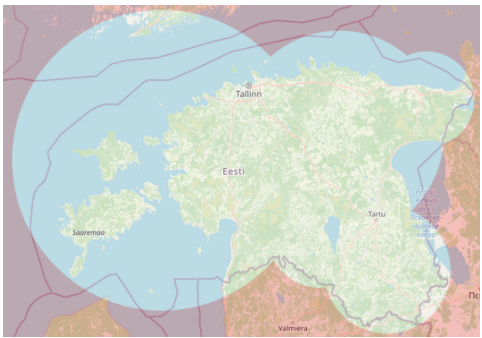
Polymorphism

```
fn sum[N : Nat, $S, @D](xs : list[uint[N] $S @D]) -> uint[N] $S @D {
        let mut s = 0;
        for i in 0..length(xs) { s = s + xs[i] }
        s
}
```

Interleaving

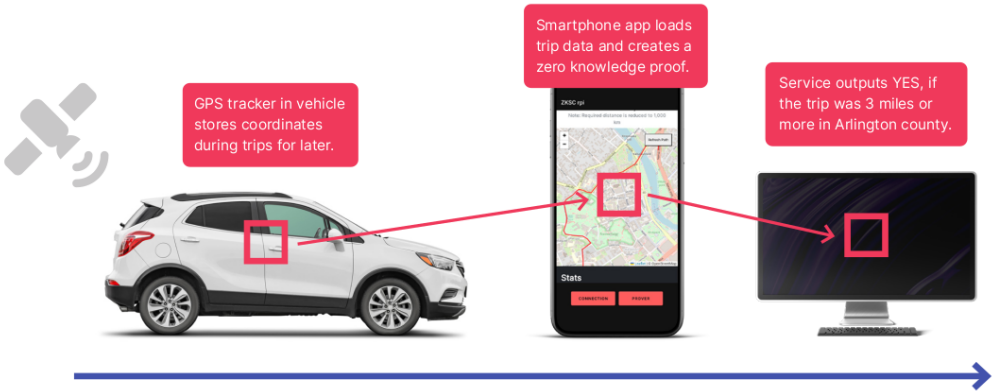
- Can interleave on- and off-circuit computation
- Valuable for complex statements
- FFI for Rust
- Requires an effect system

Vehicle Subsidy Demo



- Grant terms: 80,000km travelled, 80% of it in Estonia
- Prove compliance without revealing GPS data
- Increased transparency to the user

Vehicle Subsidy Demo



Vehicle Subsidy Demo

Prover	Tracking duration	Runtime
Pixel 5a	Month	127s
Pi 5	Month	23s
Pi 5	Year	152s

Assuming 1h a day driving, 1 coordinate per 30sec.

Changing protocols

We built using:

- Mersenne61 prime
- Arya inequalities
  - Verifier's challenges

Ligero supported:

- FFT-friendly prime
- No challenges

Conditional compiling

Type predicates and branching for features

- Field switching
- Verifier's challenges
- Function gates
- Vectorization

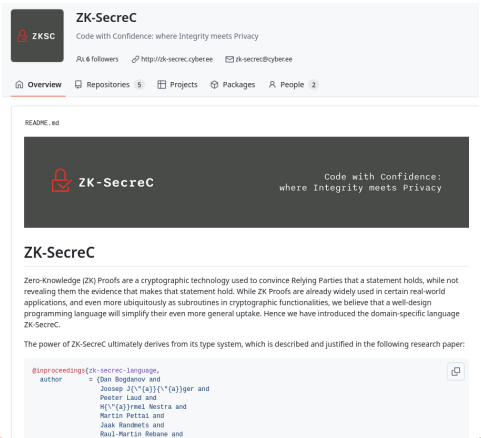
Backends

- Circom, SieveIR
- Galois Mac'n'Cheese
  - Field switching
  - Function gates
  - Vectorized calls
  - Verifier challenges
- emp-zk
- zkb++

Language Integrations

- Standard library includes
  - Bigints
  - EC
  - JSON parsing
  - Fractional numbers
  - Poseidon
- Maximize code reuse in both domains
- Off-circuit: Rust FFI
- On-circuit: CirCom FFI (coming)

Other Examples



github.com/zk-secrec/examples

- Face recognition
- Server log audit
- Bank record audit
- Medical check

Thank you

Acknowledgments

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