ZK in Rollups

Full Validity Proving on the OP Stack

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ZK Rollups are the endgame

ZK is the only way that ____________ will get solved.

- Fast finality for rollups
- Interoperability across Ethereum
- Unified liquidity for users
- Bridging across ecosystems
- Good UX

Decentralization imposes overhead by requiring redundant computation. ZKPs fix this.

Until recently, ZK rollups have been challenging

zk_evm / evm_arithmetization / src / cpu / kernel / asm / main.asm

Code Blame 109 lines (93 loc) · 4.28 KB

```
global start_txn:
    // stack: (empty)
    %mload_global_metadata(@GLOBAL_METADATA_TXN_NUMBER_BEFORE)
    // stack: txn_nb
    DUP1 %scalar_to_rlp
    // stack: txn_counter, txn_nb
    DUP1 %num_bytes %mul_const(2)
    // stack: num_nibbles, txn_counter, txn_nb
    %increment_bounded_rlp
    // stack: txn_counter, num_nibbles, next_txn_counter, next_num_nibbles, tx
    %mload_global_metadata(@GLOBAL_METADATA_BLOCK_GAS_USED_BEFORE)

    // stack: init_gas_used, txn_counter, num_nibbles, next_txn_counter, next_r

    // If the prover has no txn for us to process, halt.
    PROVER_INPUT(no_txn)
    %jumpi(execute_withdrawals)

    // Call route_txn. When we return, we will process the txn receipt.
    PUSH txn_after
    // stack: retdest, prev_gas_used, txn_counter, num_nibbles, next_txn_counte
    DUP4 DUP4

    %jump(route_txn)

global txn_after:
    // stack: success, leftover_gas, cur_cum_gas, prev_txn_counter, prev_num_ni
    %process_receipt
    // stack: new_cum_gas, txn_counter, num_nibbles, txn_nb
    SWAP3 %increment SWAP3
    %jump(execute_withdrawals_post_stack_op)

global execute_withdrawals:
    // stack: cum_gas, txn_counter, num_nibbles, next_txn_counter, next_num_nib
    %stack (cum_gas, txn_counter, num_nibbles, next_txn_counter, next_num_nibbl
execute_withdrawals_post_stack_op:
    %withdrawals
```

- χ-step:

$$A[x,y] = B[x,y] \oplus ((\text{NOT } B[x+1,y]) \text{ AND}$$

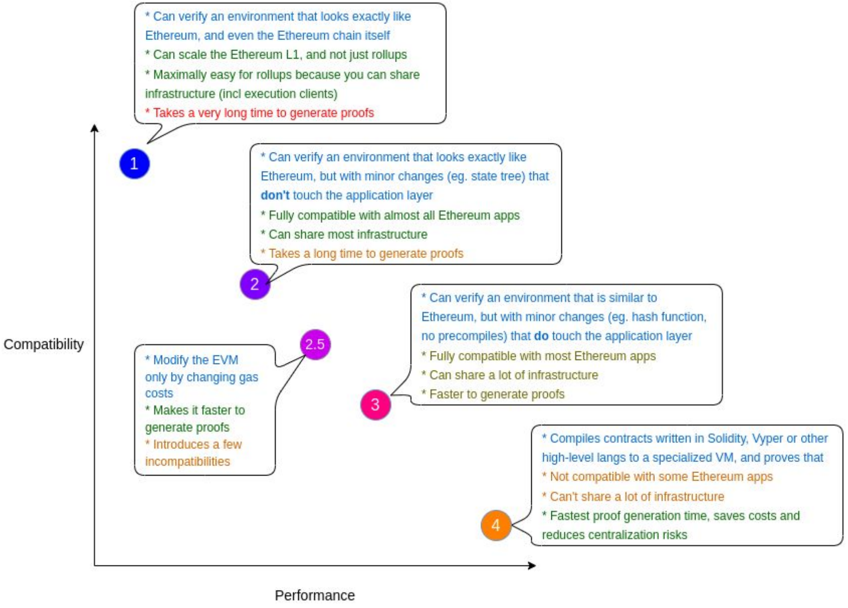
- ι-step:

$$A[0,0] = A[0,0] \oplus$$

In the above all the operations on the indices are do permutation state array and $A[x,y]$ denotes a partic and $D[x]$ are intermediate variables. The symbol $\oplus$ NOT the bitwise complement and AND the bitwise denotes the bitwise cyclic (right) shift operation, mo $i + r$ (modulo the lane size).

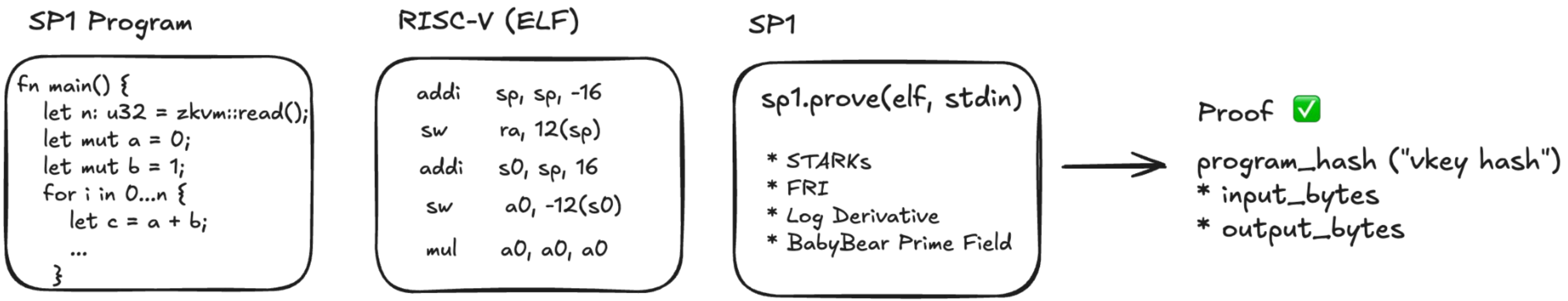
Cyclic shift offset constants $r[x,y]$ are picked accor

$r(x,y)$	$x=3$	$x=4$	$x=0$	$x=1$	$x=$
$y=2$	25	39	3	10	43
$y=1$	55	20	36	44	6
$y=0$	28	27	0	1	62
$y=4$	56	14	18	2	61
$y=3$	21	8	41	45	15



What is SP1?

SP1: a blazing fast zkVM that enables any developer to create real-world ZKP applications by simply writing Rust.



SP1 makes ZK rollups great (again)

	Before SP1	With SP1
Required expertise	❌ Specialized	✔️ Little
Customization & maintenance burden & upgradeability	❌ Poor	✔️ Excellent “cargo update reth”
Security surface area	❌ Large	✔️ Leverages existing codebases + audits
EVM compatibility	❌ No	✔️ Type 1
Expensive	✔️ Not really	✔️ Not really

Step 1 to building a ZK rollup: ZKP execution of a block

Proving Ethereum blocks with SP1 + Reth

We wrote an SP1 program using Reth to execute individual Ethereum blocks.

1. **Execute block with “RPC DB” to fetch all relevant merkle proofs in “host”.**
2. Construct “ClientInput” with current block, previous block + merkle proofs
3. Execute inside client program
4. Generate proof in SP1

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1139 LOC total: https://github.com/succinctlabs/rsp

SP1 + Reth Cost Estimates

From benchmarking data on cloud GPU

Block Number	Gas Used	Transaction Count	Number of Cycles	Cycles Per Transaction	Cost Per Transaction
20528720	13831834	150	682,513,352	4,550,089	$0.0033
20528721	13182083	139	562,562,943	4,047,215	$0.0029
20528722	25483756	349	1,004,427,115	2,878,014	$0.0021
20528723	12057640	217	580,214,305	2,673,798	$0.0020
20528724	12641380	167	610,973,878	3,658,526	$0.0027
20528725	15256584	182	722,433,945	3,969,417	$0.0029

SP1's novel ZK innovations + hardcore perf engineering enables low costs

Precompile-centric architecture

- keccak + secp256k1 + sha256 precompiles reduce cycle count by 6-10x
- bn254 and bls12-381 precompiles help with pairings + KZG point eval

Optimized GPU prover

- Improves cost + latency by ~5x over CPU prover

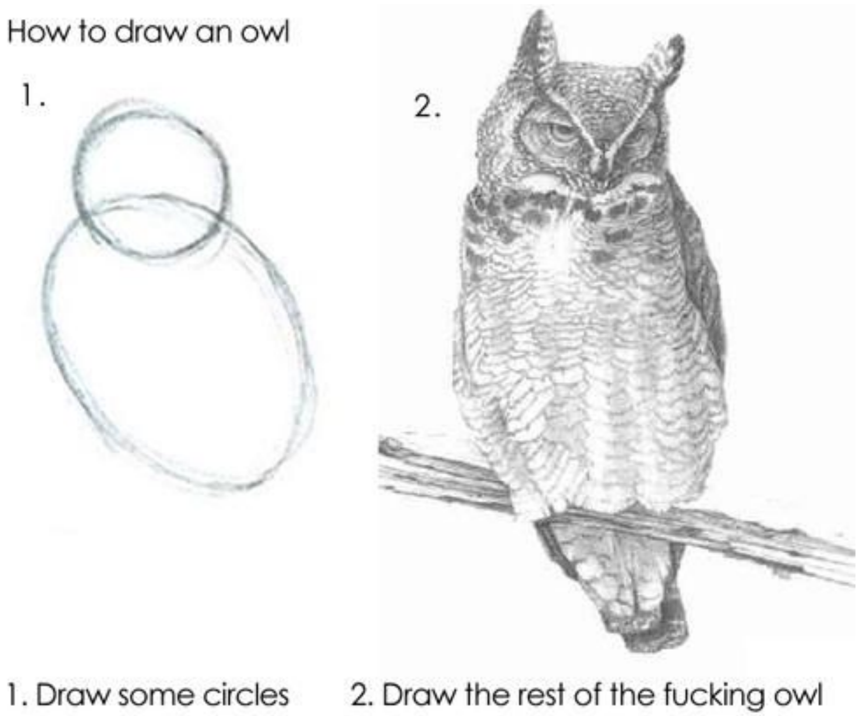
Other algorithmic optimizations

- "Memory in the head" argument that doesn't pay for merkleized memory
- Smaller blowup factor + multi-table batch FRI

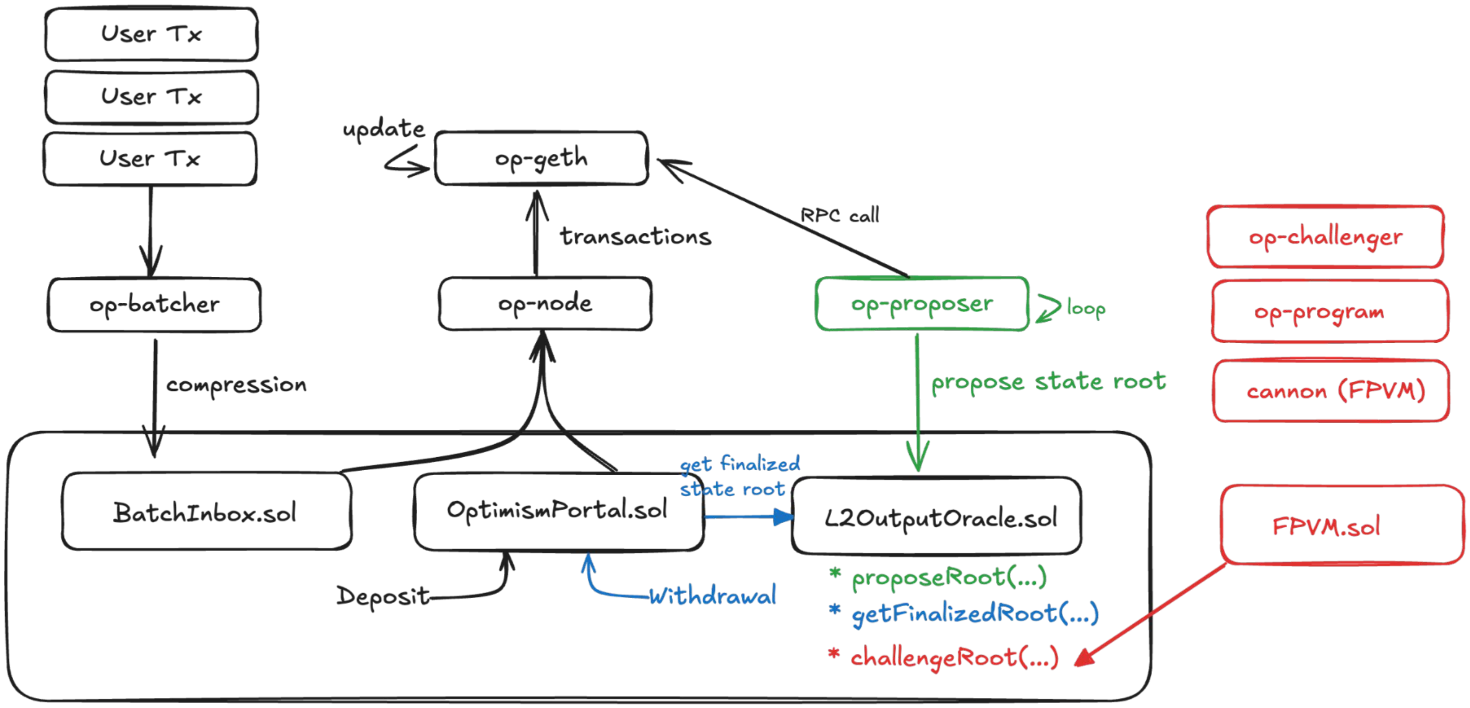
Takeaways

- Costs are cheap (currently $0.001-0.003 proving costs per transaction)
- Easily customizable
- Minimal LOC
- Minimal maintenance surface area
- Easily upgradeable

Step 2 to building a ZK rollup: everything else


How to draw an owl
1.
2.
1. Draw some circles
2. Draw the rest of the fucking owl

OP Stack to the Rescue: How it Works



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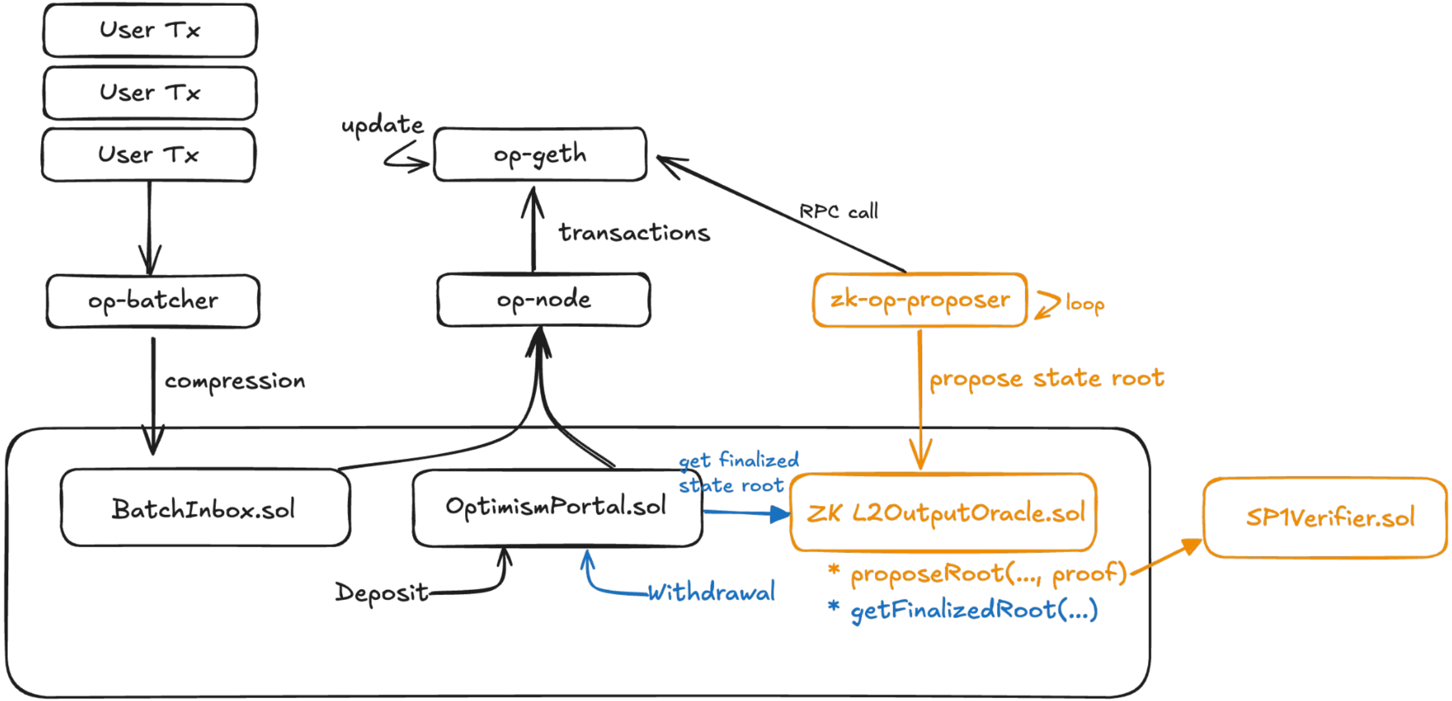
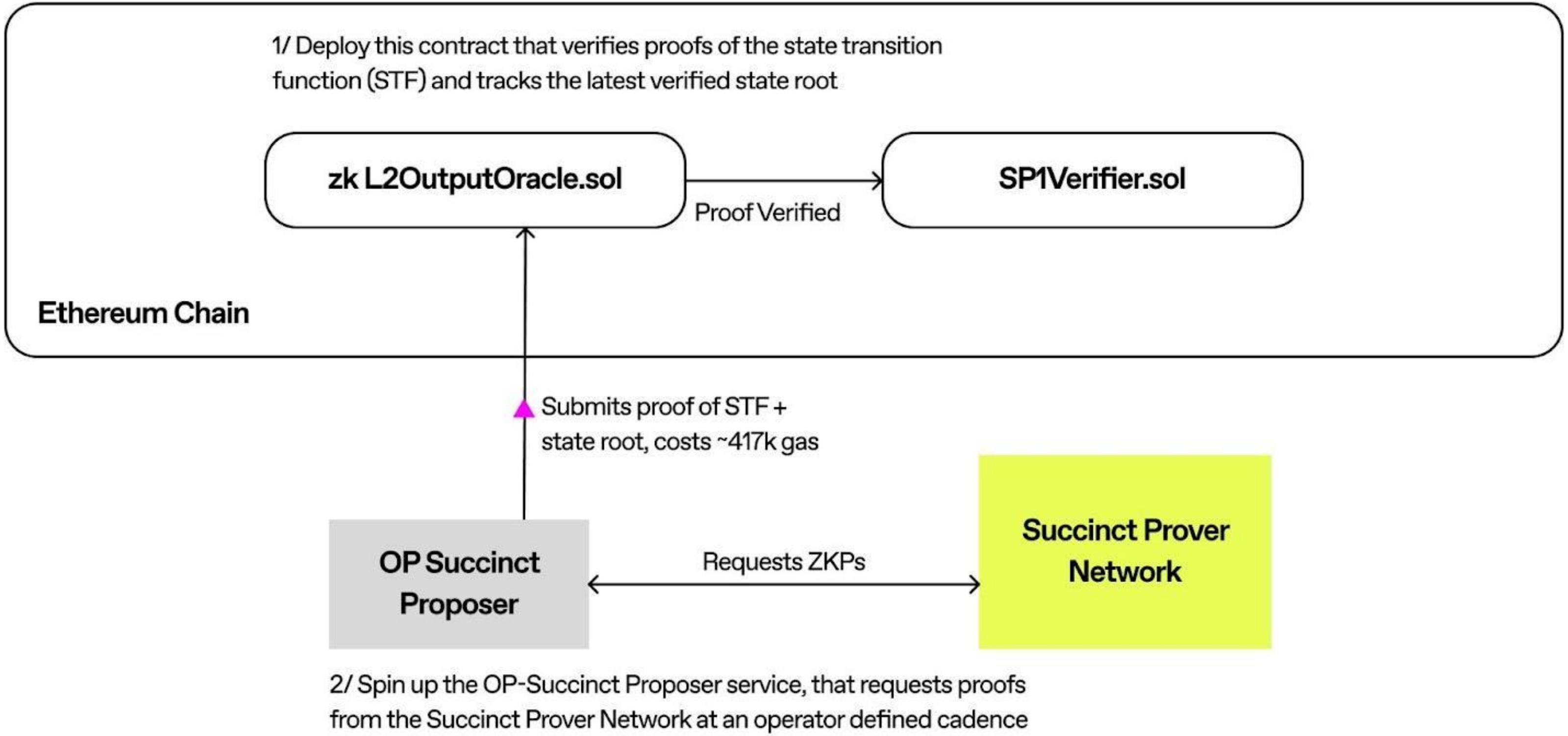
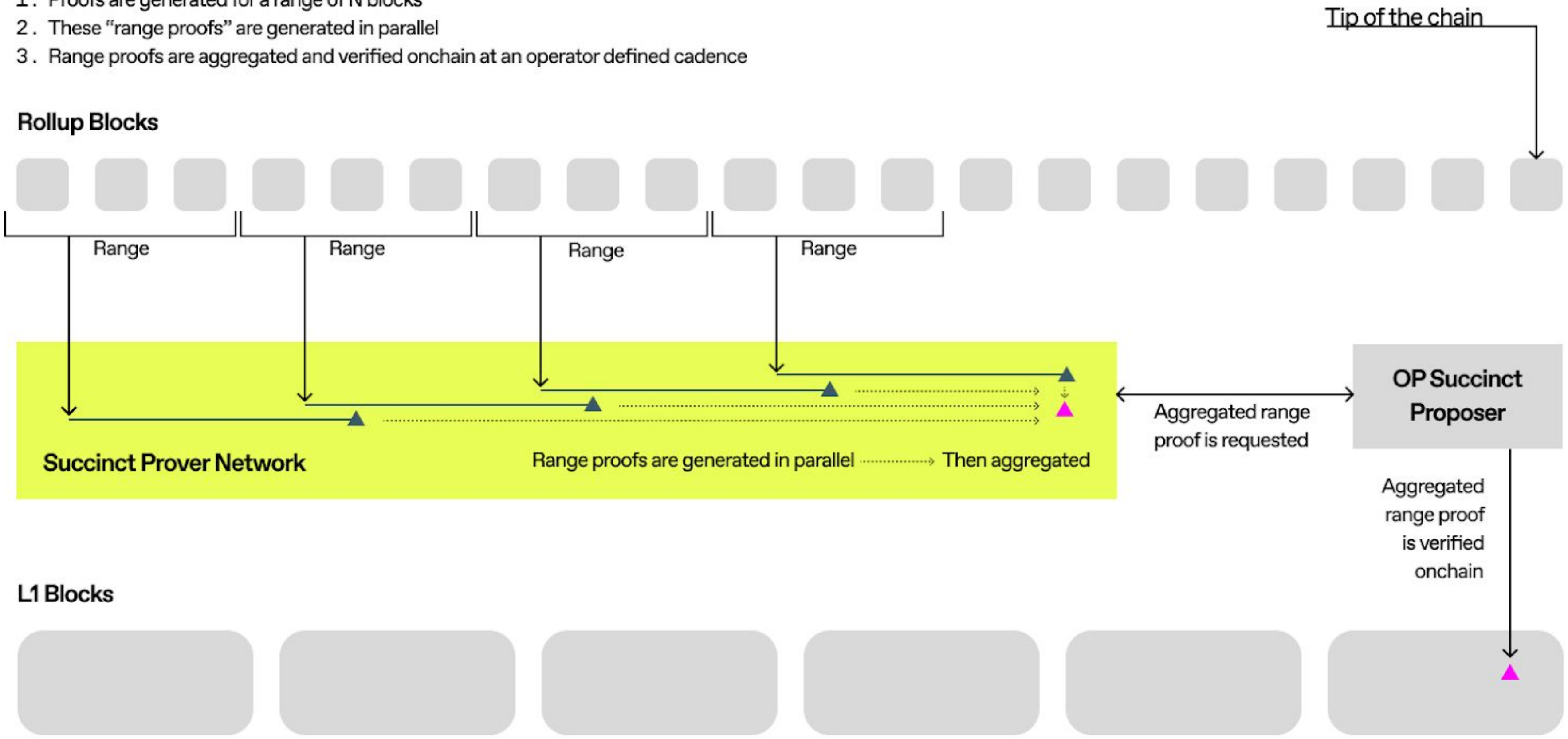


Upgrading Your OP Stack to use SP1 in 2 Steps



OP Succinct Proposer Service Architecture

1. Proofs are generated for a range of N blocks
2. These "range proofs" are generated in parallel
3. Range proofs are aggregated and verified onchain at an operator defined cadence

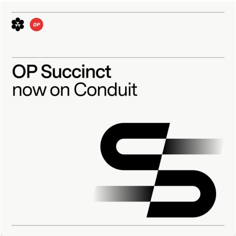


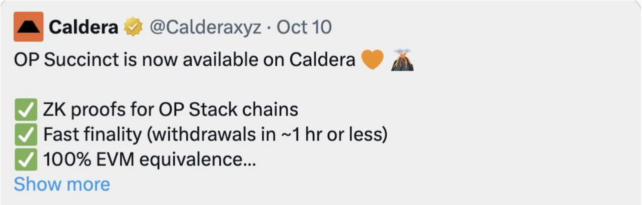
What <1 hour Finality with ZK Validity Proofs Enables

- More liquidity on the chain
  - Large users are no longer concerned about long withdrawal windows
- More capital efficient rebalancing for cross chain intent / interop protocols
  - Reduced capital costs → reduces fees for users
- <1 hr interop today!
- Live validity proofs (stage 1) today!

Practicality

Transaction Type	ETH Gas	Proving Cost
ETH Transfer	21000	$0.001
ERC-20 Transfer	65000	$0.0025
DEX Swap	185000	$0.0070





Security

Can be layered with other mechanisms for practical security assurances.

- Permissioned proof submitter (similar to whitelisted fault proof participants)
- “Mini challenge period” after proof submission

Security surface is re-used with production system

Next Steps & Reach Out

- **5-10x cost reductions on the horizon:**
  - SP1 improvements
  - Protocol and software optimizations to Rust implementation of OP Stack's state transition function
- **Reach out**: @pumatheuma, https://partner.succinct.xyz/
- **Repos**
  - https://github.com/succinctlabs/rsp
  - https://github.com/succinctlabs/op-succinct