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Scaling blockchains zkRollup

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Technical Lead

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Rollup limits (In ETH 1.0)

Current Eth:	32 Tx/s
Before Istanbul:	682 Tx/s
After Istanbul:	**2.048 Tx/s**

VISA network estimates

Average use:	2.000 Tx/s
Daily Peak:	4.000 Tx/s
Max. Capacity:	54.000 Tx/s

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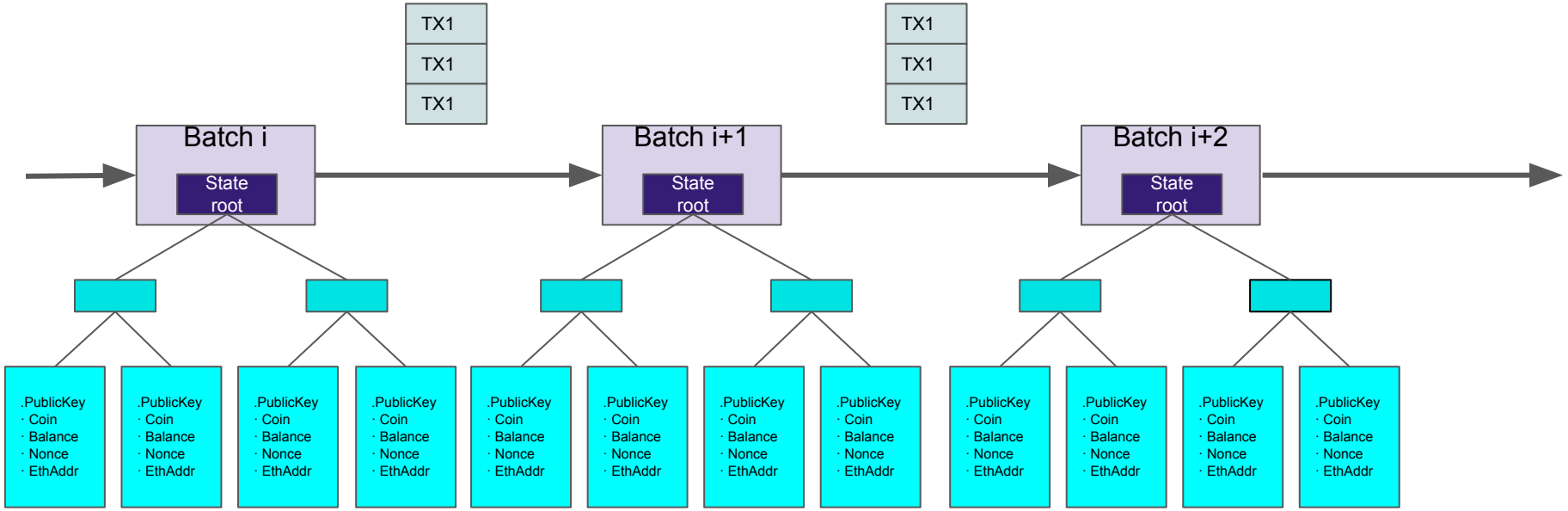
Rollup scalability general idea



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Succinct Verification

- Constant verification time
- Small size
- Fast proving time
- Secure
- Quantum resistant
- No trusted setup

zk-Snarks

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Data availability

- On Chain <- ROLLUP
- Other chains (BCH ?)
- Ethereum 2.0
- Filecoin
- A federation of servers.
- ...

We don't need consensus. We just need the data to be available.

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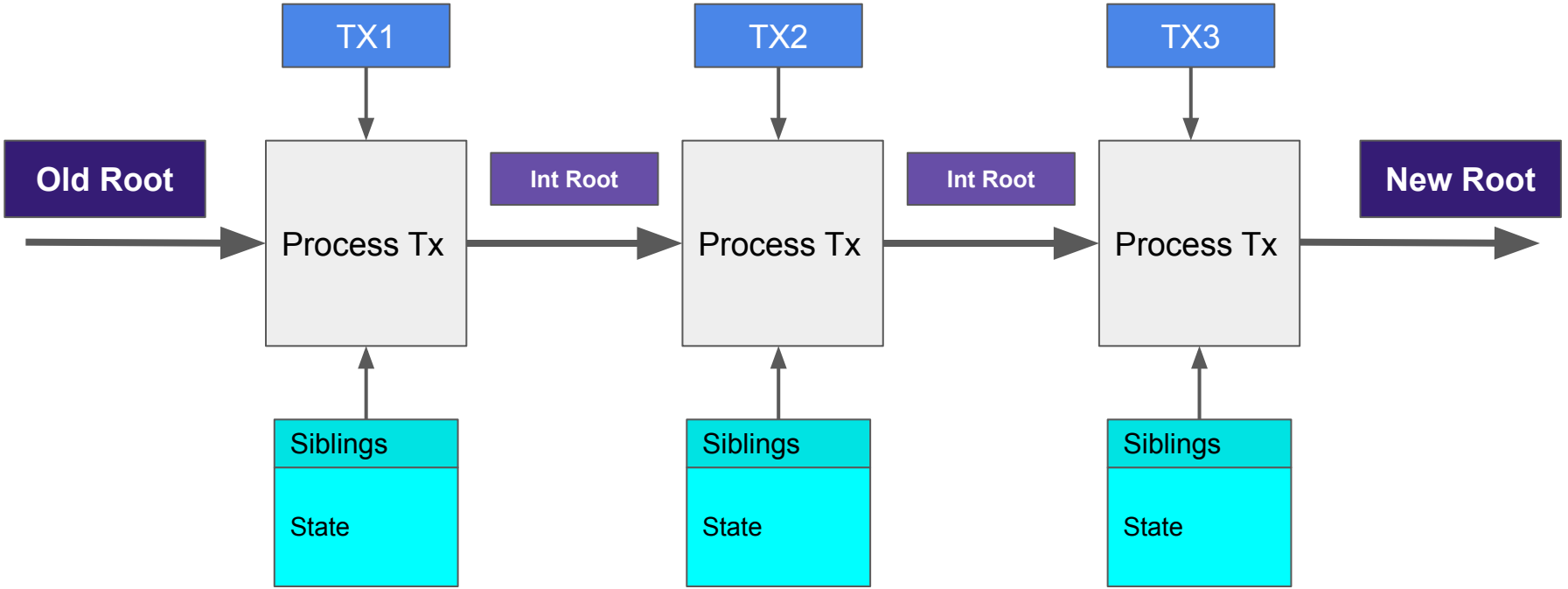
Rollup main circuit



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Circuit that process a TX.

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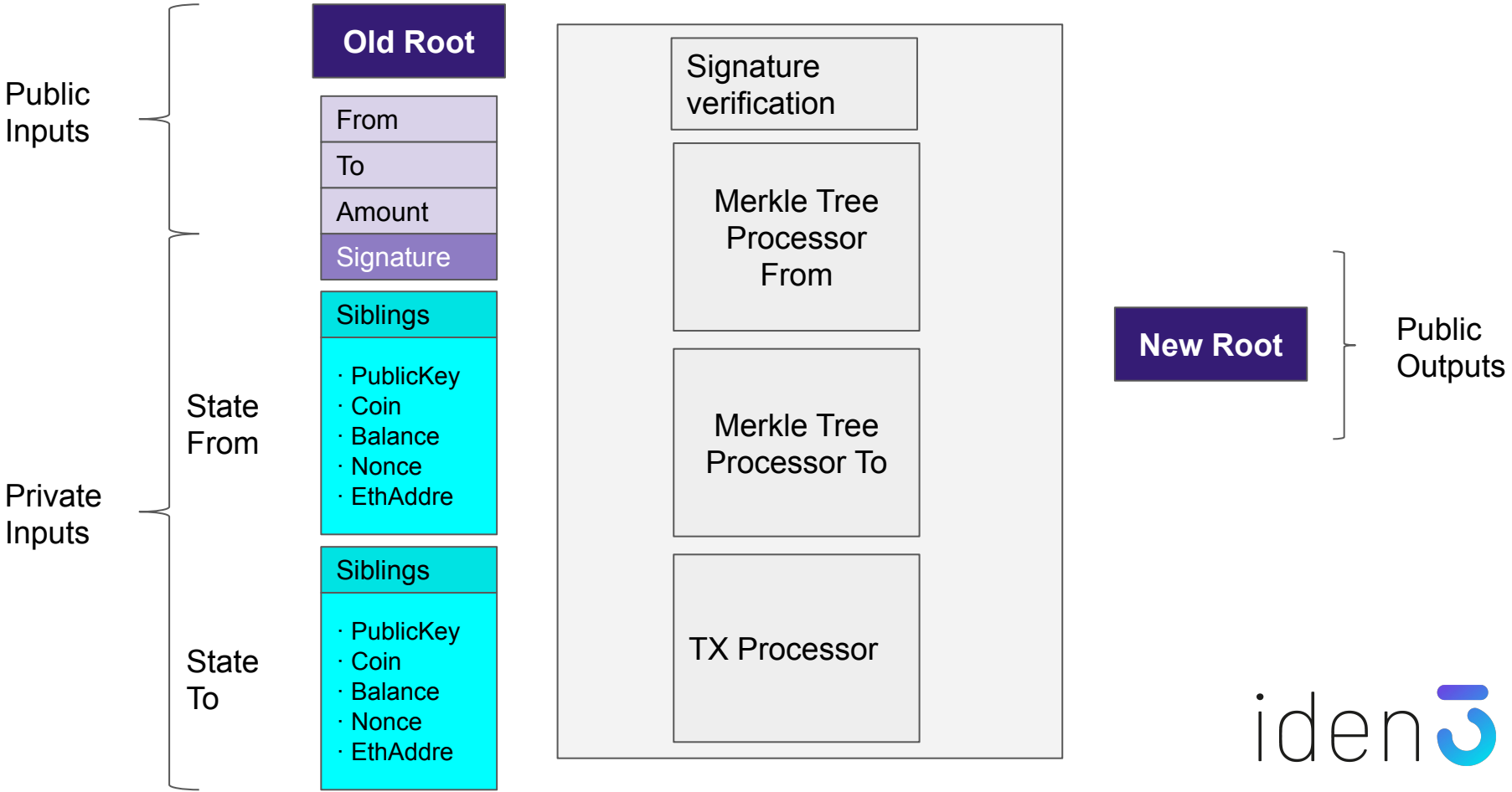

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Types of TXs

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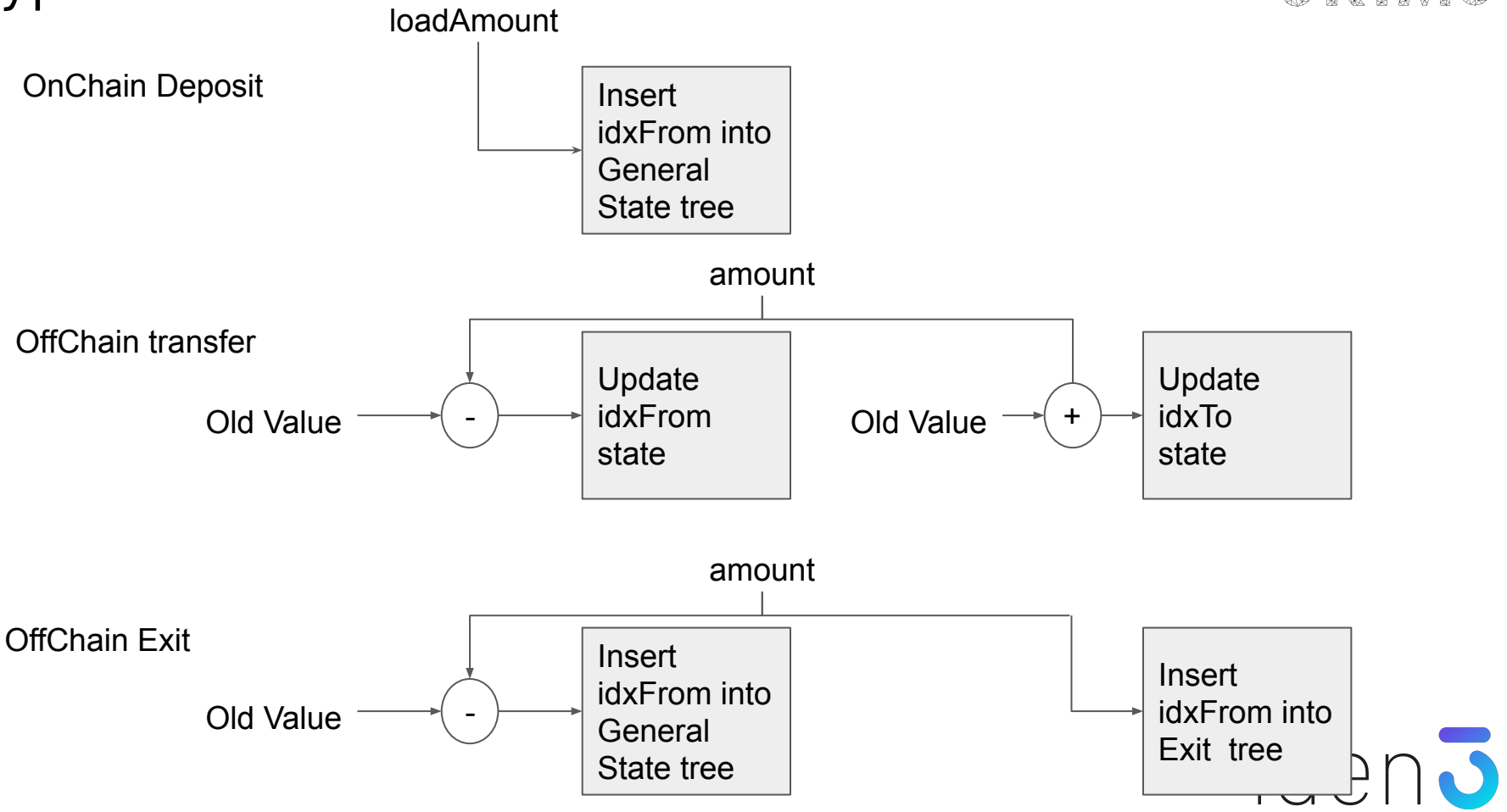
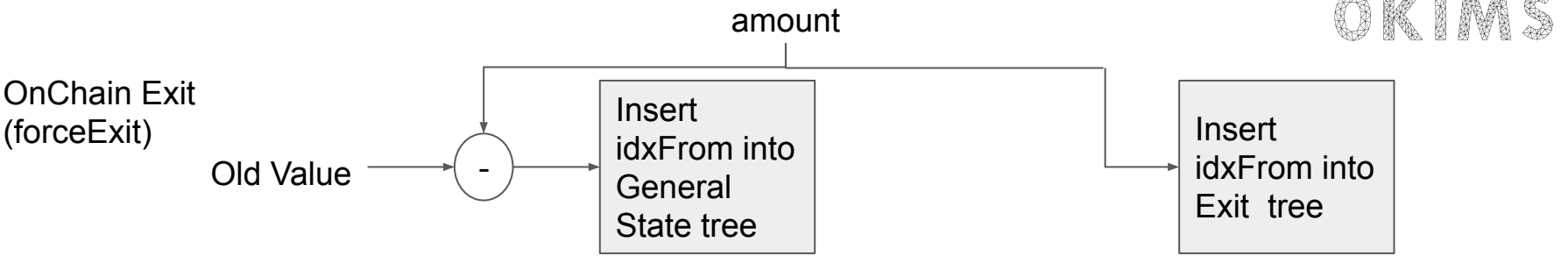
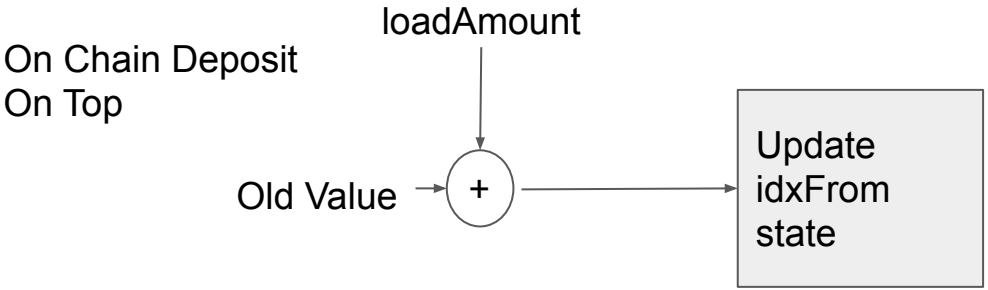
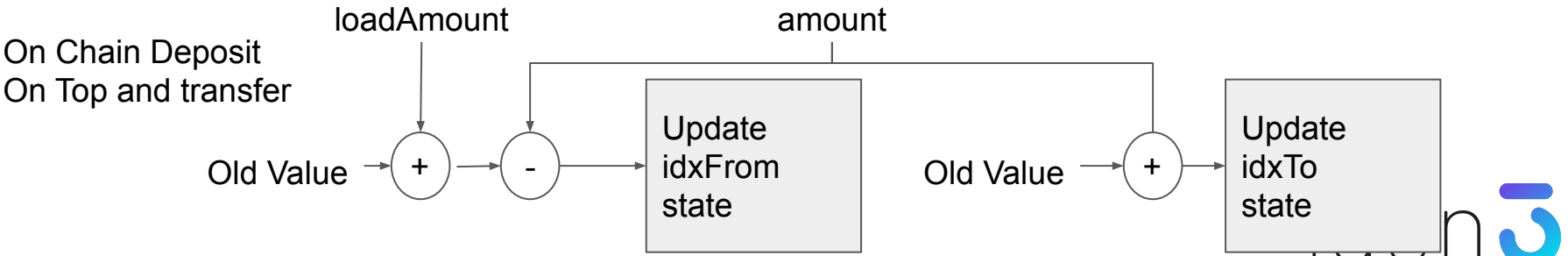



amount
OnChain Exit
(forceExit)
Old Value
-
Insert
idxFrom into
General
State tree
Insert
idxFrom into
Exit tree


loadAmount
On Chain Deposit
On Top
Old Value
+
Update
idxFrom
state


loadAmount
amount
On Chain Deposit
On Top and transfer
Old Value
+
-
Update
idxFrom
state
Old Value
+
Update
idxTo
state

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Exit Mechanism

- Sends to 0 TX which are considered exits.
- In each batch there is an Exit tree.
- To withdraw, users have to prove they are in the exit tree.
- You can force an exit by sending an onchain transaction.

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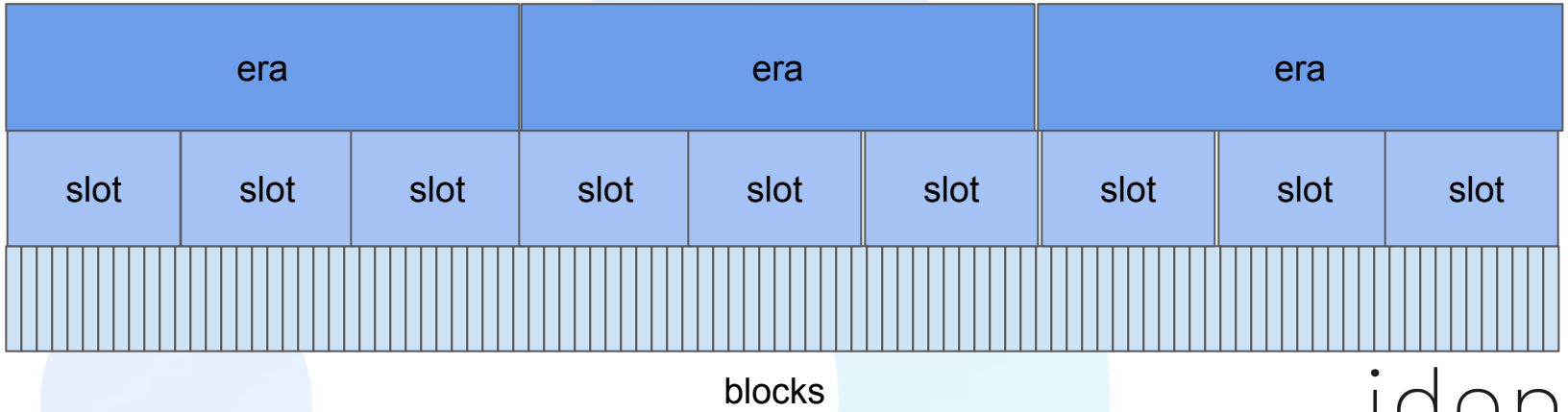
Decentralized operator

- Fixed # blocks per slot. Fixed # slots per era.
- Registration / deregistration happens in era+2



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The raffle

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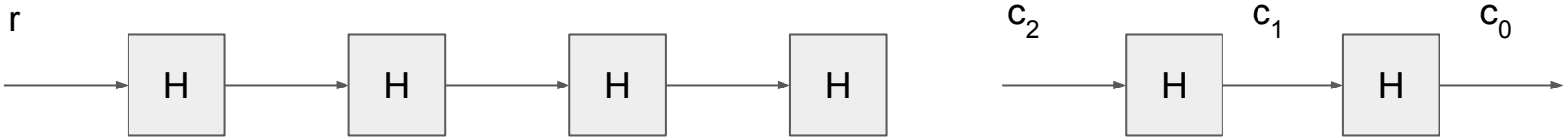
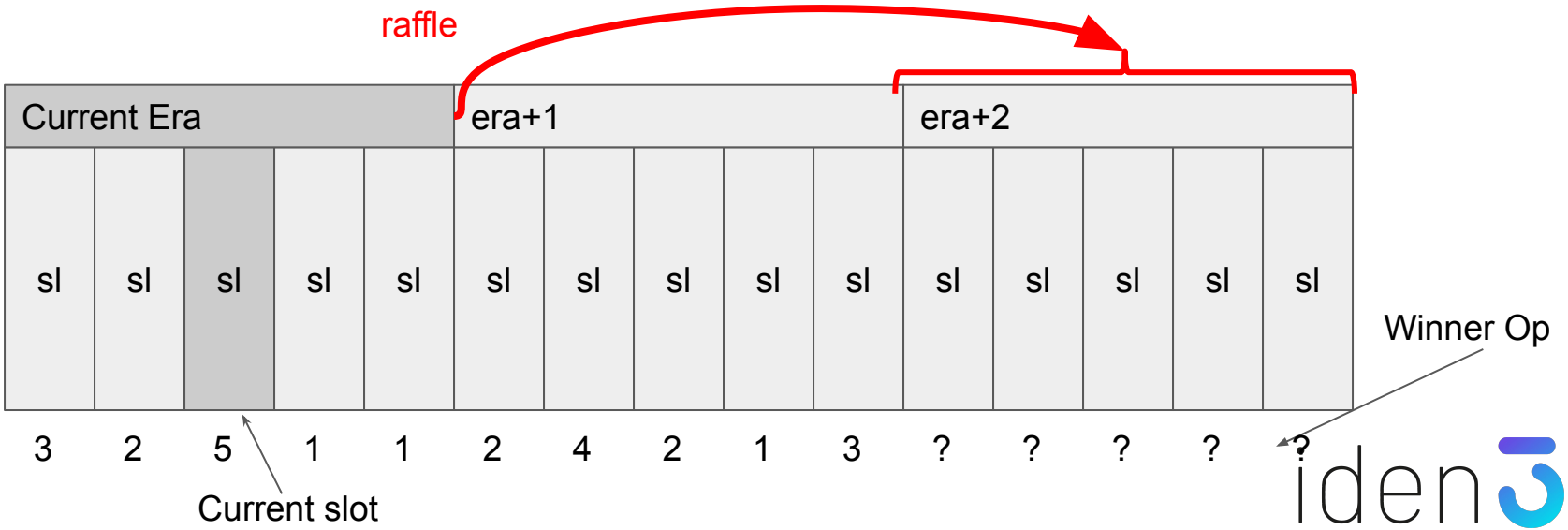
The operators reveals a precommited random number in the first batch of each slot.



The hash of all revealed randoms, determine the seed for the raffle of the era+2



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Effective Stake:
Compensation for risk concentration

$$
\begin{aligned}
f(2x) &= (1+p)2f(x) \\
f(x) &= x^{1+log_2(p)} \\
10\% &\Rightarrow x^{1.13} \\
20\% &\Rightarrow x^{1.26} \\
50\% &\Rightarrow x^{1.58} \\
100\% &\Rightarrow x^{2}
\end{aligned}
$$

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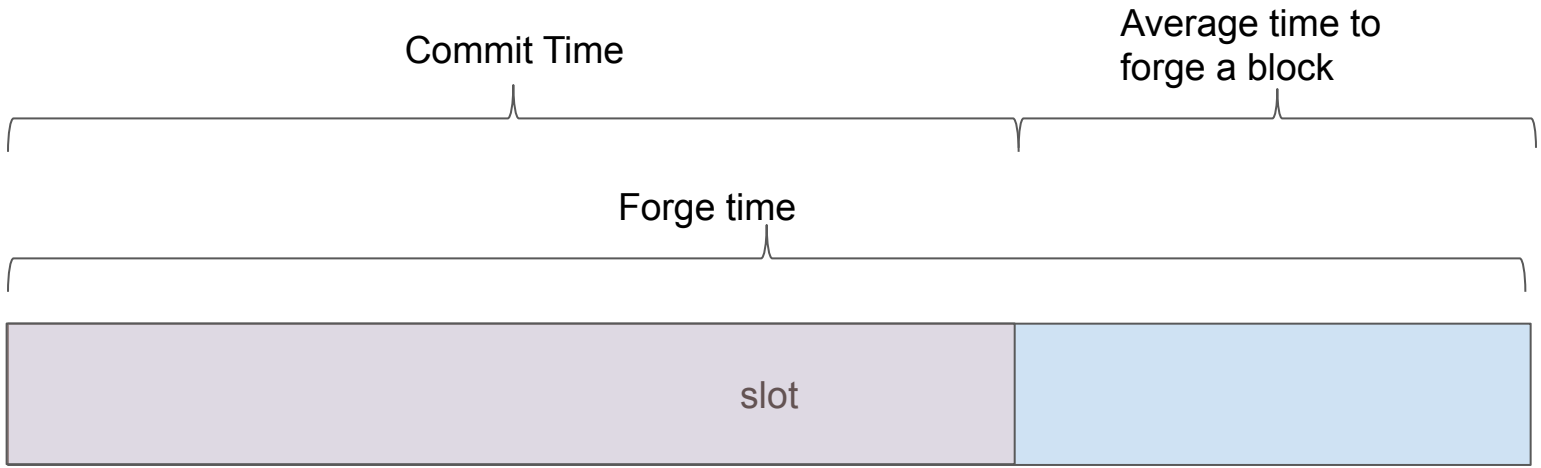
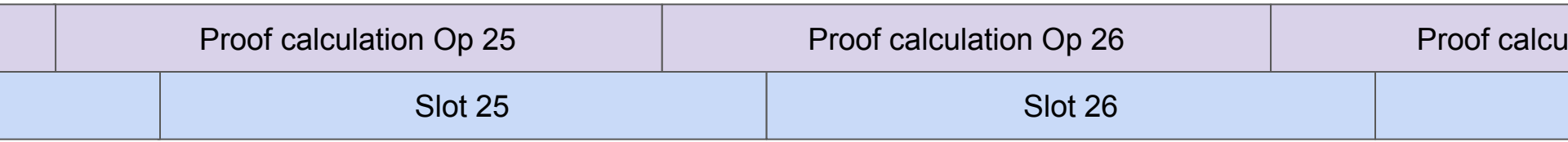
Pipeline batch forging





Parallelize Batch calculation

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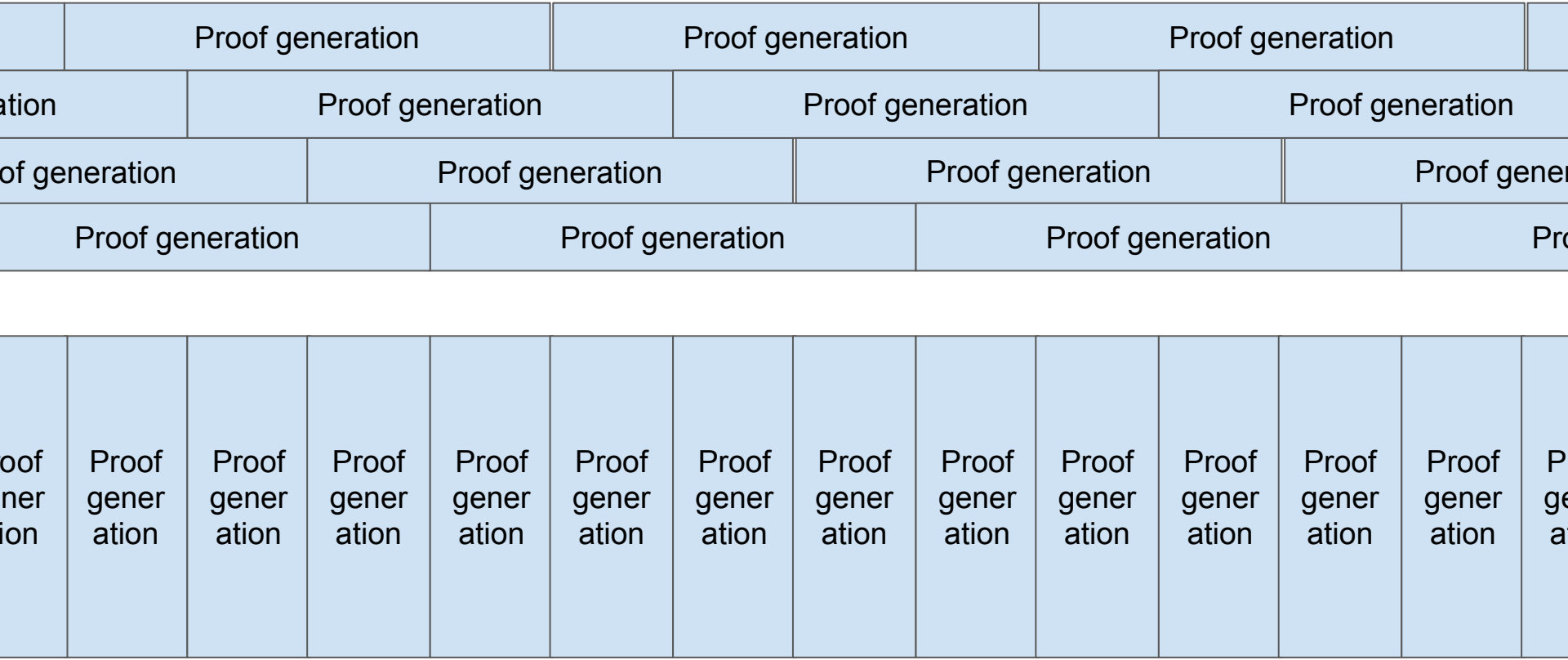

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Slashing

Operators are slashed with the full stake if:

- They don't forge a single block in the assigned slot.
- They don't forge a committed block.

Instead of being burnt, the slashed stake is sent to a pot. This pot is used to reward developers who are able to break cryptographic primitives.

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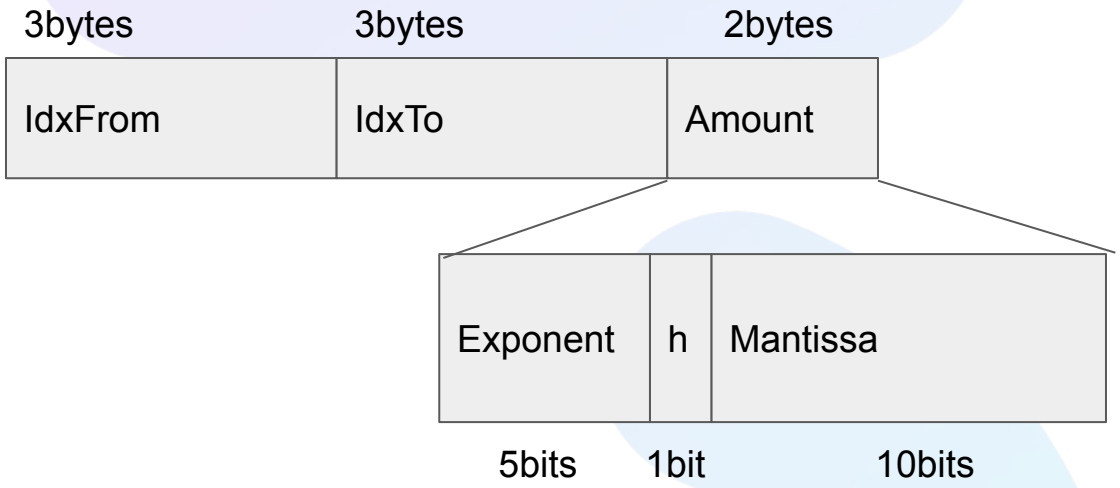
Tx Format



m*10^exp + h*(10^exp)/2

3.5 Decimal Digits

Examples

8.34
15.35
464.50
1830
1835

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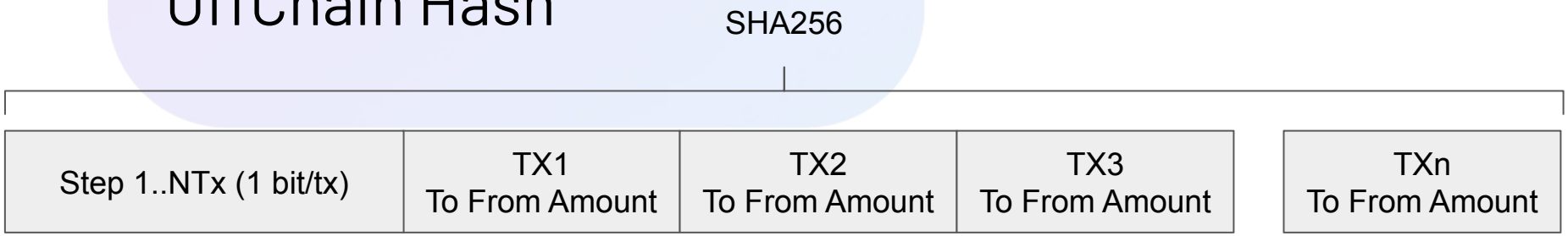
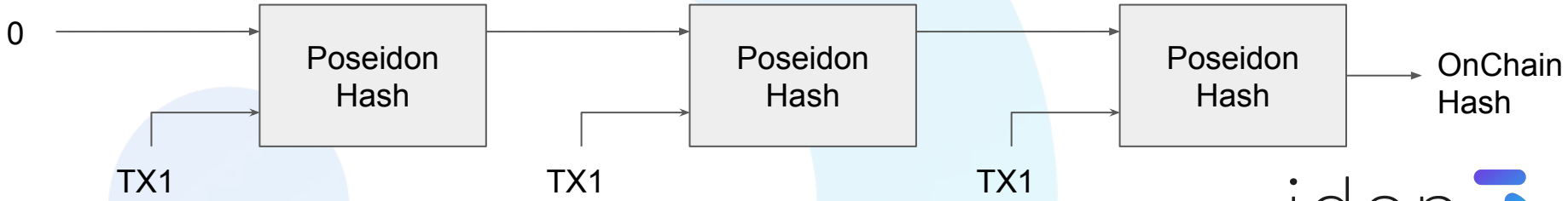
OffChain Hash



OnChain Hash



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Fees

Fee Plan

CoinIdx1	Fee1
CoinIdx2	Fee2
...	
CoinIdx15	Fee15

CoinIdx15	.....	CoinIdx2	CoinIdx1

Fee15	.....	Fee2	Fee1

FeePlanCoin

FeePlanFee

Public Inputs

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Signature verification

- EDDsa Using Baby Hub
- Poseidon hash function
- Batching ?? -> Requires Operations Module the order of the BabyJub Curve.

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On chain transactions

- Force Exit
- Deposit New account / On top
- Force transfer (Works with smart contracts).

Operators are forced to include onchain TX in order for the batch to be valid.

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Atomic Swaps

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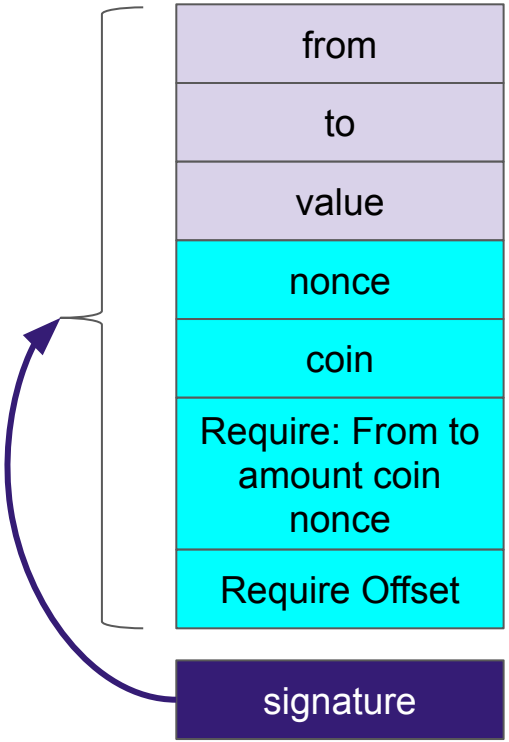
TX i-3	TX i-2	TX i-1	TX i	TX i+1	TX i+2	TX i+3



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CuSnarks development

- Parallel implementation of Groth16 prover based on snarkjs over curve BN128.
- Written in CUDA and wrapped in Python.
- Works together with circom and snarkjs.
- Objective is speed.

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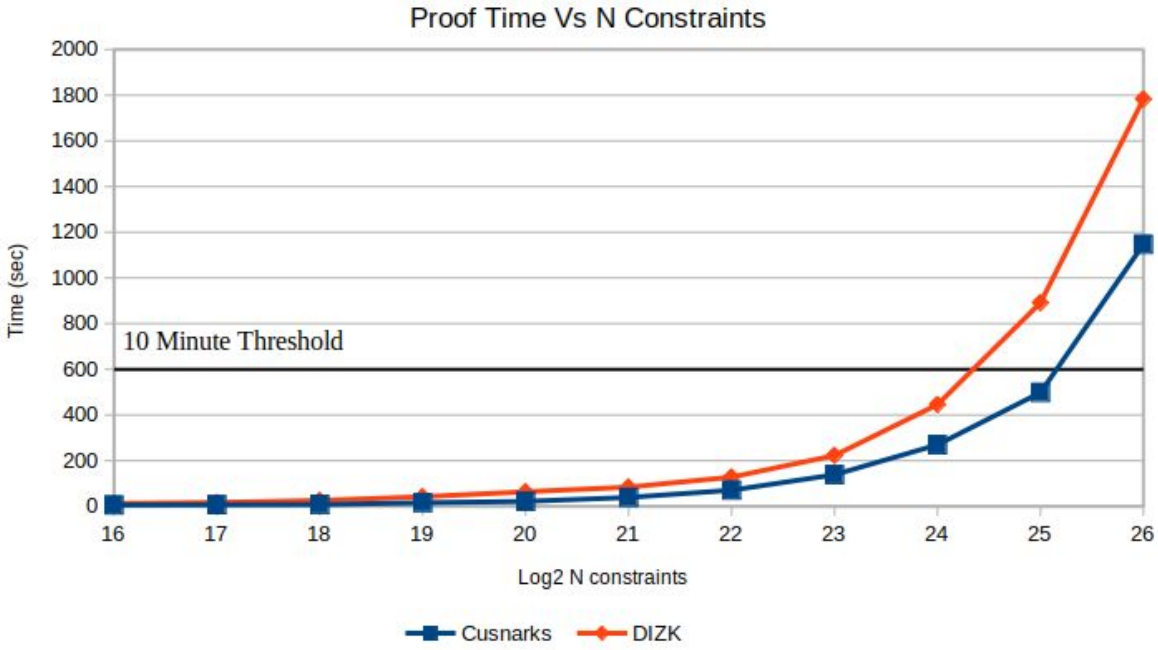
CuSnarks benchmarking

- With the current system, and 2^{26} constraints, the proof takes 19 minutes
- Dell T640 server - 2xIntel Xeon Silver 4110@2.1GHz (32 cores total) /128GB memory / 2xGPU GTX 1080 (2560 cores@1607MHz/ 8GB GDDRX5) - **$10K**



DIZK : results taken from H.Wu, W. Zheng, A. Chiesa, R.A. Popa, and I. Stoica. DIZK: A distributed zero knowledge proof system. Results obtained with a different circuit but same number of constraints. Results provided as a reference.

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Rollup limits (In ETH 1.0)

Current Eth: 10M / 21K / 15 = **32 Tx/s**

Before Istanbul:

Data cost/batch: 1 block: 2048tx * 8.125bytes/tx * 68gas/byte = 1,131,520

TX proof/batch = 800,000 (aprox)

Tx/s = 5 Batches/Block -> **682tx/s**

After Istanbul:

Data: 1 block: 2048tx * 8ebytes/tx * 16gas/byte = 266,240

TX proof = 350,000 (aprox)

Tx/s = 15 batches/Block -> **2,048tx/s**

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Costs estimations

An investment of 20,000$ Can mine 2048tx / 10min

Amortization cost: 20,000$ / (2048 * 6 * 24 * 365 * 5) = 0.00003$/tx

Electricity cost: (4Kw * 0,15 $/KwH) / (2048 * 6) = 0,00006$/tx

Other operation costs: 10,000/year = 0.00009 $/tx

Gas TX Cost: 350,000*10Gwei = 0.0003 $/tx

So the cost of the TX = 0.00048$ = **0.048¢/tx**

Current Ethereum TX cost = **4¢/tx**

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zkSnarks Tools

- Circom
  - Building specs for version 1.0
  - https://github.com/iden3/circom
- Circomlib
  - Auditing
- Snarkjs
  - Should migrate to websnark
  - Will be keeped for academic uses.
  - https://github.com/iden3/snarkjs
- Websnark
  - MNT Verification support. Completing other curves.
  - Possible development of PLONK
  - https://github.com/iden3/websnark
- CuSnarks
  - Target is to forge a proof of 2^{27} constraints in less than 10 min
- Trusted setup with trusted hardware.
  - Working in a SGX compatible version.

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Let’s go scale!

Current limit at **2.048 tx/s** and increasing

Atomic transactions

Lower transaction cost

Current state: Preparing and auditing for test network

@jbaylina
@identhree

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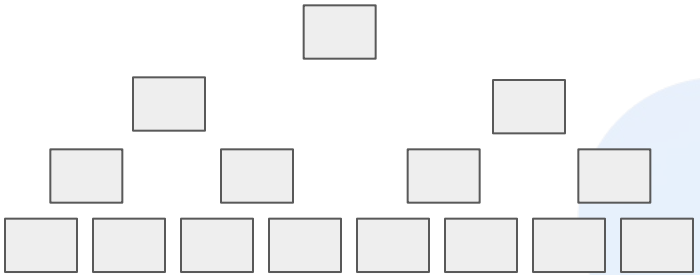
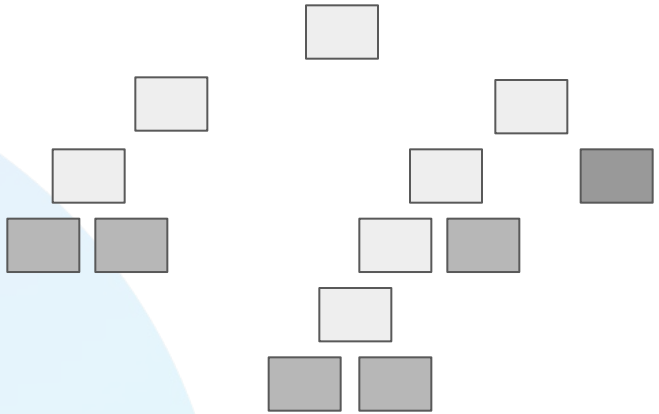
Normal Tree - Sparse Merkle tree - Other Accumulators



Normal tree



Sparse merkle

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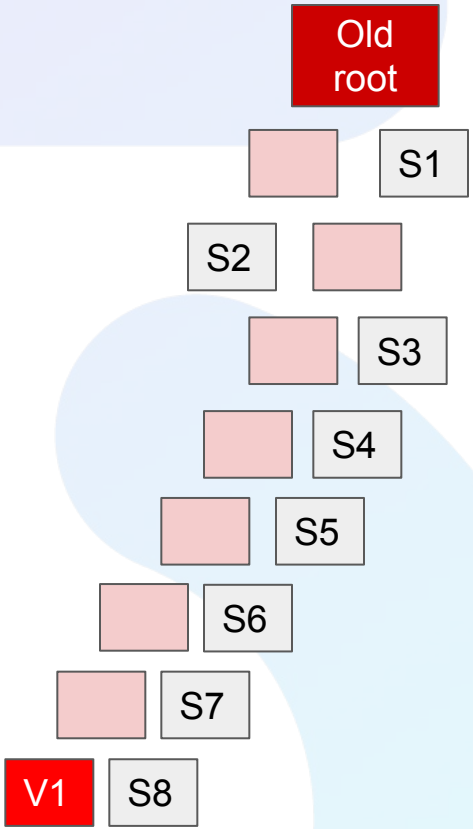
Verifying state



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Updating State