Zero Knowledge

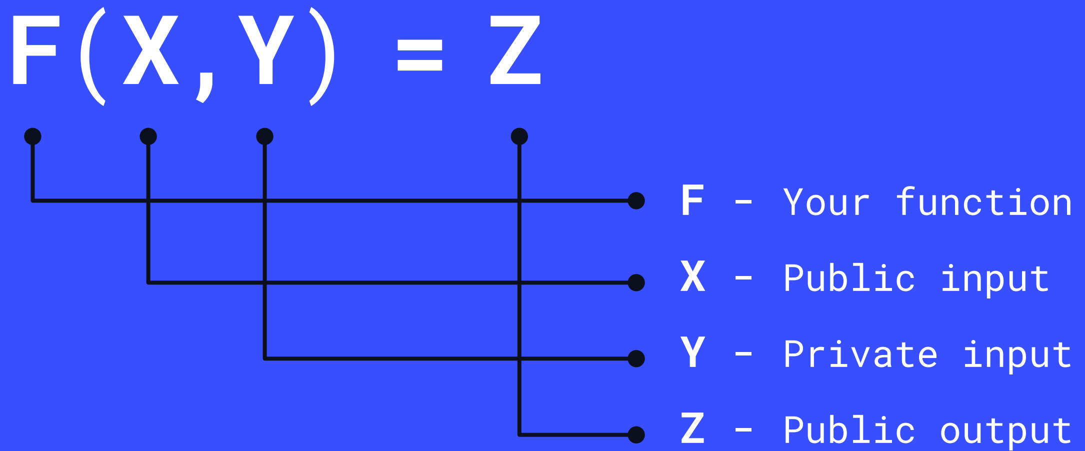
application area & developer tools

Zero Knowledge Proofs

What is Zero Knowledge Proofs (ZKP)?

Why & where do we need ZKP?

What technologies can be used for programming?



$F(X,Y) = Z$

F - Your function

X - Public input

Y - Private input

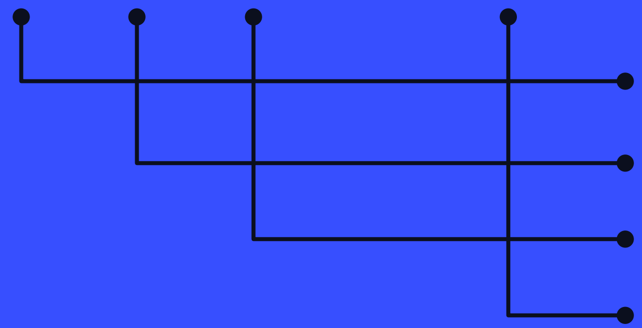
Z - Public output

Proof

*Here is **X** and **Z**, I know of an **Y** such that **F(X, Y) = Z***

Range (Age) proof example

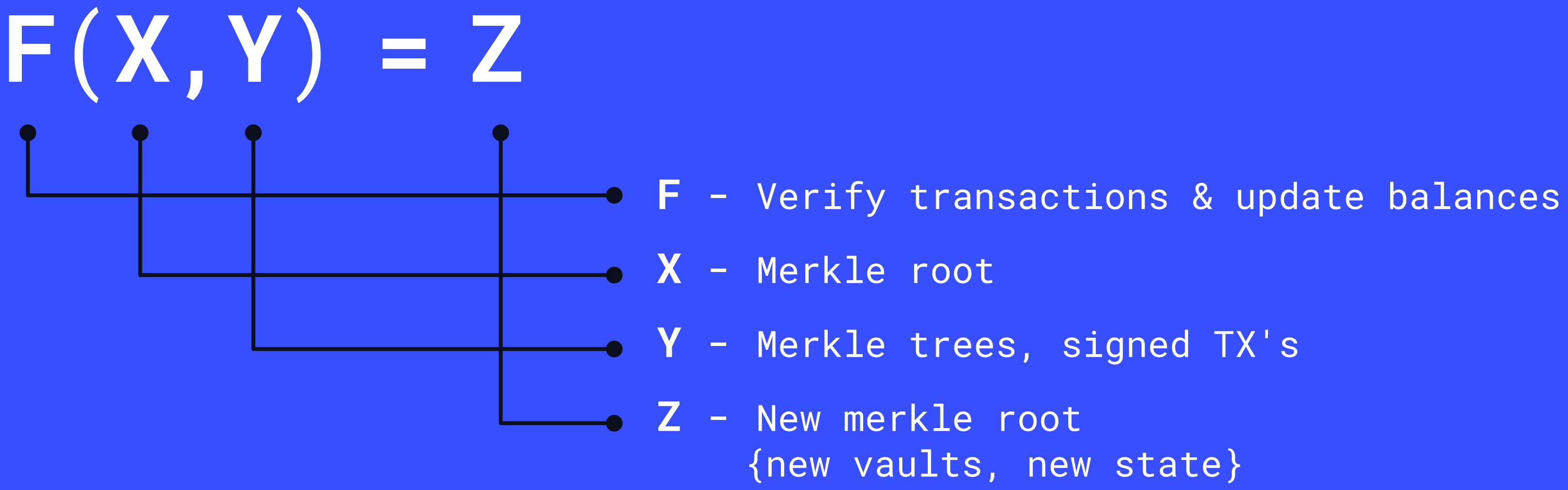
$$F(X,Y) = Z$$



- **F** - Your function (check 18+)
- **X** - Public input (id)
- **Y** - Private input (your age)
- **Z** - Public output (Confirmation 18+)

Proof

Here is ***X*** *and* ***Z****, I know of an* ***Y***
such that ***F(X, Y) = Z***



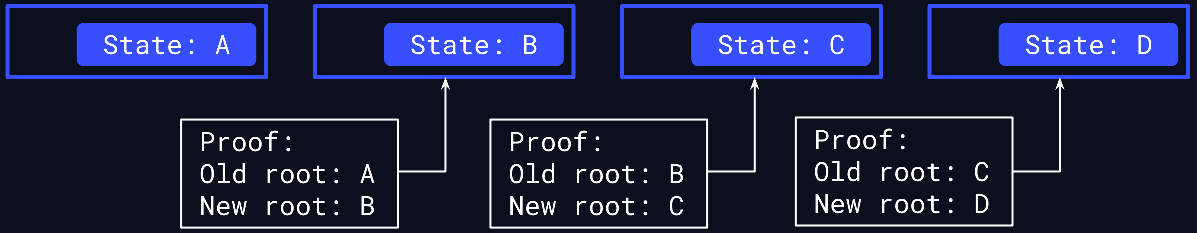
$F(X,Y) = Z$

F - Verify transactions & update balances

X - Merkle root

Y - Merkle trees, signed TX's

Z - New merkle root
{new vaults, new state}



State: A

State: B

State: C

State: D

Proof:
Old root: A
New root: B

Proof:
Old root: B
New root: C

Proof:
Old root: C
New root: D

Application area

Scaling

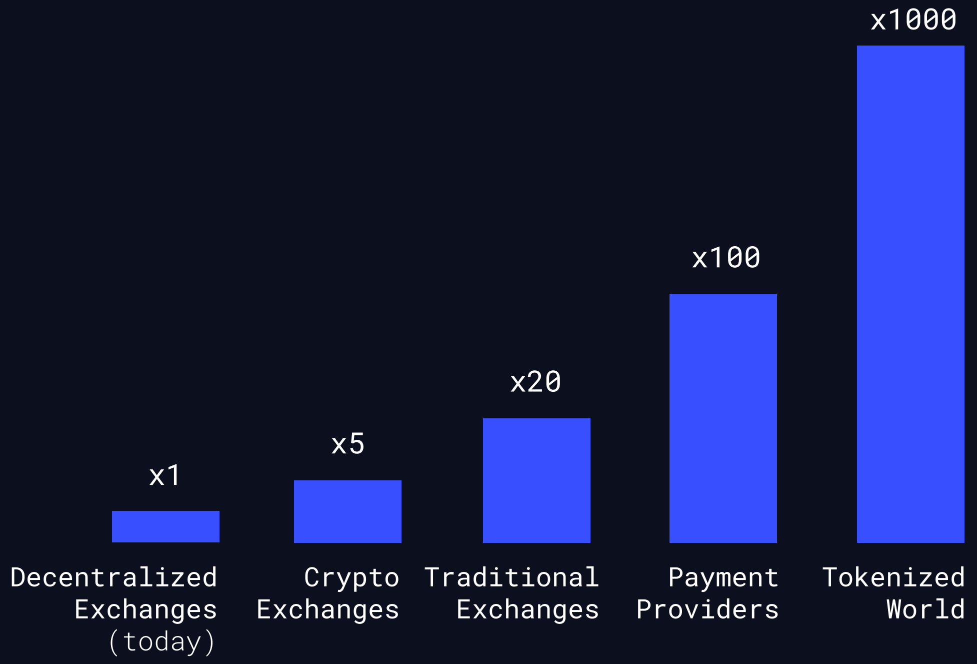
Privacy

Universal L2
solution for DeFi

Scaling

Scaling

Why scaling?



1. Enable new use-cases (games, prediction, logistics, etc.)
2. Future need for many TXs

Scaling blockchains

Ethereum 2.0

Cosmos

Near

DFinity

Polkadot

TON

1 Layer

2 Layer

State Channels
(L4, Raiden)

Plasma

Future 0x

Ignis

Rollup

Loom

Poa

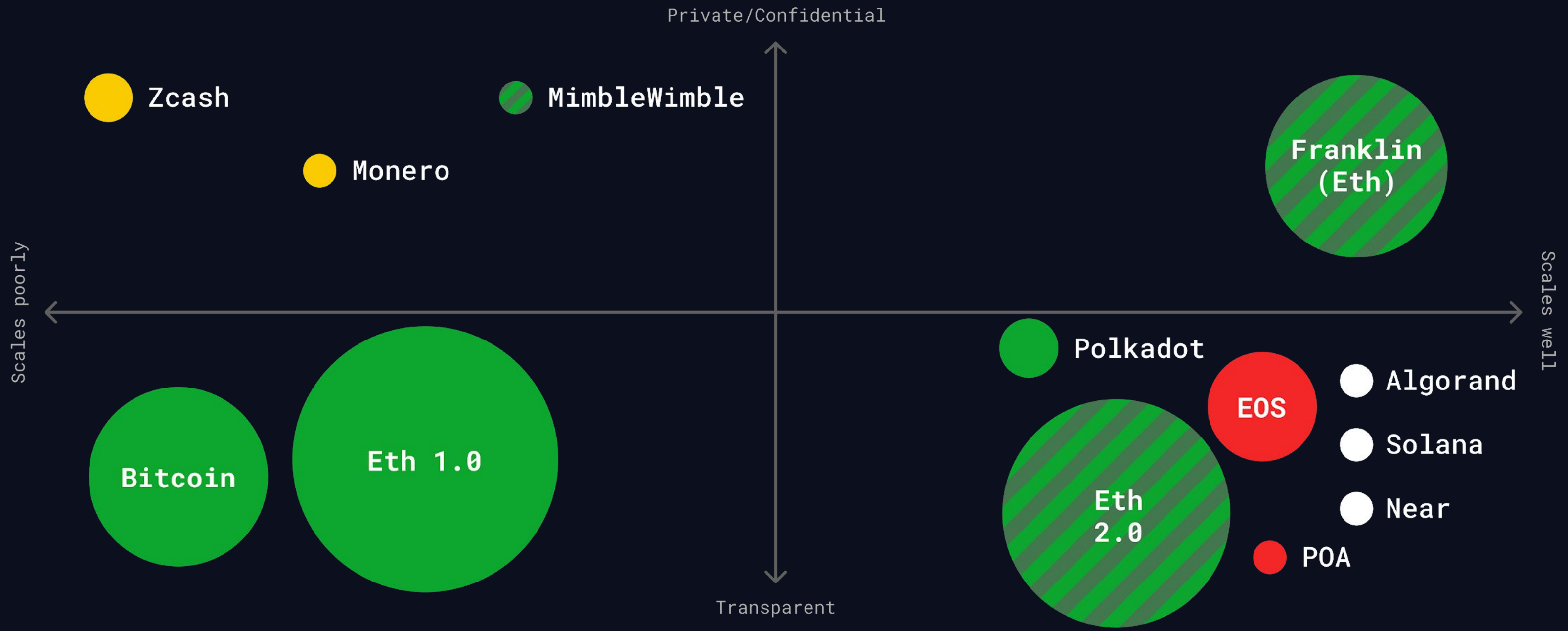
etc

Comparison

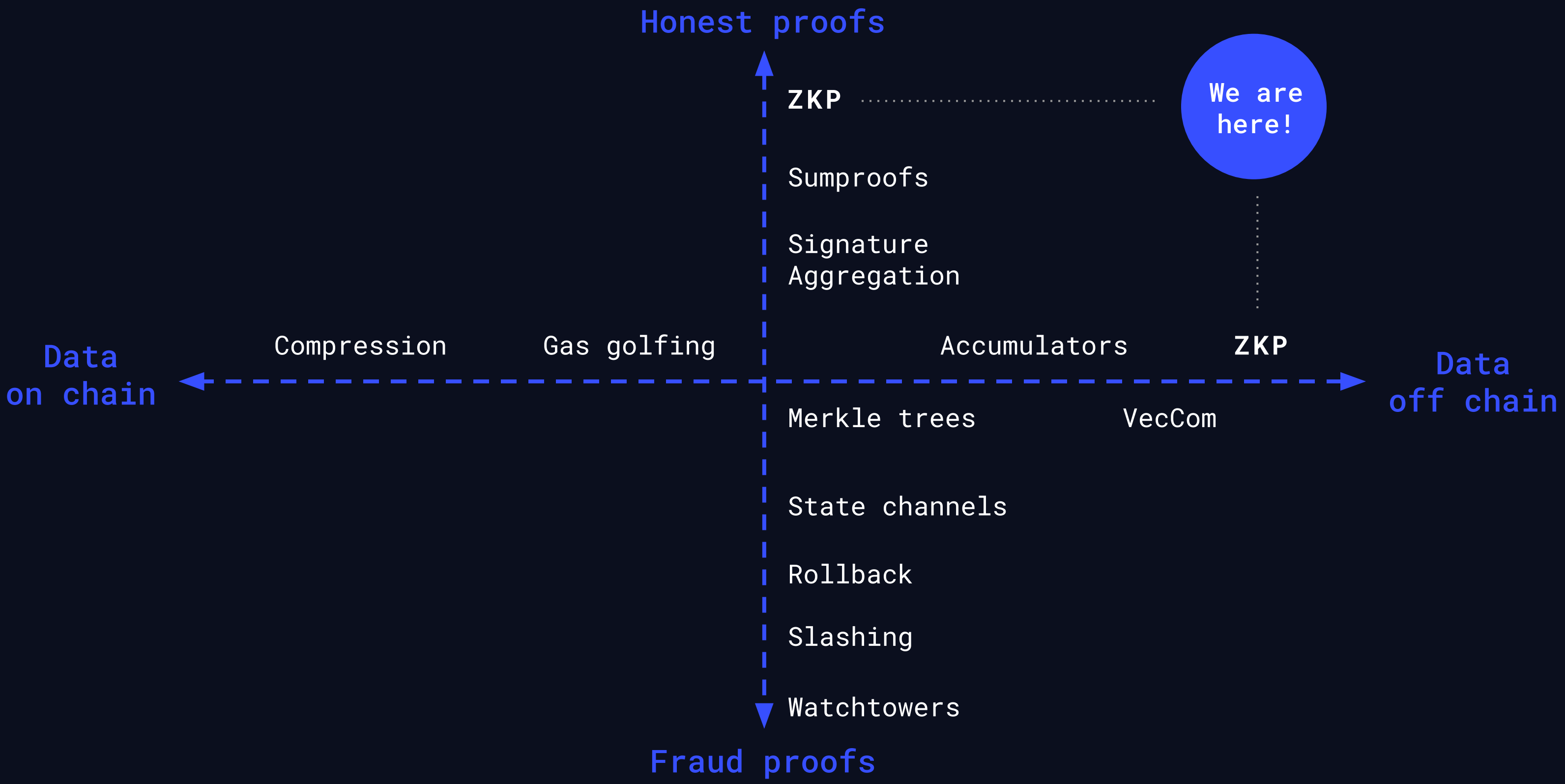
🟢 Secure 🟡 Less secure 🔴 Insecure

▨ Not available yet

○ Radius = size of existing ecosystem



Layer two scaling



Privacy

1

Secure Payments

mixers

2

Settlement layer for DEXes

prevent front-running attack

3

Private smart contracts

Tech approach

zkSNARKs

zkSTARKs

Bulletproofs

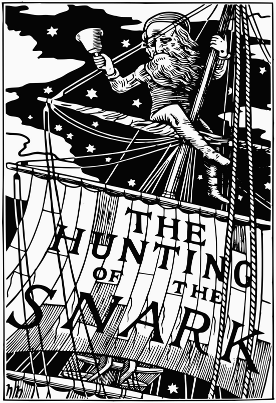
Based on range proof &
pedersen commitments
(Monero)

Aztec

Custom privacy protocol
With custom elliptic curve

Legend

- ZKP = Zero-Knowledge Proof
- zkSNARK = ZK Succinct Non-Interactive ARgument of Knowledge
- zkSTARK = ZK Scalable Transparent ARgument of Knowledge
- AZTEC = Anonymous Z(K) Transactions with Efficient Communication



VS

SNARKs

- Required trusted setup: Groth16 SONIC
- Based on elliptic curves: BN256 for Ethereum, bls12-381 for Zcash

STARKs

- Based on hashes in merkle trees
- Not proven by time
- Post quantum resistant

SNARKs vs STARKs

	SNARKs	STARKS
Algorithmic complexity: power	O(N * log(N))	O(N * poly-log(N))
Algorithmic complexity: verifier	~ O(1)	O(poly-log(N))
Communication complexity (proof size)	~ O(1)	O(poly-log(N))
Size estimate for 1 TX	Tx: 200 bytes, Key: 50 MB	45 kb
Size estimate for 10.000 TX	Tx: 200 bytes, Key: 500 MB	135 kb
Ethereum/EVM verification gas cost	~ 600k (Groth16)	~ 2.5M (estimate, no impl.)
Trusted setup required?	YES 😒	NO 😄
Post-quantum secure	NO 😒	YES 😄
Crypto assumptions	Strong 😒	Collision resistant hashes 😄

https://github.com/gluk64/awesome-zero-knowledge-proofs

What are SONICs?

SONIC is a proof system, that:

- Universal
- Updatable

https://eprint.iacr.org/2019/099

Libraries

#first_in_class

- **ZoKrates**

  Python style, Rust based
  Oldest one

#faster

- **LibSnark / EthSnarks**

  C++ based
  Examples: Roll_up, miximus

#user_friendly

- **Iden3 – Circom**

  JS based
  Recommended as entry point

#faster

- **Bellman**

  Used by zCash, Rust based

Contact

GitHub / Telegram / Twitter

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Developer |
ETHusiast |

Proposal

1. Precompile for generic elliptic curves (BN256, Groth16)
2. Cost of transaction data vs Storage
3. Wallet support for DApp specific crypto
4. WebAssembly support for ADDC, MULQ, CMUL
5. WebCrypto support for custom crypto?

Ethereum Improvement Proposals

✨ Fellowship of Ethereum Magicians ✨

Reduce the cost of transaction data

🟩 EIPs istanbul, eip, scaling, gas

Extensible crypto for wallets

🟨 Working Groups 🟩 Wallet Ring security

ZKP study links

BASICS

- ↗ **Awesome ZKP list**
  https://github.com/gluk64/awesome-zero-knowledge-proofs
- ↗ **ZKP From Zero to Hero: R1CS + QAP** (Quadratic Arithmetic Programs)
  https://medium.com/@VitalikButerin/quadratic-arithmetic-programs-from-zero-to-hero-f6d558cea649

ELLIPTIC CURVES IMPLEMENTATIONS

- ↗ https://github.com/dis2/bls12
- ↗ https://github.com/ethereum/go-ethereum/tree/master/crypto/bn256

PAIRING

- ↗ **Explainer** (by Vitalik)
  https://medium.com/@VitalikButerin/exploring-elliptic-curve-pairings-c73c1864e627
- ↗ **About Pairings by zcash:**
  https://z.cash/blog/snark-explain7/

ZKP dev links

CIRCUM

- https://github.com/iden3/circom/

Examples:

- **Original**
  https://github.com/iden3/circom/blob/master/TUTORIAL.md
- **Confidential transactions – EthDenver winner project**
  https://github.com/zdai-io/zDai-mixer
- https://github.com/GuthL/roll_up_circom_tutorial

LIBSNARK / ETHSNARKs

- https://github.com/HarryR/ethsnarks
- https://github.com/howardwu/libsnark-tutorial

ZKP dev links

BELLMAN (RUST)

- ↗ https://github.com/matter-labs/bellman

Examples:

- ↗ **Edcon2019 material**
  https://github.com/matter-labs/Edcon2019_material
- ↗ **Igor's example**
  https://github.com/snjax/bellman_cube
- **ZKP in WebAssembly**
  ↗ https://github.com/kobigurk/wasm_proof
- ↗ https://blog.decentriq.ch/zk-snarks-primer-part-one/
- ↗ https://slideslive.com/38911801/snarks-for-mixing-si

Zokrates

- ↗ **Devcon ZKPs tutorial**
  https://github.com/leanthebean/puzzle-hunt

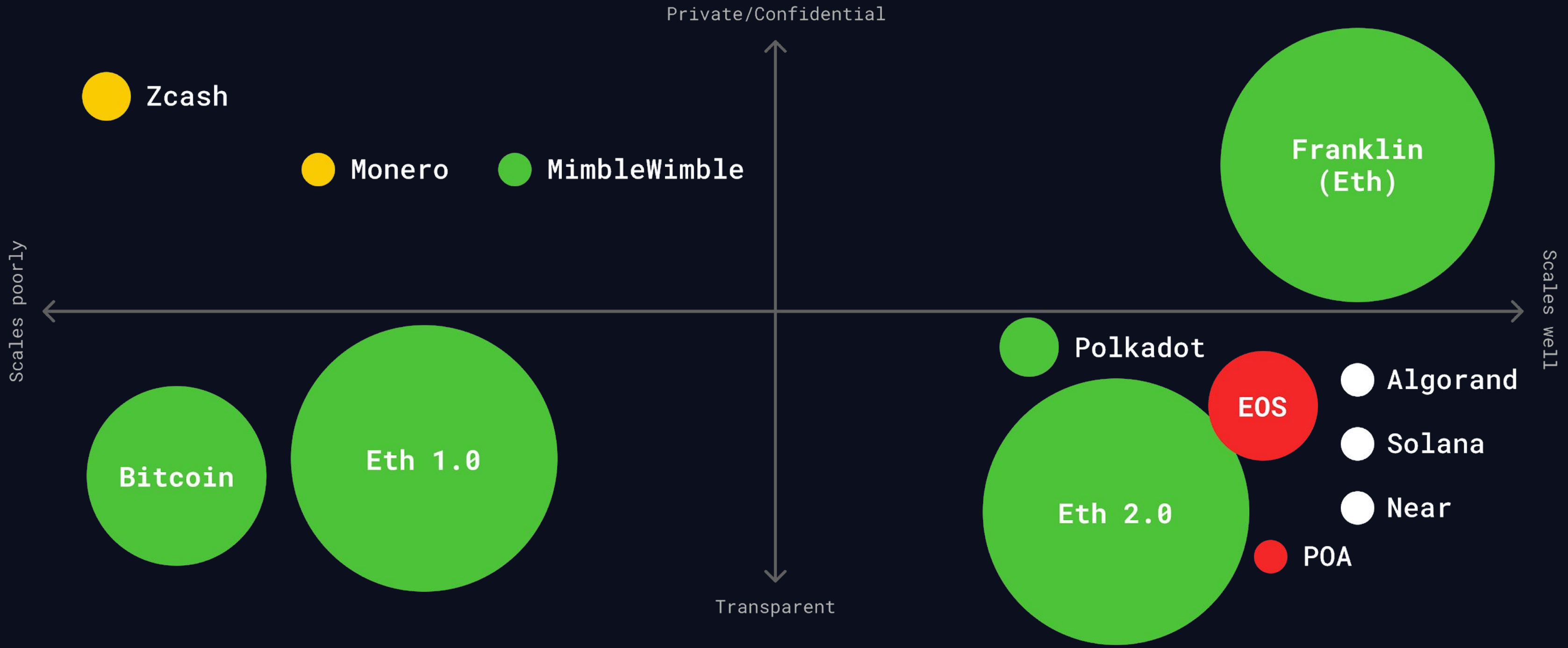
SNARKs vs STARKs

	SNARKs	STARKS	Bulletproofs
Algorithmic complexity: power	O(N * log(N))	O(N * poly-log(N))	O(N * log(N)
Algorithmic complexity: verifier	~ O(1)	O(poly-log(N))	O(N)
Communication complexity (proof size)	~ O(1)	O(poly-log(N))	O(log(N))
Size estimate for 1 TX	Tx: 200 bytes, Key: 50 MB	45 kb	1.5 kb
Size estimate for 10.000 TX	Tx: 200 bytes, Key: 500 MB	135 kb	2.5 kb
Ethereum/EVM verification gas cost	~ 600k (Groth16)	~ 2.5M (estimate, no impl.)	N/A
Trusted setup required?	YES 😒	NO 😄	NO 😄
Post-quantum secure	NO 😒	YES 😄	NO 😒
Crypto assumptions	Strong 😒	Collision resistant hashes 😄	Discrete log 😏

https://github.com/gluk64/awesome-zero-knowledge-proofs

Comparison

🟢 Secure 🟡 Less secure 🔴 Insecure ○ Radius = size of existing ecosystem


Private/Confidential
Transparent
Scales poorly
Scales well
Zcash
Monero
MimbleWimble
Franklin (Eth)
Polkadot
EOS
Algorand
Solana
Near
POA
Bitcoin
Eth 1.0
Eth 2.0