Decentralized Finance

Introduction to Blockchain technology

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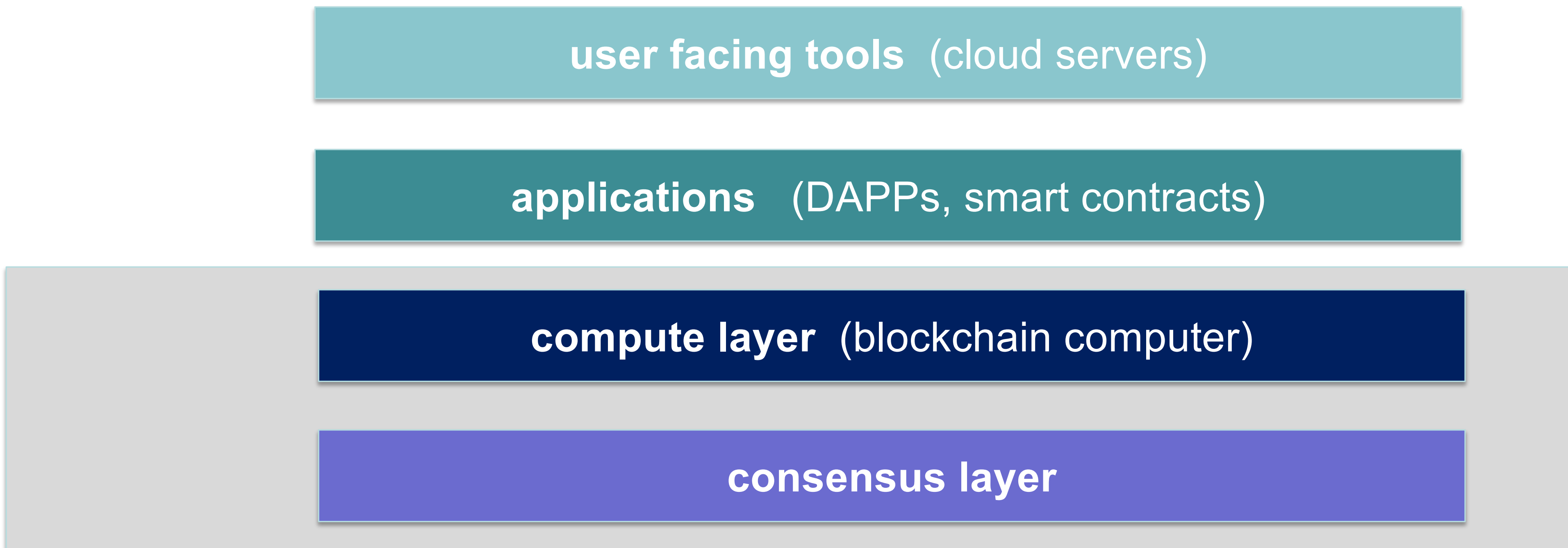
What is a blockchain?

Abstract answer: a blockchain provides
coordination between many parties,
when there is no single trusted party

if trusted party exists ⇒ no need for a blockchain

[financial systems: often no trusted party]

What is a blockchain?



Consensus layer (informal – not the topic of this course)

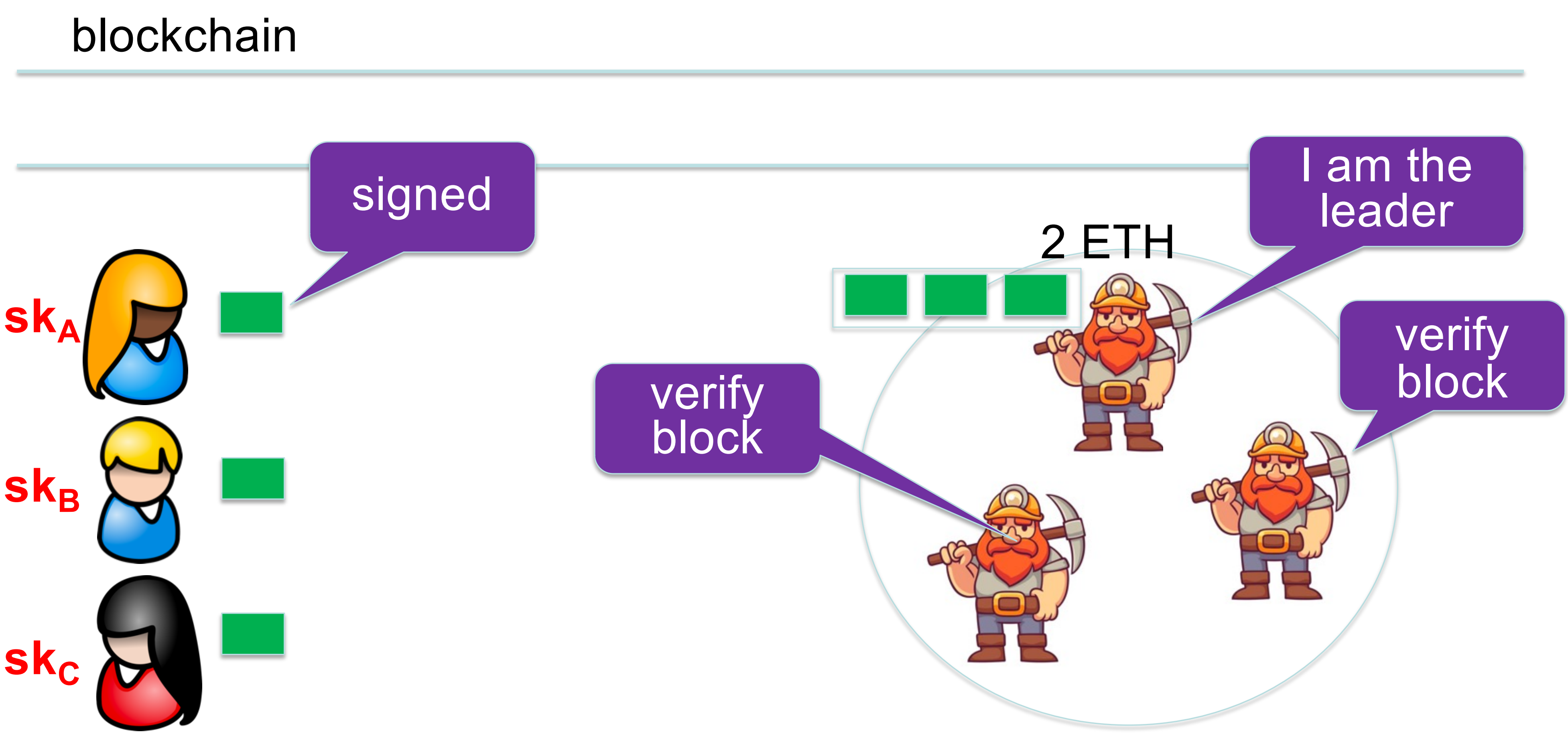
achieved by replication

A **public** append-only data structure:

- **Persistence**: once added, data can never be removed*
- **Consensus**: all honest participants have the same data**
- **Liveness:** honest participants can add new transactions
- **Open(?)**: anyone can add data

Layer 1: consensus layer

How are blocks added to chain?



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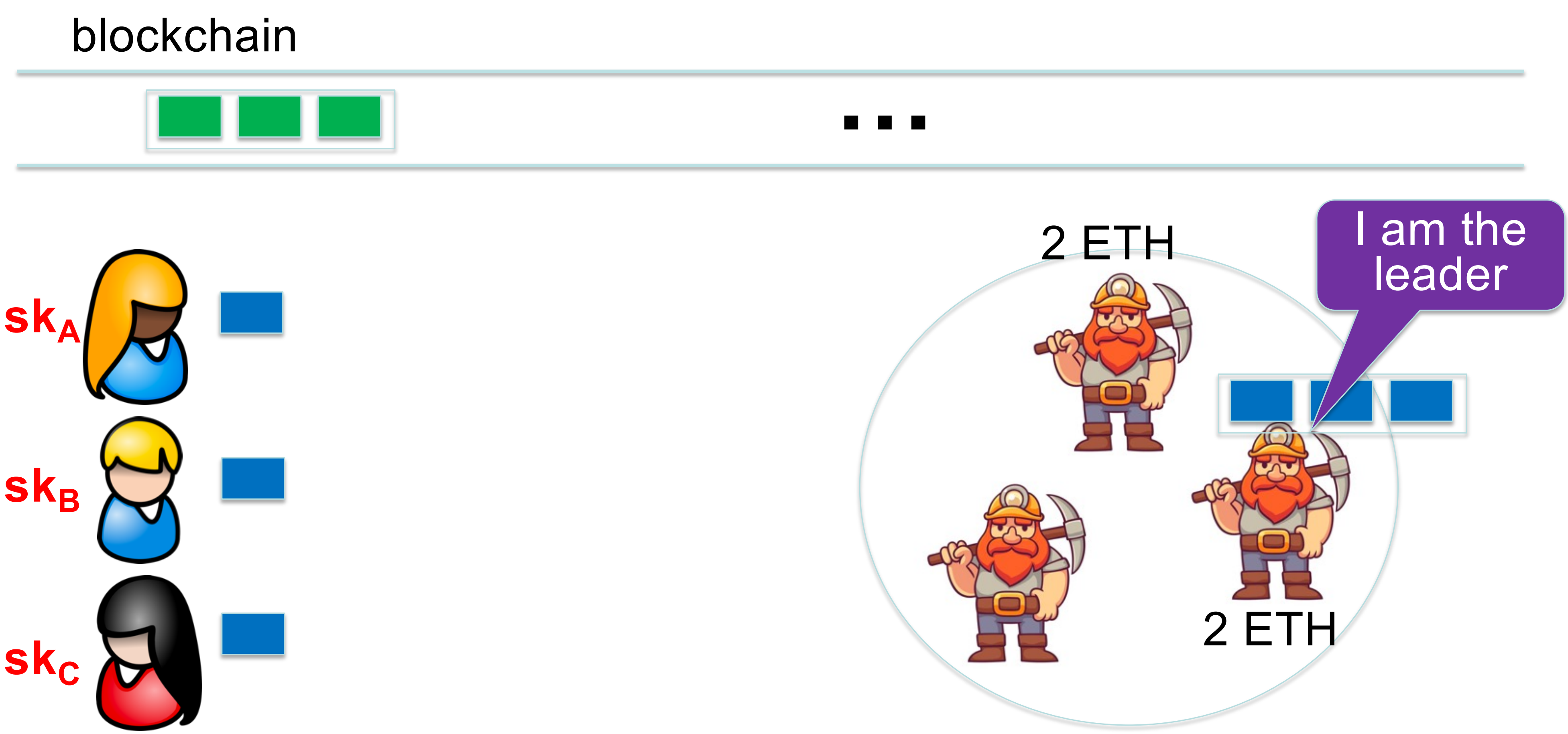


Compute layer: The blockchain computer

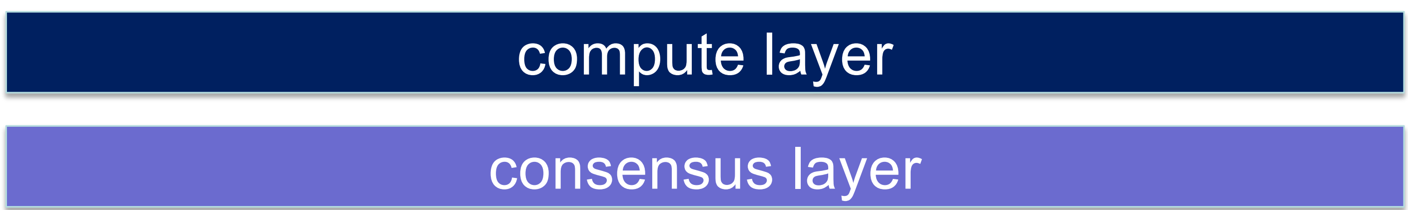
DAPP logic is encoded in a program that runs on blockchain

- Rules are enforced by a <u>public</u> program (public source code)

  ⇒ **<u>transparency</u>**: no single trusted 3rd party

- The DAPP program is executed by parties who create new blocks

  ⇒ **<u>public verifiability</u>**: everyone can verify state transitions



Apps layer: Decentralized applications (DAPPS)

Run on blockchain computer

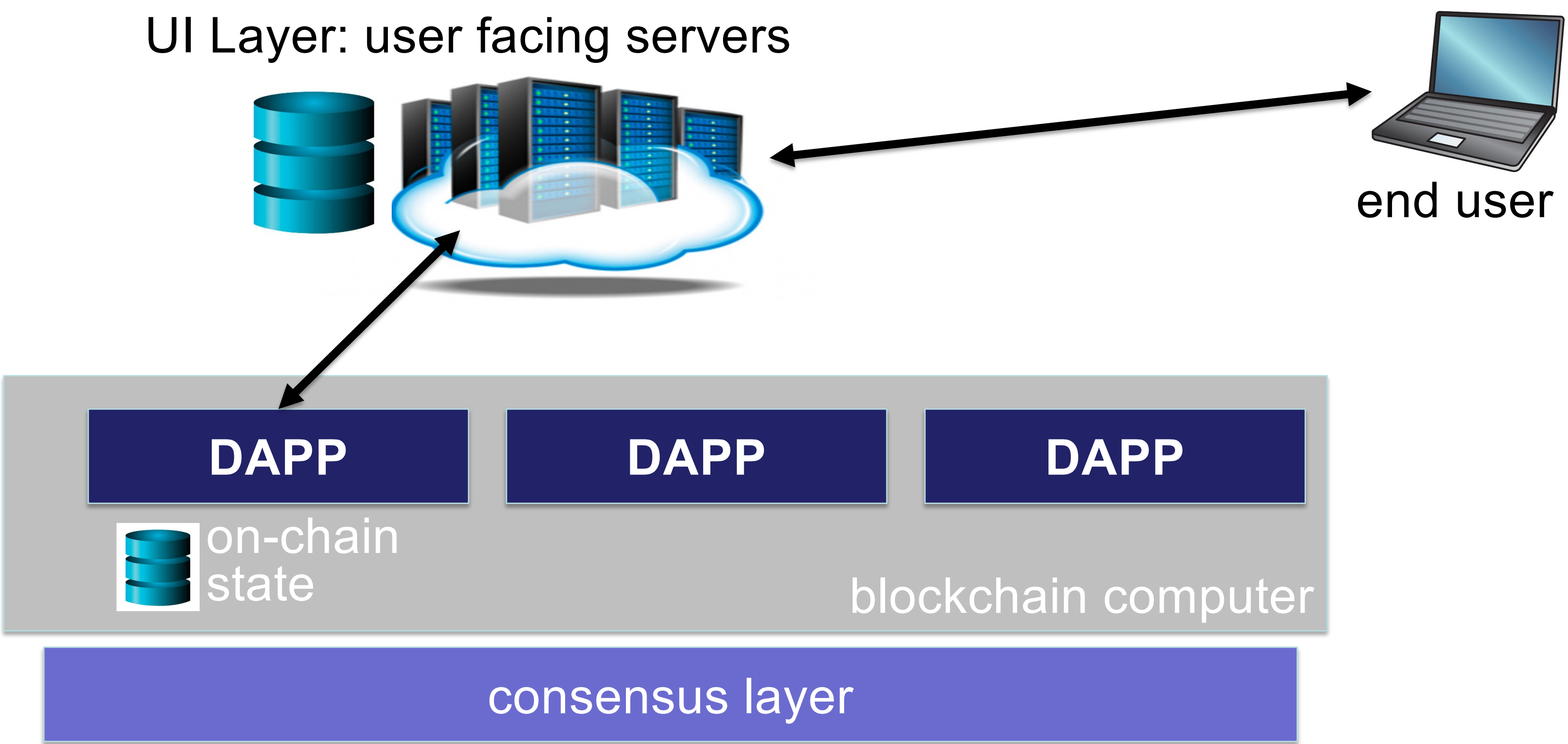
δY/δX

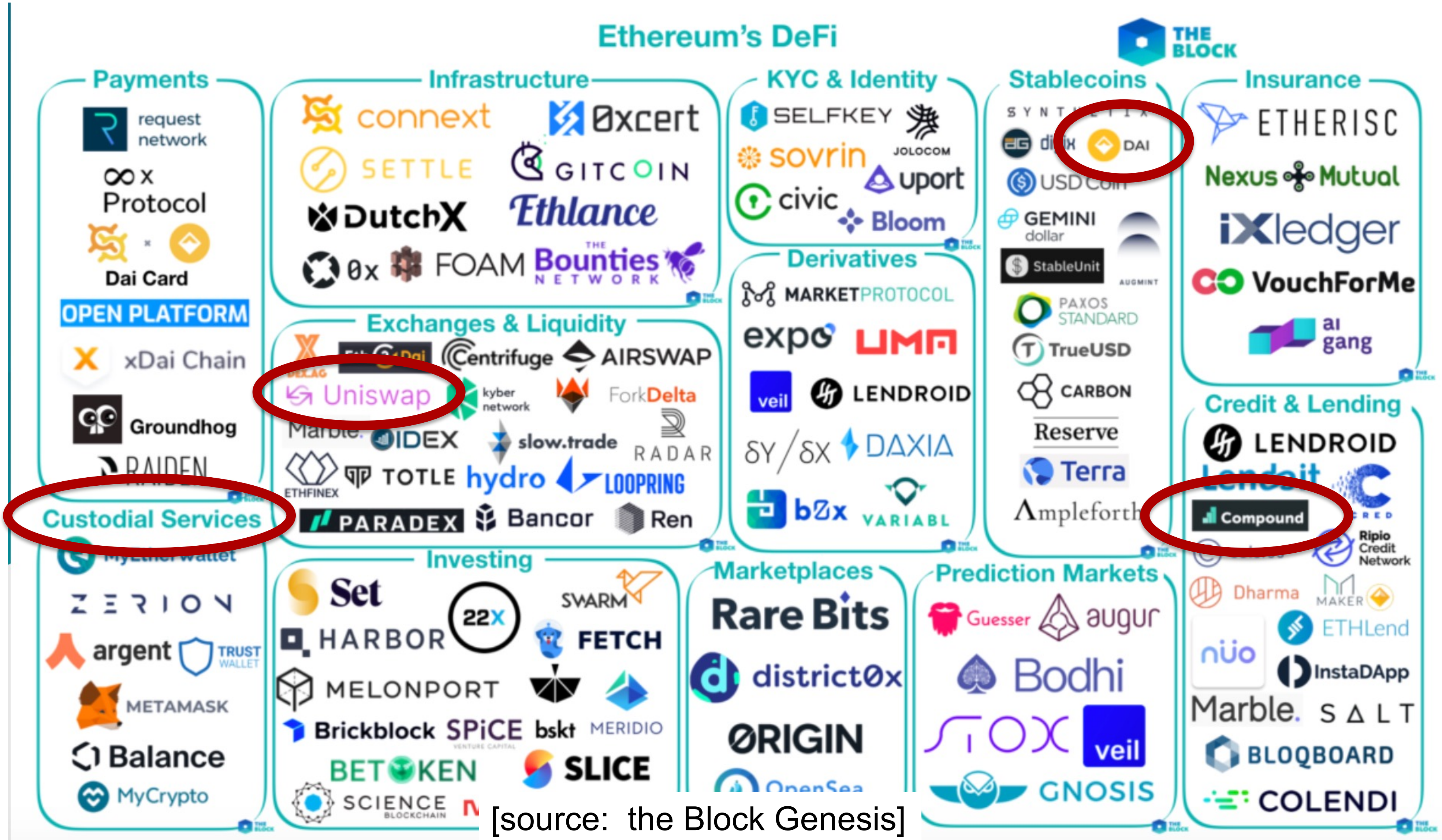
applications (DAPPs, smart contracts)

blockchain computer

consensus layer

UI Layer: Common DAPP architecture





[source: the Block Genesis]

lots of experiments …

DEFI PULSE	Name	Chain	Category	Locked (USD) ▼
🏆 1.	Aave	Multichain	Lending	$15.63B
🥈 2.	Curve Finance	Multichain	DEXes	$10.71B
🥉 3.	InstaDApp	Ethereum	Lending	$10.66B
4.	Compound	Ethereum	Lending	$10.43B
5.	Maker	Ethereum	Lending	$9.11B
6.	Uniswap	Ethereum	DEXes	$7.29B
7.	Convex Finance	Ethereum	Assets	$5.59B

Let's get started …

Next segment: cryptographic background

See you there

Cryptographic Background:

hash functions

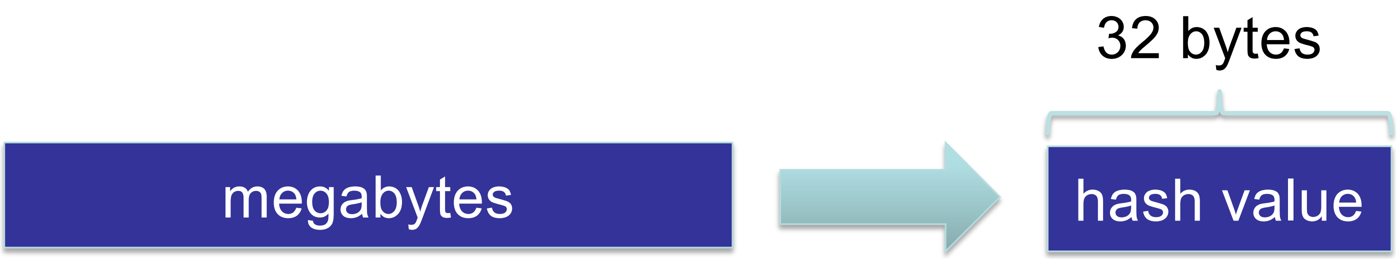
https://defi-learning.org/

Cryptography Background

(1) cryptographic hash functions

An efficiently computable function $H: M \to T$

where $|M| \gg |T|$



$T = \{0,1\}^{256}$

Collision resistance

Def: a **collision** for $H: M \to T$ is pair $x \neq y \in M$ s.t. $H(x) = H(y)$

$|M| \gg |T|$ implies that many collisions exist

Def: a function $H: M \to T$ is **collision resistant** if it is "hard" to find even a single collision for H (we say H is a CRH)

Example: **SHA256**: $\{x : \text{len}(x) < 2^{64} \text{ bytes}\} \to \{0,1\}^{256}$

details in crypto MOOC

An application: committing to data

Alice has a large file m. She publishes $h = H(m)$ (32 bytes)

Bob has h. Later Alice sends m' s.t. $H(m') = h$

H is a CRH $\Rightarrow$ Bob is convinced that $m' = m$
(otherwise, m and m' are a collision for H)

We say that $h = H(m)$ is a **binding commitment** to m

(note: not hiding, h may leak information about m)

Committing to a list (of transactions)

Alice has $S = (m_1, m_2, \ldots, m_n)$

32 bytes

<u>Goal</u>:

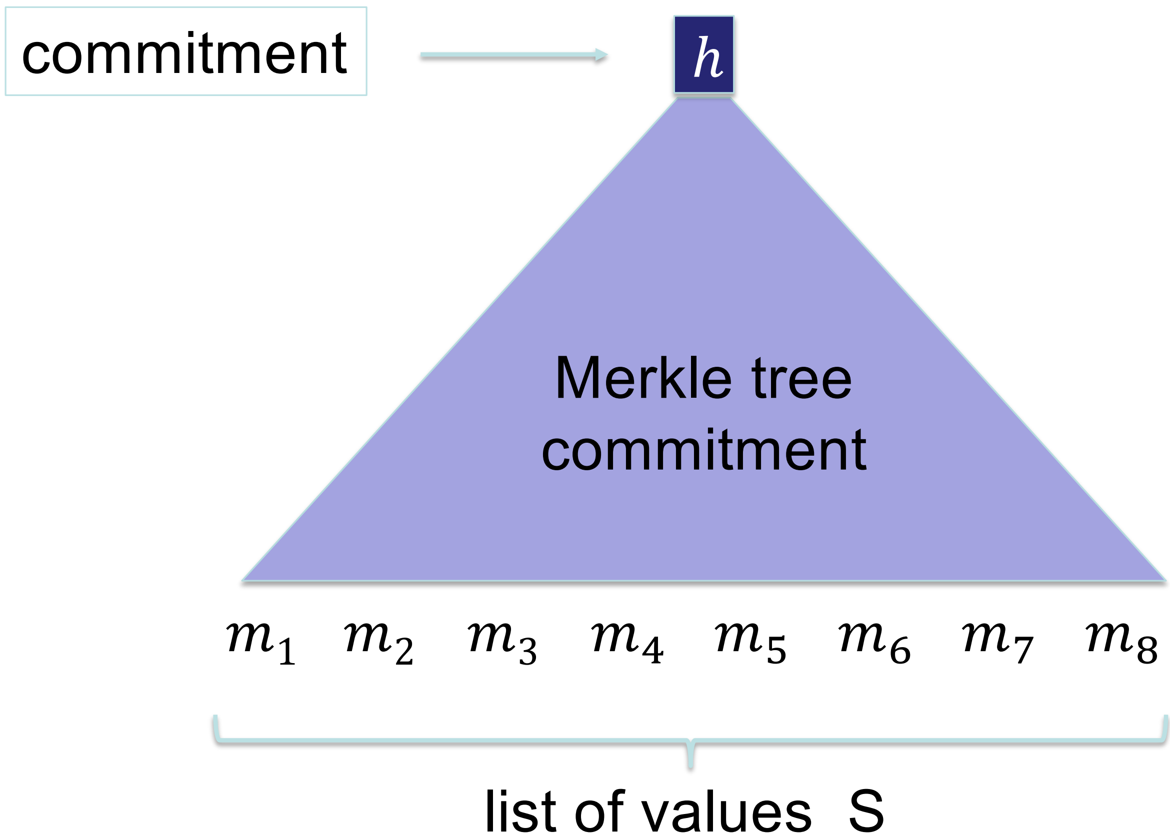
- Alice publishes a <u>short</u> binding commitment to S, $h = \text{commit}(S)$
- Bob has h. Given $(m_i,\ \text{proof}\ \pi_i)$ can check that $S[i] = m_i$

  Bob runs $\text{verify}(h, i, m_i, \pi_i) \rightarrow$ accept/reject

security: adv. cannot find (S, i, m, π) s.t. $m \neq S[i]$ and

$\text{verify}(h, i, m, \pi) = \text{accept}$ where $h = \text{commit}(S)$

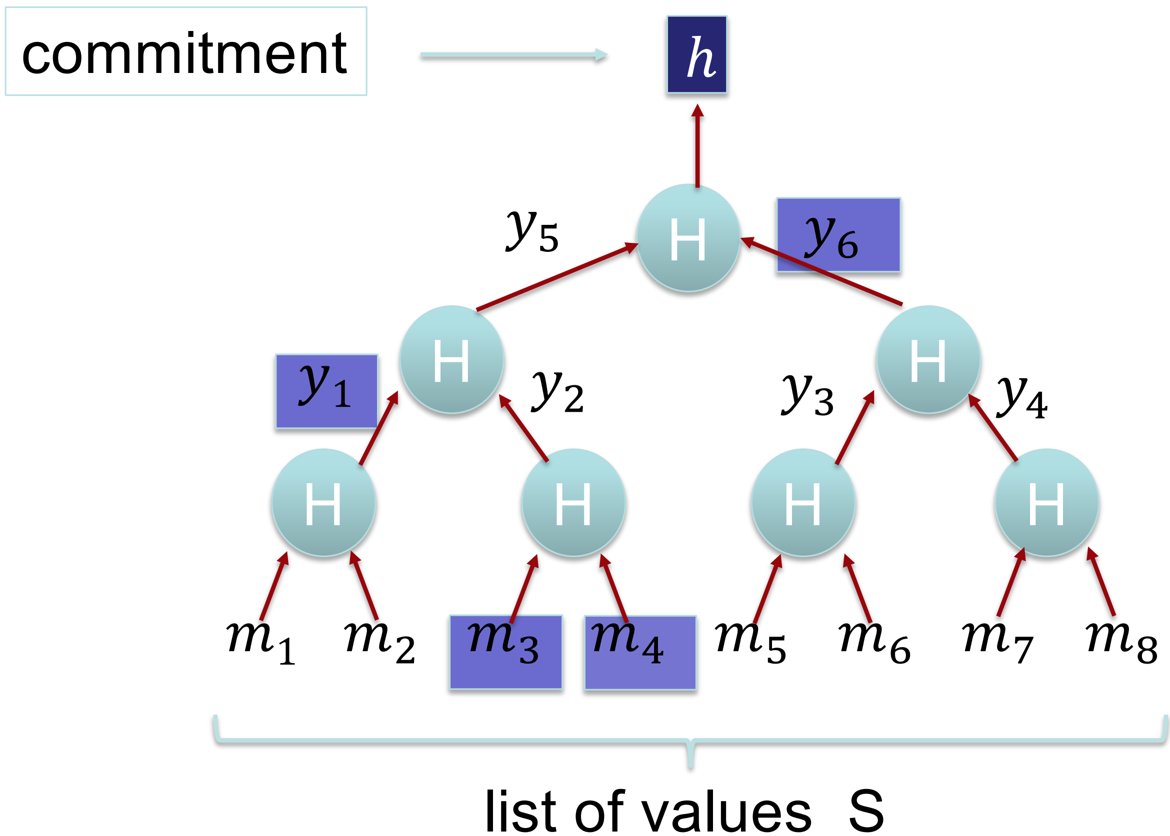
Merkle tree (Merkle 1989)



Goal:

- commit to list S of size n
- Later prove $S[i] = m_i$

Merkle tree (Merkle 1989)



Goal:

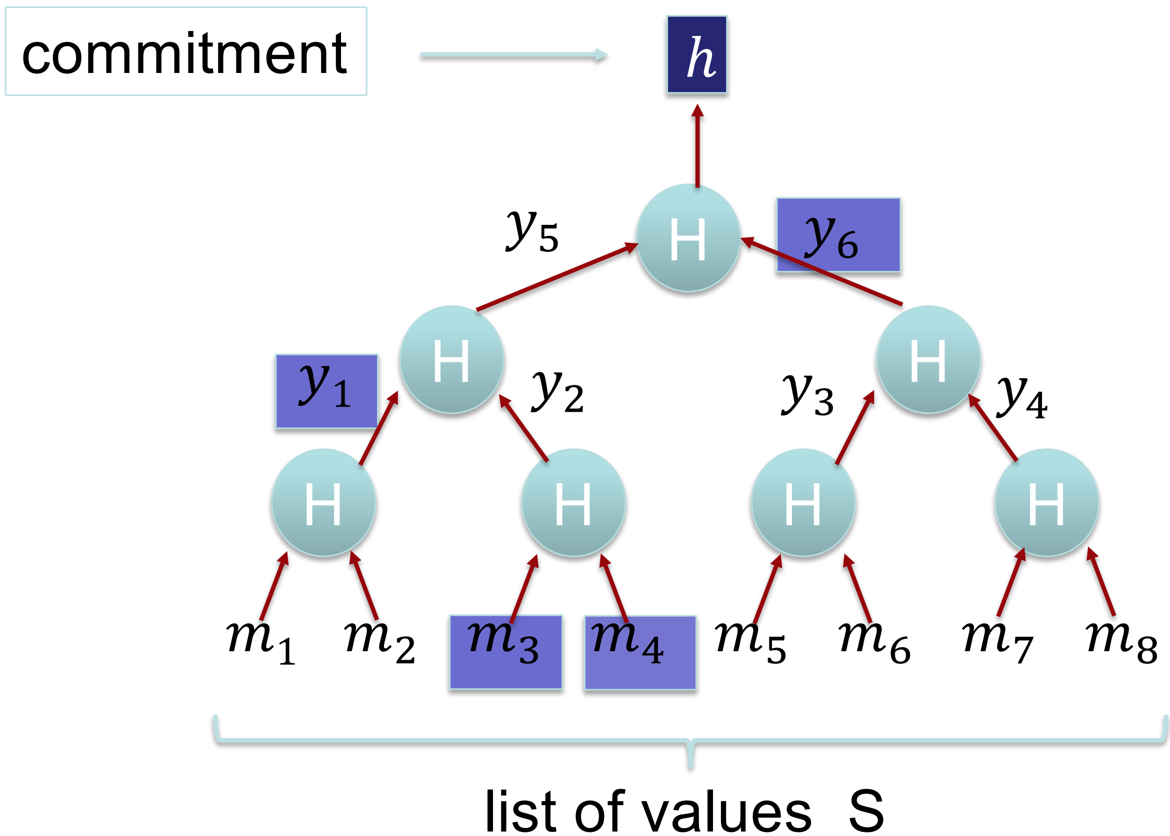
- commit to list S of size n
- Later prove $S[i] = m_i$

To prove $S[4] = m_4$

proof $\pi = (m_3, y_1, y_6)$

length of π: $\log_2 n$

Merkle tree (Merkle 1989)



To prove $S[4] = m_4$

proof $\pi = (m_3, y_1, y_6)$

Bob does:

$y_2 \leftarrow H(m_3, m_4)$

$y_5 \leftarrow H(y_1, y_2)$

$h' \leftarrow H(y_5, y_6)$

accept if $h = h'$

Merkle tree (Merkle 1989)

Thm: H CRH $\Rightarrow$ adv. cannot find (S, i, m, π) s.t. $m \neq S[i]$ and

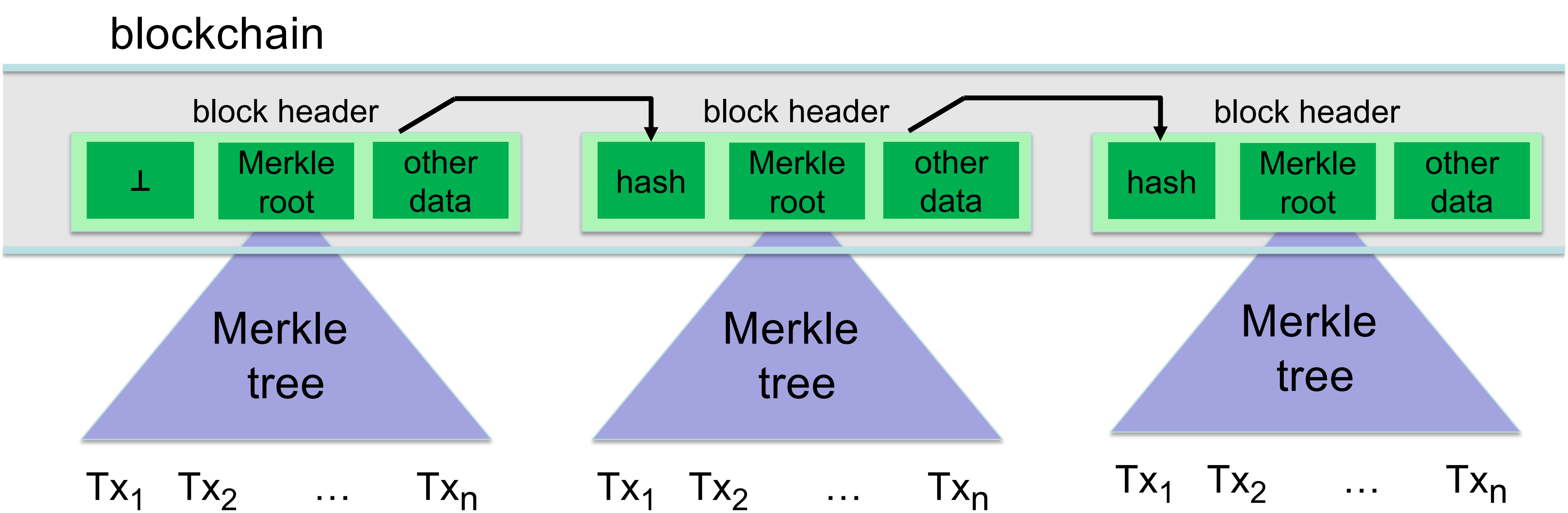
$$\text{verify}(h, i, m, \pi) = \text{accept} \quad \text{where} \quad h = \text{commit}(S)$$

(to prove, prove the contra-positive)

How is this useful? Super useful. Example:

- When writing a block of transactions S to the blockchain, suffices to write commit(S) to chain. Keep chain small.
- Later, can prove contents of every Tx.

Abstract block chain



Merkle proofs are used to prove that a Tx is “on the block chain”

Next segment: digital signatures

How to authorize transactions??

Cryptographic Background:

Digital Signatures

https://defi-learning.org/

Digital Signatures

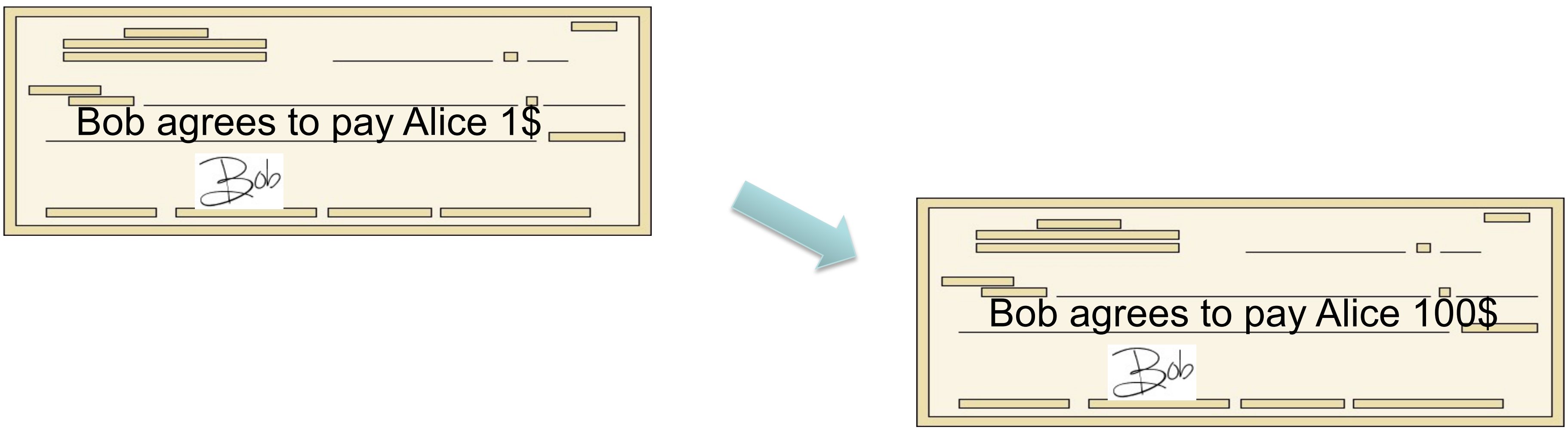
- In the last segment we looked at cryptographic hash functions.

- In this segment we will look at digital signatures:

how to approve a transaction?

Signatures

Physical signatures: bind transaction to author

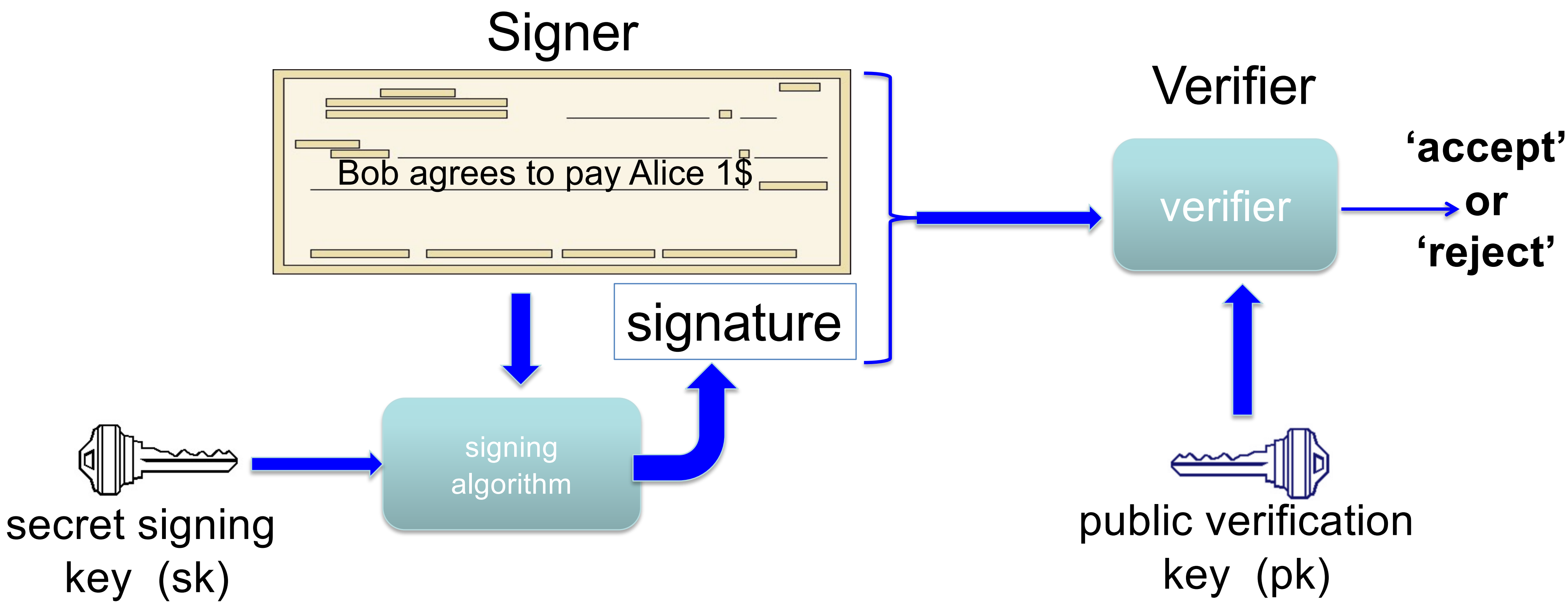


Problem in the digital world:

anyone can copy Bob’s signature from one doc to another

Digital signatures

Solution: make signature depend on document



Digital signatures: syntax

Def: a signature scheme is a triple of algorithms:

- **Gen**(): outputs a key pair (pk, sk)
- **Sign**(sk, msg) outputs sig. σ
- **Verify**(pk, msg, σ) outputs 'accept' or 'reject'

Secure signatures: (informal)

Adversary who sees pk and sigs on many messages of her choice, cannot forge a signature on a new message.

Families of signature schemes

1. RSA signatures (not used in blockchains):
   - long sigs and public keys (≥256 bytes), fast to verify

2. Discrete-log signatures: Schnorr and ECDSA (Bitcoin, Ethereum)
   - short sigs (48 or 64 bytes) and public keys (32 bytes)

3. BLS signatures: 48 bytes, aggregatable, easy threshold

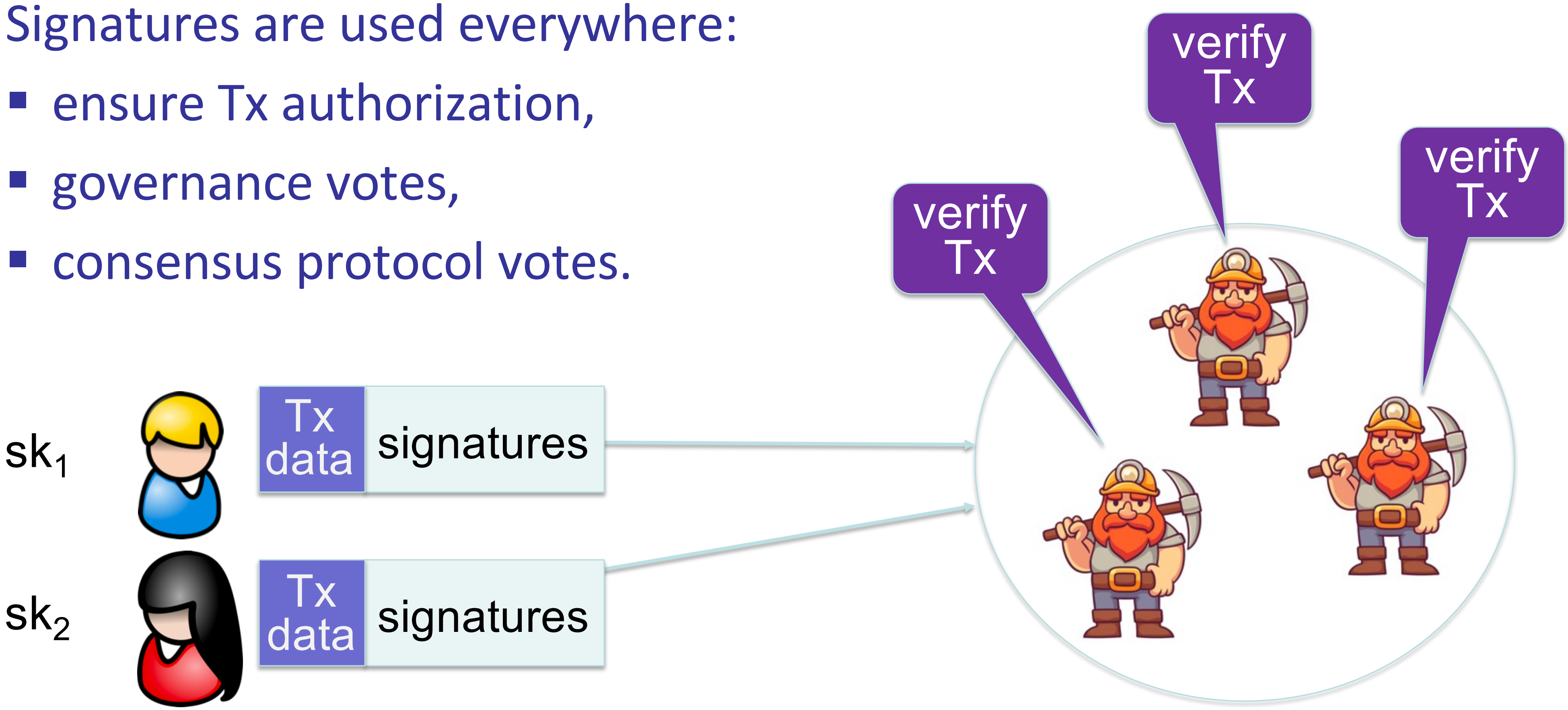
   (Ethereum 2.0, Chia, Dfinity)

4. Post-quantum signatures: long (≥768 bytes)

Signatures on the blockchain

Signatures are used everywhere:

- ensure Tx authorization,
- governance votes,
- consensus protocol votes.



SNARK proofs

We covered two important cryptographic primitives:

1. Collision resistant hash functions and Merkle trees,
2. Digital signatures.

Another important cryptographic primitive is a **SNARK proof**:

- Used for scaling and privacy
- We will discuss SNARKs in detail in the lecture on privacy

Next segment: scaling the blockchains

Can we make it fast??

Scaling Blockchains

https://defi-learning.org/

Scaling

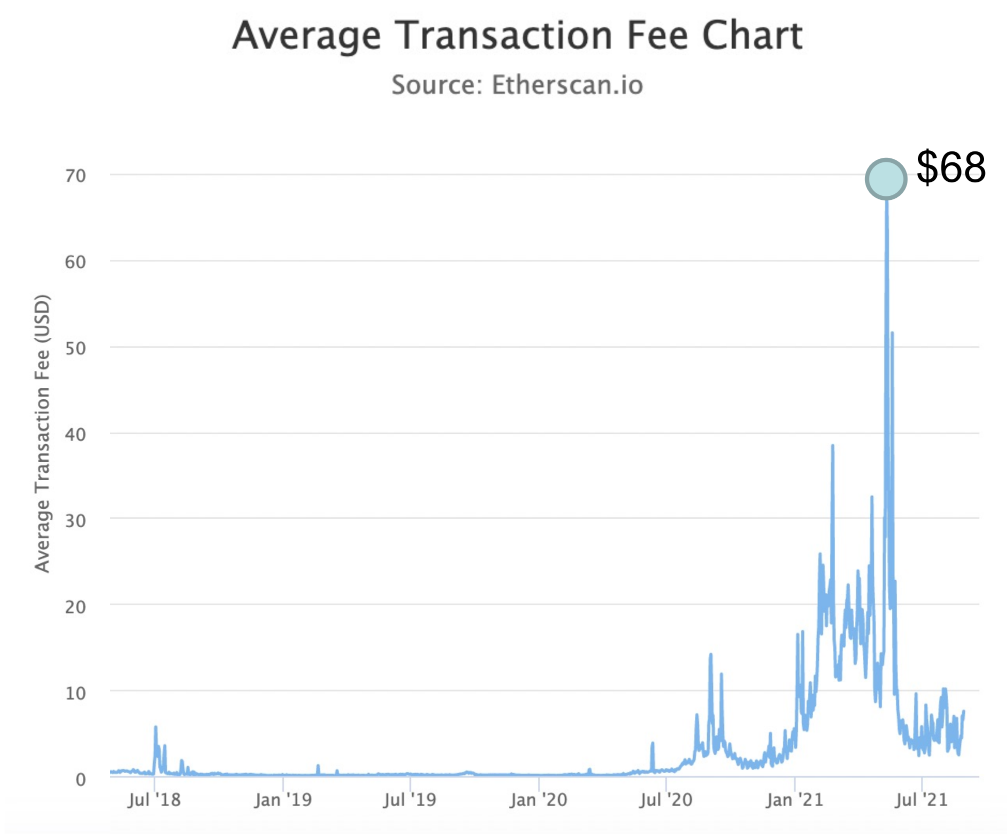
Transaction rates (Tx/sec):

- Bitcoin: can process about **5 (Tx/sec)**
- Ethereum: can process about **20 (Tx/sec)**

Tx Fees fluctuate:

2$ to 60$ for simple Tx

Ethereum Tx fees (gas prices)



Scaling

Transaction rates (Tx/sec):

- Bitcoin: can process about **5 (Tx/sec)**
- Ethereum: can process about **20 (Tx/sec)**

Tx Fees fluctuate:

2$ to 60$ for simple Tx

- The visa network: can process up to **24,000 (Tx/sec)**

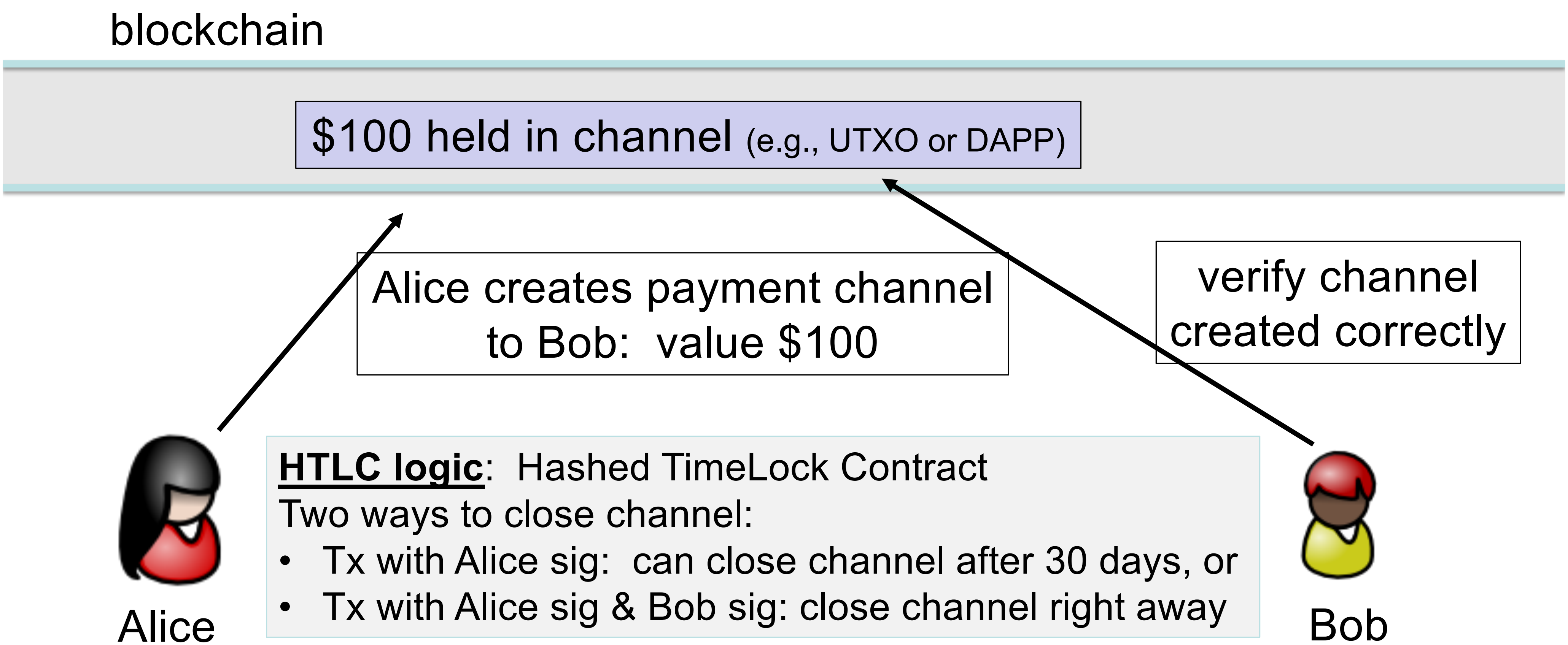
Can we scale blockchains to visa speeds? … with low Tx fees

Scaling approaches

Many approaches to scaling blockchains:

- **Faster consensus**: modern blockchains (e.g., Solana, Polkadot, Avalanche, …)
- **Payment channels**: most Tx are off chain Peer-to-Peer (e.g., Lightening)
- **Layer 2 approaches:**
  zkRollup, optimistic Rollup: batch many Tx into a single Tx
- Sidechains: Polygon and others
- many other ideas …

(1) Payment channels (high level idea)



(1) Payment channels (high level idea)

blockchain

$100 held in channel (e.g., UTXO)

Bob can sign Tx and close channel
… but he would rather wait (up to 30 days)

Alice

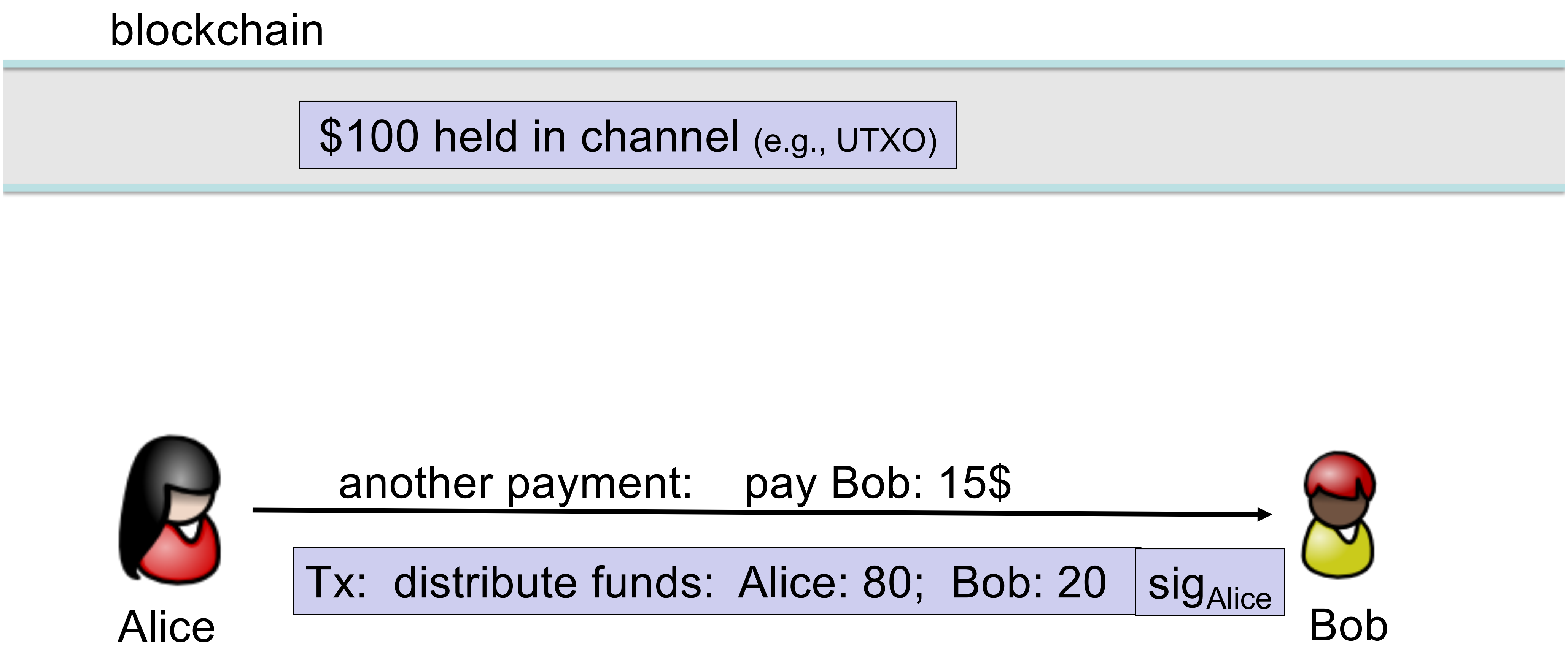
pay Bob: 5$

Tx: distribute funds: Alice: 95; Bob: 5 | $\text{sig}_{\text{Alice}}$

Bob

(off chain message!)

(1) Payment channels (high level idea)



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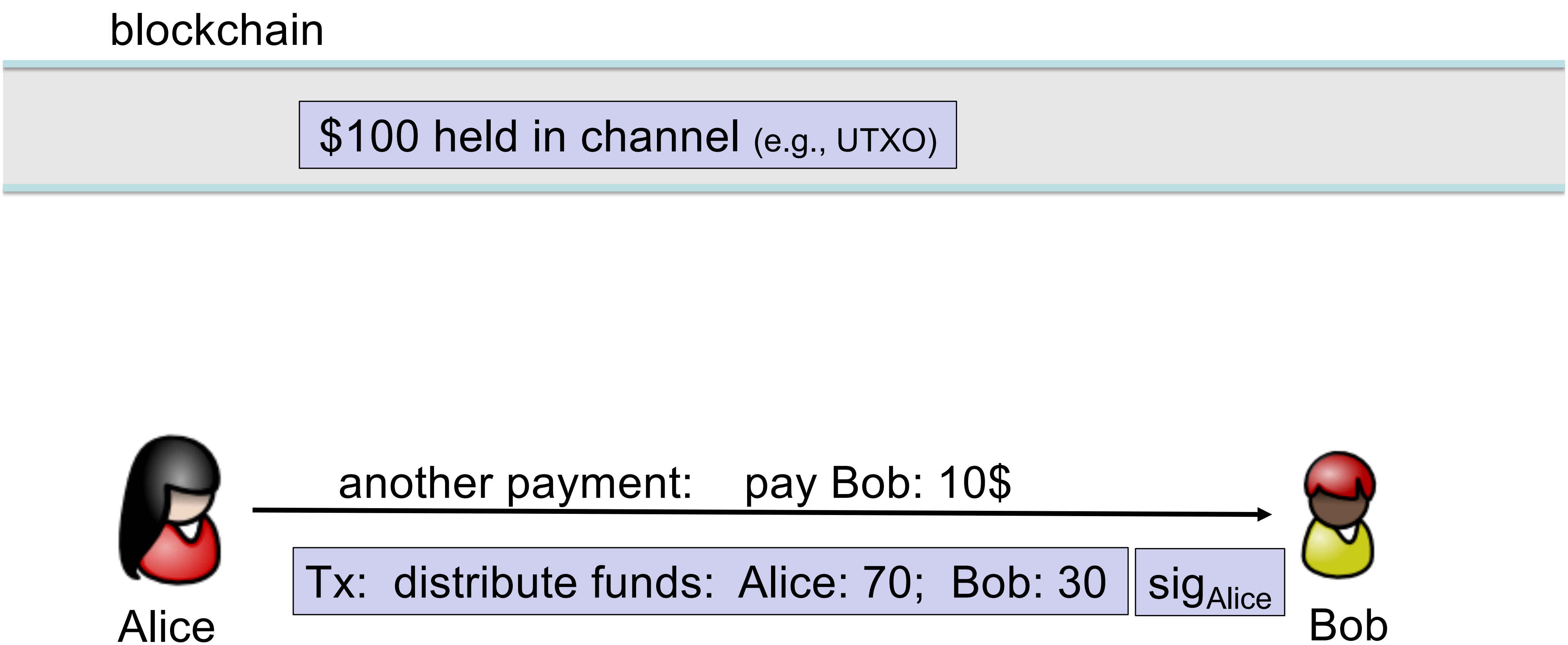

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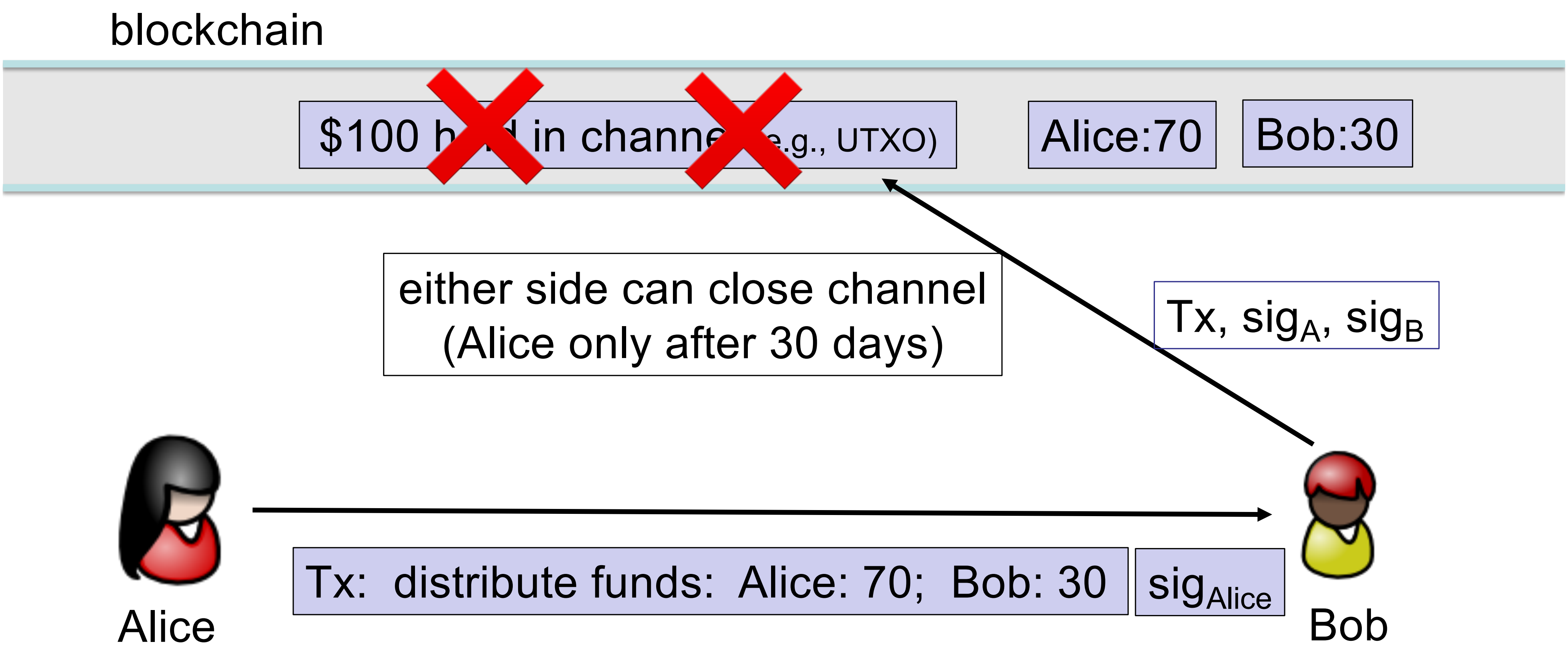

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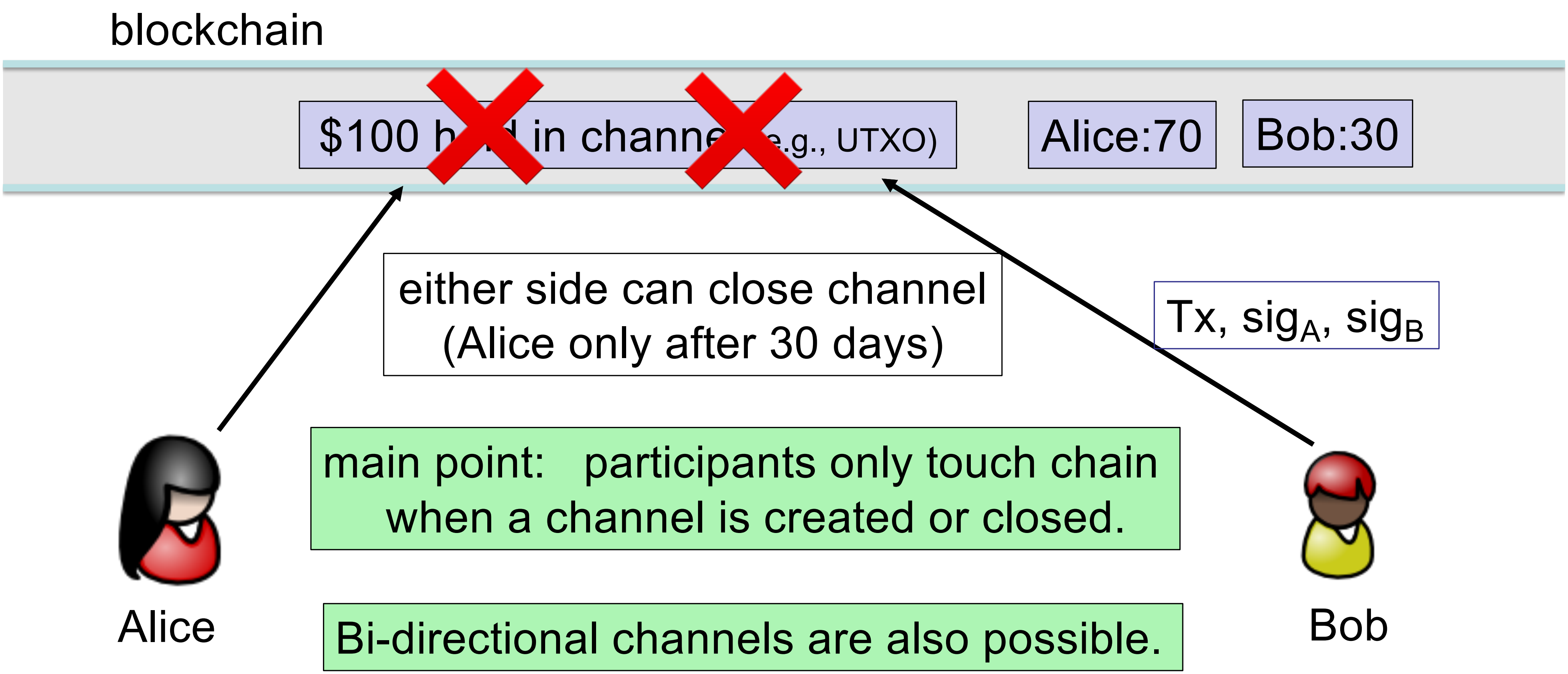
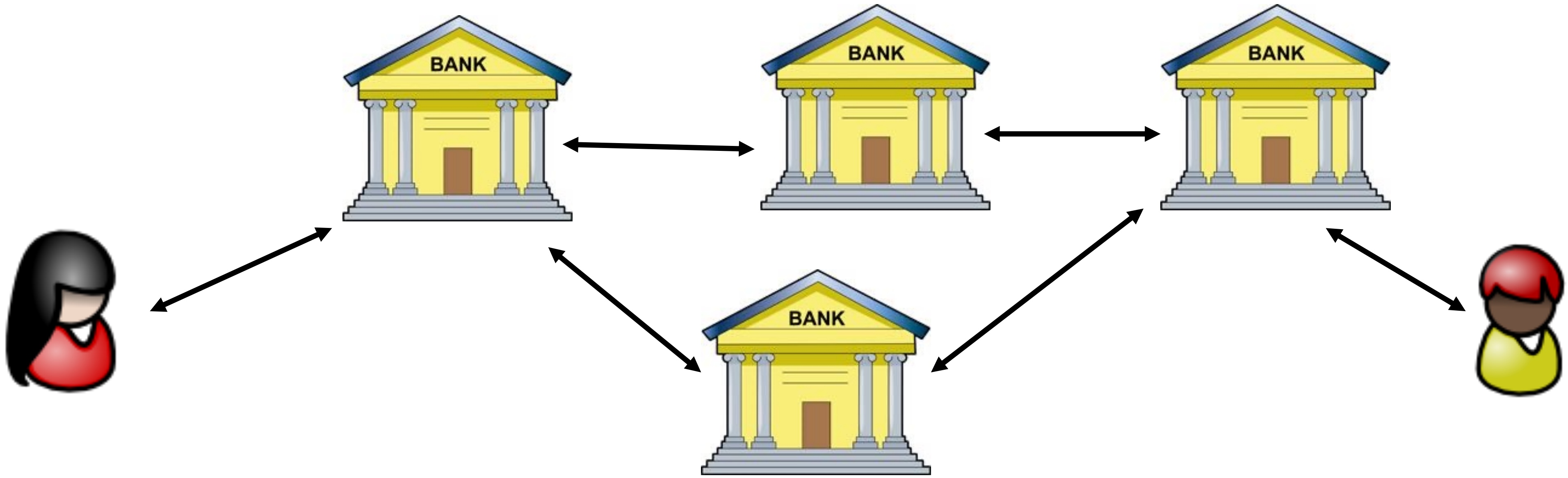


Payment networks

Lots of bi-directional payment channels



Alice pays Bob by finding the cheapest route through the network

$\Longrightarrow$ while channels are open, nothing touches the blockchain

The case of El Salvador

June 24, 2021
8:18 PM PDT
Last Updated 2 months ago

Technology

Bitcoin to become legal tender in El Salvador on Sept 7, 2021

3 minute read

Reuters

Payment channels are necessary to enable state-wide adoption

- Strike wallet: connects to the Bitcoin Lightening network

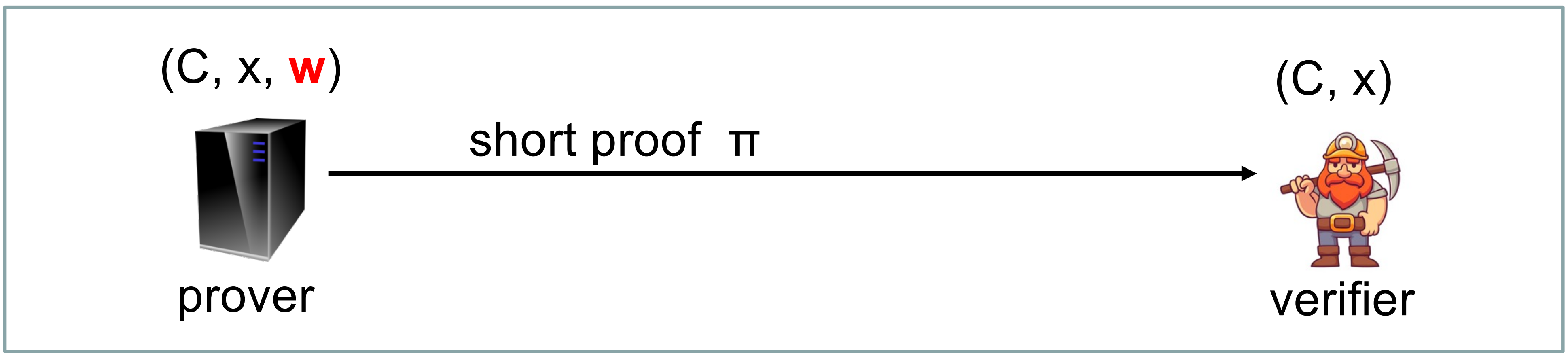
(2) Scaling Ethereum Using Rollup

(2) Scaling Ethereum Using Rollup

Main tool: SNARK (much more on SNARKs later)

C: a program that always terminates in ≤B steps

x: public input to C, **w**: private input to C



(2) Scaling Ethereum Using Rollup

Main point:
Verifier's run time is
much less than running C

more on SNARKs

I am convinced
prover knows w
s.t. C(x, w) = 1

inates in ≤B ste

x: public input to C, private input to C

(C, x, **w**)

short proof π

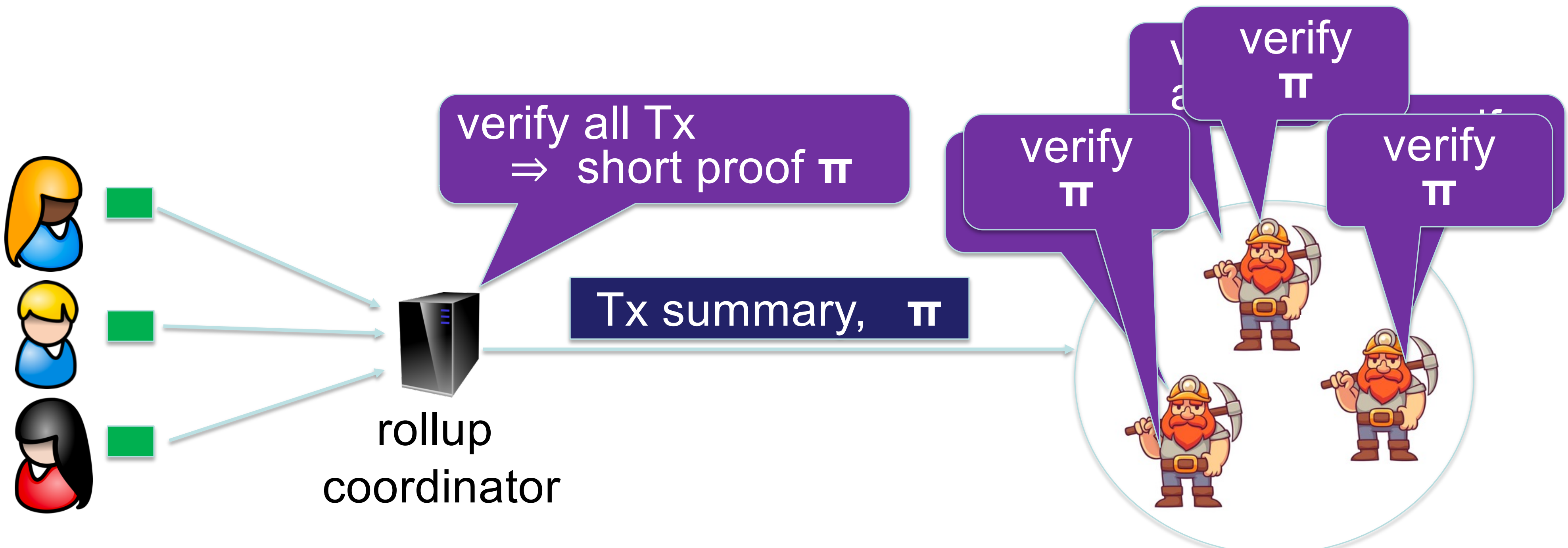
(C, x)

prover

verifier

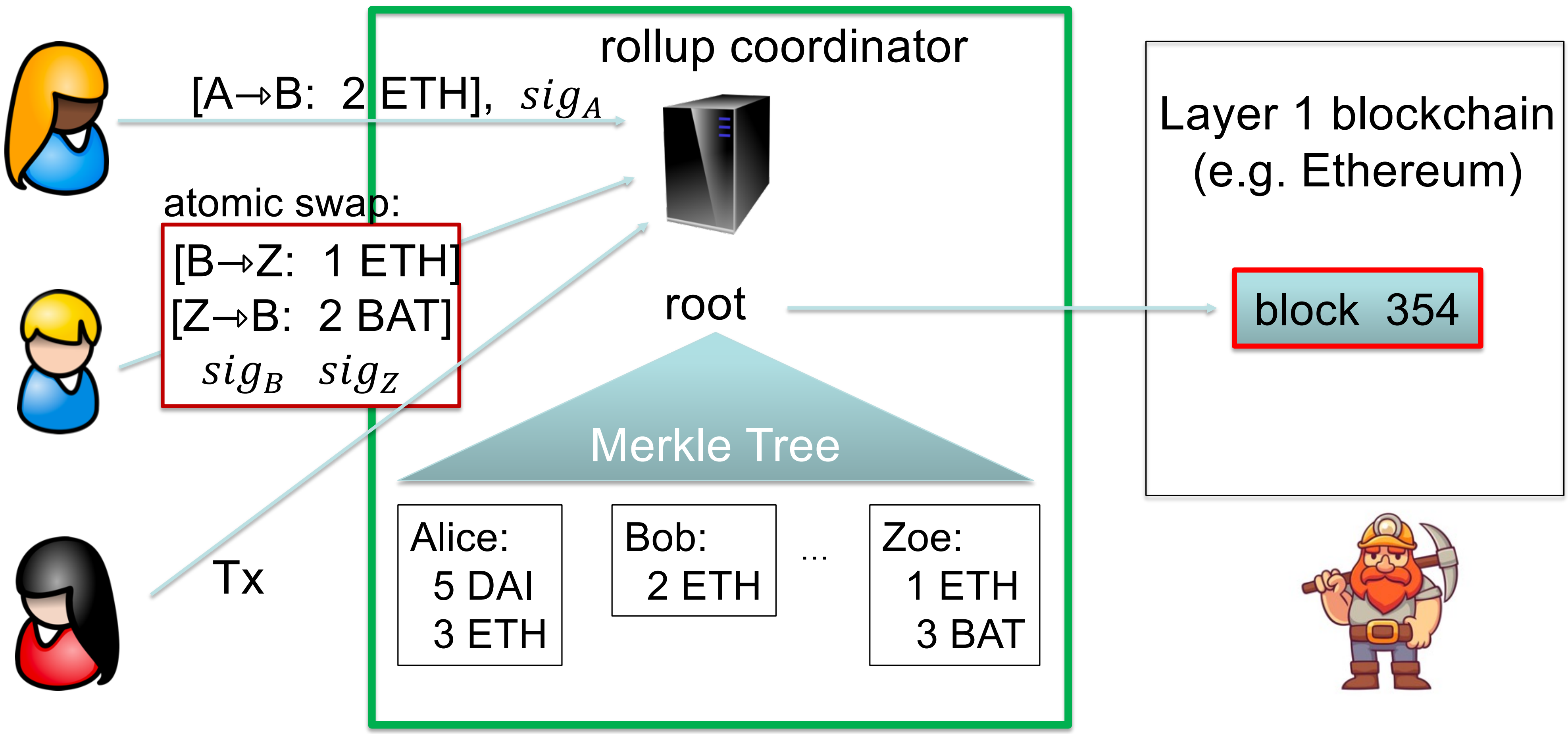
(2) Rollup: zk and optimistic

Standard L1 chains: every miner must verify every posted Tx

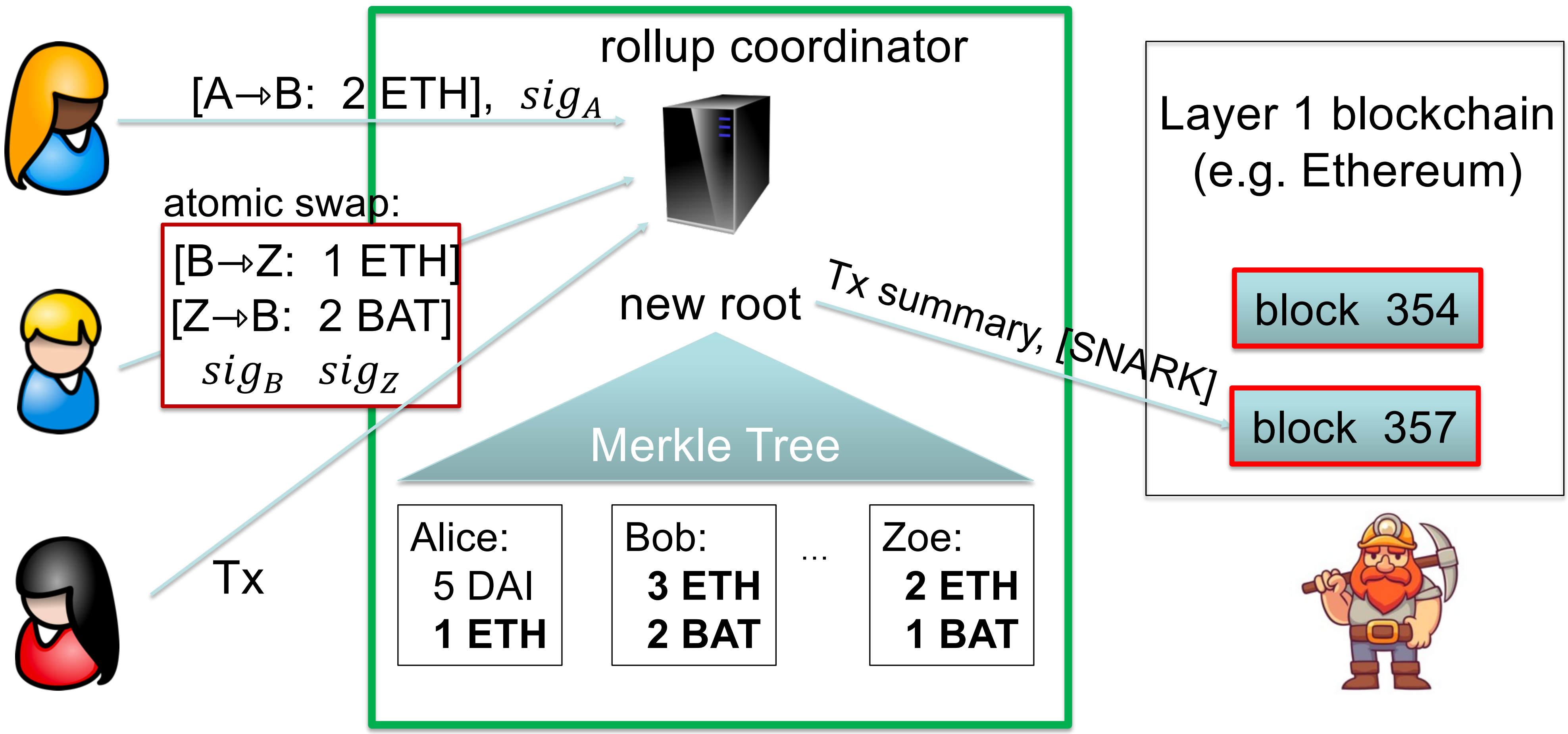


Rollup coordinator: compresses a thousand Tx into one on-chain proof (SNARK)

zkRollup (simplified)



zkRollup (simplified)



Transferring assets to and from L2

- Transactions within a Rollup system are easy:
  - Batch settlement on L1 network (e.g., Ethereum)

- Moving funds in to or out of Rollup system (L1 $\Leftrightarrow$ L2) is more expensive:
  - Requires posting more data on L1 network $\Longrightarrow$ higher Tx fees.

- Moving funds from one Rollup system to another (L2 $\Leftrightarrow$ L2)
  - Either via L1 network (expensive), or via a direct L2 $\Leftrightarrow$ L2 bridge (cheap)

Migrating a project from L1 Ethereum to L2 zkRollup

Upcoming development: **zkEVM** (e.g., MatterLabs and others).

Solidity compatibility:

- Coordinator can produce a SNARK proof for the execution of a short Solidity program:

$\Longrightarrow$ easy to migrate a DAPP from L1 Ethereum to L2 zkRollup.

$\Longrightarrow$ reduced Tx fees and increased Tx rate compared to L1

Optimistic Rollup (simplified) [e.g., Optimism, Arbitrum]

Same principle as zkRollup, but no SNARK proof

Instead: coordinator posts Tx data on chain without a proof

- Then give a few days for validators to complain:

  if a posted Tx is invalid $\Longrightarrow$

  anyone can submit a **fraud proof** and win a reward,

  Rollup server gets slashed.

Benefit: simple full EVM compatibility, less work for server.

Data availability: zkSync vs. zkPorter

Is the coordinator a central point of failure? (centralization fears??)

Answer: No!

coordinator fails $\Longrightarrow$ users find another coordinator to produce proofs

- Complication: new coordinator needs all current account information
  - How to get the data if the old coordinator is dead?

- Two solutions: zkSync and zkPorter. They work concurrently.

Data availability: zkSync vs. zkPorter

- **zkSync**: store all Tx summaries on the L1 blockchain (Ethereum)
  - L1 chain accepts Tx batch only if it includes summary of all Tx
  - Other coordinators can reconstruct L2 state from L1 blockchain
  - Downside: higher Ethereum Tx fees. Good for high value assets
- **zkPorter**: store Tx data on a new blockchain
  - maintained by a set of staked coordinators
  - Cheap off-chain storage, but lower guarantee than zkSync
- Customer can choose how coordinator will store its account.

That’s it on this topic …

Next segment: interoperability

How to move assets from one chain to another

Interchain Interoperability

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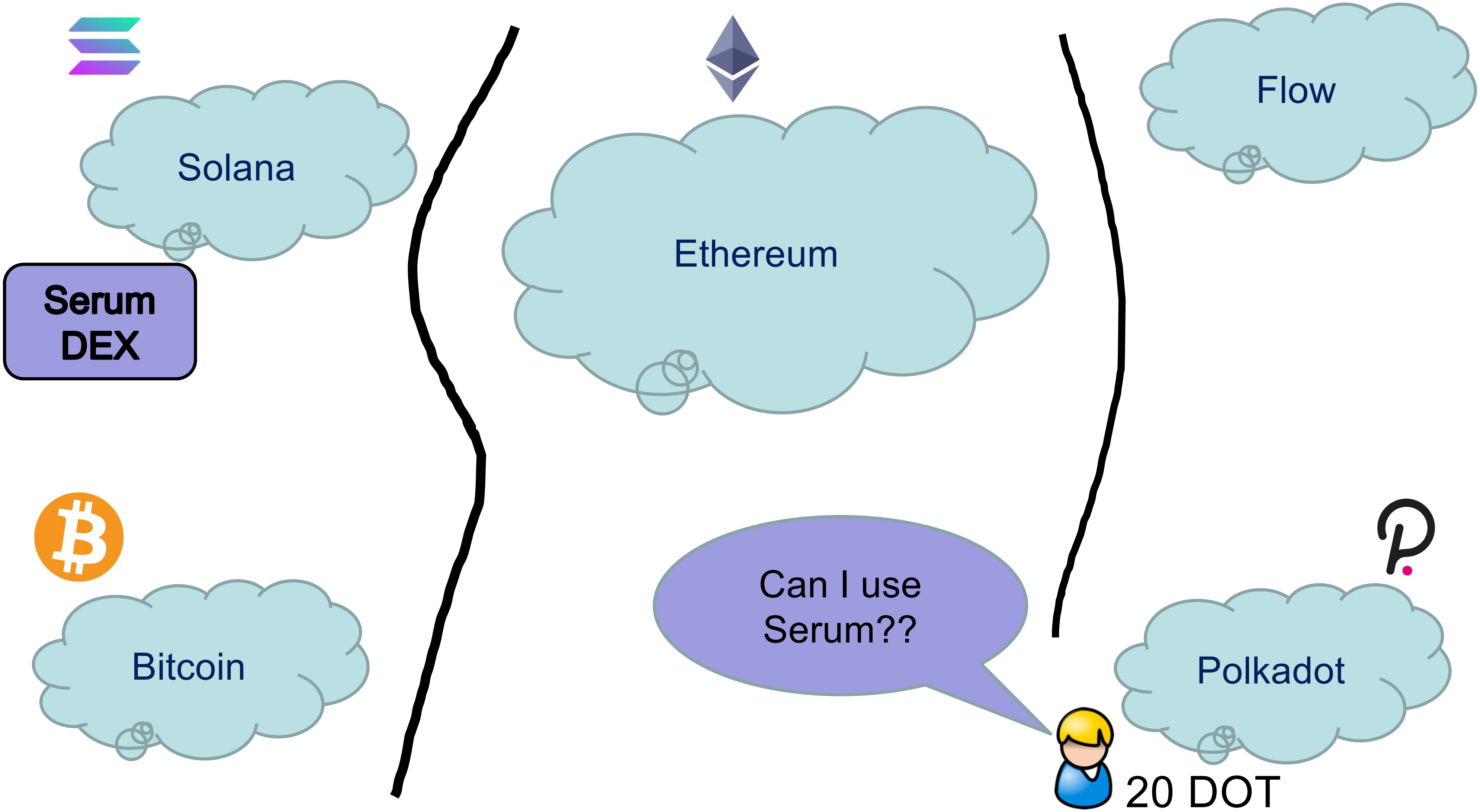

Solana
Serum DEX
Bitcoin
Ethereum
Can I use Serum??
Flow
Polkadot
20 DOT

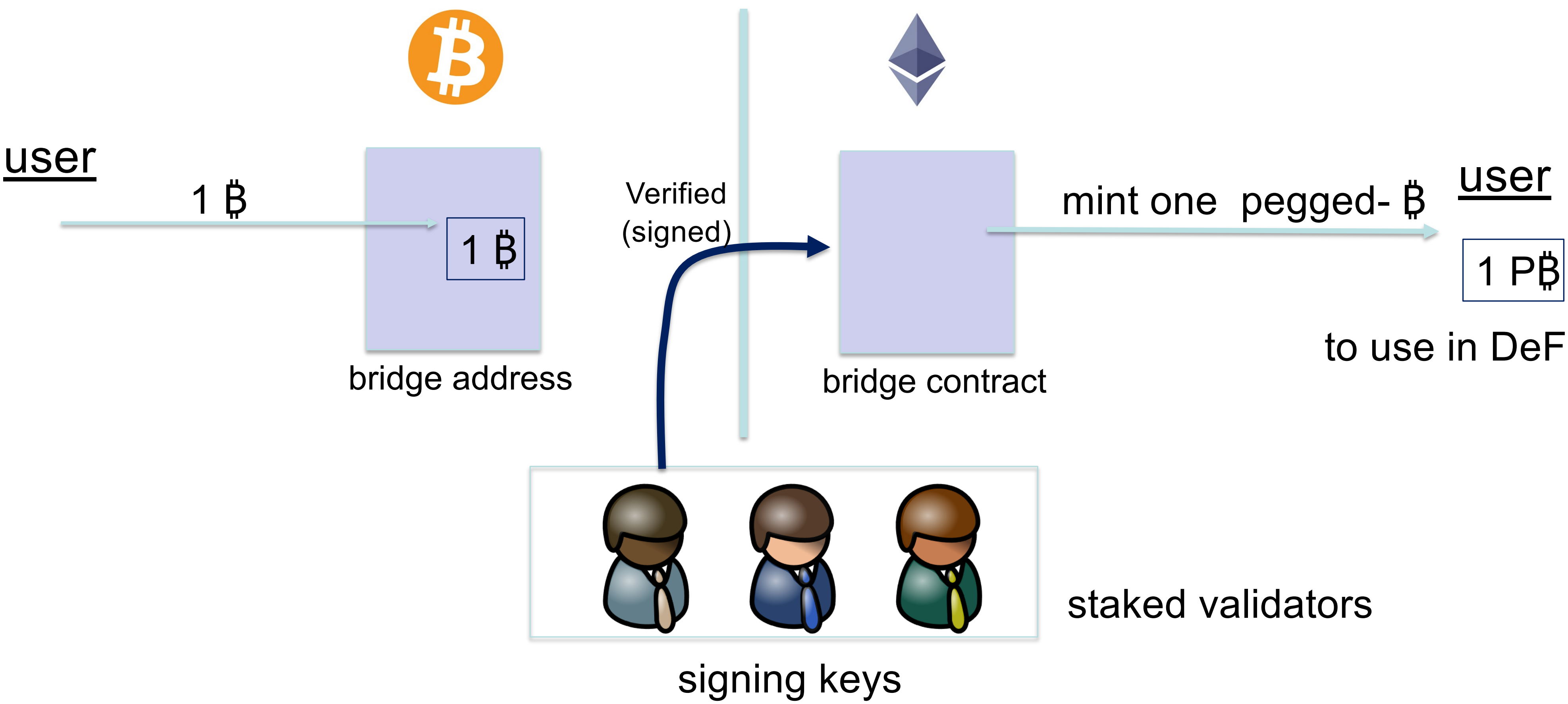
Interoperability

- **Interoperability**:
  - a user owns funds or assets on one blockchain system.
    Goal: enable the user to move funds and/or assets to another system.
- **Composability**:
  - enable a DAPP on one blockchain to call a DAPP on another

Both are easy if the entire world used Ethereum

- In reality: many blockchain systems that need to interoperate
- Several cross-chain protocols: XCMP, IBC, …

How to move assets? Building a federated bridge (simplified)



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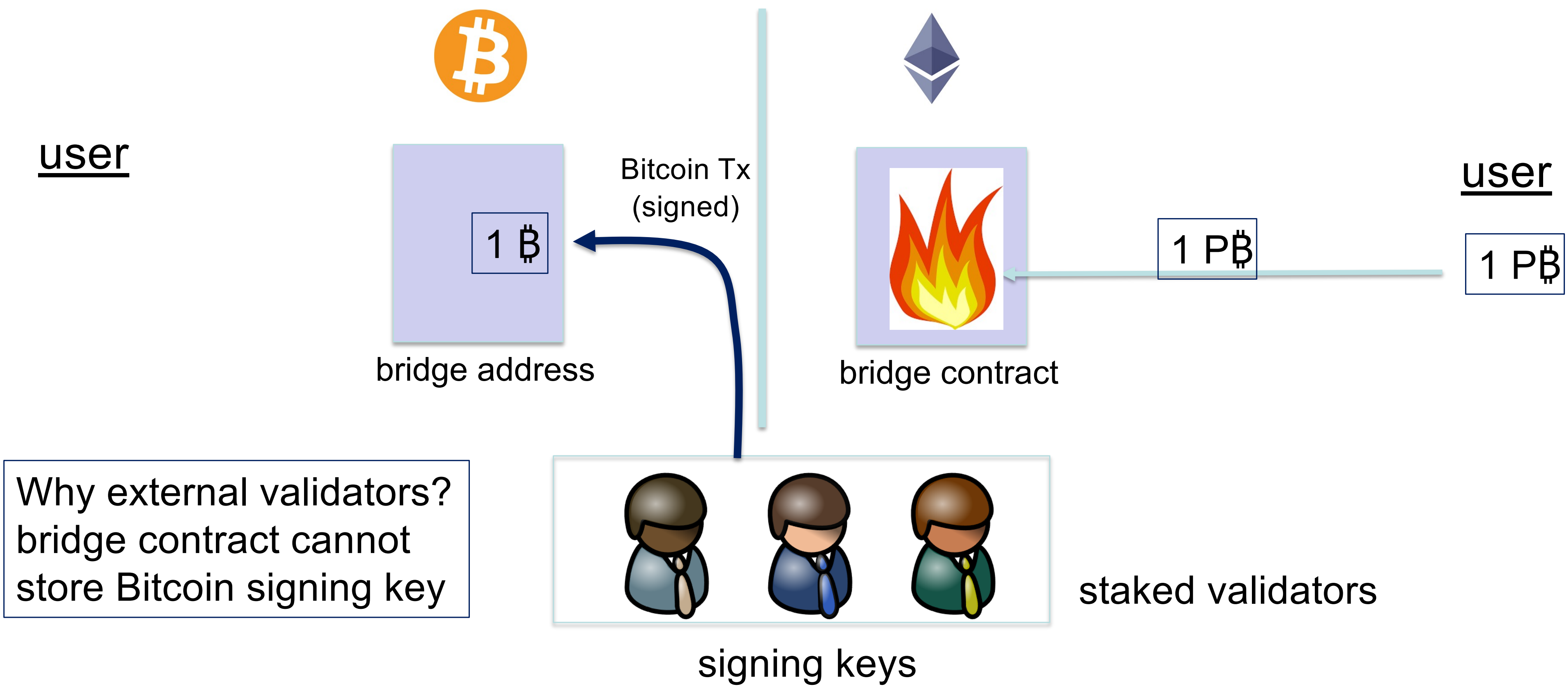

End of lecture: quick review

Cryptographic primitives:

- Hash functions: committing to large amounts of data
- Digital signatures: authorizing actions

Scaling the blockchain

- Payment channels and Rollups

Interoperability: via bridges and pegged coins.


END OF TOPIC
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