Lecture #13:
Light and Stateless Clients

COMS 4995-001:
The Science of Blockchains

URL: https://timroughgarden.org/s25/

Tim Roughgarden

Goals for Lecture #13

1. Block headers and light clients.
   – headers = metadata, light clients = know only headers

2. Simplified payment verification (SPV).
   – verifying properties of state from metadata + proofs
   – UTXO-based and accounts-based models

3. Stateless clients and statelessness.
   – checking block validity without knowing the state

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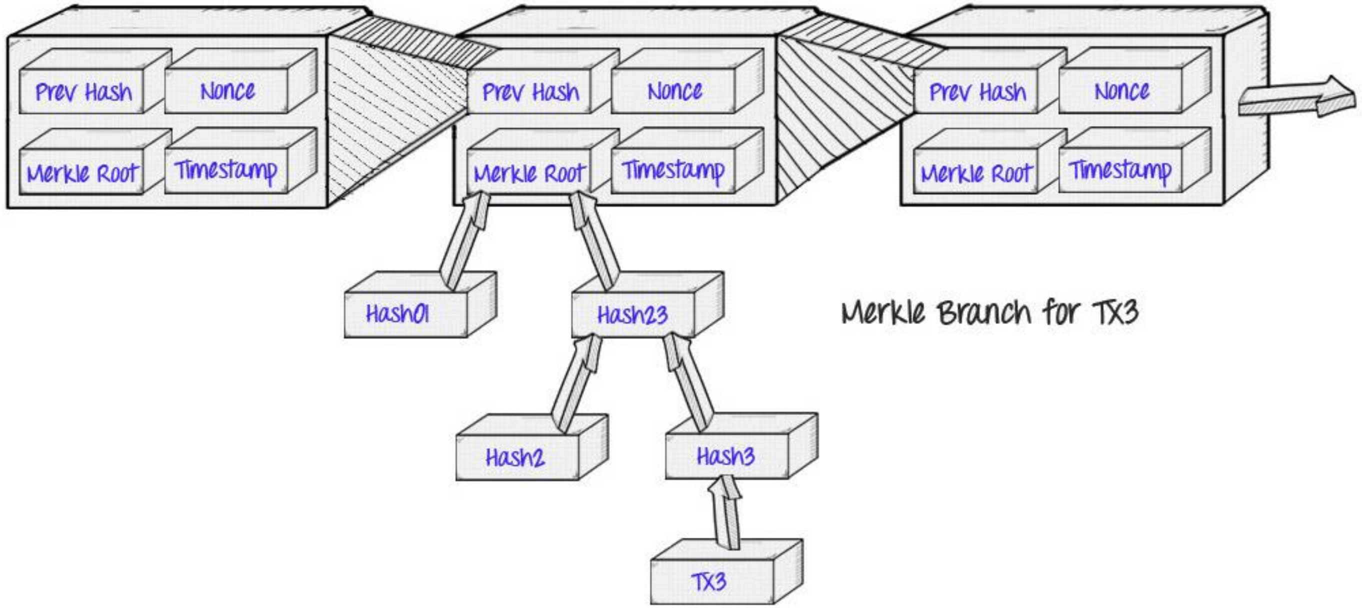

From "Merkling in Ethereum" by Vitalik Buterin https://blog.ethereum.org/2015/11/15/merkling-in-ethereum/

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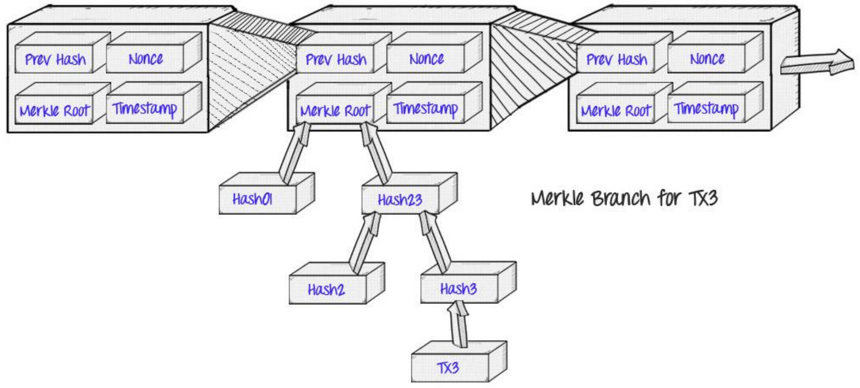

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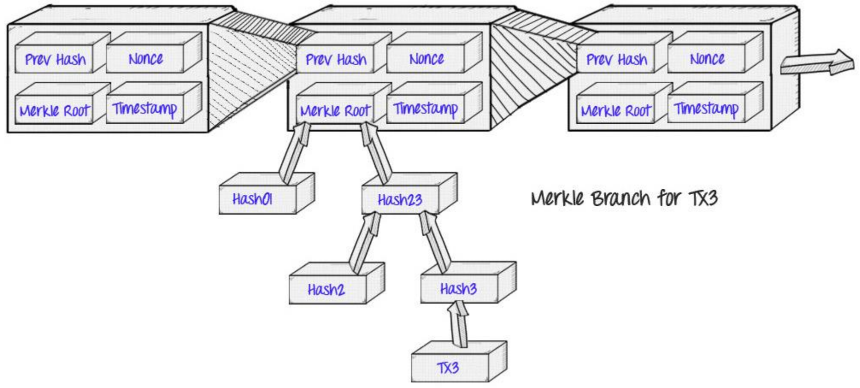

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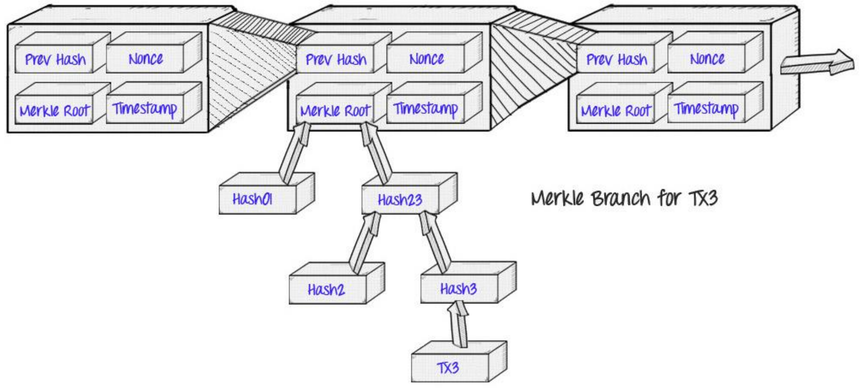

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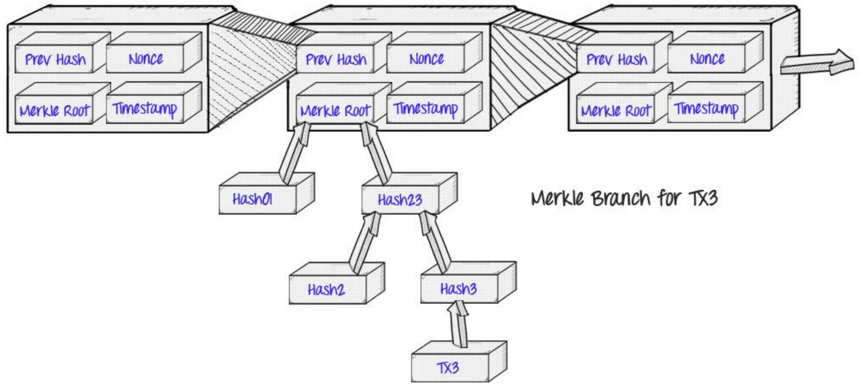

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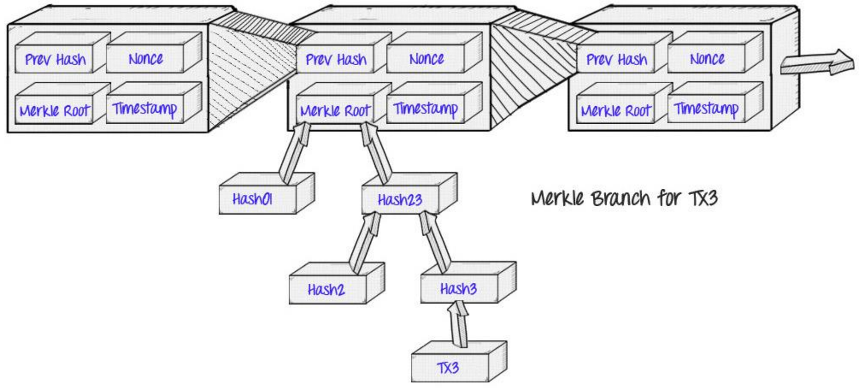
  - consensus-related data (e.g., signature of proposer, view #, etc.)
    - details vary for permissioned vs. proof-of-work vs. proof-of-state



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- example #1: app running on user's phone
- example #2: smart contract on a blockchain ("bridge contract")
- typically associated with one or small number of public keys/accounts
- generally no PKI, not participating in or following consensus
    - just subscribing to a "block header service"

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Goal: enable 1+2 through short + verifiable (Merkle) proofs.

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4. Light client: store only block headers, trust that state roots are correct.
5. Stateless client: verify correctness of state roots in block headers.
   – future: validators might just be stateless clients (with block-building outsourced)

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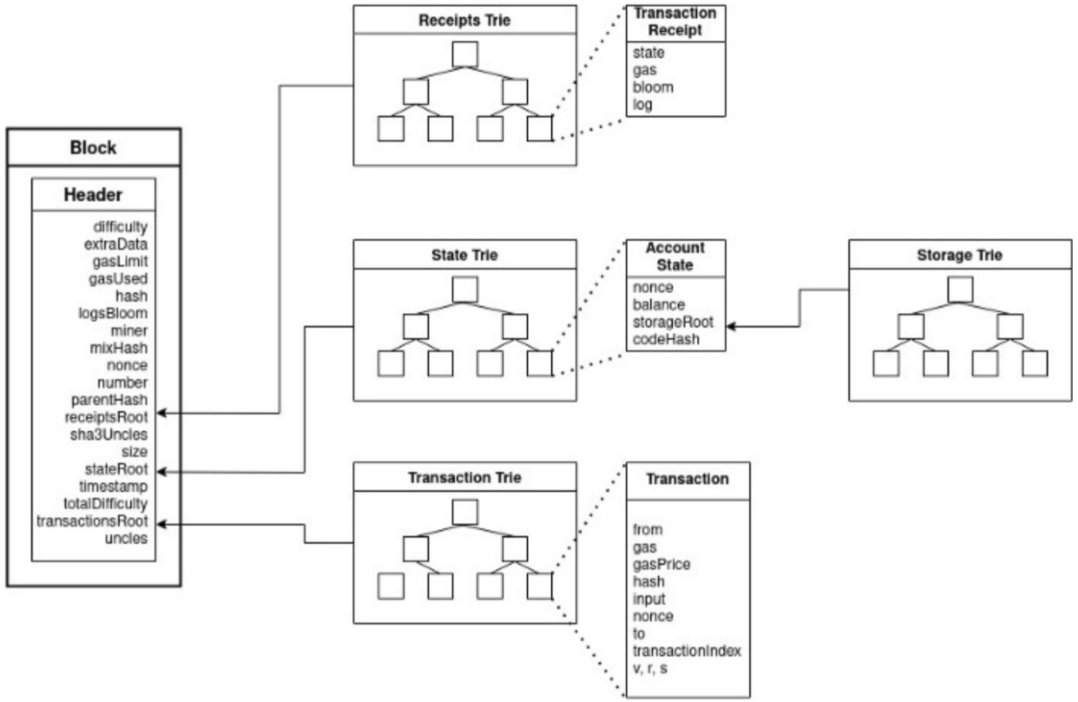
  - trust block header only if ≥ k blocks deep on the longest chain
    - k = a user-specified security parameter

Light Clients in the Accounts-Based Model

Example: Ethereum.

- state = accounts, each account has balance/code/data



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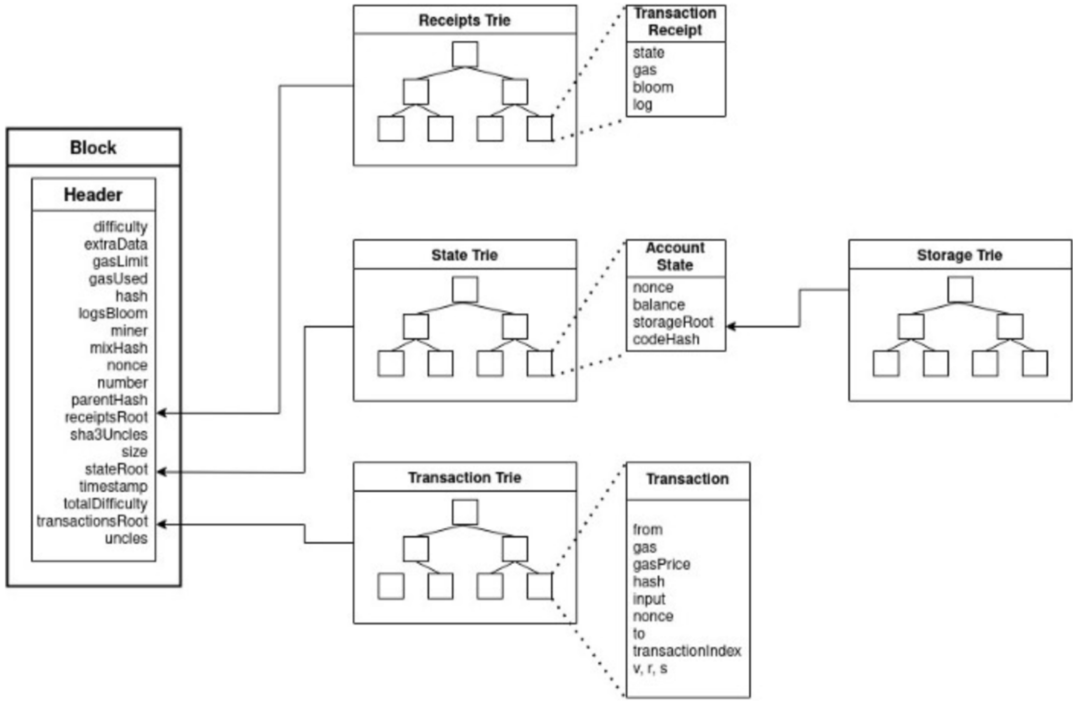

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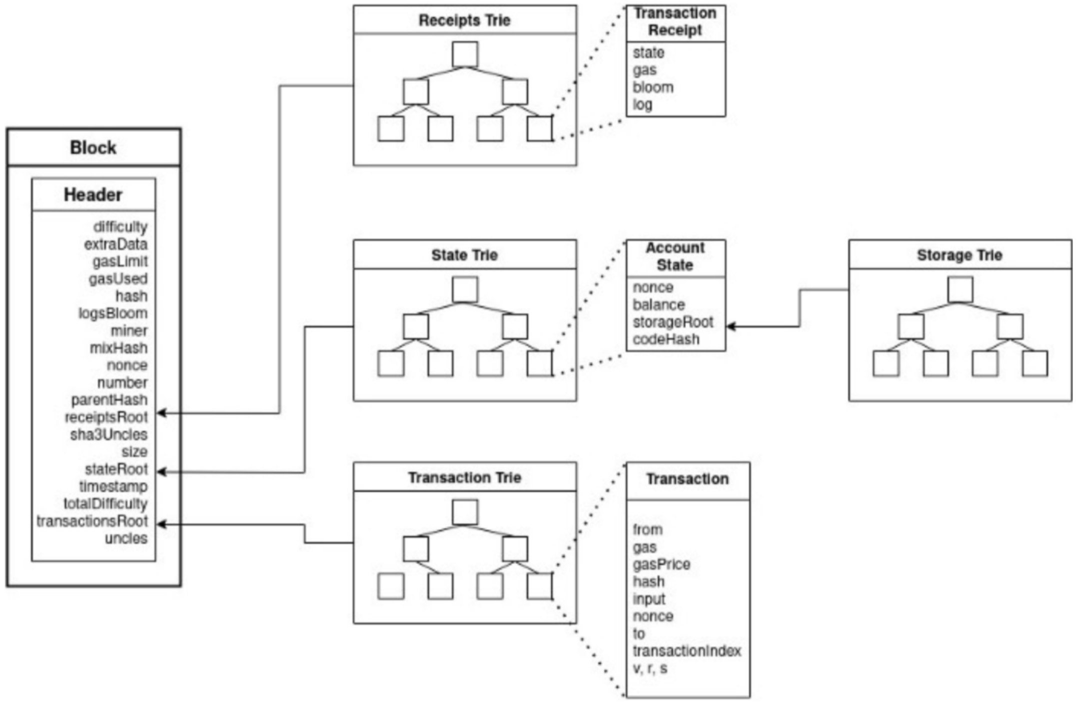

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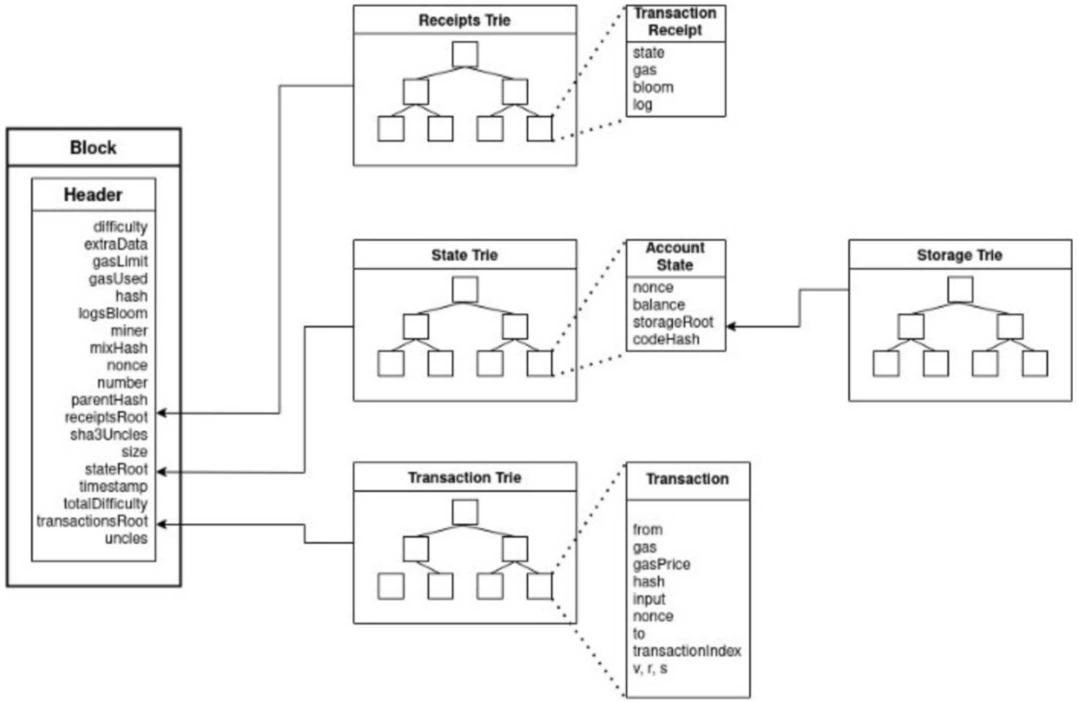

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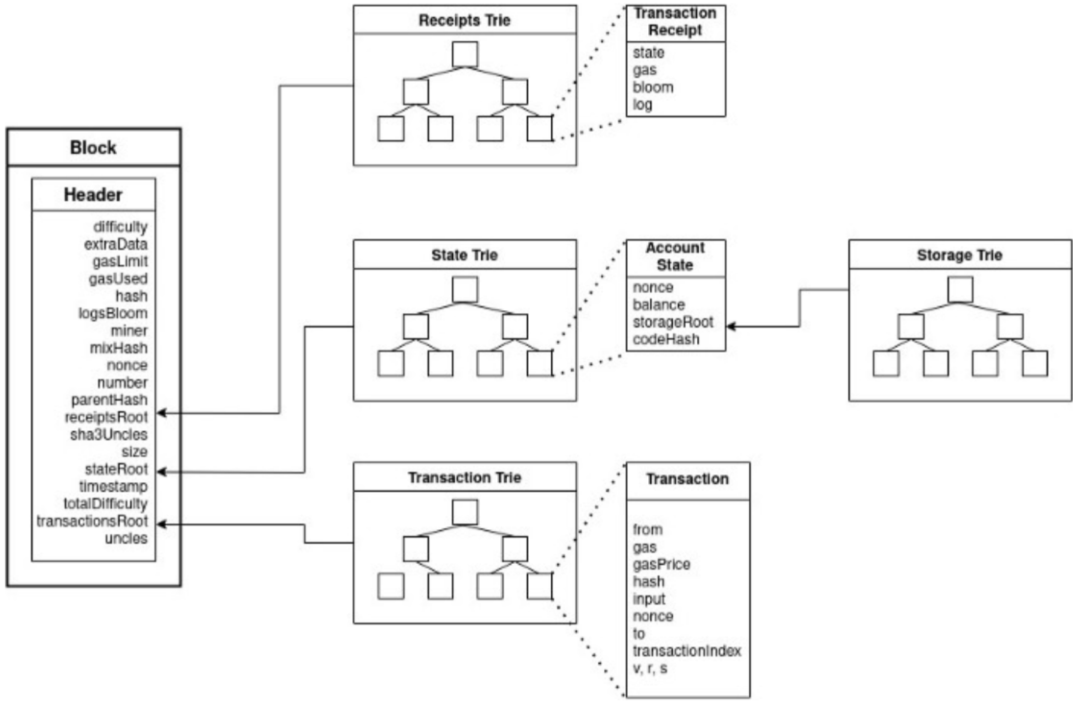

- to check tx inclusion: same as UTXO case (use tx root)
- to check account balance: Merkle proof (but now use state root)
  - assume state root is correct (otherwise rejected by honest validators)

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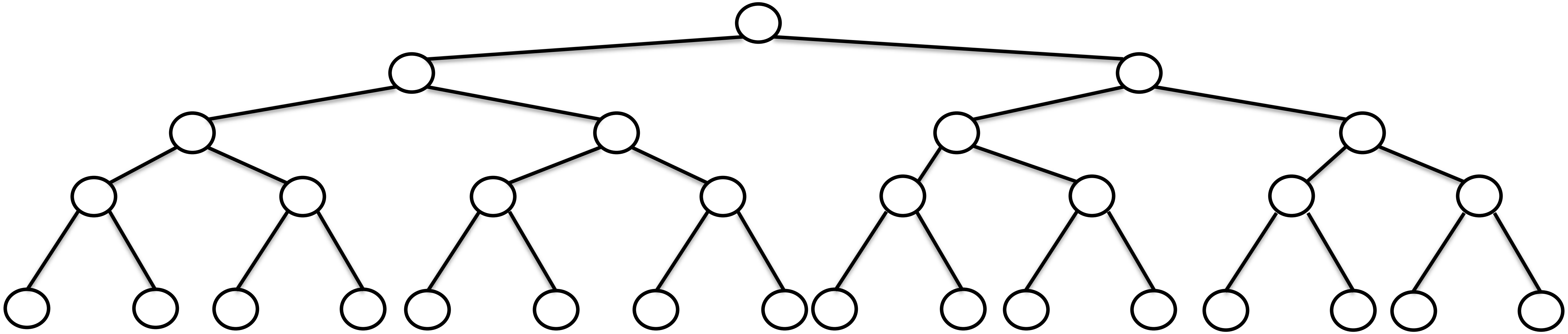

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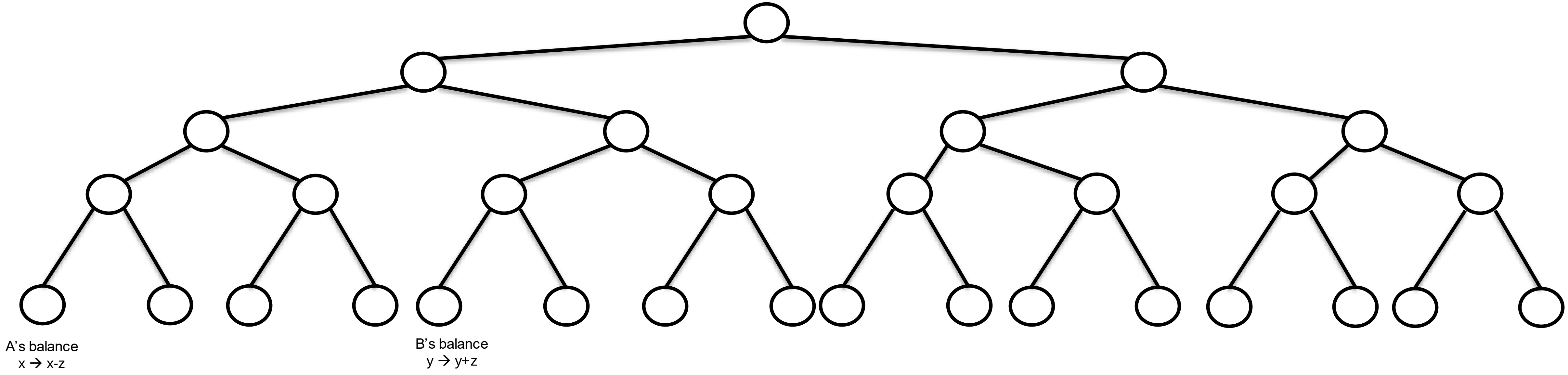

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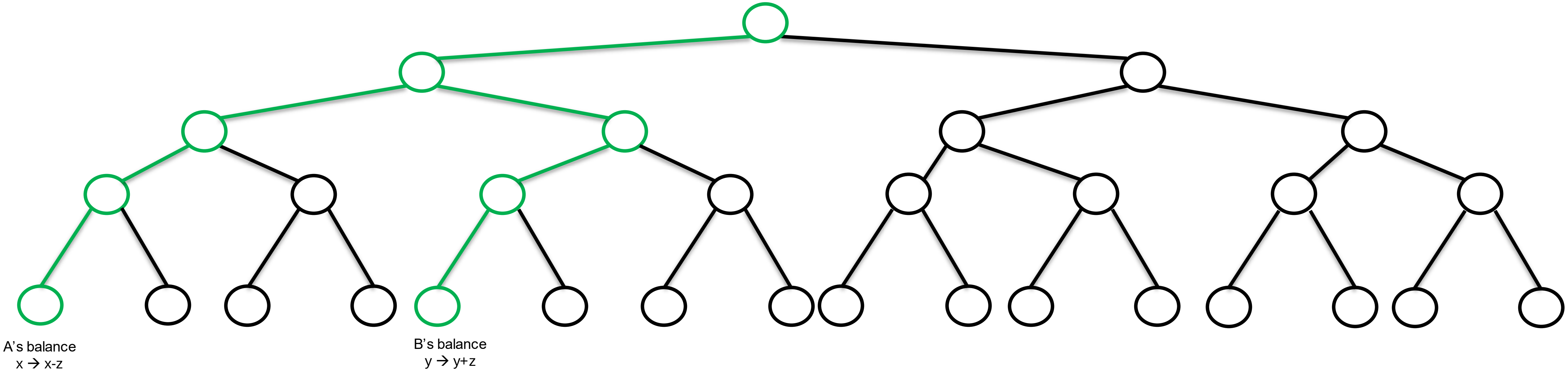

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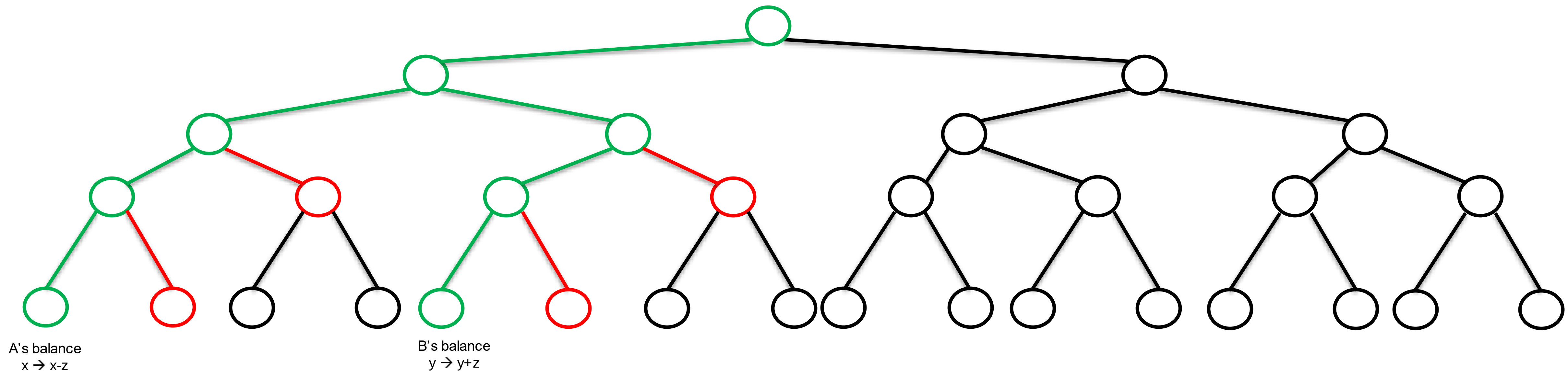

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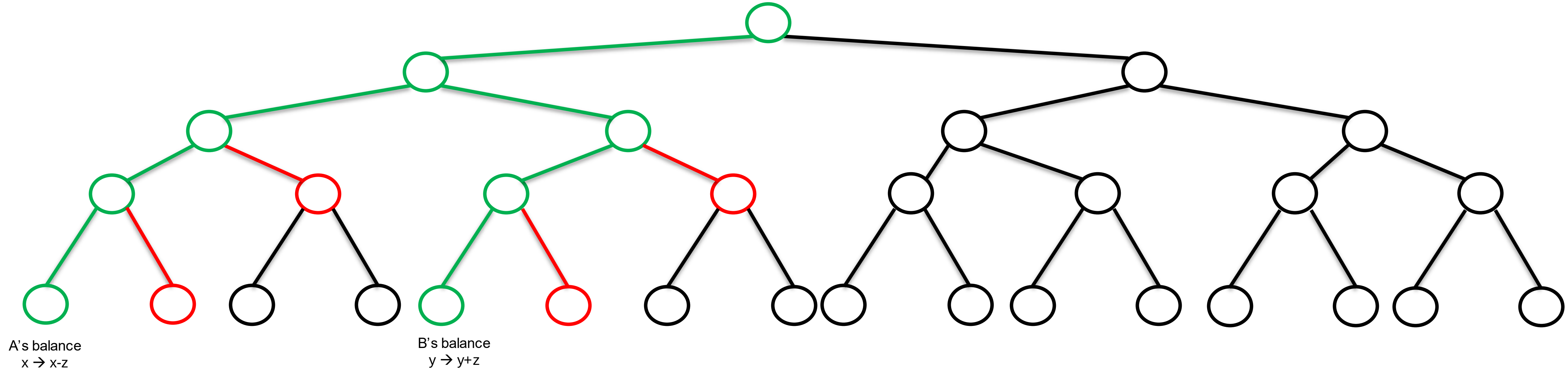

- sufficient to supply Merkle proofs for balances of A and B
  - stateless client then has enough info to compute new Merkle root

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- after processing all txs, can check if new state root = r'

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- one possible future: Verkle trees (using KZG commitments)
- another: each block includes SNARK proving its correctness