

Ethereum

Introduction

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Ethereum

Overview

Ethereum 1 (deprecated) was a Proof of Work blockchain that used several of the improvements discussed previously.

- Ethereum uses 12 sec block delay.
- Different P2P network.
- Ethereum uses a different Proof of Work function to protect against ASICs.
- Ethereum uses uncles.
- Ethereum uses the GHOST rule, instead of longest chain rule.

Similar to Bitcoin, Ethereum uses *hashes of a public key as address*, and signatures for authentication.

Ethereum has a cryptocurrency, Ether.

What are Smart Contracts

Bitcoin scripts scripts

Spending conditions

Transactions:

$$tx = \langle [(id_1, rd_1), (id_2, rd_2)], [(s_a, value_a), (s_b, value_b)] \rangle$$

Inputs

Outputs

- s_a a **spending condition**: output can be used if a value is supplied, that evaluates s_a to true
- rd_1 a **redeeming argument**: should ensure the script s_{id_1} returns true

UTXO scripts

Examples

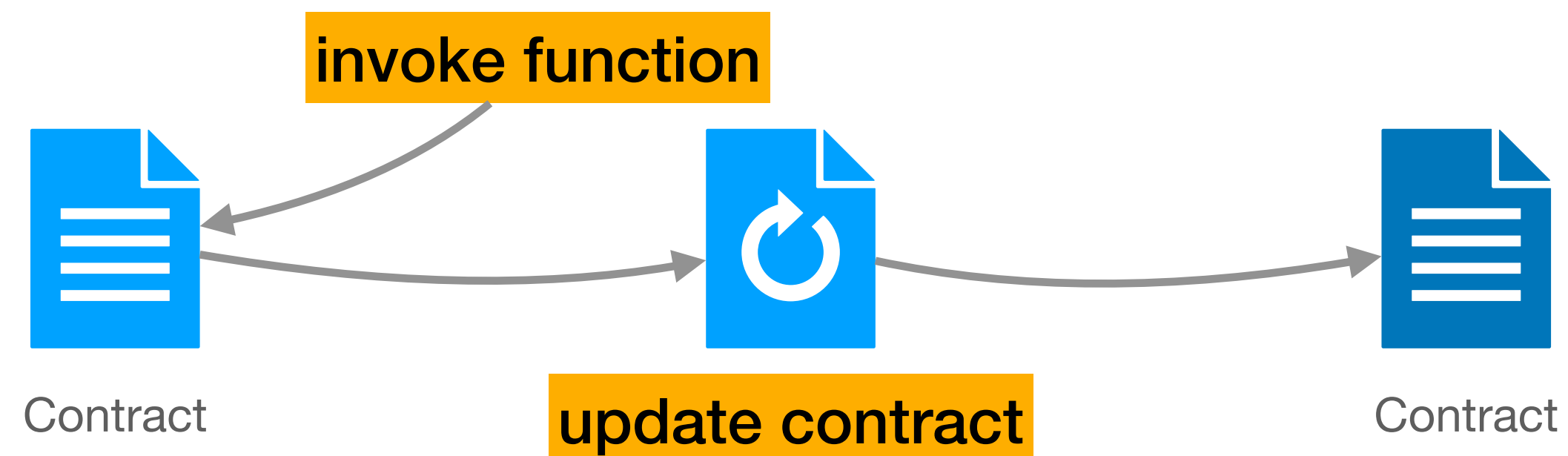
Name	Spending condition	Redeeming argument	
P2Pk Pay to public key	Public key	Signature	
P2PkH Pay to public key hash	Hash of Public key	Public key and signature	
Multisig	m public keys and parameter k	k signatures	

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Smart Contracts

In ethereum, a contract is like a object from OOP, with fields and methods

- variables containing state (stored in account, mutable)
- functions



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Example: Simple Storage

compiler version

```
pragma solidity ^0.5.11;
```

contract

```
contract SimpleStorage {
```

```
    uint256 public storedData;
```

state

```
    function get() public view returns (uint256){  
        return storedData;  
    }
```

```
    function set(uint x_) public {  
        storedData = x_;  
    }
```

functions

```
}
```

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Example: Simple Storage

Simple online IDE: <https://remix.ethereum.org/>

Fun tutorial: <https://cryptozombies.io/>

- Constructors
- Basic types and collections
- Visibility (private, public)
- Inheritance
- Modifiers (view, pure)

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Example: Simple Storage

Who can invoke functions?

- any user

Who can view values?

- anyone

Who can change the code?

- noone

```
pragma solidity ^0.5.11;

contract SimpleStorage {
    uint256 public storedData;

    function get() public view returns (uint256){
        return storedData;
    }

    function set(uint x_) public {
        storedData = x_;
    }
}
```

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Smart Contract code

Smart contract code is immutable and public

- Anyone can trust smart contract (if it is not too complex)
 - No need to trust the creator of the contract
- No one can fix bugs in the contract
- Anyone can find and exploit bugs in the contract

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Smart Contract code

- Assembly for Ethereum Virtual machine (EVM)
- Compiled from higher level language (Solidity)
- Stored in account (codeHash)

How does Ethereum enable Smart Contracts

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Accounts

Ethereum uses accounts instead of UTXO.
Thus the state of Ethereum contains for every account:

- **address:** e.g. pub-key hash
- **balance:** amount of Ether the address owns
- **nonce:** sequence number of last transaction sent from this account
- **storage root:** *only for non-user accounts (contract account)*
- **code hash:** *only for non-user accounts (contract account)*

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Accounts

Smart Contracts are also represented as accounts.

A contract account has:

- **address:** *e.g. hash from creator address & creation transaction nonce*
- **balance:** amount of Ether the address owns
- **nonce:** number of other contract created by this contract
- **storageRoot:** hash of data stored in this contract
- **codeHash:** hash of the code of this contract

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Accounts

In a contract written in Solidity, you can access:

- The address of the current contract:

```
address contractaddress = address(this);
```

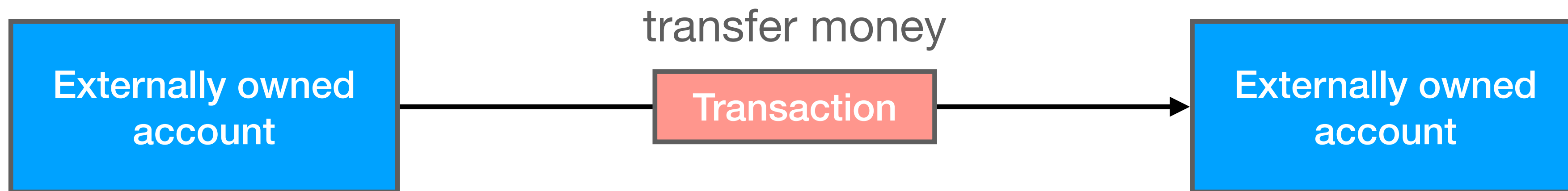
- The balance of the contract:

```
uint balance = contractaddress.balance;
```

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Transactions and authentication

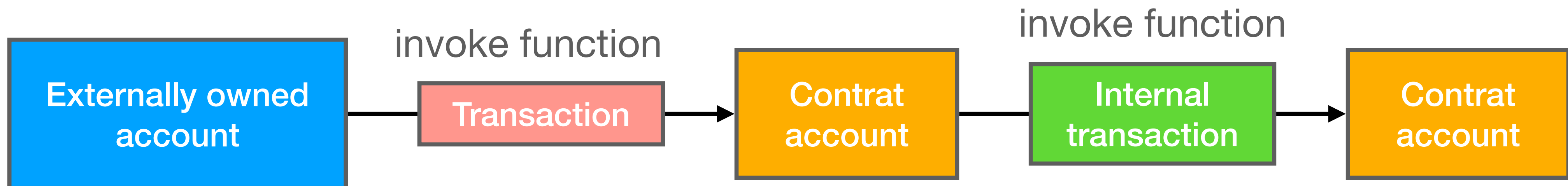
Transactions are used to transfer ether, invoke functions, and deploy new contracts.



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Transactions and authentication

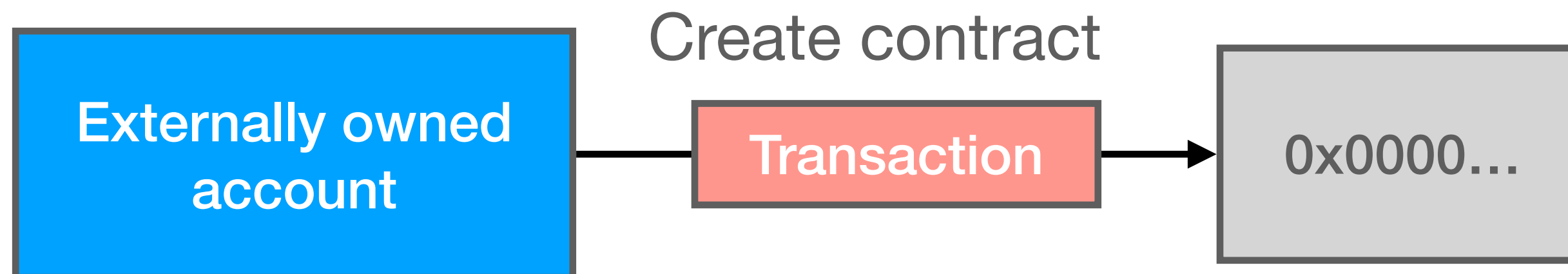
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Transactions and authentication

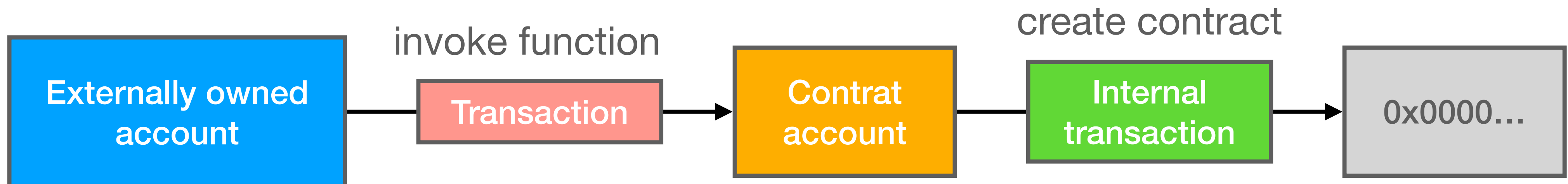
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Transactions and authentication

Transactions are used to transfer ether, invoke functions, and deploy new contracts.



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Transactions and authentication

Transactions contain:

- *Nonce*: next sequence number for sender account
- *Gas price*: later
- *max gas*: later
- *Recipient*: destination Ethereum address
- *Value*: Amount of ether send to destination
- *Data*: Payload binary, e.g. function identifier and arguments
- *Signature*: Signature from sender, including his public key

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Transaction validation

Transaction validation includes the following checks

- *Nonce*: is next sequence number for sender account
- Sender has sufficient balance to pay value and fees
- Transaction is correctly signed

When authenticating users in smart contract, we can rely on transaction validation!
Use *msg.sender* to access address invoking transaction.

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Solidity example

```
contract SimpleBank {
    mapping(address => uint) private balances;
    address public owner;

    // function SimpleBank() deprecated syntax for
    constructor() public {
        owner = msg.sender;
    }

    function deposit() public payable returns(uint) {
        balances[msg.sender] += msg.value;
        return balances[msg.sender];
    }

    function withdraw(uint withdrawAmount) public returns (uint remainingBal){
        if (balances[msg.sender] >= withdrawAmount){
            balances[msg.sender] -= withdrawAmount;
            // this throws an error if fails.
            msg.sender.transfer(withdrawAmount);
        }
        return balances[msg.sender];
    }

    function balance() view public returns (uint) {
        return balances[msg.sender];
    }
}
```

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Solidity example

What happens if data is empty?

- Money transfered to account. Default function run.

What is *msg.sender* for internal transactions?

- address of sending contract
 - a contract can have money in our bank!

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Solidity exceptions

If a smart contract throws an exception, or error, state is reverted.

**State stored in Ethereum
blockchain**

Bitcoin

Block structure

Header:

PrevBlockhash
Nonce
Timestamp

Transaction data

Merkle tree

Merkle tree allows to easily proof that a transaction is included in a block.

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Block structure

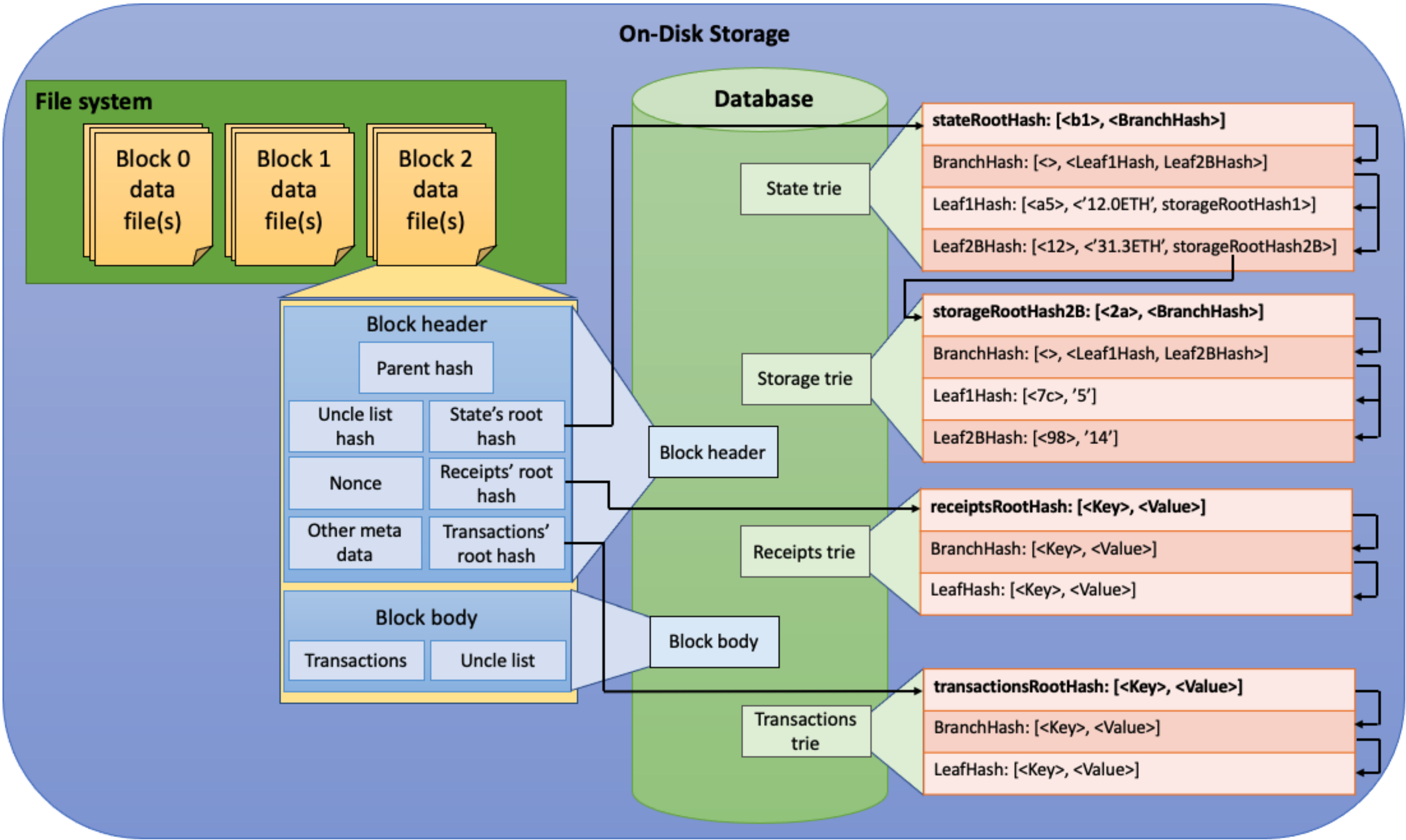
Header:

PrevBlockhash
Nonce
Timestamp

State root hash
Receipts root hash

Transaction data

Merkle tree



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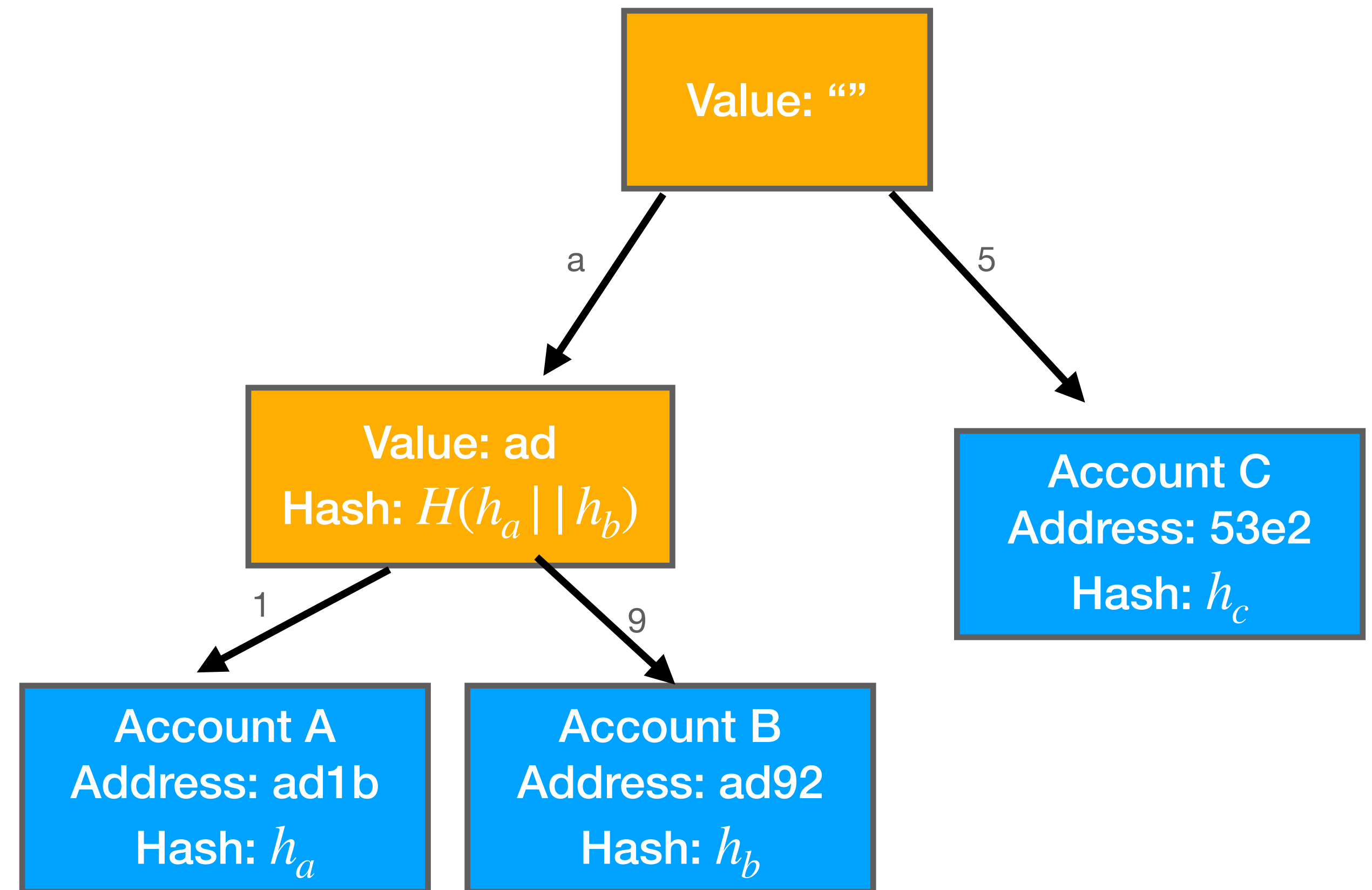
State trie

Stores accounts:

Address:
[Value,
Nonce,
StorageRoot,
CodeHash]

Trie:
Merkle tree that supports

update
lookup
proof



On new block, only changed nodes get added.

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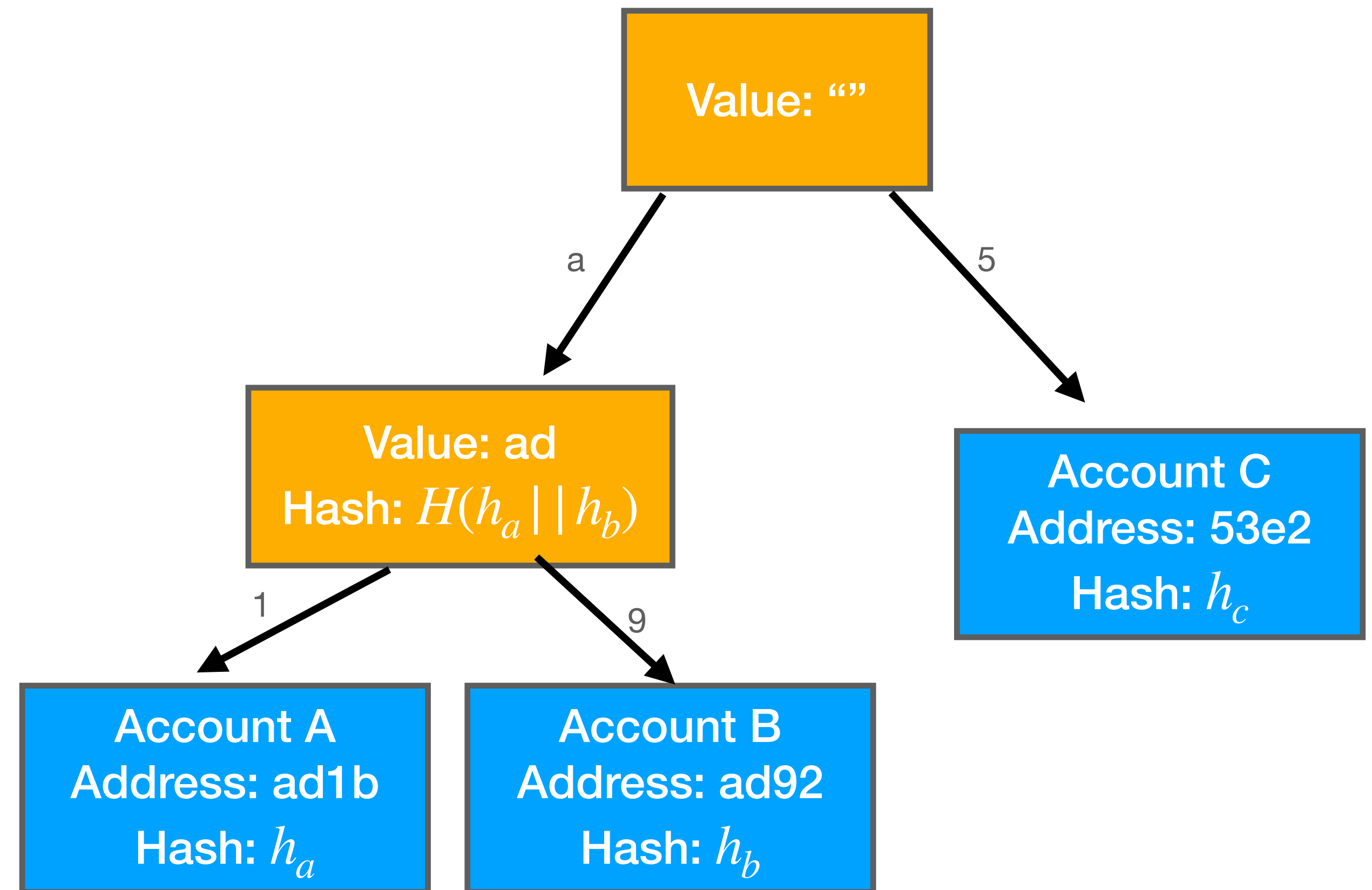
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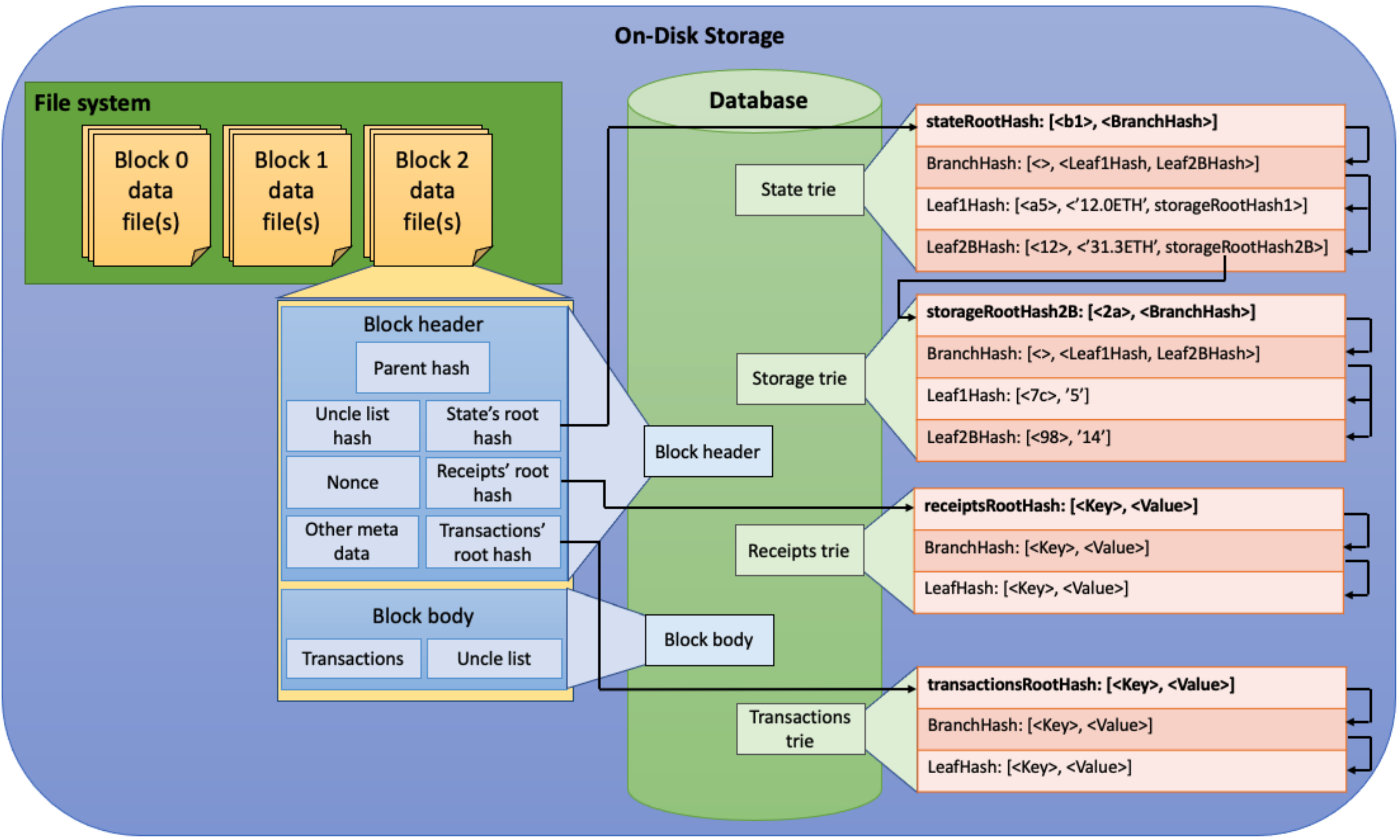
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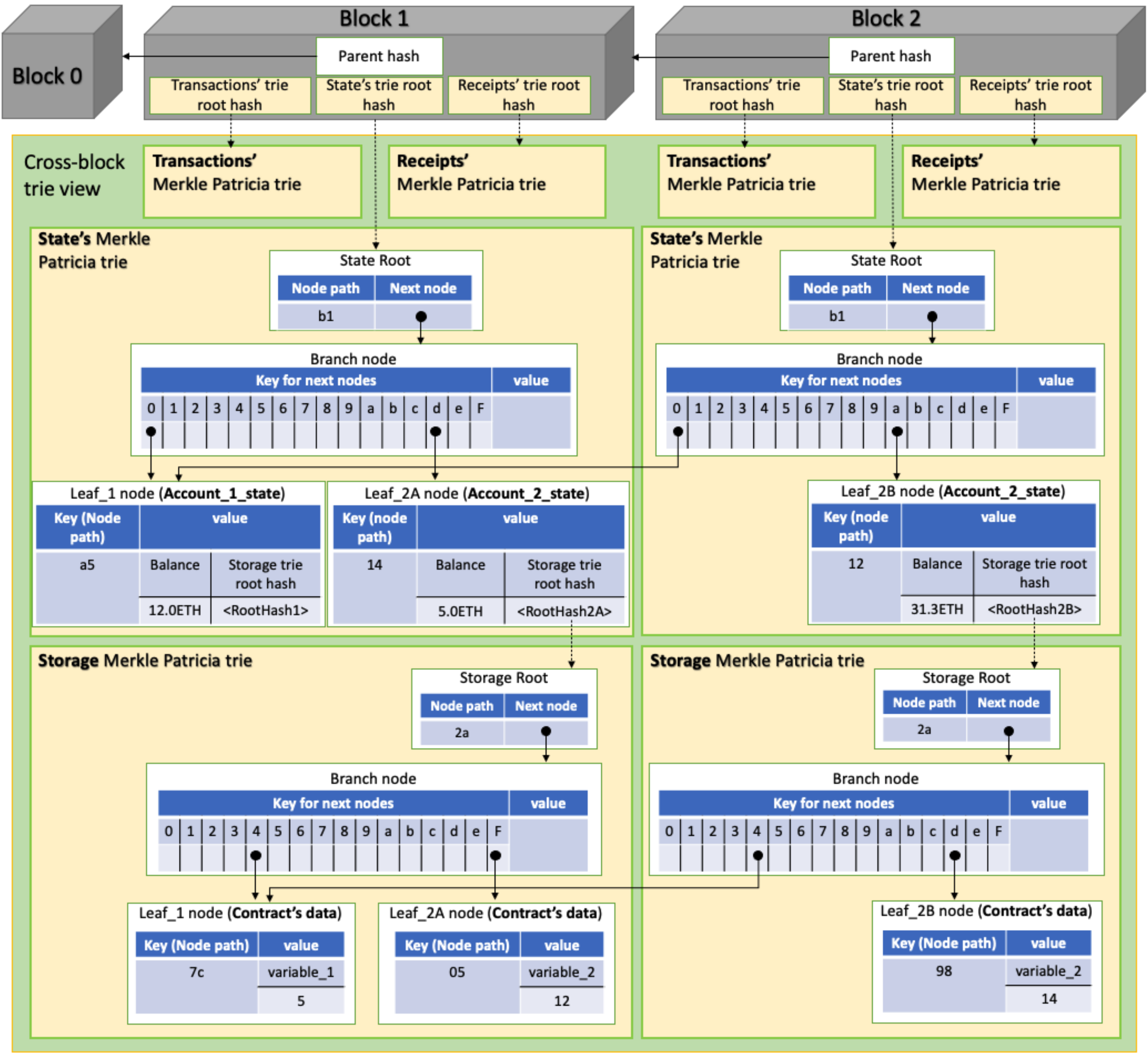
update
lookup
proof



StorageRoot is the root of a different trie.

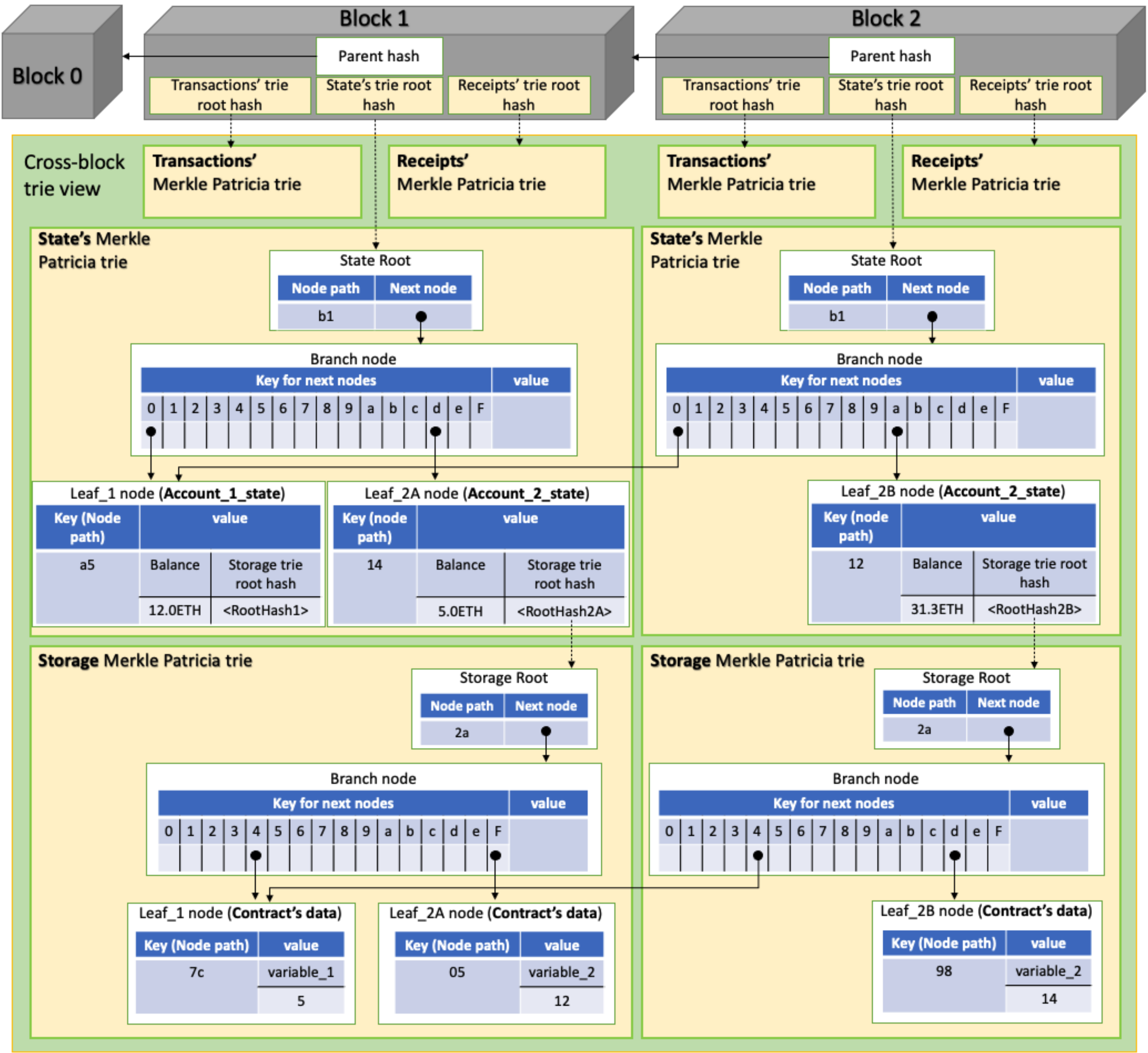
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State trie



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State trie



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Read contract state

1. ask trusted node
2. receive inclusion proof for

stateRoot: storageTrie
account state: stateTrie

and block header

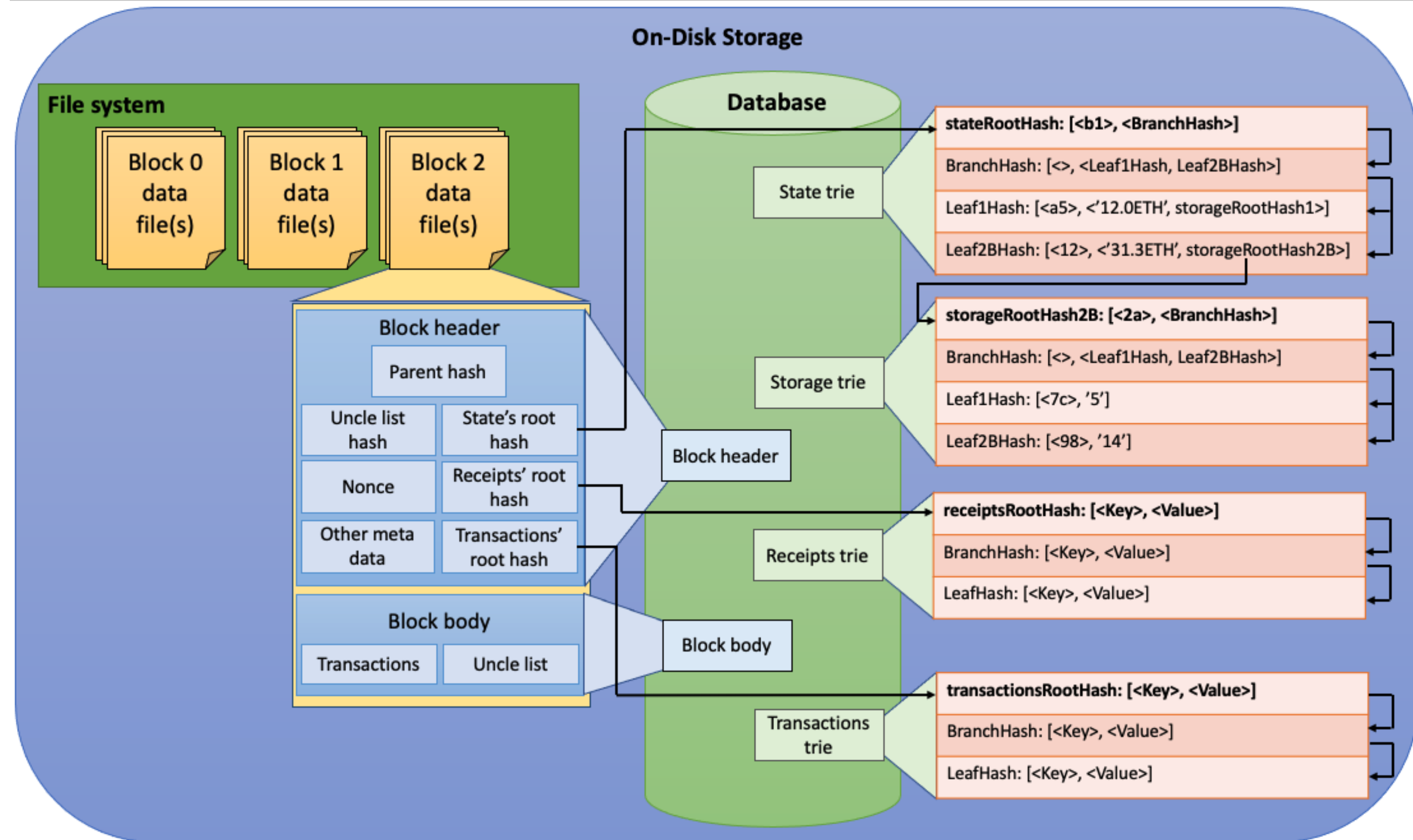
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Receipts trie

Stores transaction results:

```
From: address
To: address
Status: ... // aborted?
Logs: events
ContractAddress address
// new contract address,
// if created
```

Return transaction results,
by emitting Events,
which are added to the logs.



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Gas

How to pay transaction fees in Ethereum?

- all bytecode instructions have a cost specified in Gas
- transaction has fixed cost in Gas
- especially: storing values is expensive

Transactions specify *Gas price* and *Gas limit*

- *Gas price* is ether given per gas
- *Gas limit* is how much the transaction may spend at most

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Gas

Why specific gas per instruction:

- An infinite loop will cost infinitely much gas -> avoid denial of service

What happens if you hit the *Gas limit*?

- Exception is thrown and transaction reverted.
- Gas is still payed!

Which transactions are included?

- Miners will include transactions offering the highest gas price.