Ethereum

Saravanan Vijayakumaran

Associate Professor
Department of Electrical Engineering
Indian Institute of Technology Bombay

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Ethereum

- A blockchain platform for building decentralized applications
  - Application code and state is stored on a blockchain
  - Transactions cause code execution and update state, emit events, and write logs
  - Frontend web interfaces can respond to events and read logs
- Most popular smart contract platform
  - Initial Coin Offerings (ICOs)
  - Non-Fungible Tokens (NFTs)
  - Decentralized Finance (DeFi)
- Ethereum History
  - Proposed by then 19 y.o. Vitalik Buterin in 2013
  - Vitalik visited the Mastercoin team in Oct 2013
  - Released the Ethereum white paper in Dec 2013
  - Bitcointalk announcement on Jan 24th, 2014
  - A presale in July-Aug 2014 collected 31,591 BTC worth 18 million USD in return for 60,102,216 ETH
  - About 12 million ETH created to pay early contributors and setup non-profit foundation
  - Release 1.0 on July 30, 2015
  - Switched to proof-of-stake on September 15, 2022

Bitcoin vs Ethereum

	Bitcoin	**Ethereum**
Specification	Bitcoin Core client	Ethereum yellow paper
Consensus	SHA256 PoW	Proof-of-Stake
Contract Language	Script	EVM bytecode
Block interval	10 minutes	$\approx$ 12 seconds[1]
Block size limit	4 MB	141 KB to 272 KB (Jan 2024)[2]
Currency supply	Fixed to 21 million	Variable (120 million in Jan 2024)[3]
Currency units	1 BTC = 10^8 satoshi	1 ETH = 10^{18} Wei

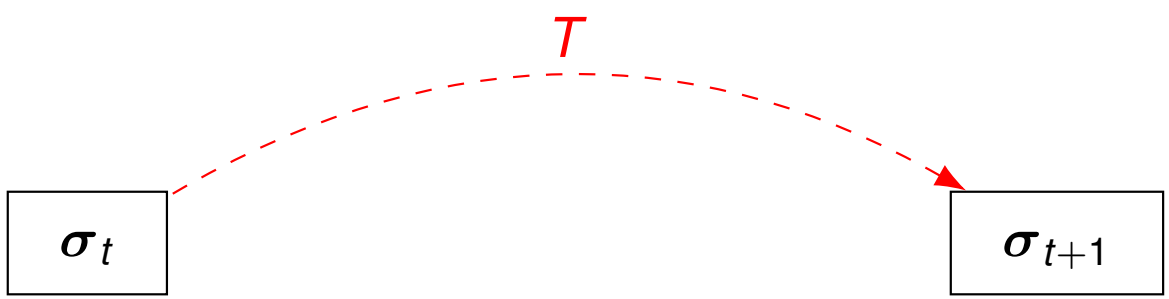
[1] https://etherscan.io/chart/blocktime
[2] https://etherscan.io/chart/blocksize
[3] https://etherscan.io/chart/ethersupplygrowth

Ethereum Architecture

- Specified in the Ethereum yellow paper by Gavin Wood
- Implemented in Go, C++, Python, Rust
- Yellow paper models Ethereum as a transaction-based state machine

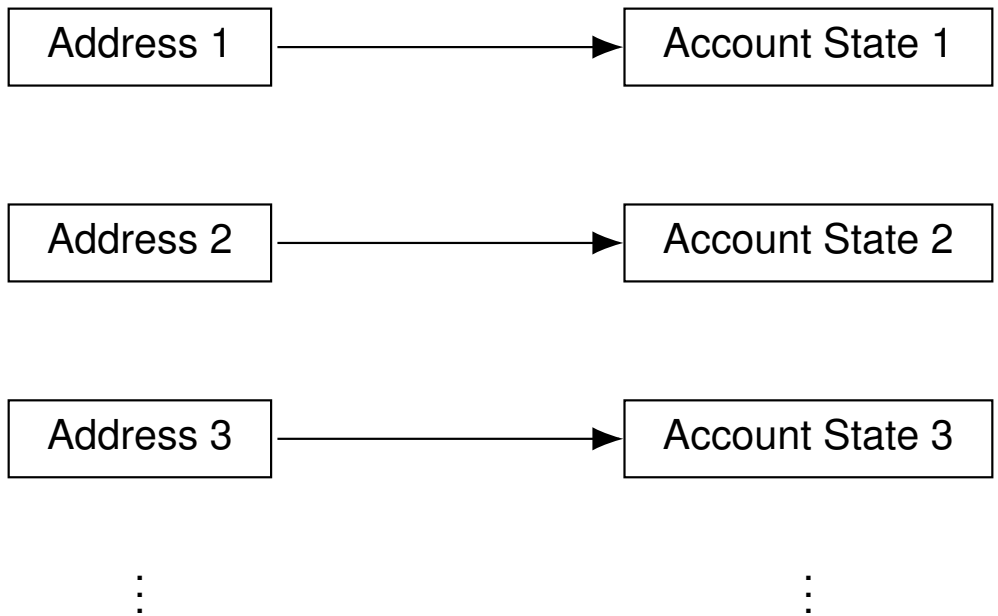
$$\sigma_{t+1} = \Upsilon(\sigma_t, T)$$

  - σ_t = State at time t
  - T = Transaction
  - Υ = Transaction-level state-transition function



Ethereum World State

- World state consists of **accounts**
- Each account has an address and account state



- The world state is maintained in a Merkle Patricia trie
  - Trie = Tree optimized for information re**trie**val
  - Patricia = Practical Algorithm To Retrieve Information Coded in Alphanumeric
  - Merkle: Tree nodes are hashed to generate a root hash

Ethereum Accounts

- Account types
  - **Externally owned accounts (EOAs)**: Controlled by private keys
  - **Contract accounts**: Controlled by contract code

- Account state
  - **nonce**: Number of transactions sent or contract-creations made
  - **balance**: Number of Wei owned by this account
  - **storageRoot**: Root hash of account storage Merkle Patricia trie
  - **codeHash**: Hash of EVM code if contract account
- The storage root and code hash will be empty for EOA accounts
- For contract accounts, the code and storage variables will be stored in a key-value database
- Each account has a 20-byte address
  - EOA address = Right-most 20 bytes of Keccak-256 hash of public key
  - Contract address = Right-most 20 bytes of Keccak-256 hash of [senderAddress, nonce]

Keccak-256

- Cryptographic hash function used by Ethereum
- NIST announced competition for new hash standard in 2006
- Keccak declared winner in 2012
- In August 2015, FIPS 202 "*SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions*" was approved
- Ethereum adopted Keccak-256 but NIST changed the padding scheme
- Keccak-256 and SHA3-256 give different outputs for the same message
  - `https://ethereum.stackexchange.com/questions/550/which-cryptographic-hash-function-does-ethereum-use`

Ethereum Smart Contracts

Ethereum Contracts

- “Smart contracts” is a misnomer
  - Not smart or legally binding
- Contract = Collection of functions and state at a specific address
- Contract logic is stored in EVM bytecode
  - EVM Opcodes `https://www.evm.codes/`
- Written in a high level language which compiles to bytecode
  - Solidity `https://solidity.readthedocs.io`
  - Vyper `https://vyper.readthedocs.io`
- Components of a contract
  - State variables
  - Functions
  - Events

SimpleStorage Contract

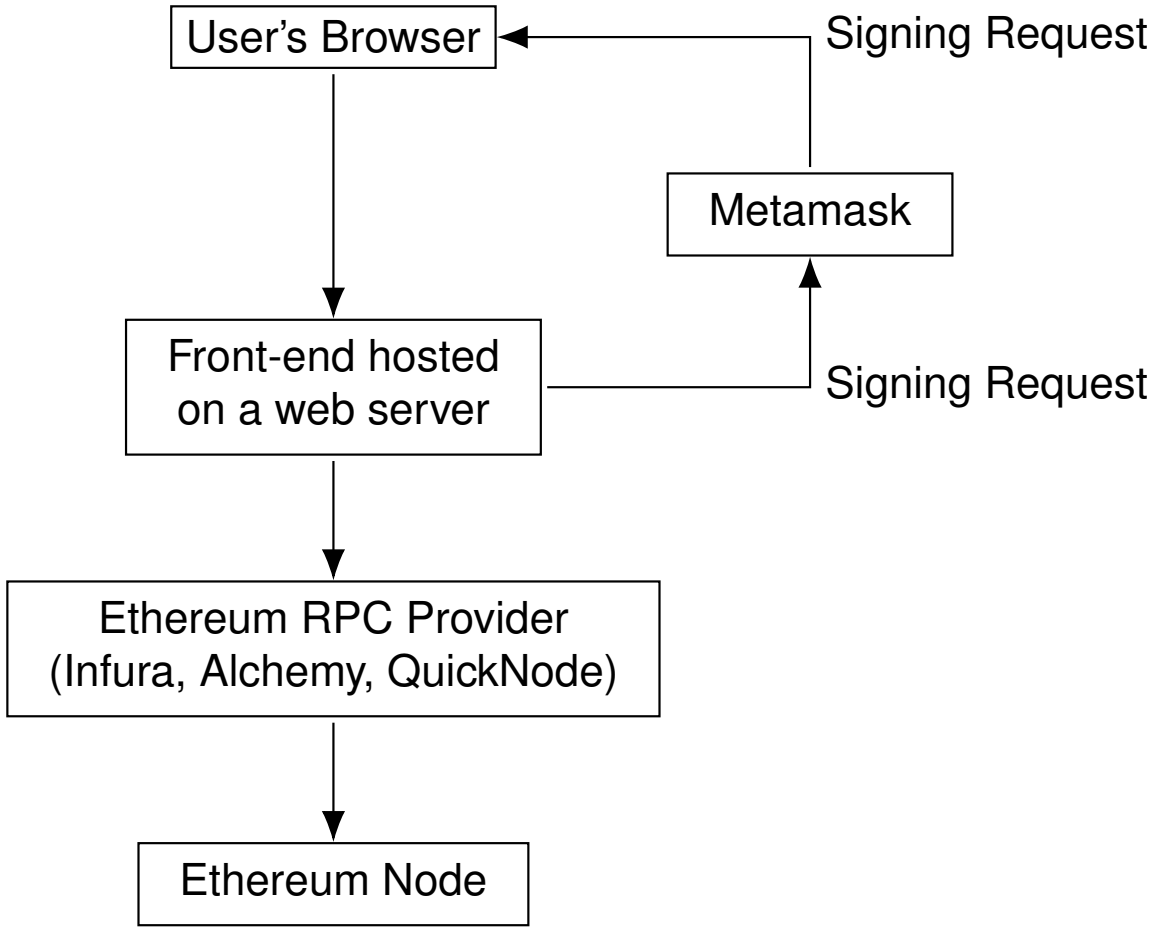
```
pragma solidity >=0.4.16 <0.9.0;

contract SimpleStorage {
    uint storedData;

    function set(uint x) public {
        storedData = x;
    }

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

- `storedData` is a 256-bit unsigned integer
- Once the contract is deployed on Ethereum, anyone can set the value in `storedData`
  - Setting the value involves sending an Ethereum transaction
  - Costs transaction fees
- Anyone with RPC access to a full Ethereum node can read the value in `storedData` (no transaction or fees required)

Deploying a Contract

- Deploying a contract on Ethereum requires a contract creation transaction
  - Contract needs to be first compiled to get EVM bytecode
  - An externally owned account needs to pay the transaction fees for contract creation
- Demo using Remix on Sepolia Testnet
  - Remix is a browser-based IDE for smart contract development
  - Testnets are instances of a blockchain used for testing
  - Testnet coins are available from websites called faucets
    - Alchemy Faucet (requires signup) `https://sepoliafaucet.com/`
    - PoWFaucet `https://sepolia-faucet.pk910.de/`
  - Metamask browser plugin can be used to generate an Ethereum address to receive the testnet coins
  - Instructions at `https://www.ee.iitb.ac.in/~sarva/ethlab/remix/remix.html`

Anatomy of an Ethereum Application



Applications to Try on Sepolia Testnet

- Ethereum Name Service `https://ens.domains/`
- OpenSea NFT Marketplace `https://testnets.opensea.io/`
- Mirror Publishing Platform `https://mirror.xyz`

References

- Yellow paper https://ethereum.github.io/yellowpaper/paper.pdf
- A Prehistory of the Ethereum Protocol https://vitalik.ca/general/2017/09/14/prehistory.html
- Ethereum announcement on Bitcointalk https://bitcointalk.org/index.php?topic=428589.0
- History of Ethereum https://ethereum.org/history
- Ethereum App Architecture https://www.preethikasireddy.com/post/the-architecture-of-a-web-3-0-application
- Testnet Opensea NFT Marketplace https://testnets.opensea.io/
- Solidity Documentation https://solidity.readthedocs.io
- Remix IDE https://remix.ethereum.org
- Metamask https://metamask.io/
- Solidity by Example https://solidity-by-example.org/