Blockchain Specialist Program

ethereum

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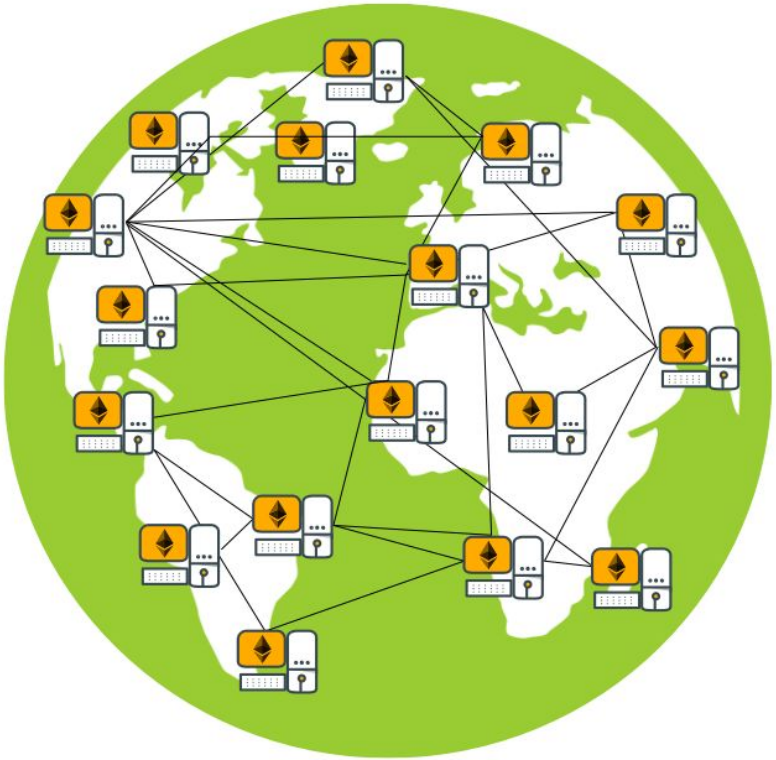
The World Computer



Ethereum is a decentralized platform that runs smart contracts applications that run exactly as programmed without any possibility of downtime, censorship, fraud or third party interference

The Birth of Ethereum

1. Toward the end of 2013, Vitalik Buterin, a young programmer and Bitcoin enthusiast, started thinking about further extending the capabilities of Bitcoin and Mastercoin (an overlay protocol that extended Bitcoin to offer rudimentary smart contracts).
2. In October of that year, Vitalik proposed a more generalized approach to the Mastercoin team,
3. one that allowed flexible and scriptable (but not Turing-complete) contracts to replace the specialized contract language of Mastercoin.
4. While the Mastercoin team were impressed, this proposal was too radical a change to fit into their development roadmap.

The Birth of Ethereum

1. In December 2013, Vitalik started sharing a whitepaper that outlined the idea behind Ethereum:
    a. A Turing-complete,
    b. General-purpose blockchain.

The Birth of Ethereum

1. A blockchain without a specific purpose, that could support a broad variety of applications by being *programmed*.
2. The idea was that, a developer could program their particular application without having to implement the underlying mechanisms of
   a. peer-to-peer networks,
   b. blockchains,
   c. consensus algorithms, etc.
3. The Ethereum platform was designed to abstract these details and provide a deterministic and secure programming environment for decentralized blockchain applications.

Chapter 1

What is Ethereum

What Is Ethereum?

From a computer science perspective:

Ethereum is a deterministic but practically unbounded state machine, consisting of a globally accessible singleton state and a virtual machine that applies changes to that state.

What Is Ethereum?

From a computer practical perspective:

Ethereum is an open source, globally decentralized computing infrastructure that executes programs called smart contracts. It uses a blockchain to synchronize and store the system's state changes, along with a cryptocurrency called ether to meter and constrain execution resource costs.

What Is Ethereum?

The Ethereum platform enables developers to build powerful decentralized applications with built-in economic functions. While providing high availability, auditability, transparency, and neutrality, it also reduces or eliminates censorship and reduces certain counterparty risks.

Ethereum Compared to Bitcoin

Ethereum shares many common elements with other open blockchains:

1. a peer-to-peer network connecting participants
2. a Byzantine fault–tolerant consensus algorithm for synchronization of state updates (a proof-of-work blockchain)
3. the use of cryptographic primitives such as digital signatures and hashes
4. and a digital currency (ether)

Ethereum Compared to Bitcoin

1. Ethereum’s purpose is not primarily to be a digital currency payment network.
2. While the digital currency ether is both integral to and necessary for the operation of Ethereum
3. ether is intended as a utility currency to pay for use of the Ethereum platform as the world computer.

Ethereum Compared to Bitcoin

1. Bitcoin has a very limited scripting language
2. Bitcoin's Script language is, intentionally, constrained to simple true/false evaluation of spending conditions
3. Ethereum is designed to be a general-purpose programmable blockchain that runs a virtual machine capable of executing code of arbitrary and unbounded complexity.
4. Ethereum's language is Turing complete, meaning that Ethereum can straightforwardly function as a general-purpose computer.

Components of a Blockchain

1. A peer-to-peer (P2P) network connecting participants and propagating transactions and blocks of verified transactions, based on a standardized "gossip" protocol
2. Messages, in the form of transactions, representing state transitions
3. A set of consensus rules, governing what constitutes a transaction and what makes for a valid state transition
4. A state machine that processes transactions according to the consensus rules

Components of a Blockchain

5. A chain of cryptographically secured blocks that acts as a journal of all the verified and accepted state transitions
6. A consensus algorithm that decentralizes control over the blockchain, by forcing participants to cooperate in the enforcement of the consensus rules
7. A game-theoretically sound incentivization scheme (e.g., proof-of-work costs plus block rewards) to economically secure the state machine in an open environment
8. One or more open source software implementations of the above ("clients")

Components of a Blockchain

1. In Bitcoin, the reference implementation is developed by the *Bitcoin Core* open source project and implemented as the *bitcoind* client.
2. In Ethereum, rather than a reference implementation there is a *reference specification*, a mathematical description of the system in the Yellow Paper.
3. There are a number of clients, which are built according to the reference specification.

Ethereum's Four Stages of Development

1. The four main development stages are codenamed
    a. Frontier
    b. Homestead
    c. Metropolis
    d. Serenity
2. The intermediate hard forks are codenamed
    a. Ice Age
    b. DAO
    c. Tangerine Whistle
    d. Spurious Dragon
    e. Byzantium
    f. Constantinople

Ethereum’s Four Stages of Development

Both the development stages and the intermediate hard forks are shown on the following timeline, which is "dated" by block number

1. **Block #0**
    a. *Frontier*—The initial stage of Ethereum, lasting from July 30, 2015, to March 2016
2. **Block #200,000**
    a. *Ice Age*—A hard fork to introduce an exponential difficulty increase, to motivate a transition to PoS when ready.
3. **Block #1,150,000**
    a. *Homestead*—The second stage of Ethereum, launched in March 2016.

Four Stages of Development

4. **Block #1,192,000**
    a. *DAO*—A hard fork that reimbursed victims of the hacked DAO contract and caused Ethereum and Ethereum Classic to split into two competing systems.
5. **Block #2,463,000**
    a. *Tangerine Whistle*—A hard fork to change the gas calculation for certain I/O-heavy operations and to clear the accumulated state from a denial-of-service (DoS) attack that exploited the low gas cost of those operations.

Four Stages of Development

6. **Block #2,675,000**
    a. *Spurious Dragon*—A hard fork to address more DoS attack vectors, and another state clearing. Also, a replay attack protection mechanism.
7. **Block #4,370,000**
    a. *Metropolis Byzantium*—Metropolis is the third stage of Ethereum, current at the time of writing this book, launched in October 2017. Byzantium is the first of two hard forks planned for Metropolis.

After Byzantium, there is one more hard fork planned for Metropolis: Constantinople. Metropolis will be followed by the final stage of Ethereum's deployment, codenamed Serenity.

A General-Purpose Blockchain

1. Ethereum is distributed state machine.
2. Ethereum track state of currency ownership, and state transitions of a general-purpose data store, i.e., a store that can hold any data expressible as a *key–value tuple*
3. Ethereum has memory that stores both code and data, and it uses the Ethereum blockchain to track how this memory changes over time.
4. Ethereum can load code into its state machine and *run* that code, storing the resulting state changes in its blockchain
5. Two of the critical differences from most general-purpose computers are that Ethereum state changes are governed by the rules of consensus and the state is distributed globally

Turing Completeness

1. Ethereum can compute any algorithm that can be computed by any Turing machine, given the limitations of finite memory.
2. Groundbreaking innovation is to combine the general-purpose computing architecture of a stored-program computer with a decentralized blockchain, thereby creating a distributed single-state (singleton) world computer.
3. Ethereum programs run "everywhere," yet produce a common state that is secured by the rules of consensus.
4. The fact that Ethereum is Turing complete means that any program of any complexity can be computed by Ethereum

Turing Completeness

5. Flexibility of computing any complexity brings some security and resource management problems.
6. Turing proved that you cannot predict whether a program will terminate by simulating it on a computer
7. Turing-complete systems can run in "infinite loops," a term used (in oversimplification) to describe a program that does not terminate.

Turing Completeness and GAS

1. To answer this challenge, Ethereum introduces a metering mechanism called *gas*.
2. As the EVM executes a smart contract, it carefully accounts for every instruction (computation, data access, etc.).
3. Each instruction has a predetermined cost in units of gas.
4. Transaction that triggers the execution of a smart contract must include an amount of gas that sets the upper limit of what can be consumed
5. EVM will terminate execution if the amount of gas consumed by computation exceeds the gas available in the transaction.

How does one get gas

1. You won’t find gas on any exchanges.
2. Only be purchased as part of a transaction, and can only be bought with ether.
3. Ether needs to be sent along with a transaction and it needs to be explicitly earmarked for the purchase of gas, along with an acceptable gas price.
4. Just like at the pump, the price of gas is not fixed.
5. Gas is purchased for the transaction, the computation is executed, and any unused gas is refunded back to the sender of the transaction.

Decentralized Applications (DApps)

DApp is a web application that is built on top of open, decentralized, peer-to-peer infrastructure services.

A DApp is composed of at least:

- Smart contracts on a blockchain
- A web frontend user interface

In addition, many DApps include other decentralized components, such as:

- A decentralized (P2P) storage protocol and platform
- A decentralized (P2P) messaging protocol and platform

Chapter 2

Ethereum Basics

Ethereum Currency Units

1. Ethereum's currency unit is called *ether*
2. It identified as "ETH" or with the symbols Ξ (from the Greek letter "Xi" or, less often, ♦
3. For example: 1 ether, or 1 ETH, or Ξ1, or ♦1

Ether Smallest Unit = WEI

ethereum

1. Ether is subdivided into smaller units, *wei*.
2. One ether is 1 quintillion wei (10^18 or 1,000,000,000,000,000,000).
3. Ethereum is the system, ether is the currency.
4. When you transact 1 ether, the transaction encodes 1,000,000,000,000,000,000 wei as the value.

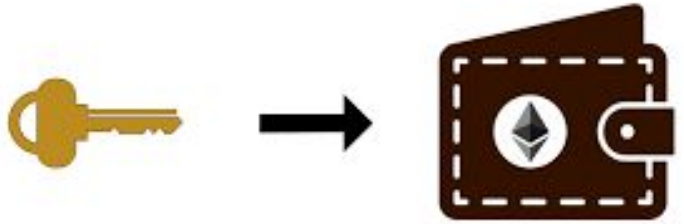
Value (in wei)	Exponent	Common name	SI name
1	1	wei	Wei
1,000	10^3	Babbage	Kilowei or femtoether
1,000,000	10^6	Lovelace	Megawei or picoether
1,000,000,000	10^9	Shannon	Gigawei or nanoether
1,000,000,000,000	10^{12}	Szabo	Microether or micro
1,000,000,000,000,000	10^{15}	Finney	Milliether or milli
1,000,000,000,000,000,000	*10^{18}*	*Ether*	*Ether*
1,000,000,000,000,000,000,000	10^{21}	Grand	Kiloether
1,000,000,000,000,000,000,000,000	10^{24}		Megaether

Choosing an Ethereum Wallet

1. "Wallet" means a software application that manage your Ethereum account.
2. It holds your keys & can create and broadcast transactions on your behalf.
3. If you choose a wallet and don’t like you can change wallets quite easily.
4. Make a transaction to sends your funds from the old wallet to the new
5. Export your private keys and import them into the new one.

Types of Wallet

1. Mobile wallet,
2. Desktop wallet, and
3. Web-based wallet.



Generally the more popular a wallet application is, the more trustworthy it is likely to be.

It is good practice to avoid "putting all your eggs in one basket" and have your Ethereum accounts spread across a couple of wallets.

Some good starter wallets

MetaMask

1. Browser extension wallet that runs in your browser.
2. It is easy to use and convenient for testing,
3. as it is able to connect to a variety of Ethereum nodes and test blockchains.
4. MetaMask is a web-based wallet.

Some good starter wallets

Jaxx

1. Multiplatform and multicurrency wallet that runs on a variety of operating systems
2. It is often a good choice for new users as it is designed for simplicity and ease of use.
3. Jaxx is either a mobile or a desktop wallet

Some good starter wallets

MyEtherWallet (MEW)

1. Web-based wallet that runs in any browser.

Emerald Wallet

1. It’s an open source desktop application
2. Can run a full node/ connect to public remote node, working in light mode.
3. It also has a companion tool to do all operations from the command line.

Control and Responsibility

1. Open Blockchain & operate as Decentralize System
2. Each user can control their own private keys
3. That mean: control access to funds and smart contracts.
4. We sometimes call the combination of access to funds and smart contracts an "account" or "wallet."

With control comes a big responsibility

1. If you lose your private keys, you lose access to your funds and contracts.
2. No one can help you regain access—your funds will be locked forever.
3. Some users choose to give up control over their private keys by using a third-party custodian, such as an online exchange.

Tips to manage this responsibility

1. Do not improvise security. Use tried-and-tested standard approaches.
2. The more important the account the higher security measures should be.
3. The highest security is gained from an air-gapped device, but this level is not required for every account.
4. Never store your private key in plain form, especially digitally.
5. Private keys can be stored in an encrypted form, as a digital "keystore" file. Being encrypted, they need a password to unlock. When you are prompted to choose a password, make it strong, back it up, and don’t share it.

Tips to manage this responsibility

6. If you don’t have a password manager, write it down and store it in a safe and secret place. To access your account, you need both the keystore file and the password.
7. Do not store any passwords in digital documents, digital photos, screenshots, online drives, encrypted PDFs, etc. Again, do not improvise security. Use a password manager or pen and paper.
8. When you are prompted to back up a key as a mnemonic word sequence, use pen and paper to make a physical backup. Do not leave that task "for later"; you will forget.

Tips to manage this responsibility

9. However, they can also be used by attackers to get your private keys, so never store them digitally, and keep the physical copy stored securely in a locked drawer or safe.
10. Before transferring any large amounts (especially to new addresses), first do a small test transaction (e.g., less than $1 value) and wait for confirmation of receipt.

Tips to manage this responsibility

11. When you create a new account, start by sending only a small test transaction to the new address. Once you receive the test transaction, try sending back again from that account. There are lots of reasons account creation can go wrong, and if it has gone wrong, it is better to find out with a small loss. If the tests work, all is well.
12. Public block explorers are an easy way to independently see whether a transaction has been accepted by the network. However, this convenience has a negative impact on your privacy, because you reveal your addresses to block explorers, which can track you.

Tips to manage this responsibility

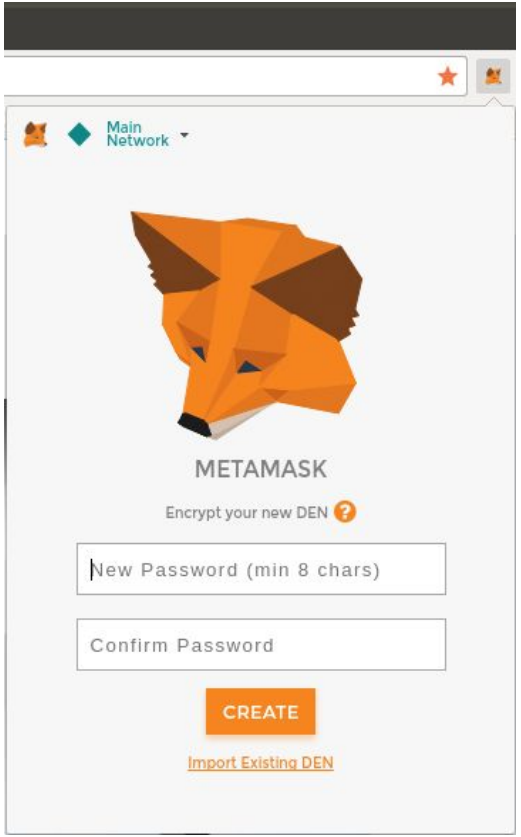
13. Do not send money to any of the addresses shown in this book. The private keys are listed in the book and someone will immediately take that money.

Getting Started with MetaMask

https://metamask.io

Getting Started with MetaMask

1. Once MetaMask is installed you should see a new icon in your browser's toolbar.
2. Click on it to get started.
3. You will be asked to accept the terms and conditions and then to create your new Ethereum wallet by entering a password



Switching Networks

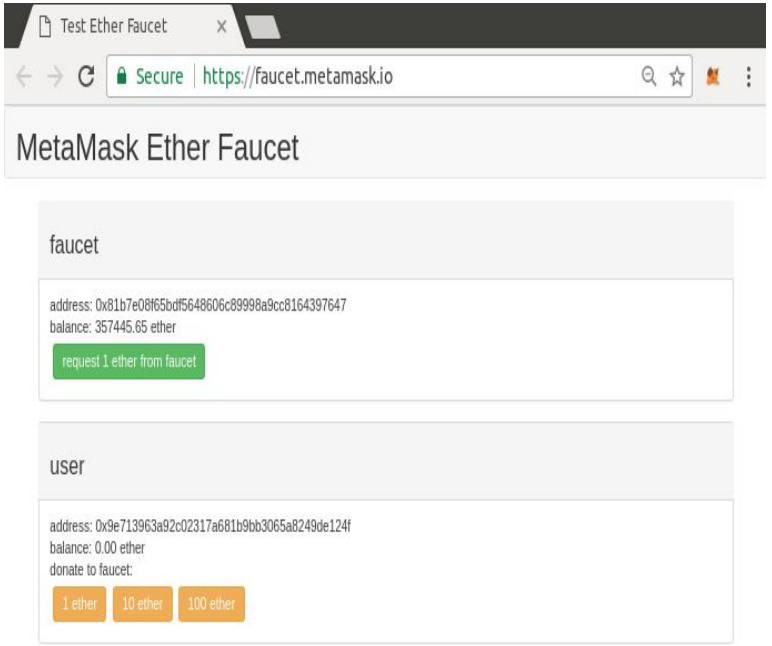
1. **Main Ethereum Network**
   a. By default, MetaMask will try to connect to the main public network.
   b. Real ETH, real value, and real consequences.
2. **Ropsten Test Network**
   a. Ethereum public test blockchain and network.
   b. ETH on this network has no value.
3. **Kovan Test Network**
   a. Ethereum public test blockchain and network using consensus protocol - Proof of authority ETH on this network has no value. The Kovan test network is supported by Parity only.

Switching Networks

4. **Rinkeby Test Network**
    a. Ethereum public test blockchain and network, using consensus protocol - proof of authority
    b. ETH on this network has no value.
5. **Localhost 8545**
    a. Connects to a node running on the same computer as the browser.
    b. The node can be part of any public blockchain (main or testnet), or a private testnet.
6. **Custom RPC**
    a. Allows you to connect MetaMask to any node with a Geth-compatible Remote Procedure Call (RPC) interface. The node can be part of any public or private blockchain

Getting Some Test Ether

1. New transaction will be mined and your MetaMask wallet will show a balance of 1 ETH.
2. Click on the transaction ID it take you to a *block explorer*. MetaMask uses the Etherscan block explorer,
3. The transaction containing the payment from the Ropsten Test Faucet is shown in Etherscan Ropsten block explorer.



Demo
Deploying A Simple Contract

Chapter # 3

Ethereum Client

Ethereum Client

- An Ethereum client is a software application that implements the Ethereum specification.
- Ethereum is defined by a formal specification called the "Yellow Paper"
- Different Ethereum clients *interoperate* if they comply with the reference specification and the standardized communications protocols.

Ethereum Improvement Proposals - EIP

This yellow paper, in addition to various Ethereum Improvement Proposals - EIP, defines the standard behavior of an Ethereum client.

The Yellow Paper is periodically updated as major changes are made to Ethereum.

Benefit of Specification vs Implementation

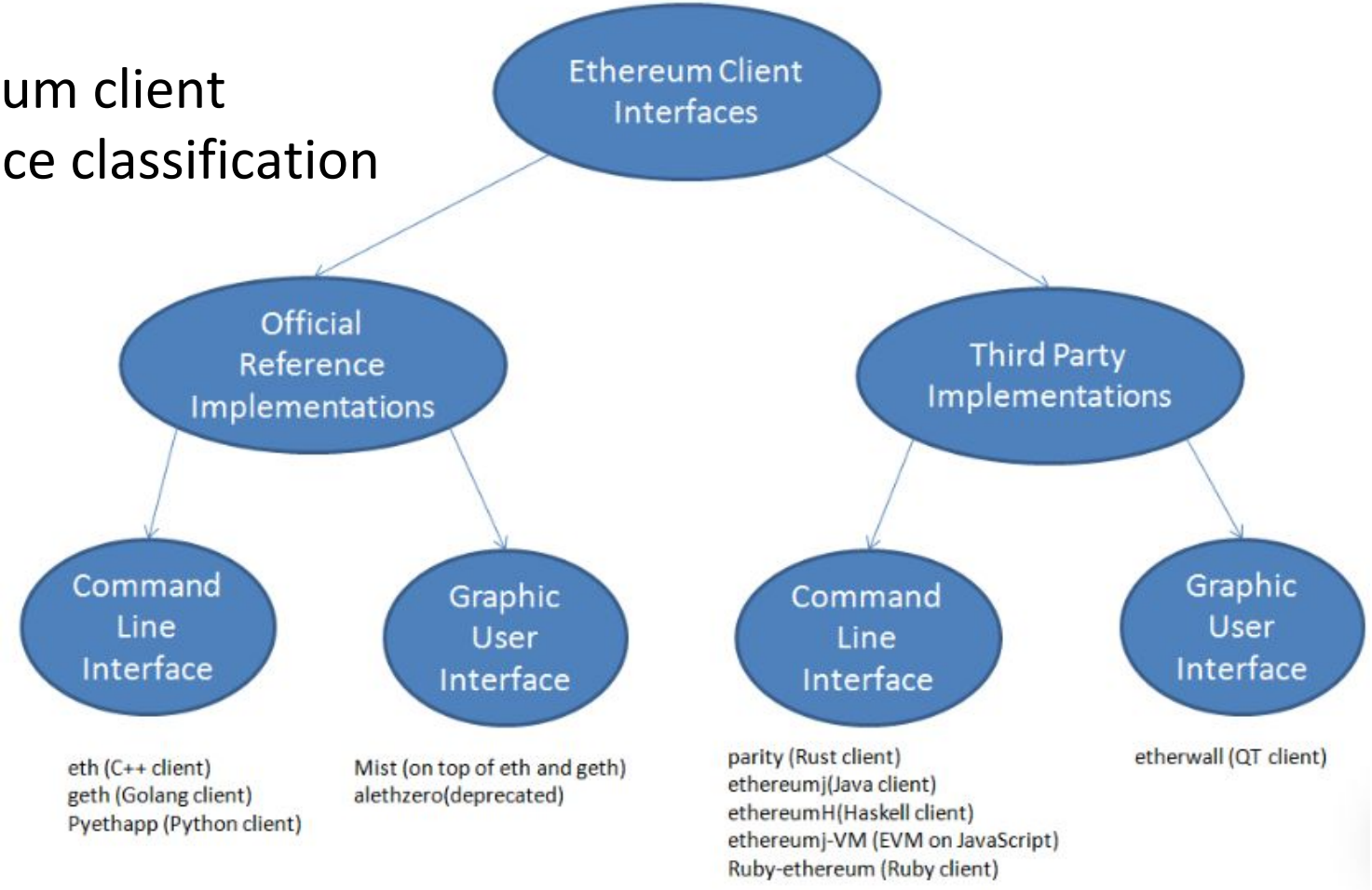
Built on specification proven itself to be an excellent way of defending against attacks on the network, because exploitation of a particular client's implementation strategy simply hassles the developers while they patch the exploit, while other clients keep the network running almost unaffected.

Ethereum Network

Currently, there are six main implementations of the Ethereum protocol, written in six different languages:

- **Parity**, written in **Rust**
- **Geth**, written in **Go**
- **cpp-ethereum**, written in **C++**
- **pyethereum**, written in **Python**
- **Mantis**, written in **Scala**
- **Harmony**, written in **Java**

Ethereum client interface classification



Should I run full Node?

For Ethereum development a full node running on a live *mainnet* network is not necessary.

You can do almost everything you need to do with

- A *testnet* node,
- Local private blockchain like **Ganache**,
- **Cloud-based Ethereum client** offered by a service provider like Infura.

Remote Client

Remote Client does not store a local copy of the blockchain or validate blocks and transactions.

They are wallet and can create and broadcast transactions.

They can be used to connect to existing networks, such as;

- Own Full Node,
- Public Blockchain (Mainnet)
- Testnet or
- Private (Local) blockchain

Remote Client and Wallet

The terms "remote client" and "wallet" are used interchangeably, though there are some differences. Usually, a remote client offers an API (such as the web3.js API) in addition to the transaction functionality of a wallet.

Example MetaMask and Jaxx

ETH Remote client vs BTC Light node

Do not confuse the concept of a remote wallet in Ethereum with that of a *light client* (which is analogous to a Simplified Payment Verification client in Bitcoin)

Light clients validate block headers and use Merkle proofs to validate the inclusion of transactions in the blockchain and determine their effects, giving them a similar level of security to a full node.

Ethereum remote clients do not validate block headers or transactions. They entirely trust a full client to give them access to the blockchain, and hence lose significant security and anonymity guarantees.

Ethereum Full Node

Advantage

- Supports the resilience and censorship resistance of Ethereum-based networks
- Authoritatively validates all transactions
- Can interact with any contract on the public blockchain without an intermediary
- Can directly deploy contracts into the public blockchain without an intermediary
- Can query (read-only) the blockchain status (accounts, contracts, etc.) offline
- Can query the blockchain without letting a third party know the information you're reading

Disadvantage

- Requires significant and growing hardware and bandwidth resources
- May require several days to fully sync when first started
- Must be maintained, upgraded, and kept online to remain synced

Ethereum Testnet

Advantage

- A testnet node needs to sync and store much less data—about 10 GB depending on the network (as of April 2018).
- A testnet node can sync fully in a few hours.
- Deploying contracts or making transactions requires test ether, which has no value and can be acquired for free from several "faucets."
- Testnets are public blockchains with many other users and contracts, running "live."

Disadvantage

- You can’t use "real" money on a testnet; it runs on test ether. Consequently, you can’t test security against real adversaries, as there is nothing at stake.
- There are some aspects of a public blockchain that you cannot test realistically on a testnet. For example, **transaction fees**, although necessary to send transactions, are not a consideration on a testnet, since **gas is free**. Further, the testnets do not experience **network congestion like the public mainnet** sometimes does.

Ethereum Local blockchain

Advantage

- No syncing and almost no data on disk; you mine the first block yourself
- No need to obtain test ether; you "award" yourself mining rewards that you can use for testing
- No other users, just you
- No other contracts, just the ones you deploy after you launch it

Disadvantage

- Having no other users means that it doesn't behave the same as a public blockchain.
- No miners other than you means that mining is more predictable; therefore, you can't test some scenarios that occur on a public blockchain.
- Having no other contracts means you have to deploy everything that you want to test, including dependencies and contract libraries.
- You can't recreate some of the public contracts and their addresses to test some scenarios (e.g., the DAO contract).

Running Ethereum Client

Minimum Requirements:

- CPU with 2+ cores
- At least 80 GB free storage space
- 4 GB RAM minimum with an SSD, 8 GB+ if you have an HDD
- 8 MBit/sec download internet service

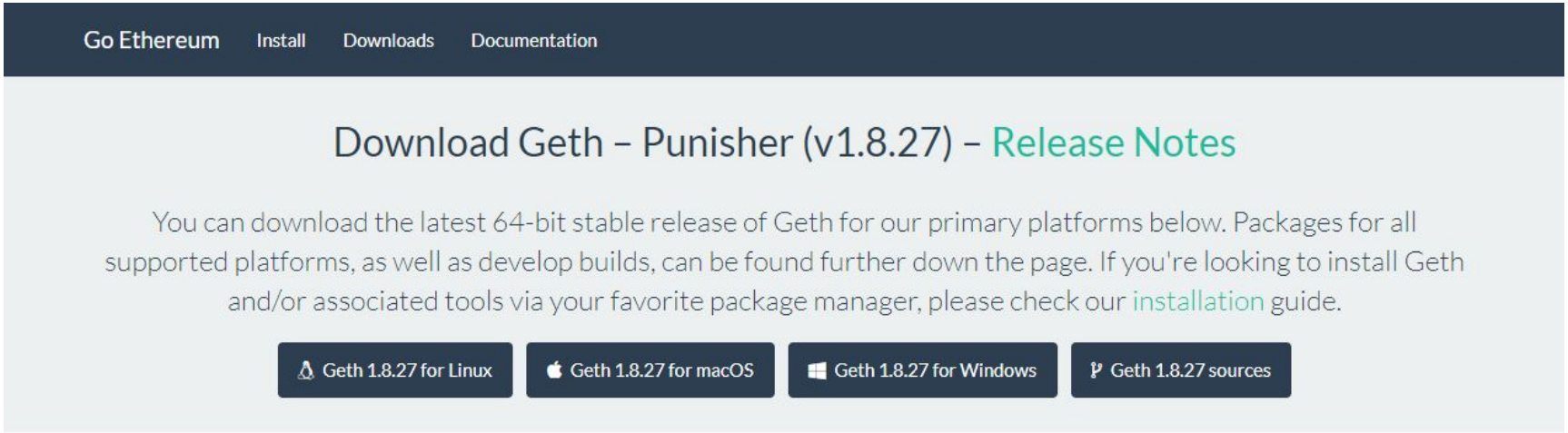
Recommended Requirements:

- Fast CPU with 4+ cores
- 16 GB+ RAM
- Fast SSD with at least 500 GB free space
- 25+ MBit/sec download internet service

The disk size requirements listed here assume you will be running a node with default settings, where the blockchain is **"pruned" of old state data**. If you instead run a **full "archival" node**, where all state is kept on disk, it will likely require more than 1 TB of disk space.

Software Requirements

Goto https://geth.ethereum.org/downloads/ and download geth



After installation run command

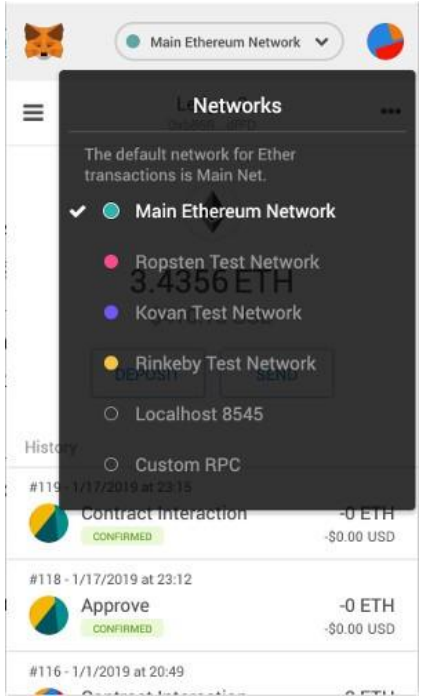
geth --testnet --networkid 3 --datadir <testnetdatapath>

Testnets

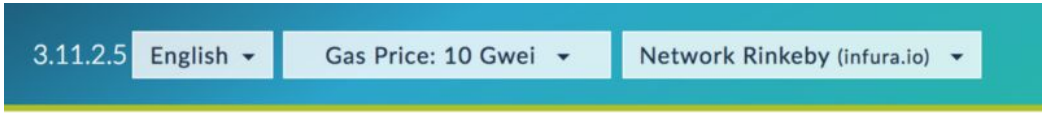
- **Ropsten**: A **proof-of-work** blockchain that most closely resembles Ethereum; you can easily mine faux-Ether.
- **Kovan**: A **proof-of-authority** blockchain, started by the Parity team. Ether can’t be mined; it has to be requested.
- **Rinkeby**: A **proof-of-authority** blockchain, started by the Geth team. Ether can’t be mined; it has to be requested.

Connecting to a testnet

MetaMask Network Selection



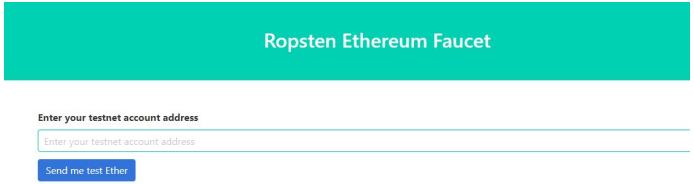
MyEtherWallet



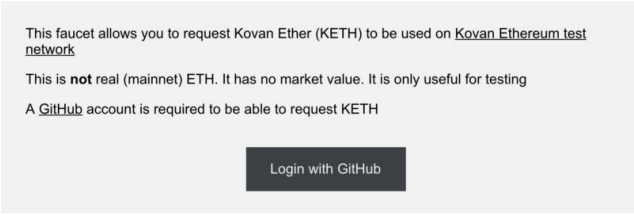
MyCrypto wallet

Acquiring Ether

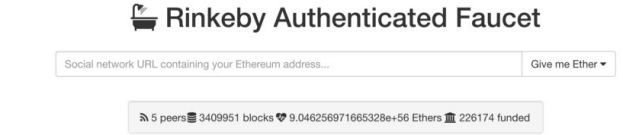
1. Ropsten Faucet: Add address and get ether



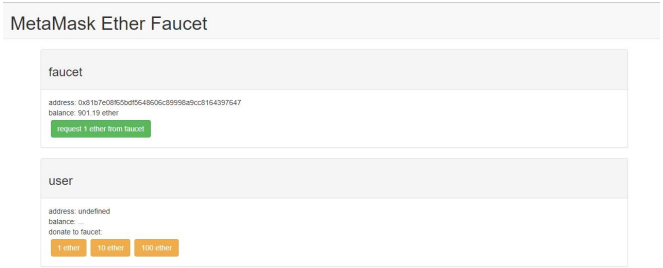
2. Kovan faucet: Required Github account



3. Rinkeby: Post social post including your address in Facebook or Twitter



4. MetaMask faucet will do all magically



Chapter # 4

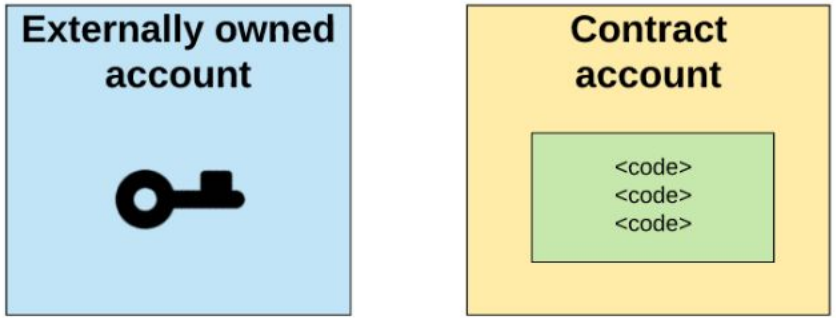
Keys & Addresses

Addresses

One of Ethereum's foundational technologies is *cryptography*

Two types of Accounts

1. Externally owned Accounts (EoA)
2. Contract Account

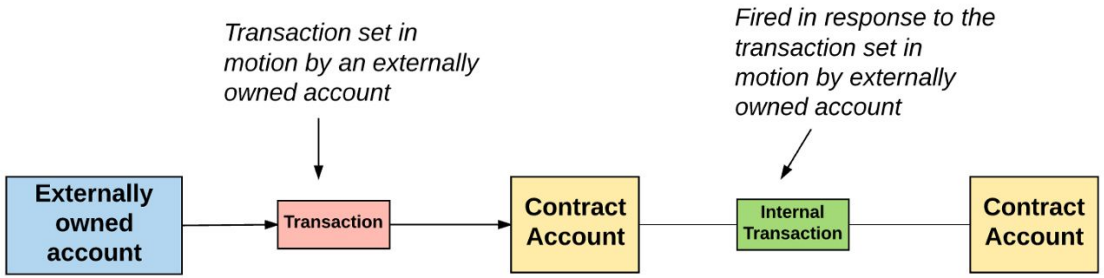


Ownership of ether by EOAs is established through

1. Digital private keys,
2. Ethereum addresses, and
3. Digital signatures

Addresses

- An externally owned account can send messages to other externally owned accounts OR to other contract accounts by creating and signing a transaction using its private key.



- Unlike externally owned accounts, contract accounts can't initiate new transactions on their own

Keys

Private keys are not used directly in the Ethereum system.

- Account addresses are derived directly from private keys.
- Private key uniquely determines a single Ethereum address, also known as an account.

Access and control of funds is achieved with digital signature

- Ethereum transactions require a valid digital signature to be included in the blockchain.
- Anyone with a copy of a private key has control of the corresponding account and any ether it holds.
- Contracts account are not backed by public-private key paris

Public Key Cryptography and Cryptocurrency

In Ethereum, we use public key cryptography (also known as asymmetric cryptography) to create the public–private key pair.

Together, they represent an Ethereum account by providing, respectively, a publicly accessible account handle (the address) and private control over access to any ether in the account and over any authentication the account needs when using smart contracts.

The private key controls access by being the unique piece of information needed to create *digital signatures*, which are required to sign transactions to spend any funds in the account. Digital signatures are also used to authenticate owners or users of contracts

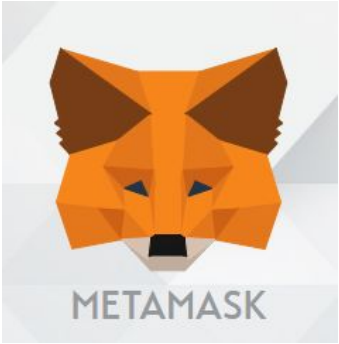
Ethereum transaction is basically a request to access a particular account with a particular Ethereum address

Chapter # 5

Wallets

Wallets

- A wallet is a software application that serves as the primary user interface to Ethereum.
- The wallet controls access to a user's money, managing keys and addresses, tracking the balance, and creating and signing transactions.
- Ethereum wallets can also interact with contracts, such as ERC20 tokens.
- Interfaces to Ethereum-based decentralized applications, or ***DApps***



ERC20

Wallet technology overview

Ethereum wallet is a *keychain* containing pairs of private and public keys. Ethereum wallet doesn’t contain ether or tokens. From these keys they control the ether or tokens.

Users sign transactions with the private keys, thereby proving they own the ether. The ether is stored on the blockchain.

Wallet Type

Non-deterministic wallet (JBOK wallet)

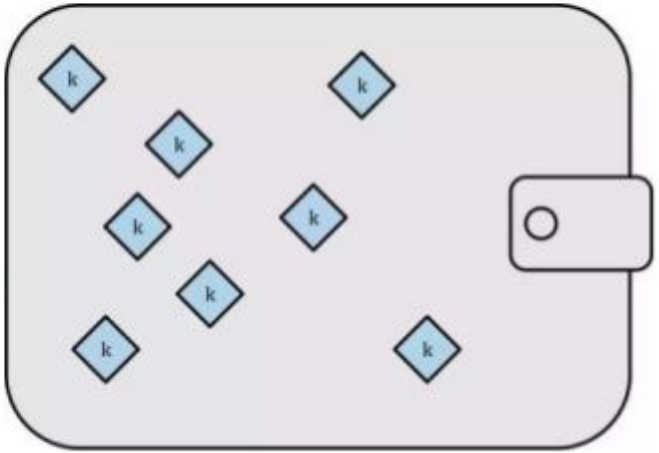
- Each key is independently generated from a different random number
- The keys are not related to each other
- Also known as JBOK (Just a Bunch of Keys) wallet

Deterministic wallet (HD Wallet)

- All the keys are derived from a single master key. Known as **Seed.**
- Keys are related to each other.
- Can be generated again from original seed.
- The most common method is tree-like structure. Also known as HD (Hierarchical Deterministic) Wallet

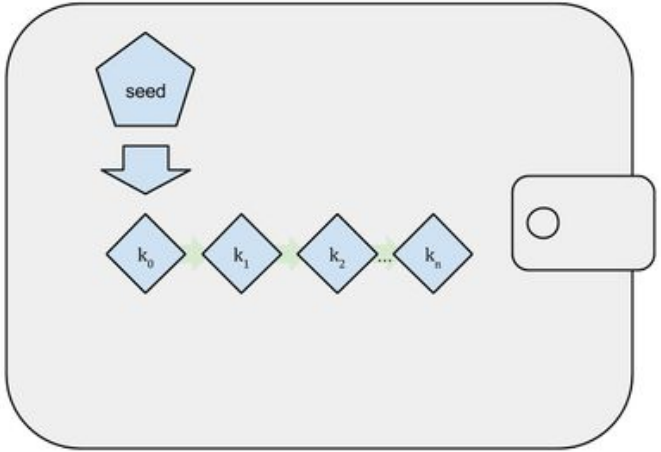
Non-deterministic (Random) wallet

- Avoiding of address reuse, non deterministic wallet needs to regularly increase its list of keys.
- Which require regular backups. Any loss of backup means loss of private keys. Which means lose access to your funds and contracts.
- The use of nondeterministic wallets is discouraged for anything other than simple tests. They are too cumbersome to back up and use for anything but the most basic of situations. Instead, use an industry-standard–based HD wallet with a mnemonic seed for backup.



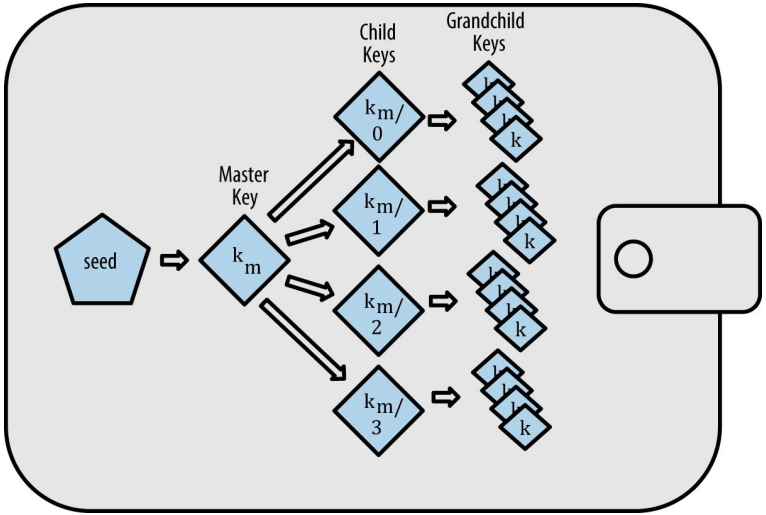
Deterministic (Seeded) Wallet

- Wallet that contain private keys derived from single master key, or seed.
- The seed is a randomly generated number that is combined with other data, such as an index number or "chain code", to derive any number of private keys
- In a deterministic wallet, the seed is sufficient to recover all the derived keys
- A single backup, at creation time, is sufficient to secure all the funds and smart contracts in the wallet.



Hierarchical Deterministic (HD) Wallets

- The most advanced form of deterministic wallet is the *hierarchical deterministic* (HD) wallet defined by Bitcoin's *BIP-32 standard*.
- HD wallets contain keys derived in a tree structure, such that a parent key can derive a sequence of child keys, each of which can derive a sequence of grandchild keys, and so on.
- HD wallets offer a few key advantages over simpler deterministic wallets.
    - The tree structure can be used to express additional organizational meaning.
    - Users can create a sequence of public keys without having access to the corresponding private keys. ***This allow your wallet to execute receive-only mode.***



Seeds and Mnemonic Codes (BIP-39)

- Using a sequence of words that, when taken together in the correct order, can uniquely recreate the private key. Known as mnemonic or seed phrase.
- BIP-39 standardized this approach.
- The seed is needed to recover a wallet in the case of data loss whether through accident or theft.
- The seed must be kept extremely private, so digital backups should be carefully avoided; hence the earlier advice to back up with pen and paper.

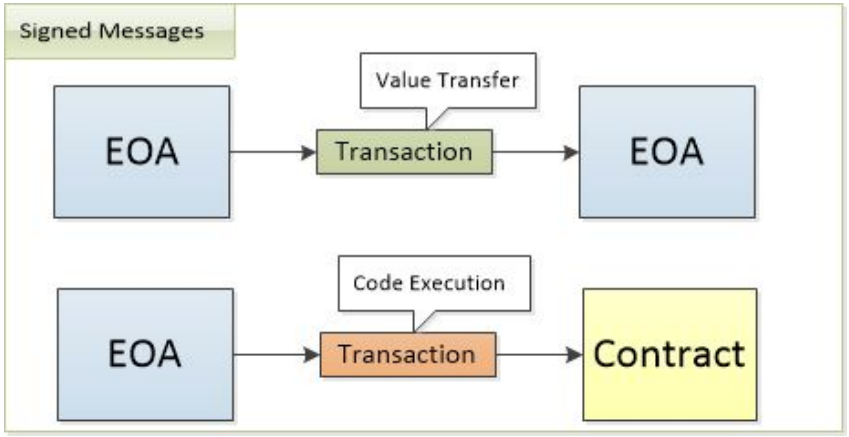
Chapter # 6

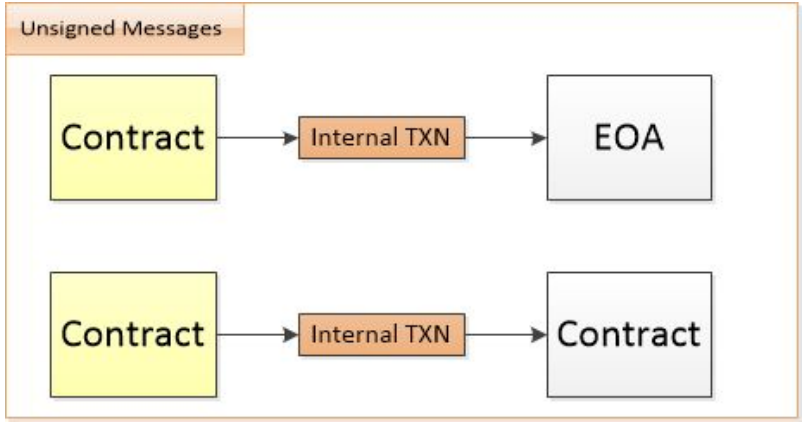
Transactions

Transactions

- Transactions are **signed messages originated by an externally owned account (EOA)**, **transmitted by the Ethereum network**, and **recorded on the Ethereum blockchain**.
- Transactions are the only things that can **trigger a change of state**, or **cause a contract to execute** in the EVM.
- Ethereum is a global singleton state machine, and transactions are what make that state machine "tick," changing its state.
- **Contracts don’t run on their own**. Ethereum doesn’t run autonomously. Everything **starts with a transaction**.

Type of Transactions





Transaction Structure

Nonce	A sequence number, issued by the originating EOA, used to prevent message replay. This number represents the number of transactions sent from the account's address
Gas Price	The price of gas (in wei) the originator is willing to pay
Gas Limit	The maximum amount of gas the originator is willing to buy for this transaction
Recipient	The destination Ethereum address
Value	The amount of ether to send to the destination
Data	The variable-length binary data payload
v,r,s	The three components of an ECDSA digital signature of the originating EOA

Transaction Structure (Cont...)

- The transaction message structure is serialized using the **Recursive Length Prefix (RLP) encoding** scheme.
- All numbers in Ethereum are **encoded as big-endian integers**, of lengths that are **multiples of 8 bits**.
- The data are **separated by fixed length**. No label is included for any field in transaction serialization.
- **There is no “from” data** in the address identifying the originator EOA. That is because the **EOA’s public key can be derived from the v,r,s components** of the ECDSA signature. The address can be **derived from the public key**.

The Transaction Nonce

> nonce: A scalar value equal to the number of transactions sent from this address or, in the case of accounts with associated code, the number of contract-creations made by this account.

For EOA

This number represents the number of confirm transactions sent from the account's address

For Contract Address

The nonce is the number of contracts created by the account.

It is important to note that the use of the nonce is actually vital for an *account-based* protocol, in contrast to the "Unspent Transaction Output" (UTXO) mechanism of the Bitcoin protocol.

Transaction Nonce

Each time you send a transaction, the nonce value *increases by 1*. There are rules about what transactions are considered valid transactions, and the nonce is used to enforce some of these rules. Specifically:

- **Transactions must be in order.** You cannot have a transaction with a nonce of 1 mined before one with a nonce of 0.
- **No skipping!** You cannot have a transaction with a nonce of 2 mined if you have not already sent transactions with a nonce of 1 and 0

Transaction Nonce (Cont..)

Why does it matter?

This value prevents **double-spending**, as the nonce will always specify the order of transactions. If a double-spend does occur, it's typically due to the following process:

- A transaction is sent to one party.
- They wait for it to register.
- Something is collected from this first transaction.
- Another transaction is quickly sent with a high gas price.
- The second transaction is mined first, therefore invalidating the first transaction.

In Ethereum, this method of "double-spending" is not possible because each transaction has a nonce included with it. Even if you attempt to do the above, it will not work as the second transaction (nonce of 3) cannot be mined before the first transaction (nonce of 2).

Gap in Nonces, Duplicate and confirmation

Gaps

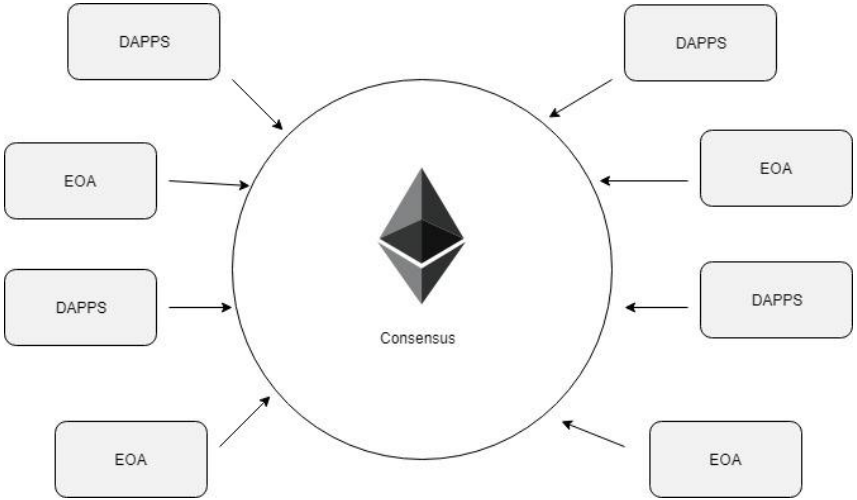
The Ethereum network processes transactions sequentially, based on the nonce. That means that if you transmit a transaction with **nonce 0** and then transmit a transaction with **nonce 2**, the second transaction will not be included in any blocks. It will be stored in the mempool, while the Ethereum network waits for the missing **nonce 1** to appear. **Gap in nonce will stuck the transactions**

Duplicate

Transmitting two transactions with the same nonce but different recipients or values, then one for them will be confirmed and other will be rejected. Confirmation will be determined by the sequence of arrival.

Concurrency

Ethereum, by definition, is a system that **allows concurrency of operations** (nodes, clients, DApps) but **enforces a singleton state through consensus.**



Concurrency Problem

Now, imagine that you have multiple independent wallet applications that are generating transactions from the same address or addresses.

Example Scenario:

An **exchange processing withdrawals from the exchange's hot wallet** (a wallet whose keys are stored online, in contrast to a cold wallet where the keys are never online).

There are **more than one computer processing withdrawals**, so that it doesn't become a bottleneck or single point of failure. However, this **quickly becomes problematic,** as having **more than one computer producing withdrawals will result in some thorny concurrency problems**, not least of which is the **selection of nonces**.

How do multiple computers generating, signing, and broadcasting transactions from the same hot wallet account coordinate?

Potential Solutions:

1. **Seperate Computer to assign nonce:**

You could use a **single computer to assign nonces**, on a first-come first-served basis, **to computers signing transactions**.

Pro:

Avoided gap and duplication of nonce

Con:

1. Single Point of failure
2. Transaction can be stuck on non-confirmation

Potential Solutions: (cont..)

2. Full Node will assign the nonce

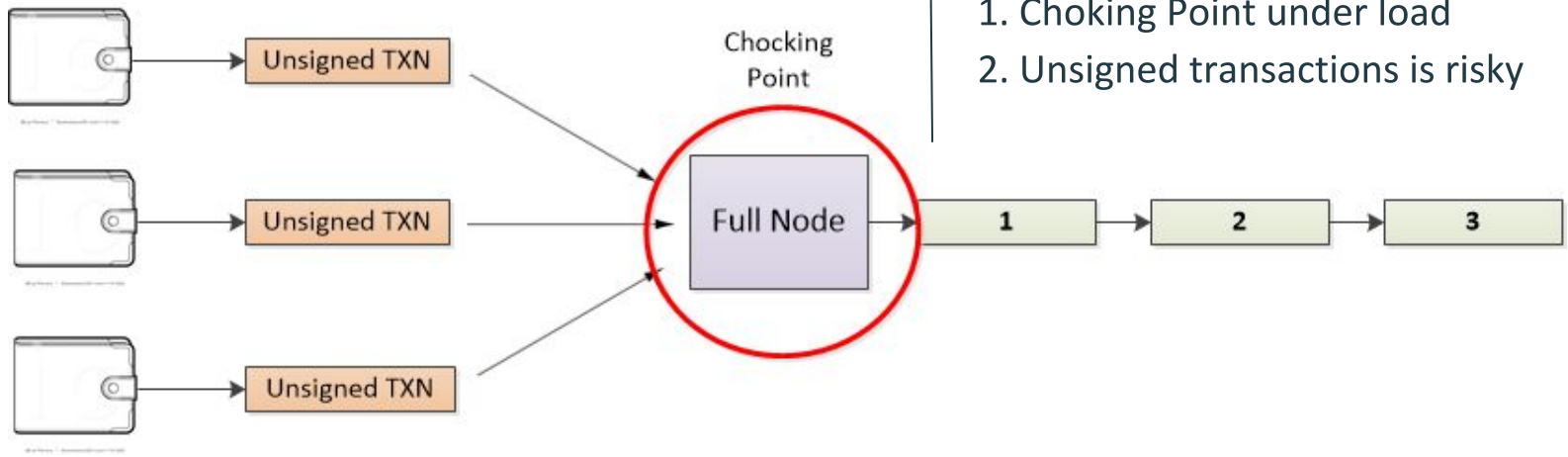
Send unsigned transaction and queue on **single node to sign, assign nonces and process transactions**

Pro:

Avoided gap and duplication of nonce

Con:

1. Choking Point under load
2. Unsigned transactions is risky



Avoid Concurrent Transactions

These concurrency problems, on top of the difficulty of tracking account balances and transaction confirmations in independent processes, force most implementations toward avoiding concurrency and creating bottlenecks such as a single process handling all withdrawal transactions in an exchange, or setting up multiple hot wallets that can work completely independently for withdrawals and only need to be intermittently rebalanced.

Transaction GAS

- Gas is the **fuel of Ethereum**.
- Gas is not ether—it's a **separate virtual currency**
- Gas has **its own exchange rate** against ether.
- Ethereum uses gas to **control resources usage** of transaction.
- The open-ended (Turing-complete) computation model requires some form of **metering** in order to avoid **denial-of-service attacks** or **inadvertently resource-devouring transactions**.

Gas Price

- Wallets can adjust the gasPrice in transactions they originate to achieve faster confirmation of transactions
- The higher the gasPrice, the faster the transaction is likely to be confirmed
- The minimum value that gasPrice can be set to is zero
- GasLimit gives the maximum number of units of gas the transaction originator is willing to buy in order to complete the transaction.

The highest paid Gas Price

ETH 2100

Equivalent of

US$ 628,446.40

Gas Limit

- GasLimit is the maximum gas the originator is willing to pay for the transaction.
- For Contract, the amount of gas cannot be determined with accuracy. Since contract execution is not predictable.
- This value insures that in case of an issue executing your transaction (like infinite loop), you account is not drained of all the funds.
- You are only billed for gas actually consumed by your transaction. Remaining gas is sent back to your account

Transaction Value and Data

- The main "payload" of a transaction is contained in two fields: value and data.
- Transactions can have 4 valid combinations;
  a. only value - **Payment**
  b. only data - **Invocation**
  c. both value and data - **Payment and Invocation**
  d. neither value nor data.- **Empty Transaction**
-

Transaction Recipient

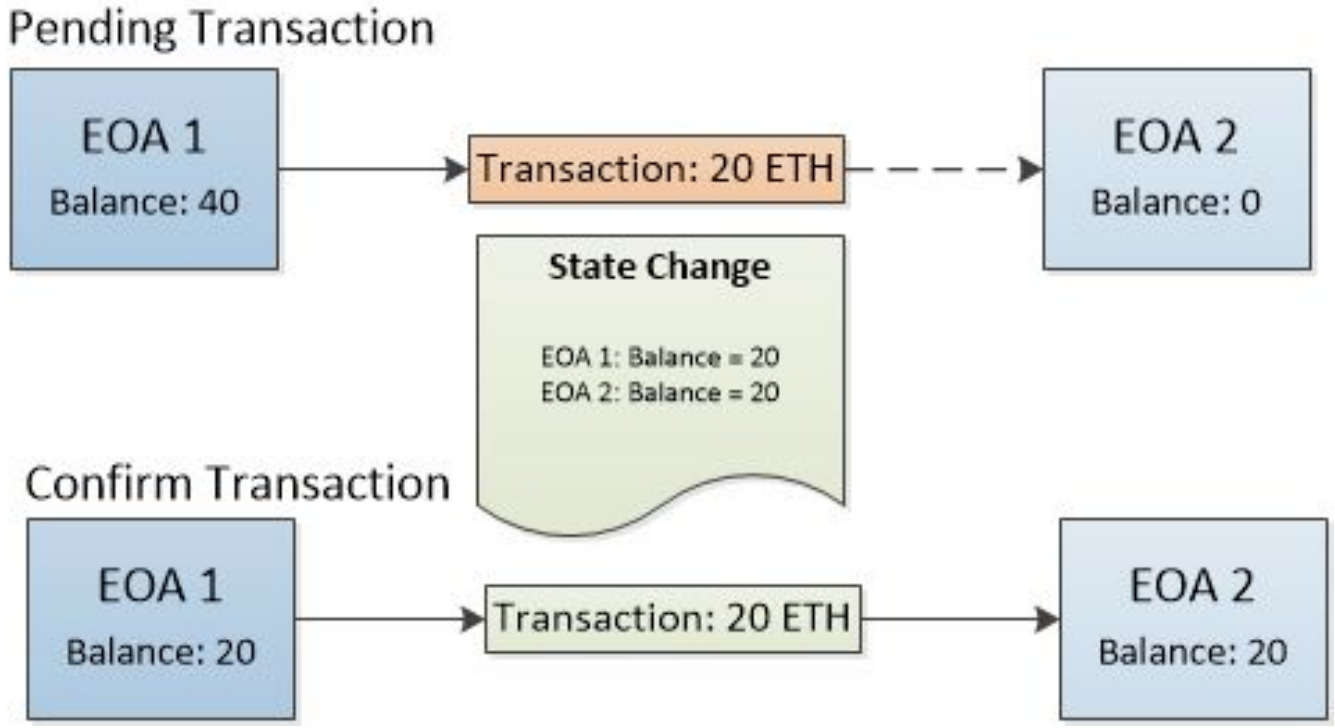
The recipient of a transaction is specified in the to field. This contains a 20-byte Ethereum address. The address can be an EOA or a contract address.

Any 20-byte value is considered valid. If the 20-byte value corresponds to an address without a corresponding private key, or without a corresponding contract, the transaction is still valid.

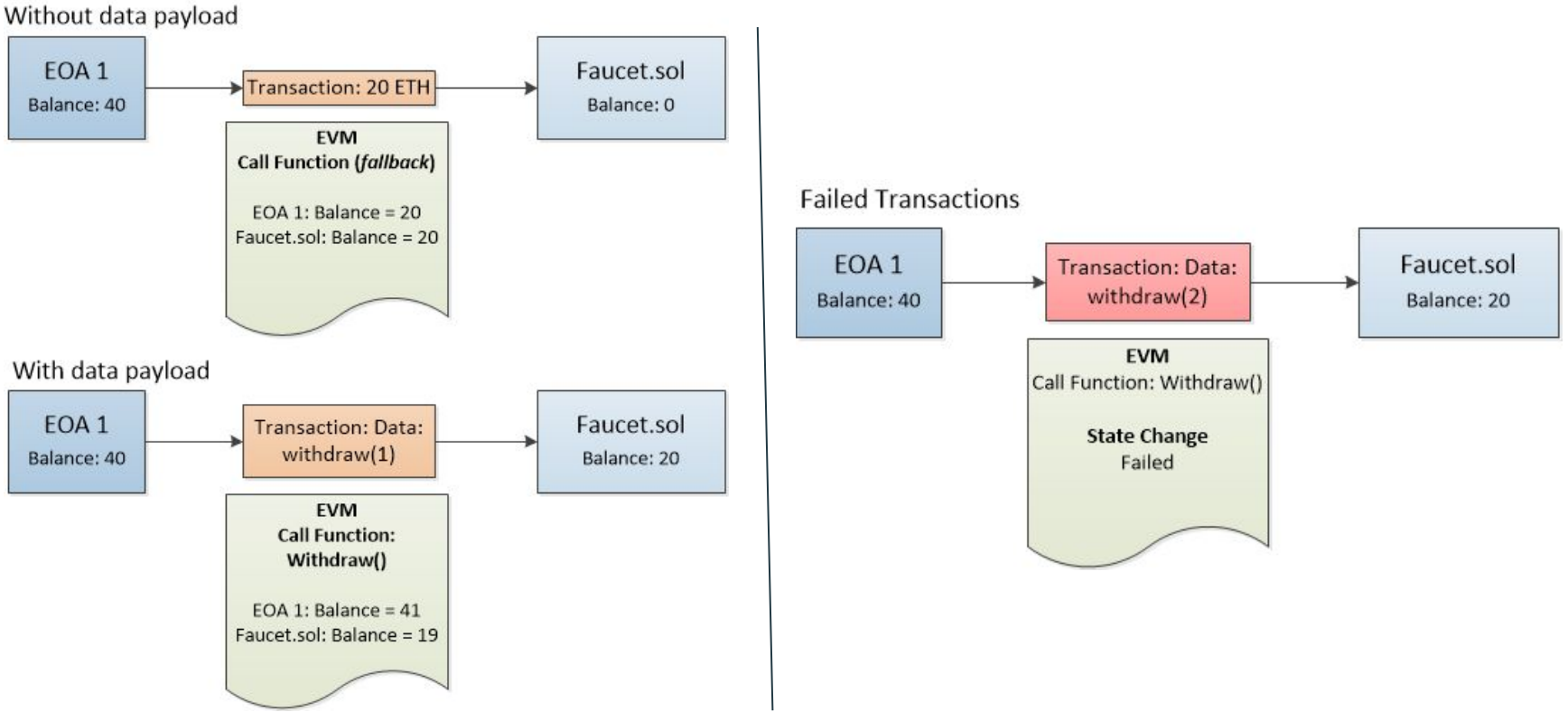
Sending a transaction to the wrong address will probably *burn* the ether sent.

Validation should be done at the user interface level.

Transmitting Value to EOA



Transmitting Value to Contract



Transmitting Data to EOA

You can send a data payload to an EOA—that is completely valid in the Ethereum protocol.

Most wallets also ignore any data received in a transaction to an EOA they control.

Transmitting data payload to an EOA is not subject to Ethereum’s consensus rules, unlike a contract execution.

Transmitting Data to Contract

The data will be interpreted by the EVM as a *contract invocation*. Most contracts use this data more specifically as a *function invocation*, calling the named function and passing any encoded arguments to the function.

The data payload is a hex-serialized encoding of:

A function selector

The first **4 bytes of the Keccak-256 hash** of the function's prototype. This allows the contract to unambiguously identify **which function you wish to invoke**.

The function arguments

The function's arguments, **encoded according to the rules for the various elementary types** defined in the ABI specification.

Special Transaction: Contract Creation

Contract creation transactions are sent to a special destination address called the *zero address*; **0x0**

It can never spend ether or initiate a transaction. It is only used as a destination, with the special meaning "create this contract."

Burn Address

```
0x000000000000000000000000000000000000dEaD
```

Any ether sent to the designated burn address will become unspendable and be lost forever.

Transaction Lifecycle

Step 1. **Construct Raw Transaction**

Step 2. **Sign the Transaction**

Step 3. **Transaction is validated locally**

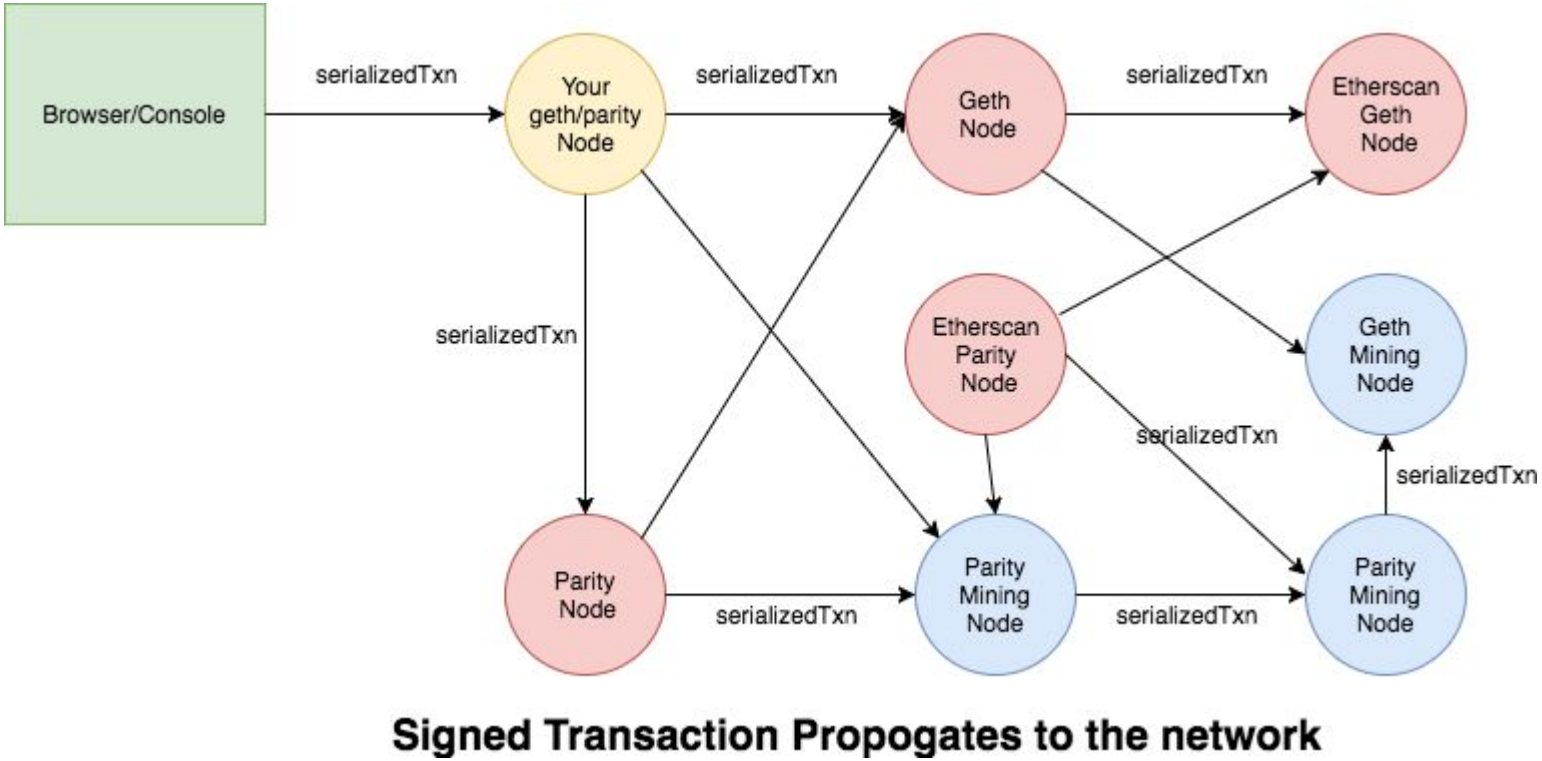
Step 4. **Broadcast to network**

Step 5. **Miner Node accepts**

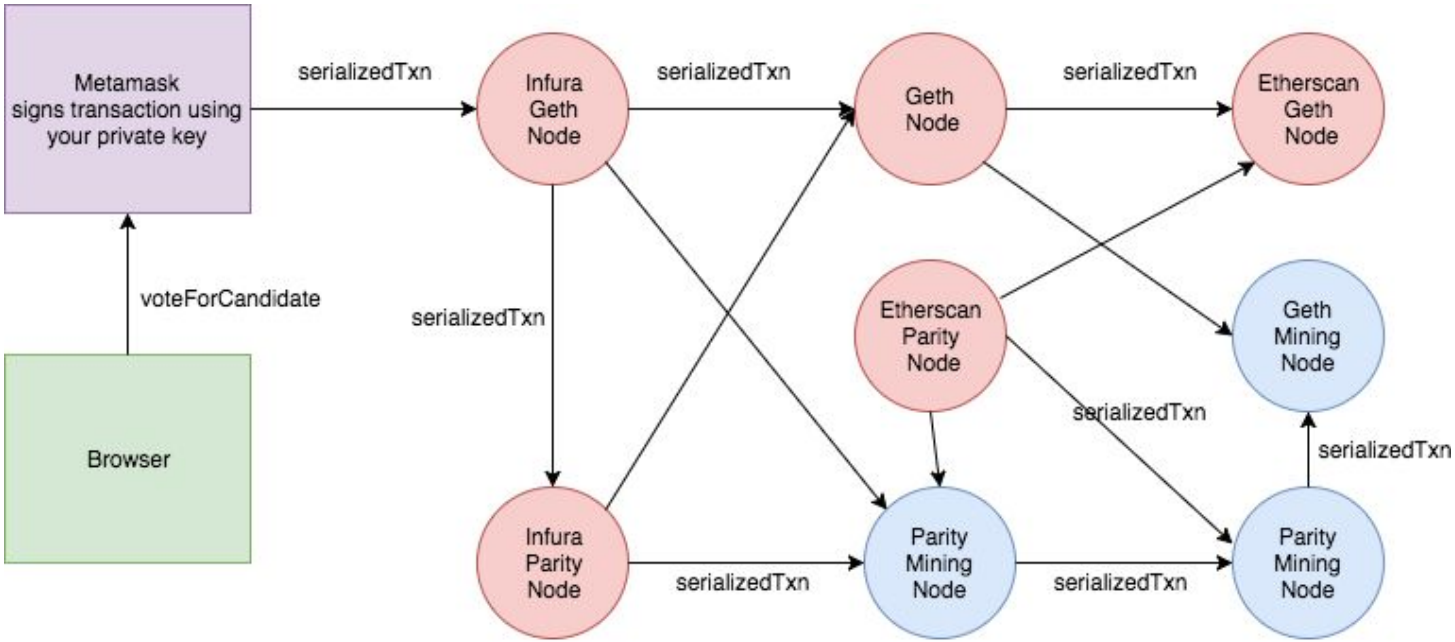
Step 6. **Miner Node finds a valid block and broadcast**

Step 7. **Local Node received/Sync the new block**

Transaction Lifecycle: Local Node



Transaction Lifecycle: From Remote Client

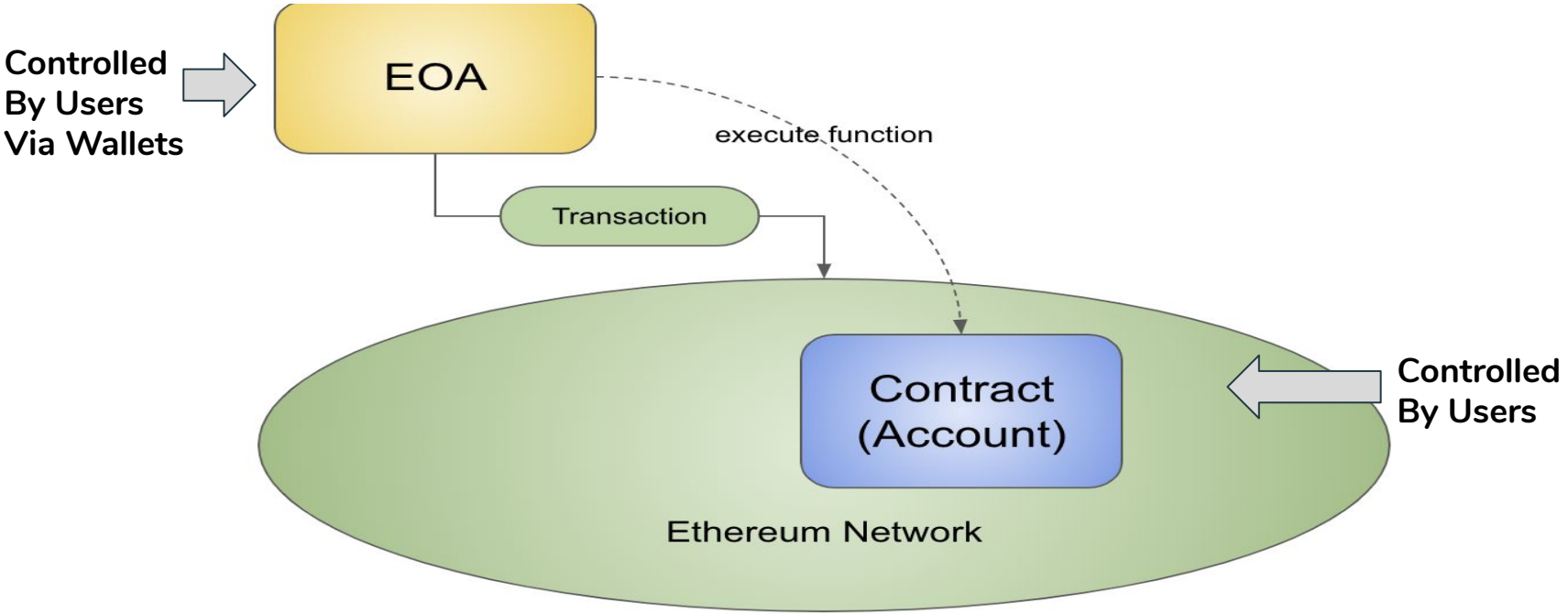


Using Metamask instead of running a local node

Chapter # 7

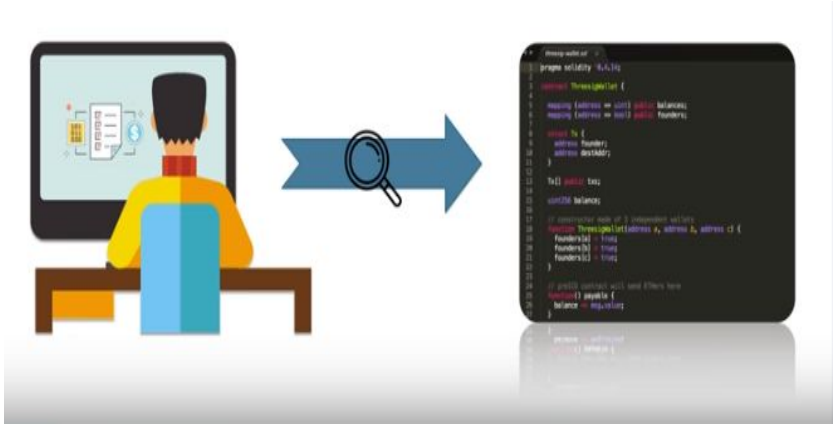
Smart Contracts & Solidity

Smart Contracts & Solidity



Smart Contract

- Computer Program
- Immutable
- Deterministic
- EVM Context
- Decentralized World Computer



In the 1990s, cryptographer Nick Szabo coined the term and defined it as “a set of promises, specified in digital form, including protocols within which the parties perform on the other promises.”

Life Cycle of a Smart Contract

- Written in a **high-level language,** such as **Solidity**
- Compiled to the low-level **bytecode** that runs in the **EVM**.
- **Deployed** using a special *contract* **transaction**
- **Contract Address can be used** in a transaction as the **recipient** for **Sending funds** to the contract or **calling** one of the **contract's** functions
- **Contracts *only run if they are called by a transaction***
- Contracts never run **"on their own"** or **"in the background."**
- Smart contracts are not executed **"in parallel"** in any sense

Smart Contract execution

- **Can call another contract** that can call another contract, and so on,
- **First contract** in a chain of execution will always have been **called by a transaction from an EOA**
- **Recorded only if all execution terminates successfully**, other wise **Roll Back**
- **Failed transaction is still recorded** as having been attempted,
- **Ether spent** on gas for the execution **is deducted from originating account**,
- Otherwise has **no other effects on contract or account state**

Deleting a Smart Contract

- **Contract's code cannot be changed**
- By **Removing the code** and its **Internal state (storage)** from its address,
  - Leaving a blank account.
- Executing an EVM opcode called **SELFDESTRUCT**
- Costs **"negative gas,"** a gas refund (Incentive for releasing network resources)
- **Does not remove the transaction history** (past) of the contract. - *IMMUTABILITY*
- SELFDESTRUCT capability will only be available if the contract to have that functionality.

Introduction - Ethereum High-Level Languages

EVM is a **virtual machine** that runs a special form of code called **EVM bytecode**

- Any high-level language could be adapted to write smart contracts
- a number of special-purpose languages have emerged for programming smart contracts.

Declarative (Functional) programming languages (Haskell and SQL)

Imperative (Procedural) programming languages (C++ and Java)

Hybrids include Lisp, JavaScript, and Python

Why Declarative Language?

- In smart contracts, **bugs literally cost money**.
- It is important to write smart contracts without unintended effects.
- We must be able to **predict expected behavior** of the program.
- Most widely used language for smart contracts (Solidity) is imperative.
- So, declarative languages play a much bigger role in smart contracts than they do in general-purpose software.

Ethereum Smart Contract Languages

Solidity

- Influenced by javascript
- Uses a .sol extension
- Most popular

Serpent

- Influenced by python
- Uses a .se extension
- Was popular a while back

LLL

LLL

- Based on lisp
- Stands for Lisp-like language
- Simple and Minimalistic

Solidity

- Created by **Dr. Gavin Wood** (coauthor of this book)
- **Explicitly for writing smart contracts**
- The main "product" of the Solidity project is the **Solidity compiler, solc**,
- Converts programs written in the Solidity language to **EVM bytecode**.
- Each version of the Solidity compiler **compiles a specific version of the language.**

Chapter # 10

Tokens

What are Tokens

Commonly used to refer to **privately issued special-purpose coin**

- like items of **insignificant intrinsic value,**
- i. e. Transportation, food courts, and game tokens.

Nowadays, "tokens" administered on blockchains are **redefining the word** to mean **blockchain-based abstractions** that can be owned and that represent

- Assets,
- Currency, or
- Access rights.

Traditional Vs Blockchain Tokens

Traditional Tokens

Restricted to specific businesses, organizations, or locations,

Physical tokens are **not easily exchangeable** and **typically have only one function**.

Blockchain Tokens

these restrictions are lifted

Many **blockchain tokens serve multiple purposes globally** &

Can be traded for each other / for other currencies

How are Token Used

Most obvious use of tokens is as digital private currencies

This is only one possible use, **Currency is just the first application:**

Tokens can be programmed to serve many different functions

What can be those difference Functions?

How are Token Used

Currency	-	Serve as a form of currency, with a value determined through private trade
Resource	-	*Earned or Produced*
Asset	-	Represent ownership of tangible/ intangible asset
Access	-	Access rights and grant access to a digital or physical property
Equity	-	Shareholding in a DAO or legal entity

How are Token Used

Voting - Voting rights in a digital or legal system.

Collectible - Digital / physical collectible

Identity - Digital / legal identity

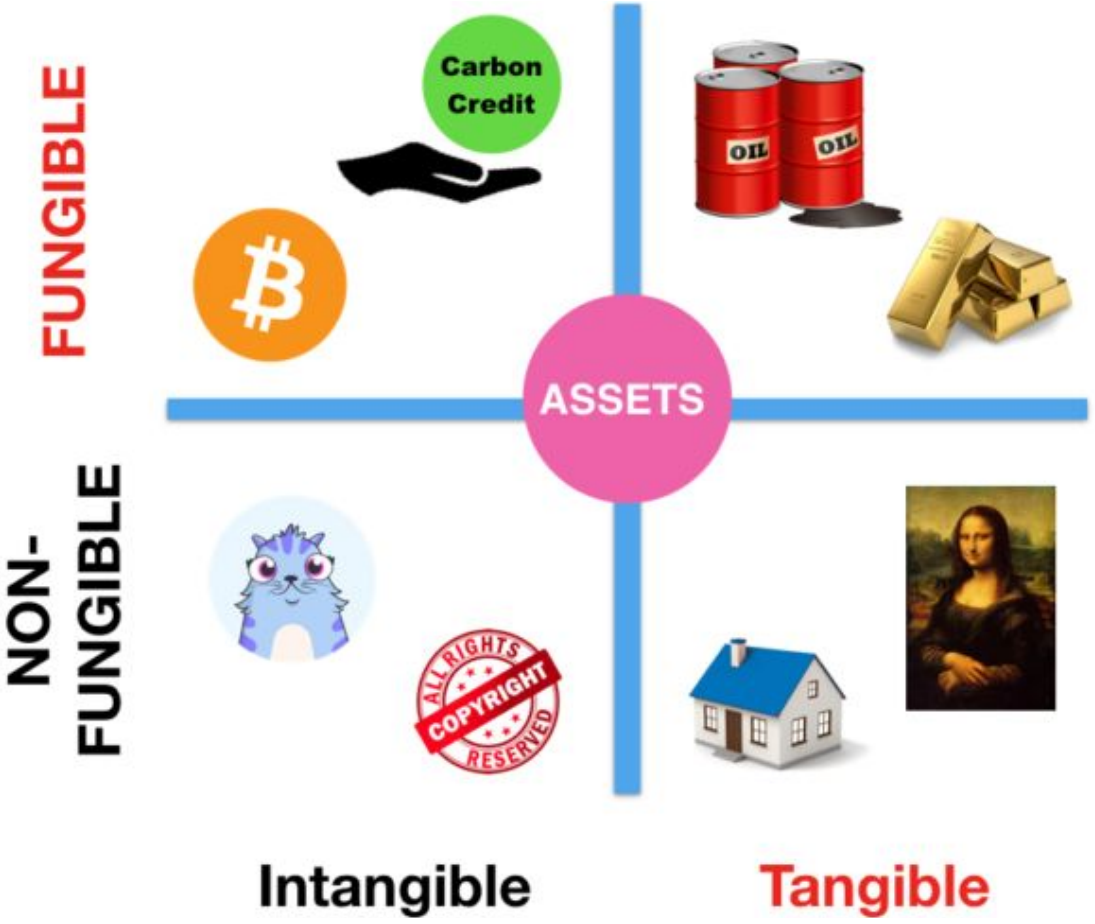
Attestation - Certification / attestation of fact by authority / decentralized reputation system

Utility - access or pay for a service.

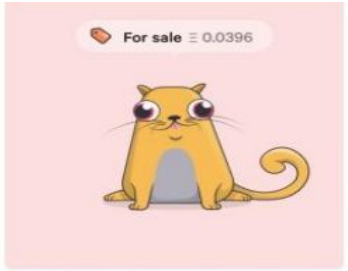
Tokens & Fungibility

“In economics, fungibility is the property of a good or a commodity whose individual units are essentially interchangeable."

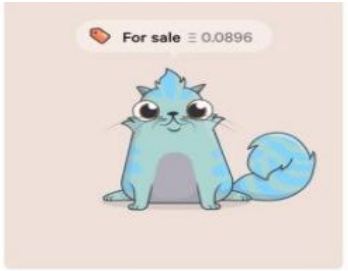
Tokens are fungible when we can substitute any single unit of the token for another without any difference in it value or function.


FUNGIBLE
NON-FUNGIBLE
Carbon Credit
OIL
OIL
ASSETS
ALL RIGHTS
COPYRIGHT
RESERVED
Intangible
Tangible

What is Crypto Kitties??



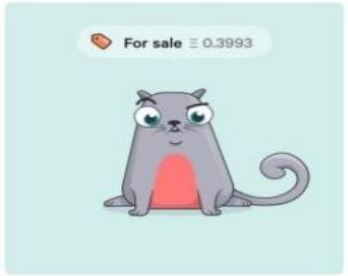
Kitty 240616 · Gen 8
Snappy



Kitty 240611 · Gen 4
Swift

Kitty 240609 · Gen 7
Snappy

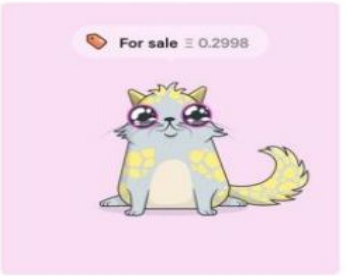
Kitty 240603 · Gen 7
Snappy



Kitty 240601 · Gen 9
Snappy

Kitty 240570 · Gen 7
Snappy

Kitty 240568 · Gen 15
Plodding



Kitty 240560 · Gen 9
Snappy

What is CryptoKitties??

CryptoKitties is a blockchain-based game in which one can breed, collect and hold kittens that are made and generated over Ethereum blockchain

These cryptokitties are just like humans that are unique and cannot be replicated, taken away or destroyed by anyone

Cryptokitties are a new form of collectibles which one can trade, buy, sell, collect like traditional collectibles

The unique thing is that one can even breed this form of crypto-collectibles and the result will be a totally unique new offspring!

The ownership will be tracked and everything will be recorded securely on a transparent blockchain of Ethereum

Tokens & Fungibility

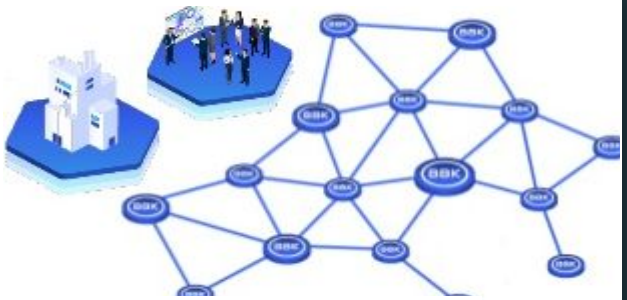
Fungibility is the property of a good or a commodity whose individual units are essentially interchangeable.

Tokens are **fungible** when we can substitute any single unit of the token for another without any difference in its value or function.

Non-fungible tokens are tokens that each represent a unique tangible or intangible item and therefore are not interchangeable.

Non-fungible tokens are unique and hold information instead of value.

Counterparty Risk



Risk that the *other* party in a transaction will fail to meet their obligations

Some transactions suffer **additional counterparty risk** if there are more than two parties involved.

when an asset is traded indirectly through the exchange of a token of ownership

- **Custodian of the asset**
- Ie. such as a certificate, deed, title, or **digital token**

In the world of digital tokens representing assets, as in the non digital world,

It is important to understand **who holds the asset** that is represented by the token

Token & Intrinsicality

Tokens that represent **intrinsic assets** do not carry additional counterparty risk

If you hold the keys for a **CryptoKitty**, you own it directly

- No other party holding that CryptoKitty for you

Conversely, many tokens are used to represent **extrinsic** things,

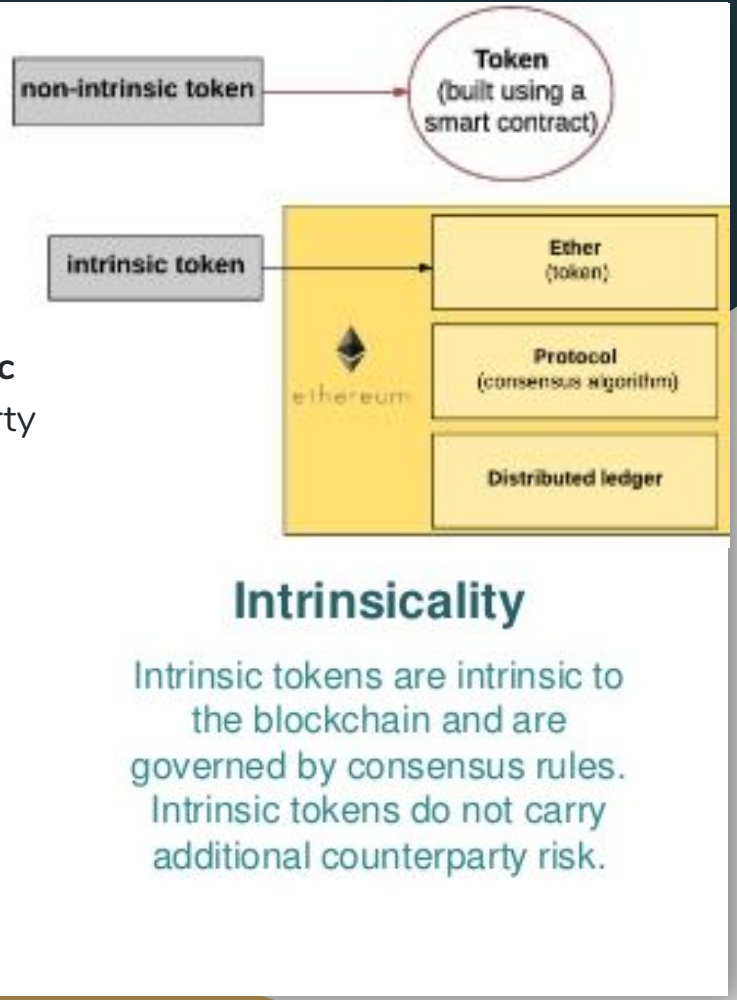
- Real estate, shares, trademarks, and gold bars
- Which are not "within" the blockchain, is governed by law, custom, and policy
- Token issuers and owners may still depend on real-world non-smart contracts.
- Extrinsic assets carry additional counterparty risk as they are held by custodians,
- i.e. Recorded in external registries, or controlled by laws outside the blockchain.

Token & Intrinsicality

Blockchain-based tokens has the ability to convert **extrinsic assets** into **intrinsic assets** and thereby remove counterparty risk.

Example:
Moving from **equity in a corporation (extrinsic)** to an

Equity or voting token in a *DAO* or similar (intrinsic) organization



Using Tokens: Utility and Equity

The majority of projects are using tokens in one of two ways: either as "utility tokens" or as "equity tokens."

Utility tokens are those where the use of the token is required to gain access to a service, application, or resource.

Equity tokens are those that represent shares in the control or ownership of something, such as a startup.

Tokens on Ethereum

Blockchain tokens existed before Ethereum.

In some ways, the first blockchain currency, Bitcoin, is a token itself.

Many token platforms were also developed on Bitcoin and other cryptocurrencies before Ethereum.

Introduction of first token standard on Ethereum led to an explosion of tokens

Token Standards - ERC20

First standard was introduced in November 2015 by Fabian Vogelsteller as an Ethereum Request for Comments (ERC). It was automatically assigned GitHub issue number 20, giving rise to the name "ERC20 token." The vast majority of tokens are currently based on the ERC20 standard.

ERC20 is a standard for fungible tokens, meaning that different units of an ERC20 token are interchangeable and have no unique properties.

The ERC20 standard defines a common interface for contracts implementing a token, such that any compatible token can be accessed and used in the same way.

Token Standards - ERC20

Here's what an ERC20 interface specification looks like in Solidity:

```
contract ERC20 {
    function totalSupply() constant returns (uint theTotalSupply);
    function balanceOf(address _owner) constant returns (uint balance);
    function transfer(address _to, uint _value) returns (bool success);
    function transferFrom(address _from, address _to, uint _value) returns
        (bool success);
    function approve(address _spender, uint _value) returns (bool success);
    function allowance(address _owner, address _spender) constant returns
        (uint remaining);
    event Transfer(address indexed _from, address indexed _to, uint _value);
    event Approval(address indexed _owner, address indexed _spender, uint _value);
}
```

Consists of a number of functions that must be present in every implementation of the standard, as well as some optional functions and attributes that may be added by developers.

ERC20 required functions and events

An ERC20-compliant token contract must provide at least the following functions and events:

TotalSupply - Returns the total units of this token that currently exist. ERC20 tokens can have a fixed or a variable supply.

BalanceOf - Given an address, returns the token balance of that address.

Transfer - Given an address and amount, transfers that amount of tokens to that address, from the balance of the address that executed the transfer.

TransferFrom - Given a sender, recipient, and amount, transfers tokens from one account to another. Used in combination with approve.

ERC20 required functions and events

Approve - Given a recipient address and amount, authorizes that address to execute several transfers up to that amount, from the account that issued the approval.

Allowance - Given an owner address and a spender address, returns the remaining amount that the spender is approved to withdraw from the owner.

Transfer - Event triggered upon a successful transfer (call to transfer or transferFrom) (even for zero-value transfers).

Approval - Event logged upon a successful call to approve.

Why Many Smart Contract Use Cases Are Simply Impossible

Smart Contract

When smart people hear the term “smart contracts”, their imaginations tend to run wild

A smart contract is just a **fancy name** for code that runs on a blockchain, and interacts with that blockchain’s state.

A smart contract is a **piece of code** that is stored on an blockchain, triggered by blockchain transactions and which reads and writes data in that blockchain’s database.

Each Language has its strengths and weaknesses – you’d be crazy to build a website in C or compress HD video in Ruby.

But in principle at least, you could if you wanted to. You’d just pay a heavy price in terms of convenience, performance, and quite probably, your hair.

Use Case 1: Contacting External Service

Smart Contract that changes its behavior in response to some external event.

First User Case:

An agricultural insurance policy pays out conditionally based on the quantity of rainfall in a given month.

Because source is outside the blockchain, there is no guarantee that every node will receive the same answer.

Possible Solution:

The smart contract waits until the predetermined time, retrieves the weather report from an external service and behaves appropriately based on the data received.

Use Case 1: Contacting External Service

Problem:

Because the source is outside of the blockchain, there is no guarantee that every node will receive the same answer. Since the smart contracts are executed independently by every node.

Perhaps the source will change its response in the time between requests from different nodes, or perhaps it will become temporarily unavailable. Either way, consensus is broken and the entire blockchain dies.

Use Case 1: Contacting External Service

Workaround:

Oracle pushes the data onto the blockchain rather than a smart contract pulling it in.

Instead of a smart contract **initiating the retrieval of external data**, one or more trusted parties **(“oracles”) creates a transaction** which embeds that data in the chain. Every node will have an identical copy of this data, so it can be safely used in a smart contract state computation.

Use Case 2: Enforcing on-chain payments

Many like the idea of a smart contract which calls a bank's API in order to transfer money.

But if every node is independently executing the code in the chain to take out money from account, The bank account got empty instantly and who is responsible for calling this API?

Solution:
A bank could proactively watch a blockchain and perform money transfers which mirror the on-chain transactions. This presents no risk to the blockchain's consensus because the chain plays an entirely passive role.

Important Observation

1. Both use cases require a **trusted entity to manage** the interactions between the blockchain and the outside world. **This creates centralization**
2. An oracle which provides external information is simply writing that information into the chain. And a service which mirrors the blockchain's state in the real world is doing nothing more than reading from that chain. In other words, **any interaction between a blockchain and the outside world is restricted to regular database operations.**

2. Enforcing on-chain payments

Smart Bond:

The idea is for the **smart contract code to automatically initiate the payments** at the appropriate times, avoiding manual processes and **guaranteeing that the issuer cannot default**.

Of course, in order for this to work, the funds used to make the payments **must live inside the blockchain** as well, **otherwise a smart contract could not possibly guarantee their payment.**

The above makes a smart bond is either **pointless for the issuer**, or **pointless for the investor**.

2. Enforcing on-chain payments

From an **investor's perspective**, the whole point of a bond is **its attractive rate of return, at the cost of some risk of default.**

And **for the issuer**, a bond's purpose is to **raise funds for a productive but somewhat risky activity,** such as building a new factory.

There is **no way** for the **bond issuer to make use of the funds** raised, while simultaneously guaranteeing that the investor will be repaid.

It should not come as a surprise that the **connection between risk and return is not a problem that blockchains can solve.**

3. Hiding Confidential Data

The biggest challenge in deploying blockchains is the radical transparency which they provide.

10 banks set up a blockchain together, and two conduct a bilateral transaction, this will be immediately visible to the other eight.

Wrong Assumption:

Every Smart contract is owner of its data and it has full control over it. It's impossible for other Smart Contract to read data directly.

3. Hiding Confidential Data

- If one smart contract can't access another's data, have we solved the problem of blockchain confidentiality?
- Does it make sense to talk of hiding information in a smart contract?

WHY?

The data is still **stored on every single node** in the chain. It's in the memory or disk of a system which that participant completely controls. And there's nothing to stop them reading the information from their own system, if and when they choose to do so.

What smart contract are for?

Blockchains enable data disintermediation, and this can lead to significant savings in complexity and cost.

In a peer-to-peer financial ledger, each transaction must preserve the total quantity of funds, otherwise participants could freely give themselves as much money as they liked.

There are two dominant paradigms, inspired by **Bitcoin** and **Ethereum**.

The Bitcoin Method

The bitcoin method, which we might call “transaction constraints”, evaluates each transaction in terms of:

(a) the database entries deleted by that transaction and

(b) the entries created.

In other word UTXO (Unspent Transactions) constraints. Both **a and b must be equal.**

Bitcoin-style **transaction constraints** provide superior **concurrency and performance**

The Ethereum Method

All modifications to a contract's data must be performed by its code.

To modify a contract's data, blockchain users send requests to its code, which determines whether and how to fulfill those requests.

The smart contract for a financial ledger performs the same three tasks as the administrator of a centralized database:

1. Checking for sufficient funds,
2. Deducting from one account and
3. Adding to another.

Ethereum-style smart contracts offer greater flexibility.