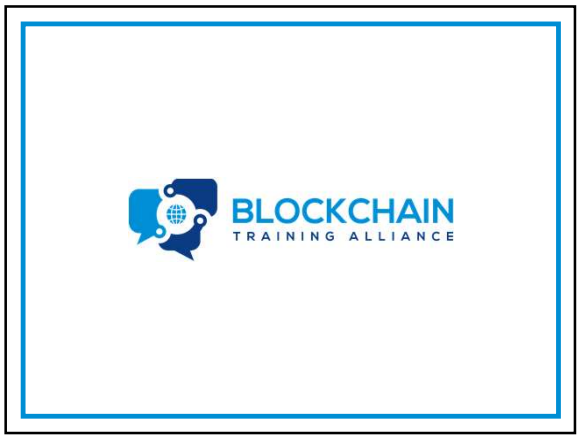
BLOCKCHAIN
TRAINING ALLIANCE

1


BLOCKCHAIN
TRAINING ALLIANCE
Ethereum Development Training
Revision 3.2
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Let's Start
At the Beginning
No prior knowledge
of *Blockchain* required,
"Coding" Knowledge is beneficial
Ethereum Blockchain and Solidity
programming language will be covered in-depth
Start with a simplified overview of how it all works, then dive
deeper into each section

3

Course Modules

- Modules covered:
  - What is Blockchain?
  - Blockchain and Cryptocurrency
  - Why Use Blockchain
  - Decentralized Networks and Ledgers
  - Blockchain 2.0 and Ethereum
  - Programmable Blockchains "Smart Contracts"
  - Types of Blockchain
  - Ethereum Blockchain Tooling Infrastructure
  - How Blocks are Created
  - Cryptography and Hashing
  - Blockchain Nodes And Web3
  - Smart Contract Life Cycle
  - Smart Contract Concurrency and Events
  - Solidity Functions and Modifiers
  - Solidity Mappings and Structs
  - Solidity Files and Inheritance
  - Understanding Transactions And Gas
  - Types of Consensus
  - Mining a Block
  - Ethereum Tooling
  - Go-Ethereum In-Depth
  - Truffle and Local Development
  - Truffle Deployment/Migration
  - Truffle Unit Testing
  - Security & Upgradeable Contracts
  - Smart Contracts Best Practices
  - Blockchains of Storage
  - Compilation of Smart Contracts
  - Blockchain Use Cases
  - Blockchain Adoption
  - Web 3.0
  - Blockchain Implementation

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What is Blockchain?

The Basics

5

The Core Principles of Blockchain

Immutable

Security

Trustless

Distributed Ledger

Decentralized

Group Consensus

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Introduction
Blockchain Defined

- In its simplest form, Blockchain is a distributed database, an unchangeable record (or Ledger) of asset ownership.
- Blockchain is primarily defined as a shared immutable ledger, or just an "unchangeable record of who owns what"
  - Global, peer to peer, and distributed immutable record of transactions.
  - Used to transfer and permanently record any change of assets between two or more parties without intermediaries.
  - Assets are defined as anything of value that requires accountability of ownership, i.e. money, cryptocurrency, real estate, records of any kind, identities, personal property, etc.

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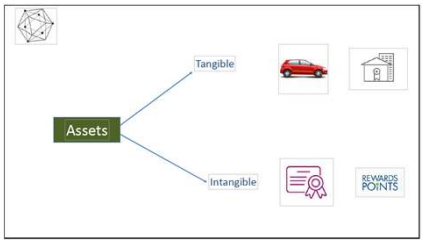
Assets Further Defined



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Blockchain Uses Old Technology

- Blockchain is a combined use of existing older technology.
  - **Ledger** – 7,000 year old technology, triple-entry accounting
  - **Cryptography** – "coding messages" has been used for thousands of years, and still used in complex S/W algorithms for military and business applications like Blockchain
  - **Computer Networking Technology** – Blockchain makes extensive use of P2P networking architectures

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The History of Ledgers

Sidebar - A Brief History of Accounting

- Ledgers appear around 5,000 BC
  - Single entry only
- 300 BC – Chanakya
  - First documented accounting standards
- Double-entry ledger appears in 1340 A.D.
  - Track debits and credits
  - Tell the story of a transaction from both / all sides
- Triple-entry ledger appears in 2009
  - aka Blockchain!
  - Debits, credits, and an immutable link to all past debits and credits

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Blockchain Rules

- Once something has happened, and a record is created, the fact that it happened never changes
- Data written into a blockchain is a historical record and is immutable
- Blockchains have to prove they haven't been tampered with
- All the nodes (computers) running on a blockchain must agree (i.e. have consensus) on ALL the data stored on it

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Blockchain is

- A record keeping system
  - To record the transfer of "tokens" or "coins" representing wealth (Monetary/currency)
    - Bitcoin and other cryptocurrencies such as Ether, LiteCoin, Monero, etc.

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Blockchain is

- A record keeping system (for any kind of data)
  - To record the transactions of importance (Non-Monetary)
    - Update to a medical record
    - Transfer of ownership
    - Training certification on Blockchain
    - Recording important single-party announcements

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Transferring Assets, Building Value

- Anything that is capable of being owned or controlled to produce value, is an asset
- Two fundamental types of asset
  - Tangible, e.g. a house
  - Intangible e.g. a mortgage
- Intangible assets subdivide
  - Financial, e.g. bond
  - Intellectual e.g. patents
  - Digital e.g. music
- Cash is also an asset
  - Has property of anonymity

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Blockchain is:

Blockchain is:

- An event tracking system
  - Announcements mark events
- Events are actionable
- Smart Contracts running on the Blockchain allow actions to be taken on events/transactions
- Blockchain is a workflow platform
  - Now being implemented in financial contracts, manufacturing supply chains, quality tracking, shipping and international transactions, international currency exchange/transfers. Unlimited Possibilities!

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Blockchain is Immutable

- Cannot change the data once it's committed to the ledger
- Data is auditable
- Change by issuing offsetting transaction
- Smart contract code

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Consensus in Distributed Networks

- In order to update the ledger, the network needs to come to consensus using an algorithm
- Consensus: what does it mean to come to consensus on a distributed network?
- Consensus methodologies will be discussed a little later

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Blockchain Beginnings

In 2008 “Satoshi Nakamoto” (who is a real person), published a whitepaper which outlined the architecture of Bitcoin

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Interesting Blockchain Dates

- 2009 first block created
- Satoshi disappears December 2010 - date of last post
- 2015 – Ethereum and Hyperledger both go live
- 2018 – 14 open jobs for every blockchain developer
- 2019 – Walmart requires produce suppliers to be using blockchain
- 2021 – Dubai hosts all gov't operations and record-keeping on blockchain

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Blockchain and Cryptocurrency

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Blockchain's Relationship to Bitcoin

Bitcoin is a digital, decentralized, disintermediated, trustless currency

Blockchain is the underlying security software that manages and controls the WW Bitcoin Network, allowing for safe, trustless, and secure P2P transfer of Bitcoin, or any other cryptocurrency.

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Bitcoin/Ether/Cryptocurrencies have *some* similar characteristics as a fiat currency

- **Durability** - Safe for long term storage
  (crypto - susceptible to individual coin market volitivity)
- **Portability** - Easy to move around and spend
  (crypto - can be exchanged P2P with small transaction fee)
- **Divisibility** - So you can spend small amounts
  (crypto - used in fractional amounts generally based on Bitcoin)
- **Fungibility** - Each unit of value is equal
  (crypto - based on market value fluctuations - BTC/U.S.$ based)
- **Scarcity** - To preserve value
  (crypto - based on market capitalization at time of ICO)
- **Acceptability** - So you can actually spend it
  (crypto - solely based on country monetary policy and merchant acceptability, plus transaction fees)

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Blockchain vs. Tokens (Currency)

Bitcoin	Ethereum	Hyperledger
• Token: Bitcoin	• Token: Ether • EVM • ERC20 Token	• Private permissioned blockchain (no public tokens)

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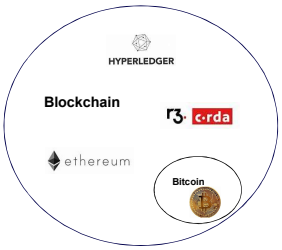
Bitcoin is a Blockchain Application

Bitcoin was the first Blockchain



Bitcoin is an application that runs on the Blockchain. Blockchains can be either public or private but share the same technology.

Similar to Facebook, where Facebook is simply an application that runs on the Internet.

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You Control Access to Ether

- Nobody actually 'has' Ether – they can't be download, or stored on a computer
- Remember: The Blockchain is a ledger - it records the transfer of Tokens (Ether, Bitcoin,…) or other assets between people or other entities i.e. companies, groups, etc.
- The records stay on the Blockchain - what is transferred is the 'control' of the bitcoin or asset.
- An example would be if 'Alice gives Bob 2btc' i.e. 'Alice transfers control of 2 of her bitcoins to Bob'
- Control is enabled through cryptography

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Control via Cryptography

- When someone sends you coins they publicly place them under the control of your public key (in the form of an Address)
- If you can prove that you have the matching public key, and the matching private key, the network lets you control the coins

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Why Use Blockchain

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Decentralization

KEY CONCEPT: Decentralization

- Decentralized - Peer-to-Peer data sharing, hosting hardware owned by many not few, fault tolerant, secure, lower performance
- Distributed - Solution components spread across hardware assets, solution components and data maintained and controlled by central authorities
- Centralized - Solution components, data, and control all maintained by a central authority

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Benefits of Blockchain

What are the benefits of Blockchain?

- Publicly verifiable
  - Accountability to customers and end-users
  - (permission-less)
- Secure
  - Control who sees what data when (permissioned)
- Quality assurance
  - Track origin of all supply chain components
  - Example – Food origin and/or safety recalls
  - Smart Contracts as a replacement for middlemen operators
- Lower transactions costs
  - Removing middlemen reduces cost

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Benefits of Blockchain

What are the benefits of Blockchain?

- Tokenization
  - Create trade-able tokens backed by real-world value
  - Fractional ownership
    - Example - Own 1 car in 1 city, or 100 cars in 100 cities
- Trade, commerce, and business process automation
  - Smart Contracts as a replacement for middlemen operators

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Drawbacks of Blockchain

What are the drawbacks of Blockchain?

- Very new technology
  - Constantly changing, still evolving
  - Number of trained resources still lagging
  - High cost for trained resources
- Best practices, recommended patterns still being formed
- Scalability, transaction speed / cost
- BaaS (Blockchain as a Service) now offered but expensive

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Drawbacks of Blockchain

What are the drawbacks of Blockchain?

- Still learning good and bad use cases
- Lack of knowledge of the technology's capability
- Stigma and history of Blockchain
  - Association with Cryptocurrency and the dark web
  - ICO/ITO scams
- Anonymity of origin – Satoshi Nakamoto
- Data in the blocks

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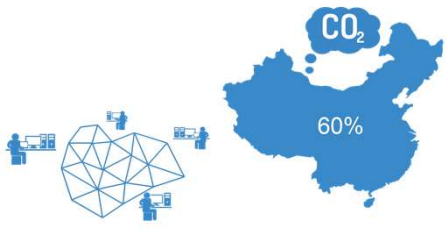
Drawbacks of Blockchain (PoW)



Because All global nodes must validate all transactions, speed, scalability and cumulative power consumption are critical issues facing Blockchain.

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Why Not a Database

Blockchains solve specific problems:

- Fully distributed - highly fault tolerant
- No centralized authority
- Low barrier to entry
- Instant, global transactional capability
- No double spending
- Very low transaction costs

- Traditional Databases have centralized control and do not perform these functions.

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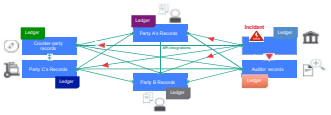
Conventional System Problem

Problem - Difficult to monitor asset ownership and transfers in a trusted business network



Inefficient, **expensive**, **vulnerable**

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Blockchain Shared Ledger Solution

Solution – a permissioned, replicated, shared ledger

ALL Nodes have (and share) the same exact copy of the ledger

Consensus, provenance, immutability, finality

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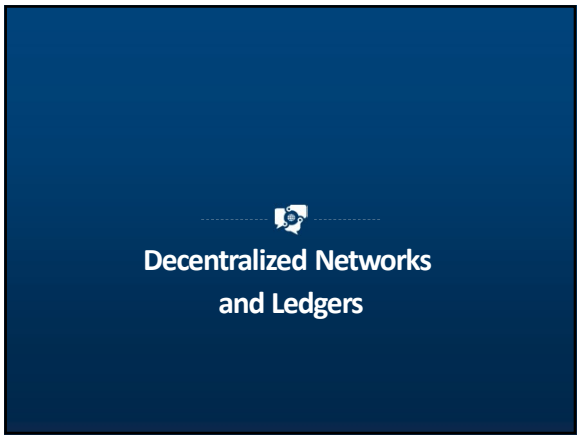

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Blockchains as Distributed Databases

- In Blockchain, everyone has a copy of the Ledger
  - Everyone running a Blockchain node is part of the network
  - New transactions are broadcast to and recorded by the network
  - Everyone updates their local copy of the blockchain
  - If everyone has a copy of the blockchain, when queried, everyone gets the same answer

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Centralized vs Decentralized Ledger

- If the single copy of the ledger were changed by any means, wealth would be lost unfairly
- With a decentralized ledger, nobody has to trust anyone else
  - Trustless environment is assumed from the beginning

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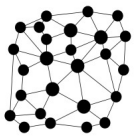
Why Decentralized?

- Distributed network
- Many nodes or peers that are connected in a network with no single point of failure or centralized control
- Security and resiliency: design the network so that if some peers crash or attack the network maliciously, the network can still operate (Byzantine Fault Tolerance)



A distributed network.

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Blockchain 2.0 and Ethereum

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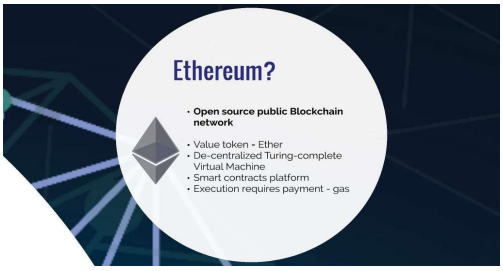
Ethereum Overview



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Blockchain - Ethereum

It provides a decentralized Turing-complete virtual machine, which can execute computer programs using an global network of nodes

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Blockchain – Current Transactions per Second

TPS = 7

TPS = 15

Visa can process over 70,000 TPS, Facebook can handle 175,000 TPS

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Ethereum Smart Contract

Smart Contract

Computer code, written in multiple languages

- Contract lives on the network
- Enforces rules
- Performs negotiated actions

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ETH Valuations

Unit	Wei Value	Wei
wei	1 wei	1
Kwei (babbage)	1e3 wei	1,000
Mwei (lovelace)	1e6 wei	1,000,000
Gwei (shannon)	1e9 wei	1,000,000,000
microether (szabo)	1e12 wei	1,000,000,000,000
milliether (finney)	1e15 wei	1,000,000,000,000,000
ether	1e18 wei	1,000,000,000,000,000,000

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ETH Supply

Ethers Supply

- **Ether creation**
  - Presale (2014): 60 Million
  - 12 Million created to fund the development
  - 5 Ethers created as reward for every block: roughly ~14 seconds
  - Sometimes 2-3 Ethers for non-winning miners (uncle rewards)
- Contract invocation – Users pay by Ethers
- Incentive for the miners

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Ethereum EVM Software

EVM

- An software that can execute Ethereum Bytecode
  - Follows the EVM specifications (Ethereum protocol)
  - Runs as a process on a computer/sever

- EVM implemented in multiple languages

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Ethereum Gas

Gas

- User invoking the transaction pays for the execution

Measures: kWH used

Measures: Gallons of water used

- Gas is the unit in which EVM resource usage is measured

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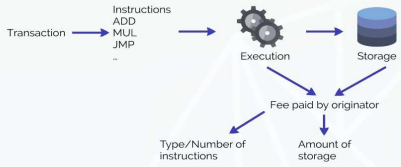
Ethereum Gas

Gas Calculation



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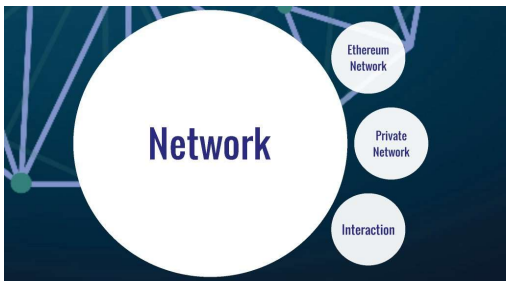
Ethereum Network



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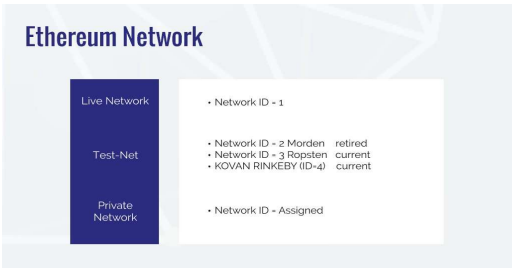
Ethereum Network



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Programmable Blockchains "Smart Contracts"

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Smart Contracts

- Ethereum Blockchain
  - Solidity/Vyper/… High-Level Language
  - Compiling to EVM Assembly
  - Reside on their own address
  - Actionable logic with access to the native token-layer
    - Smart Contracts can send (and own) Ether
  - "Self managing funds"

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Solidity

- Solidity
  - High Level Language
  - Statically typed
  - Needs compilation (solc, solc-js)
  - Very *easy* to learn
  - Very hard to *master* (bugs, Gas-consumption)
  - Very "young" language, constantly evolving (to the better)
- Alternatives
  - Vyper: Security related
  - LLL: Lisp like

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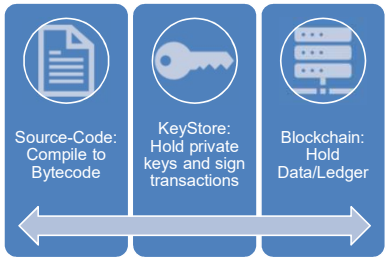
Components



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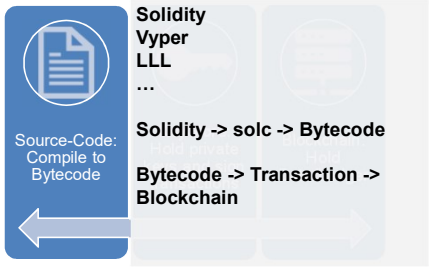
Components



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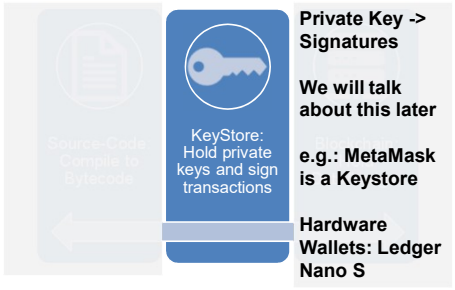
Components



Private Key -> Signatures

We will talk about this later

e.g.: MetaMask is a Keystore

Hardware Wallets: Ledger Nano S

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Components

Blockchain holds the data and takes care of consensus. We'll talk about it later!

Proof of Work: Main-Net, Ropsten, Geth Private Net

Proof-of-Authority: Ganache, Truffle-Developer-Console, Geth-Dev Network

In-Browser-Simulation? Remix

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Remix IDE

- Browser-Based
  - Pure client-side HTML/JavaScript
  - Also a NPM package
- Editor
  - Can edit Solidity files (Text-Editor)
  - Blockchain Simulaton
  - Can run transactions and test code against an internal Blockchain simulation in the browser
  - Including a Step-By-Step Transaction Debugger
- KeyStore
  - Gives you a few accounts (private keys) for the internal Blockchain

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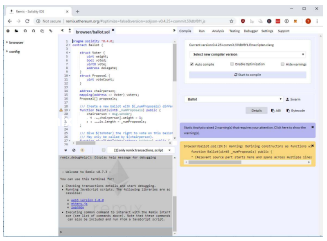
Remix IDE

Remix IDE



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Solidity Contracts

Solidity Contracts :

- Contract Layout
- Basic Types
- Memory Management
- Arrays
- Special Arrays
- Special Arrays

Contract Layout · Memory Management · Special Arrays · Basic Types · Arrays · Functions & Tuples

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Contract Layout

Contract Layout

pragma solidity ^0.4.6
- Rejected with future compiler version
- ^0.4.x will compile with compiler version 0.4.x & above but not with 0.5.x

contract name {
- Given name for the contract
- CapitilizeWords e.g., VotingContract

State/Storage variables
- State variables
- Stored in the chain as part of contract

Events
- Events/Logs emitted by the contract

Functions
- Leads to retrieval of state (0 gas)
- OR change in state (costs gas)

}

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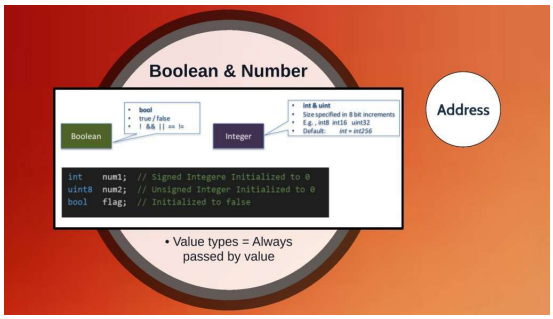
Solidity Contracts



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Address

Address

- Represents the 20 byte Ethereum address
- Value Type

balance

- address.balance — Returns balance in wei

transfer () send ()

- address.transfer(10) — Sends 10 Wei from to the address

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Bytes and Strings

- Bytes
  - Array of bytes
  - Can hold “text”, but not UTF-8
  - Can be fixed size or dynamic size
  - Index (myBytes[7]) can be accessed
  - Can be expanded (push operation)
- String
  - Not a “basic” type
  - Arbitrary Length UTF-8 encoded string
  - Dynamically sized
  - No String-Functions (search, replace) – need external libraries for that

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Variable Initialization

- Un-Initialized Variables are automatically set to their default value
  - integers => 0
  - Boolean => false
  - Strings => “” (empty)
  - …
  - NO ERROR WHEN ACCESSING UNINITIALIZED VARIABLES
- There is no “null”

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Functions

Functions

```
contract Funcs {

  string  ownerName;
  uint8   ownerAge;

  // Sets the name
  function  setOwnerInfo(string name, uint8 age){
    ownerName = name;
    ownerAge = age;
  }

  // Get the name
  function  getOwnerName() returns (string) {
    return ownerName;
  }

  // Get the age
  function  getOwnerAge() returns(uint8 age){
    // age = ownerAge;
    return ownerAge;
  }
}
```


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Output Parameters

Output Parameters

- Use keyword returns(…)
- Multiple return parameters
- You may name the return parameters
  - Named local variable available within the function body
  - Initialized to zeros
  - Values assigned to named variable are automatically returned

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Output Parameters

Output Parameters

- Declare the arguments with type/names

```
function setData(bytes name, uint8 age){
  // code for the function
}
```

- *But* may omit argument name if unused

```
function setData(bytes name, uint8 ){
  // code for the function
}
```

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Local Variables

Local Variables

- Re-declaration of the variable in the function not allowed

```
function someComplexCalculation(uint principle, uint rate) returns(uint){

  for(uint i=0; i < array.length; i++){
    // do something
  }

  uint i = 6;

  // Do something                  // Compiler will throw an error
  return 0;                        // Variable 'i' already declared
}
```

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Variables Initialization

Variables Initialization

- Bytes initialized to 0s
- Bool to false
- Variables initialized to defaults in the beginning of the function

```
function varScope() returns (uint){
  uint i = 5;

  uint j = i + k;

  uint k = 10;

  return j;
}
```

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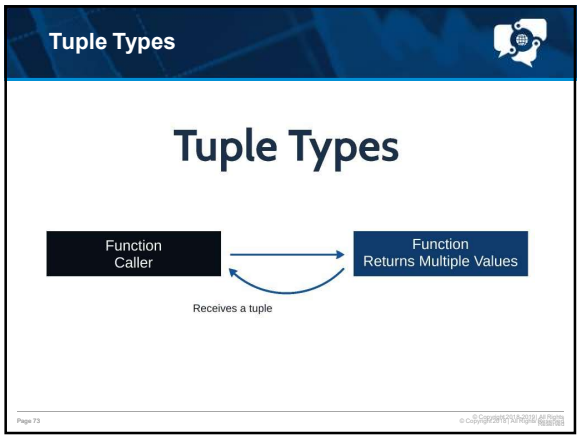
Tuple Types
Tuple Types
Function Caller
Function Returns Multiple Values
Receives a tuple

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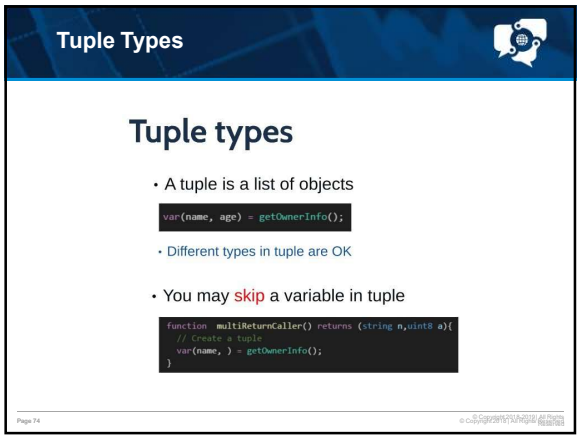
Tuple Types
Tuple types
• A tuple is a list of objects
var(name, age) = getOwnerInfo();
• Different types in tuple are OK
• You may skip a variable in tuple
function multiReturnCaller() returns (string n,uint8 a){
// Create a tuple
var(name,) = getOwnerInfo();
}

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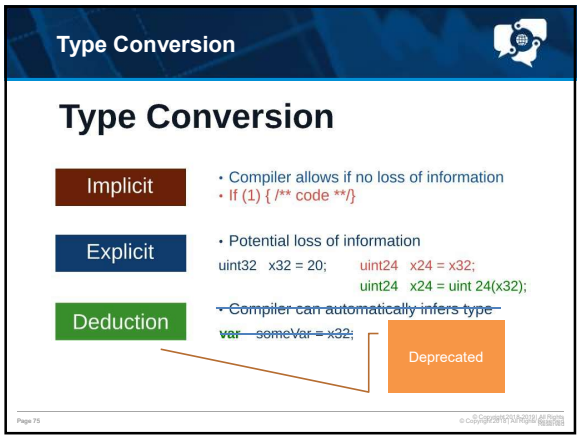
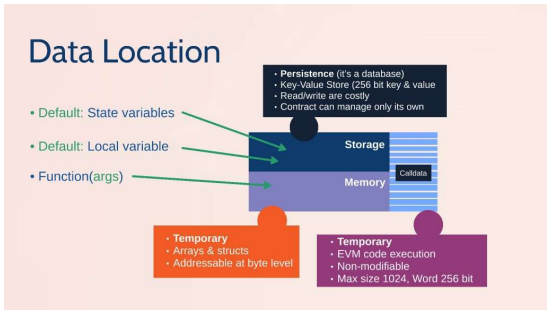

Type Conversion
Type Conversion
Implicit
• Compiler allows if no loss of information
• If (1) { /** code **/}
Explicit
• Potential loss of information
uint32 x32 = 20;
uint24 x24 = x32;
uint24 x24 = uint 24(x32);
Deduction
• Compiler can automatically infers type
var someVar = x32;
Deprecated

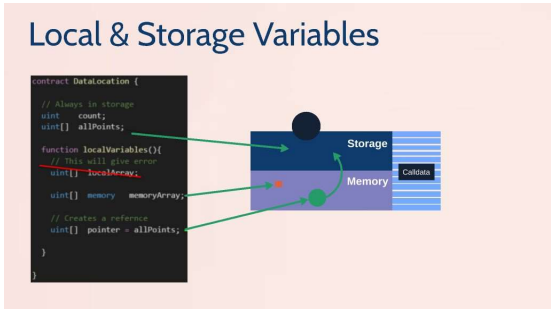
75

Data Location



76

Local & Storage Variables



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Types of Accounts

- Two types of Accounts in Ethereum
  - Externally Owned Accounts
  - Contract Accounts
- Externally Owned Accounts (EOA) are managed by a private Key
  - Send Transactions
  - Deploy Smart Contracts
- Smart Contract Deployment will lead to a new Address for the Smart Contract
  - Deterministic (based on "from" and "nonce" field in Transaction)
  - Smart Contract manages itself based on the code – no private key!

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Types of Accounts

EOA	Contract Account
Private Key	Has Address
Can send transactions	Holds/runs code
Has An Address	Not free to use

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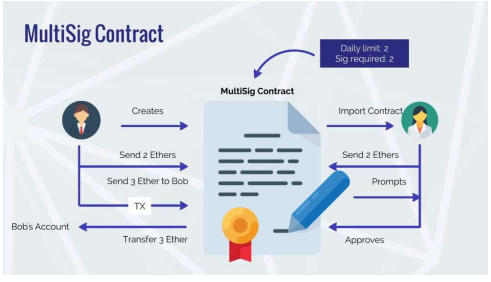
Types of Accounts

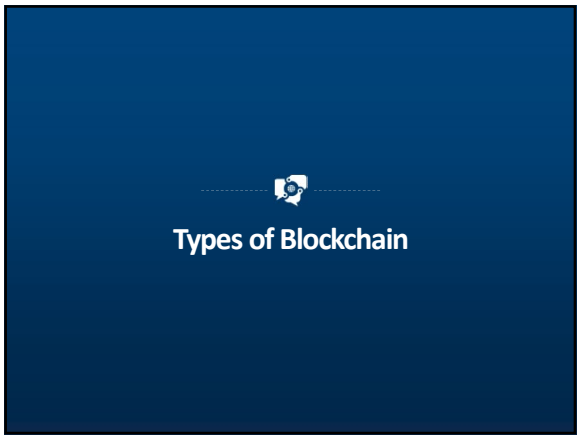
EOA	Contract Account
One Owner	One Accounts creates Smart Contract
Can't display incoming transactions	Many EOAs can manage smart Contract
See transactions -> create simple smart contract	M-of-N types of wallets • MultiSig Wallets

80

MultiSig Contract



81



82

Blockchain as History

- Blockchain as History
  - Immutable, cannot be changed
    - Remember, each block contains the hash of the previous block
  - Append-only
    - Data on the Blockchain cannot be deleted or edited, only additions can be made
    - This provides a detailed history of ALL events, not just a snapshot of the current state!

83

Types of Blockchains

- Public vs Private
  - Who can **write** data to the Blockchain?
  - Public – everyone can add a record
  - Private – only certain participants can write data
- Open vs Closed
  - Who can **read** data from the Blockchain?
  - Open – everyone can read Blockchain data
  - Closed – only certain participants can read data

84

Public or Private Blockchain

- Should the solution be a permissioned or permission-less Blockchain
  - Are all participants considered equal, or should some have abilities that others do not?
  - Election chairperson can add candidates to an election = permissioned
  - A digital currency which can exchanged and traded by all = permissionless
- Do customers understand the tech well enough to trust it with their data?
  - Great solutions may not be accepted until they have been socially normalized
  - Credit cards and early e-commerce

85

Public or Private Blockchain

- Hyperledger vs Ethereum
  - These are discussion points, NOT absolutes
  - Ethereum
    - Music and content distribution
    - Digital currency or asset-backed token
    - Blockchain-enabled mobile data service
    - Gambling and on-line gaming
    - Authoring, editing, and amending a piece of legislation
    - Group consensus is needed/required

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Public or Private Blockchain

- Hyperledger vs Ethereum
  - These are discussion points, NOT absolutes
  - Hyperledger
    - Supply Chain
    - Supplier / Manufacturer inventory management
    - Managing internal business processes across geographically distributed locations
    - Allowing elected officials to vote on initiatives without being present

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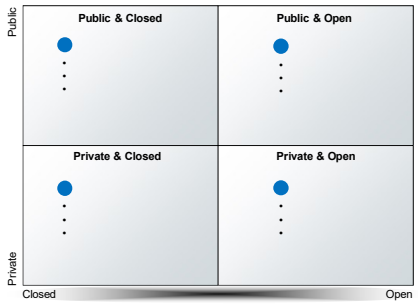
Blockchain Decision Worksheet



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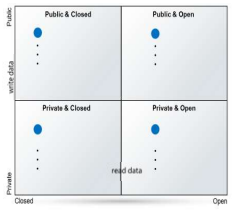
Blockchain Decision Lab

- Currency
- Securities exchange
- Betting
- Video game
- Voting records
- Supply chain data
- Government financial records
- Corporate earnings statements
- Construction tracking
- Defense programs
- Law enforcement agencies
- Others?



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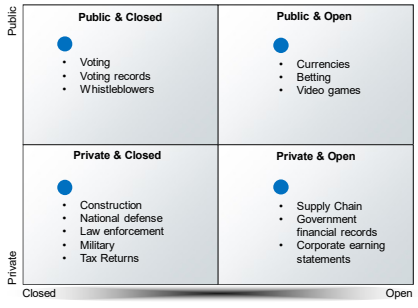
Blockchain Decision Matrix



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Public Blockchains

- What is blockchain? (public, open, permissionless)
  - Decentralized ledger
    - Can store any type of data
    - Shared ledger
  - Immutable
  - Anonymous
  - Fully-Transparent
  - Group Consensus
    - Nodes only verify data was recorded correctly
    - No ability to verify truth of the data itself
  - Smart Contracts
    - Ability to automate processes
    - Blockchain as workflow / BPM

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Blockchain for Business

- Are these properties good or bad?
  - Decentralized ledger
    - Can store any type of data
    - Shared ledger
  - Immutable
  - Anonymous
  - Fully-Transparent
  - Group Consensus
    - Nodes only verify data was recorded correctly
    - No ability to verify truth of the data itself
  - Smart Contracts
    - Ability to automate processes
    - Blockchain as workflow / BPM

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TEST Networks

- ❖What is a Test-Net? (public, open, permissionless)
  - ❖Same Protocol as a “main” net
  - ❖Different Data
  - ❖1 Ether = 0$, but not worthless
  - ❖Used for testing
    - ❖Dapps
    - ❖“Give it a try”
    - ❖Get comfortable
    - ❖Beta-Customers
- ❖Ethers on a Test-Net
  - ❖Faucets

93

Ethereum Blockchain Tooling Infrastructure

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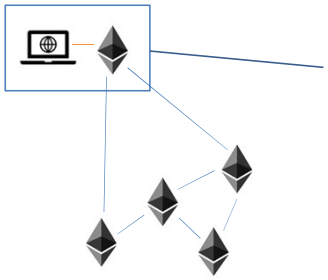
Infrastructure: Local Node



Blockchain Node Deployed locally *on the client side. (Geth, Parity)*

Node needs to "sync" in all blocks from the Network and keep syncing. Can take a long time, but secure.

Node is connected to the rest of the network.

Node can also contain the KeyStore, keys stored locally

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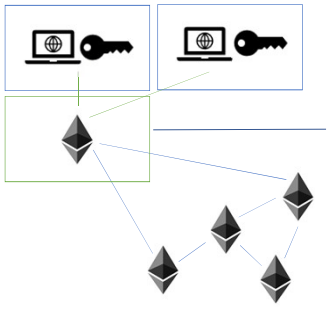
Infrastructure: Organization Hosted



Blockchain Node Deployed on Organization-Server. *(e.g. Geth, Parity)*

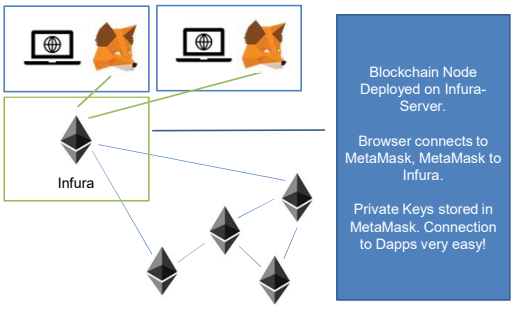
Several Clients connect to one Server directly

Node is connected to the rest of the network.

Who stores the Private Keys?

96

Infrastructure: Externally Hosted



Blockchain Node Deployed on Infura-Server.

Browser connects to MetaMask, MetaMask to Infura.

Private Keys stored in MetaMask. Connection to Dapps very easy!

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DAPP Infrastructure

- Manage accounts in a browser vault
  - Export/Import accounts
  - Send Funds
- Exposes web3 object to browser app
  - Single Page Applications
- Supports multiple endpoints
- Does not support mining

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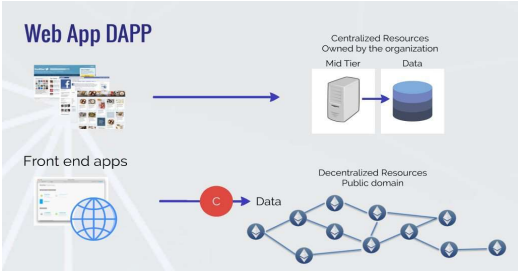
Web App vs DApp



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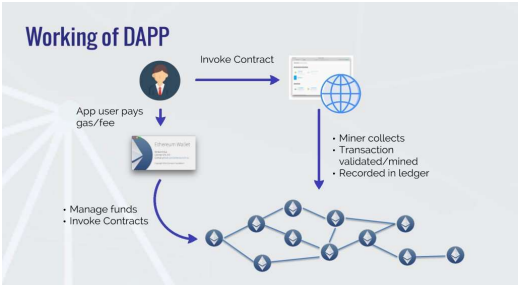
DAPP



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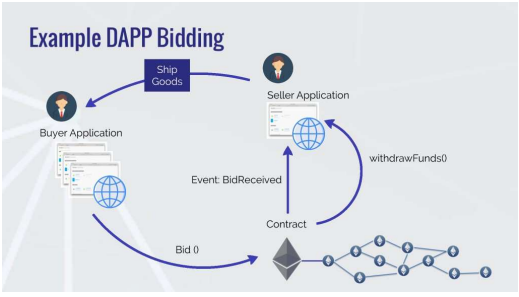
DAPP Bidding



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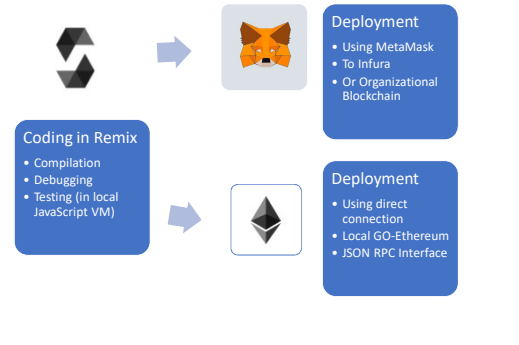
Remix



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How Blocks are Created

103

The "Blocks" of a Blockchain

- Think of a "Block" as a sheet of paper with 25 recorded transactions
  - Each of the 25 lines has a complete transaction record
  - Each record is complete with time, data, all transaction details
  - When a sheet is filled (25 transactions), the Nodes "validate" the transactions on the current page and post it on the Blockchain
  - All Nodes must agree (have Consensus) on the transaction content

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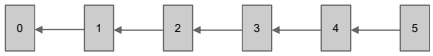
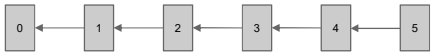
Blockchain Blocks



- Blocks are numbered in ascending order, 0 is first/oldest
- The number is the 'height' of the block
- Arrows only go from newer to older blocks - a block only directly links to the one immediately before it
- Once a block is stored, it's read-only (which is why it doesn't link to the ones after it - that would require you to update it)

105

Blockchain Blocks



- Blocks store data, in Bitcoin, it's the transactions, but it could be any digital data
- Blocks are created periodically (on average, 10mins for Bitcoin) by a process called 'mining'
- A block represents a set of events that have occurred over a particular time frame (usually, since the previous block)

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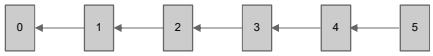
Blockchain Blocks



- Block id is the hash of the **data** in the block
  - 0=000000000019D6689C085AE165831E934FF763AE46A2A6C172B3F1B60A8CE26F
  - 1=00000000839A8E6886AB5951D76F411475428AFC90947EE320161BBF18EB6048
  - 2=000000006A625F06636B8BB6AC7B960A8D03705D1ACE08B1A19DA3FDCC99DDBD
- Block id is a digital fingerprint of that block

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What is in a Block?

- A size number to specify how much data is contained in the block
- Some metadata:
  - A version number of the block format
  - A link to the previous block that came immediately before it
  - Merkle root of all the transactions in the block
  - Timestamp of when the block was created
  - Mining difficulty (more about this later)
  - Nonce for proof-of-work (more about this later)
  - All the data of the transactions recorded in this block

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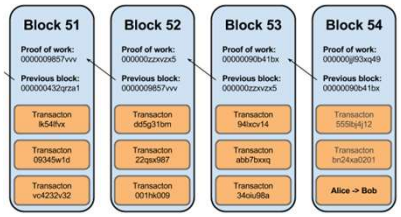
What is in a Block?



The connection between blocks means that the Blockchain is much more *tamper-proof* than standard database structures. Since Blockchain is a ledger of records, this tamper-proof record of assets is known as an "Immutable Ledger".

109

Cryptography and Hashing

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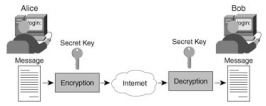
Cryptography Usage

- Cryptography to Encrypt sensible information and then decrypt it again
  - Symmetric Cryptography
  - Public-Key Cryptography (asymmetric)
- To sign information for proof of authenticity
  - Digital Signatures
- To create a non-reversable unique "fingerprint" of Data
  - Hashing

111

Cryptography

- Cryptography can be used to address the issue of privacy
- What is cryptography?
  - The study of how to send information back and forth securely in the presence of adversaries



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Cryptographic Function

What is a cryptographic function?

- A function for encoding or encrypting data to protect the contents from adversaries
- Simple example function:
  - The Secret - "Blockchain Training Alliance"
  - The Function – Swap each letter in the secret with a new letter according to the Key
  - The Key - "+2"
  - The Cipher = "Dnqemejckp Vtckpcpi Cnnkcpeg"

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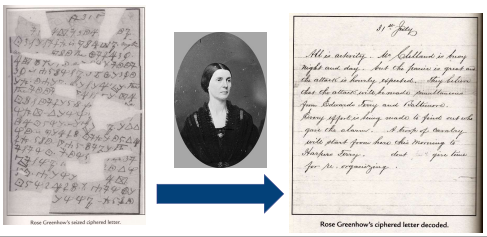
Cryptographic Function

- Real World Example: Rose Greenhow
  - Renowned confederate spy during US Civil War
  - Socialite in Washington D.C.
  - Used cryptography to communicate


Rose Greenhow's ciphered letter decoded.

114

Digital Signatures

- "A digital signature is meant to prove a message came from a particular sender; neither can anyone impersonate the sender nor can the sender deny having sent the message." source: Wikipedia

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Digital Signatures

Public Key Cryptography
- Provides identity & transaction approval
- Public Key
  - Verify the digital signature of a given key pair
- Private Key
  - Sign/approve any transaction/action that might be made by the holder of the key pair

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PUBLIC/PRIVATE KEY CRYPTO

- 2 uniquely related cryptographic keys
- Data encrypted with the public key can only decrypted with the private one (and vice versa)
- Main aim is confidentiality (in messaging)
- Also used for digital signatures

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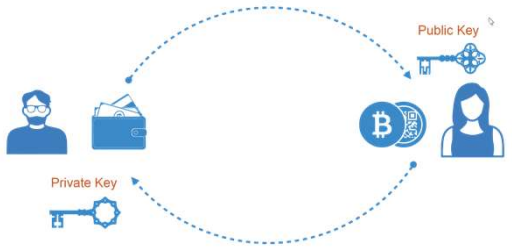
Public and Private Keys



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Important Terms

Terms:

- The Secret – The data which we are trying to protect
- The Key – A piece of data used for encrypting and decrypting the secret
- The Function – The process or function used to encrypt the secret
- The Cipher – The encrypted secret data, output of the function

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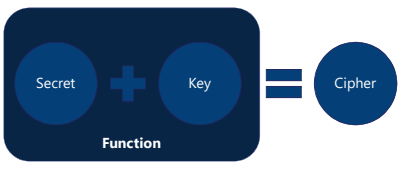
Cipher

- The Secret and the Key are passed into the Function to create the Cipher



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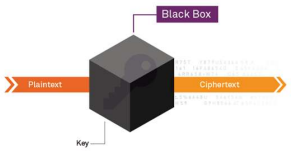
Cryptographic Hash

- What is a cryptographic hash function?
  - A hash is a one-way function, encrypted information CANNOT be decrypted
  - Each unique input generates a unique output



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Cryptographic Hash

- Why would I want to use a hash?
  - Address privacy concerns by making net worth private with a "digital thumbprint"
    - This would NOT be acceptable:
      - Sally - $418,013.45
      - John - $93,247.89
      - Mary - $9,423.11
    - This WOULD be acceptable:
      - 0376189a740845f75bde8260416b3812ab6d4377 - $418,013.45
      - 5753A498f025464d72e088a9d5d6e872592d5f91 - $93,247.89
      - 94F85995c7492eec546c321821aa4beca9a3e2b1 - $9,423.11
    - Nobody knows Sally's net worth, but Sally can always prove which account is hers

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Cryptography Example

- Cryptographic Hashing example
  - Try it out (using SHA256)
  - Go to: www.anders.com/blockchain/hash.html (or: bit.ly/2HnJS6O)
  - Demo:
    - Let's eat, Grandma
      - 45b09eea07b7896d836308e89d01986ea92227ea41d5239dc42650c66393cc01
    - Let's eat Grandma
      - aab9185e406446c4700be80ae8c274778a15e9f2914303ae803ecfa2eca19b5a

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Cryptographic Hash

- Why would I want to use a hash?
  - Landlord and tenant can compare lease documents
  - Verification of software
    - If there's ANY difference between what should be and what is, it's easy to identify
      - Malware which makes slight changes to the original codebase can be easily detected
      - Important for self-driving cars, automation, IoT, etc..
  - Instantly compare two or more LARGE volumes of data to ensure they're the same
    - Has 1 bit been flipped in a 100TB file?

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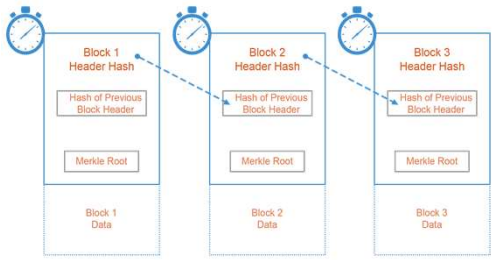
Blockchain Basics - recap



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Blockchain Nodes And Web3

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Nodes

- Different Nodes
  - Geth, Parity, Ganache, Truffle Developer Console
- Different Purpose
  - Developer-Network for Rapid Development
  - Unit Testing
- Libraries (Web3.js, Web3j, Web3PHP,…)
  - Connect to a Blockchain Node
  - "Speak" the right language (Data encoding/decoding)

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Geth

- Go-Ethereum
  - "GETH"
  - Written in GOLang
  - Can connect to Public Networks and Test-Networks
  - Integrated "Developer" Mode
  - Integrated Keystore
  - Interactive JavaScript console

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Ganache

- "Developer" Blockchain
- Exposes an HTTP-RPC Interface
- Proof of Authority (only one node)
- For Unit-Testing and Development
- Non-Persistent In-Memory Datastore

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Remix Built In Blockchain

- IDE Blockchain Simulation
- Doesn't expose an HTTP-RPC Interface
  - Only running within Remix
- Not persistent

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Web3.js

- JavaScript library to encode and decode data
- Connects to a blockchain node
- Usually using Ajax (Async) HTTP Requests or WebSockets
- Either directly (e.g. http://localhost:8545) or via MetaMask/Mist for example

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Smart Contract Life Cycle

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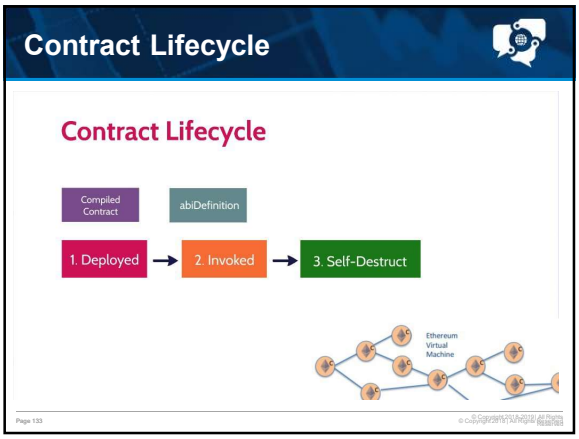
Contract Lifecycle



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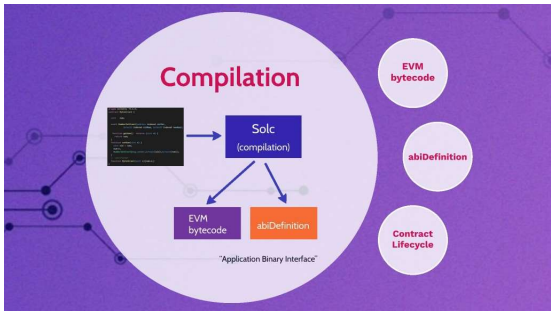
Compilation



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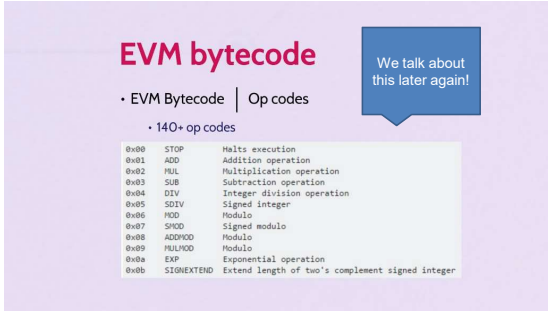
EVM bytecode



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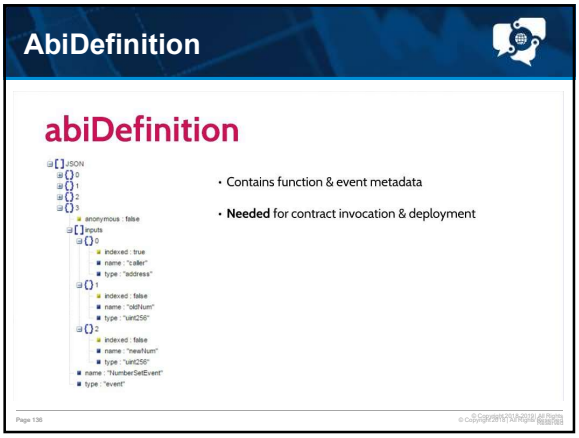
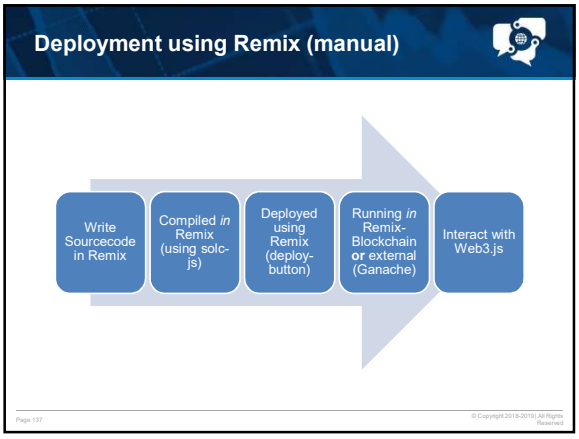
AbiDefinition



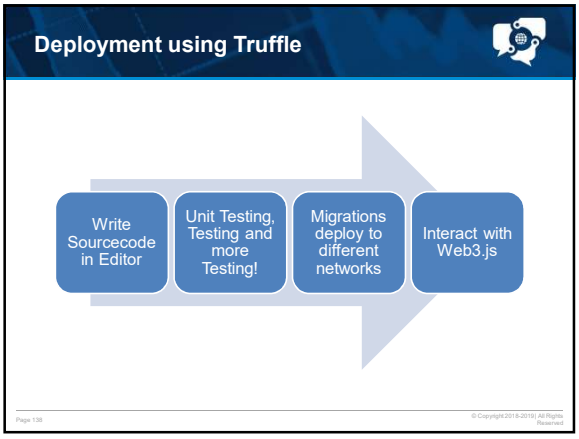
136

Deployment using Remix (manual)



137

Deployment using Truffle



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Smart Contract Concurrency and Events

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Web3 JS API

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Web3 JS API

Method. call(…)
- Executed locally on the node
- Value= Return value from function
- No state changes in contract
- 0 execution fee

Method. sendTransaction(…)
- Executed on miner nodes
- Value= Transaction hash
- State changes in contracts
- Gas paid by caller

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Call vs. Transaction

- "Call"
  - Reading operation(view/pure functions)
  - No need to reach consensus
- "Transaction"
  - Writing operation
  - Concurrent operation, Mining needs to happen, consensus has to be rached
  - Doesn't return a value, returns a transaction hash
  - Events used to "react" to this

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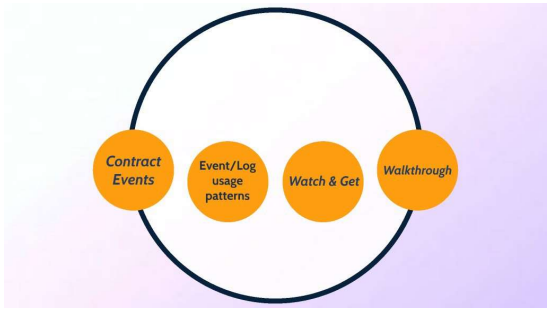
Contract Events



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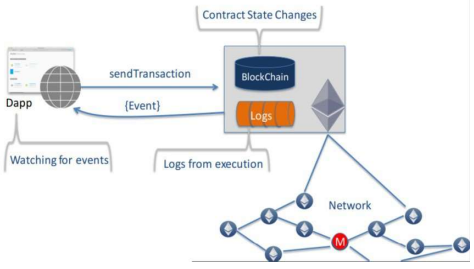
Contract Events

Ethereum Logs & Events



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Logs / Events

- Events reside on a “Side Chain”
  - Cheap data storage
- Event Listener
  - Setup “on” the blockchain node, it’s not simple polling
- Smart Contracts can’t access Events, only emit

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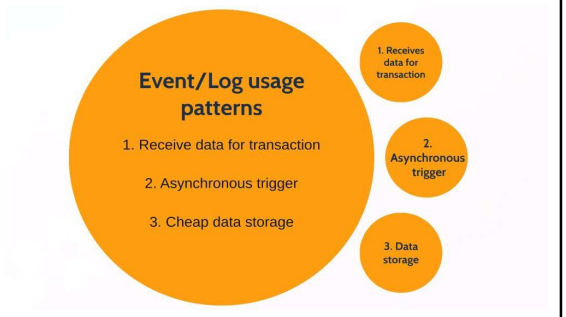
Contract Events



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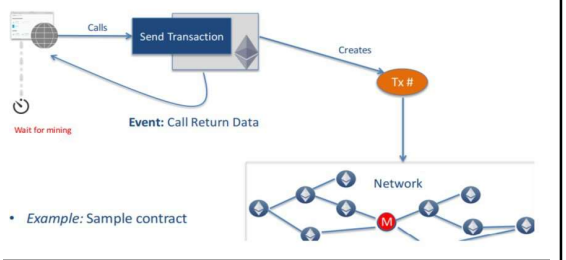
Contract Events

1. Receives data for transaction



- *Example:* Sample contract

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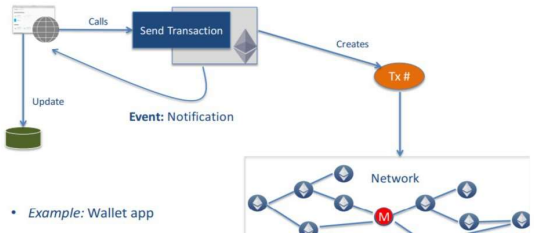
Contract Events

2. Asynchronous Notifications



- *Example:* Wallet app

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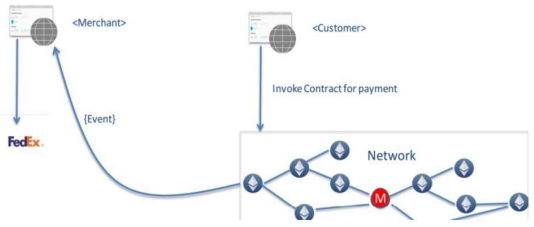
Contract Events

2. Asynchronous Notifications



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Contract Events

2. Asynchronous processing

- Front end (Dapp) can watch for events of interest
  - Example: Wallet app receives notification on receiving ethers
  - Example: Multisig contract shows transactions waiting for approval

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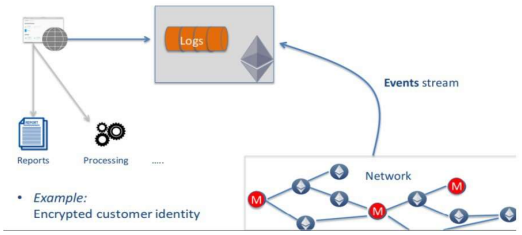
Data Storage

3. Data storage



- *Example:*
  Encrypted customer identity

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Data Storage

3. Data storage

- Cheaper than contract storage
  - Log data storage cost 8 Gas/byte
  - Contract data storage cost 20,000 Gas/32-byte
- Logs are NOT accessible from contracts

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Events vs. Filter

- Event API
  - High-Level
  - Web3js 1.0.0: "web3.eth.contract => events.EventName…"
  - Can filter for specific indexed parameters from one Contract
  - Every Solidity Event can have up to 3 indexed parameters
  - Used quite often
  - Defined by the ABI Array
- Filter-API
  - Low-Level
  - Filter for anything anywhere
  - web3.eth.subscribe('logs', options [, callback]);

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Watch vs. Get

- Watch
  - Listen for events continuously
  - React to events
  - Web3js 0.20.6:
    - Var event = myContract.MyEvent([options][,callback]);
  - Web3js 1.0.0 beta:
    - Var event = myContract.events.MyEvent([options][, callback])
  - Polling the blockchain node for event changes
    - event.stopWatching(); //web3@0.20.6
    - event.unsubscribe(); //web3@1.0.0-beta subject to change

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Watch vs. Get

- Get
  - Get a list of past events
  - Doesn't listen continuously
  - Returns an array, not an object
  - No need to stop
  - myContract.getPastEvents(event[, options][, callback]) //web3@1.0.0 beta
  - myEvent.get(function(error, logs){ ... }); //web3@0.20.6

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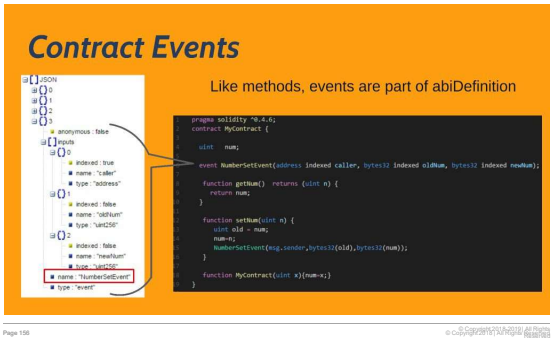
Contract Events



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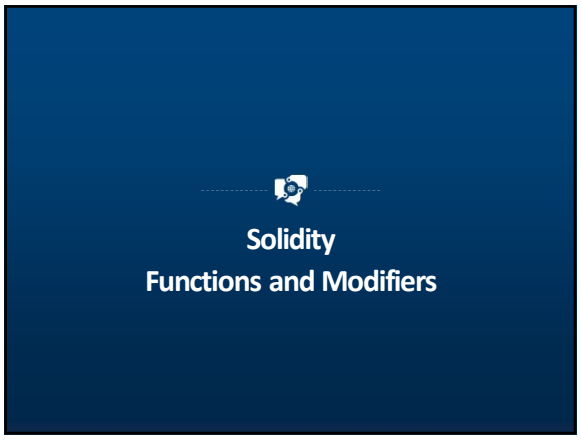

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Functions

- Keyword "function"
  - Followed by arguments
  - Static typed
  - Solidity 5: Storage location must be given
- View/Pure
  - Reading functions
- Function Visibility
  - Public/Private/Internal/External
- Payable?
- Return
  - Statically typed

```
function f(uint a, uint b) public view returns (uint) {
    return a * (b + 42) + now;
}
```

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View/Pure

- View Functions
  - Read Only
  - Read from Storage
  - Call other View or Pure functions
- Pure
  - Read Only
  - Can't read from Storage
  - Call only other Pure functions

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Getter Functions

❖compiler automatically creates getter functions for all public state variables

```
pragma solidity >=0.4.0 <0.6.0;

contract C {
    uint public data = 42;
}

contract Caller {
    C c = new C();
    function f() public view returns (uint) {
        return c.data();
    }
}
```

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Fallback Function

❖A contract can have exactly one unnamed function.

❖Cannot have arguments
❖Cannot return anything
❖Has to have “external” visibility

❖Executed on a call to the contract if none of the other functions match

❖Better only rely on 2300 gas

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Function Overloading

❖multiple functions of the same name but with different parameter types
❖ also applies to inherited functions

```
pragma solidity >=0.4.16 <0.6.0;

contract A {
    function f(uint _in) public pure returns (uint out) {
        out = _in;
    }

    function f(uint _in, bool _really) public pure returns (uint out) {
        if (_really)
            out = _in;
    }
}
```

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Function Modifiers

- used to easily change the behaviour of functions
- can automatically check a condition prior to executing the function
- inheritable properties of contracts and may be overridden by derived contracts

```
modifier costs(uint price) {
    if (msg.value >= price) {
        _;
    }
}
```

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Solidity
Mappings and Structs

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Mappings / Structs

- (u)int, Boolean, string very simple
- How can we store more advanced data structures
  - Tokens => Balance per Address
  - Supply Chain?
  - Training Certificates
  - Bonus Points
- We need better data structures!

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Mappings

- Like Arrays in usage
- Arrays are actually disadvantageous in Solidity
  - But famous
- Iterating through large datasets costs Gas
  - Easy to run out of Gas. “for each” not recommended!
- Better use Mappings
  - Like hash-maps

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Mappings

- mapping(_KeyType => _ValueType)
- The _KeyType can be any elementary type.
- _ValueType can be any type, including mappings.
- Access like arrays:
  - balances[msg.sender] = newBalance;

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Struct

- define new types

```
struct Funder {
        address addr;
        uint amount;
    }
```

- …and then use them in mappings:

```
mapping(address => Funder) myFunder;
```

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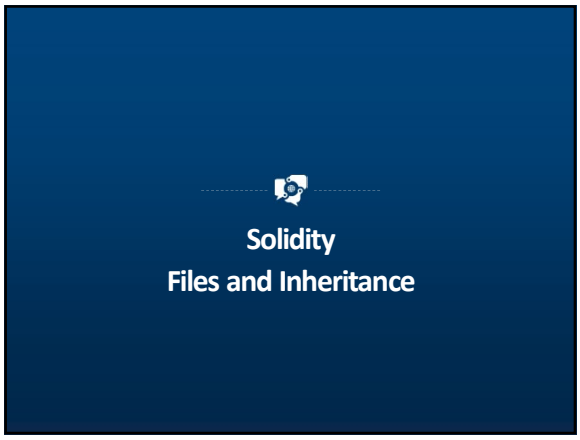

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Project Management

- Solidity can “import” files
- Truffle can import local files
  - And from eth-pm (like npm)
- Remix can import from GitHub

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Project Management

- More than one contract in one file possible
  - There is no recommendation if that’s good or bad
- Solc understands inheritance
- Multiple Inheritance possible
  - contract MyContract extends Owned,Transfer,Bookable {…}

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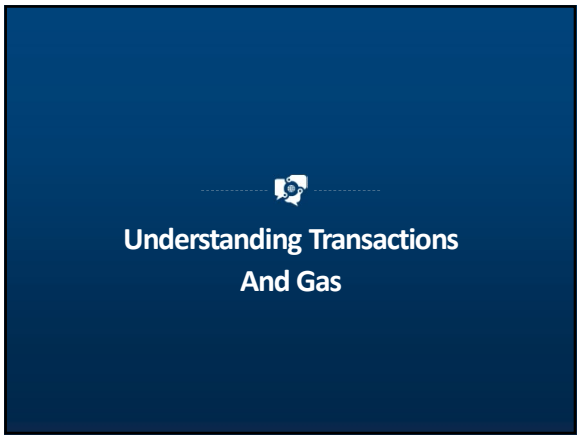

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Transactions

- "Plain-Text" Json Object
- With a "data" field
  - {from: 0xabc…, to: 0x123…, value: 0, **data:** "0xab3f…"}
- Data field = hex encoded function signature + arguments
- Storage location: Calldata
- Function myFunction(uint _arg) …
  - Becomes: bytes4(keccak256('myFunction(uint256)'))
- The rest is the argument
- Example on next slide!

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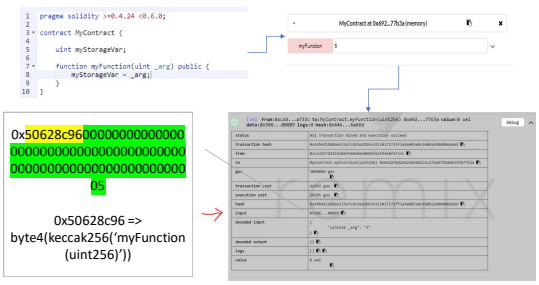
Transactions – Signature



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Ethereum Gas

Gas

- User invoking the transaction pays for the execution

Measures: kWH used

Measures: Gallons of water used

- Gas is the unit in which EVM resource usage is measured

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Gas

- ❖Gas is detached from Ether
  - ❖Gas stays constant
  - ❖Ether is volatile
- ❖Gas is used when contract is executed
  - ❖Contract Gas Usage depending on Code
  - ❖Gas *Price* is defined by User
- ❖Contract -> compile -> bytecode
  - ❖EVM Assembly Instruction bytecode representation
- ❖EVM Assembly Instructions cost Gas

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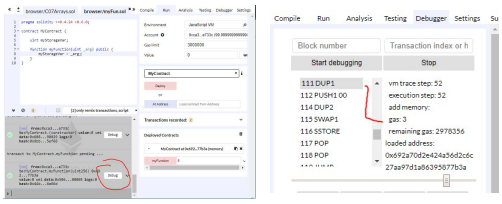
Example



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Ethereum Gas

Gas Calculation

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Ethereum Gas

Opcodes & Gas

Gas cost	QUICKSTEP	FASTESTSTEP	FASTSTEP	MIDSTEP	SLOWSTEP	EXTSTEP
	2	3	5	8	10	20
	ADDRESS	DUP	MUL	ADDMOD	JUMPI	BLOCKHASH
	ORIGIN	SWAP	DIV	MULMOD	EXPBASE	BALANCE
	CALLER	PUSH	MOD	JUMP		EXTCODESIZE
	CALLVALUE	ADD	SDIV			EXTCODECOPYBASE
	CALLDATASIZE	SUB	SMOD			
	CODESIZE	LT	SIGNEXTEND			
	GASPRICE	GT				
	COINBASE	SLT				
	TIMESTAMP	SGT				
	NUMBER	EQ				
	DIFFICULTY	AND				
	GASLIMIT	OR				
	POP	XOR				
	PC	NOT				
	MSIZE	BYTE				
	GAS	CALLDATALOAD				
		CALLDATACOPY				
		CODECOPY				
		MLOAD				
		MSTORE				
		MSTORE8				

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Ethereum Gas

Fee Calculation

gasUsed =
- Instructions executed (summed up gas)

gasPrice =
- User specified in the transaction
- Miners decides the minimal acceptable price

Transaction Fee = gasUsed * gasPrice

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Gas Price

- Gas amount fixed, but sometimes not known upfront
  - Provide more gas than necessary
  - Rest will be refunded
- Gas Price determines how *fast* the transaction will be mined
- Two types of exceptions
  - Failed require => Rest of Gas will be refunded
  - Failed assertion => All provided gas will be consumed.
- Goal: Write Low-Gas Consuming Contracts
  - There is also a "block gas limit". A Blockchain is no mainframe.

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Types of Consensus

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Consensus PoW

- Proof of Work Consensus
  - When a block is full, each node competes to solve a guessing game problem
    - This problem requires computational resources to quickly guess the "Nonce" of the transaction block
    - Miners try to guess the "nonce"
      - All block data plus the current guess (nonce) are run through a cryptographic hash
  - If the result matches the current level of "difficulty", the miner has guessed the right answer
  - The miner with the answer shares it with all other miners, Miners will confirm the answer is correct by using the nonce with their block data to try and get the correct result. When 51% of the miners confirm the nonce is correct, the transaction is added to the Blockchain
  - The result is Proof of Work Consensus

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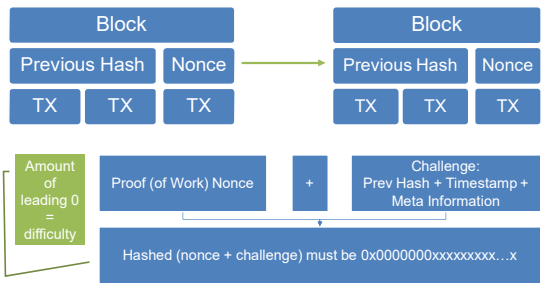
Proof of Work



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Proof of Stake (PoS)

- Proof of Stake Consensus
  - Proposed as an alternative to Proof of Work
  - Attempt to overcome scalability concerns imposed by PoW consensus
  - Removes the guessing game from consensus
  - Mining no longer requires specialized and powerful hardware
    - Many feel that specialized hardware requirements lead to centralization
      - Blockchain is about de-centralization
  - Less energy intensive form of consensus
    - Addresses concerns about “green” mining

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Proof of Stake (PoS)

- Proof of Stake Consensus
  - Ok, how does it work?
    - Block of transactions created
    - When it’s time for group consensus, all who wish to participate lock up funds in a stake
    - A random ‘player’ is selected
    - That player’s block data is shown to all other participants
    - Other players stake on the validity of the block transactions

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Proof of Stake (PoS)

- Proof of Stake Consensus
  - If the majority agree with the proposed block, the random player is rewarded, as are all who staked on that player
  - If the majority disagree, the random player gets no reward AND loses their stake!
  - Then a new player is randomly selected to share their block data

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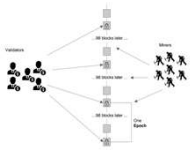
PoW vs PoS

- PoW vs PoS
  - Work for a reward vs make a safe bet for a reward
  - Security vs Speed
  - Centralization vs Decentralization
  - Proven vs New
  - Capital spent on hardware vs capital spent on staking funds
- Ethereum – quickly moving to PoS
  - Serenity (Casper)
- 0.1.0 Released May 2018



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Ethereum 2.0

- Beacon Chain
  - Proof of Stake
- 1000x higher scalability
- EWASM instead of EVM
  - EWASM = Ethereum WebAssembly
- Account Abstraction?

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Beacon Chain

- Pure PoS
- Deposit 32 Ether
  - Become a Validator
  - Anyone can be a Validator
- Main PoS Chain
- Base Layer of Sharding Solution

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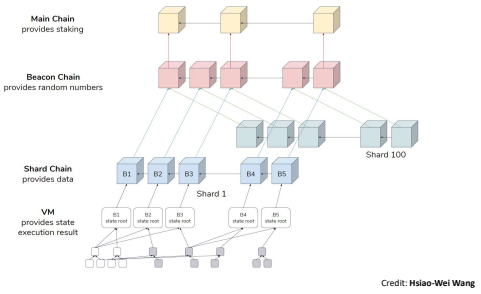
Ethereum 2.0



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Beacon Chain

- Managing Validators
  - 32 Ether into a Smart Contract on the PoW Chain
  - Event is emitted, picked up by beacon chain clients
  - Validator is then active
  - Exit after 97 days (might change), refund only to Shard Chain, not on the old Main-Net
- Provide Randomness
- Block Proposers
- Committee

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Beacon Chain

- Managing Validators
- Provide Randomness
  - RANDAO => Many contributors with random numbers will lead to one single random output number
  - Commit-Reveal Scheme
  - Sufficiently Robust
- Block Proposers
- Committee

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Beacon Chain

- Managing Validators
- Provide Ramdomness
- Block Proposers
  - Eth2.0 has a 16 seconds heartbeat
  - Called “slots”
  - Proposers chosen randomly will propose a new block based on attestations from validators
  - A committee votes on the block to be added
- Committee

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Beacon Chain

- Managing Validators
- Provide Randomness
- Block Proposers
- Committee
  - Critical for security
  - Vote on the true history of the chain
  - Ideally *all* validators
  - Or as much validators which are quick enough
  - Validating each shards proposers

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Beacon Chain

- Rewards
  - Unknown yet, but probably 1-5 ETH?
  - Subject to change
- Penalties
  - Slashing: Some Ethers are removed for bad behavior
  - Ejecting: They are removed as validators
  - Being Absent ("quadratic leak"): small penalty
  - If <16 Ether automatically ejected
- Crosslinks
  - Combine all Shards state into the beacon-chain and finalize it

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Simple Terms

- Put 32 Ether in PoW Chain Smart Contract
  - Contract emits event
  - 32 Ether are locked *forever*
- 32 Ether then pop up on the Beacon Chain
  - You become a validator
- The rest is abstracted away from you as developer
  - The only noticeably good thing: It will be much faster

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Proof of Stake (PoS)

- Proof of Stake Consensus
  - No "computing" is ever performed during consensus, only staking/wagering
  - Any kind of device can stake, regardless of computing power

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Other Consensus Mechanisms

- Other consensus mechanisms
  - Proof of Activity
    - Hybrid of PoW and PoS
    - Empty template blocks are mined (PoW), then filled with transactions which are validated via PoS
  - Proof of Burn
    - Coins are “burned” by sending them to an address where they cannot be retrieved
    - The more coins you burn, the better your chances of being selected to mine the next block
    - Eventually, you must stake more by burning more coins

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Other Consensus Mechanisms

- Other consensus mechanisms
  - Proof of Capacity (aka Space)
    - Pay to play with hard drive space or memory
    - The most space you ‘stake’ the better your odds of being selected to mine the next block
    - Consensus algorithm generates large data sets called ‘plots’ which consume storage
    - Major criticism – this method has no real deterrent for bad actors

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Other Consensus Mechanisms

- Other consensus mechanisms
  - Proof of Elapsed Time
    - Created by Intel to run on their trusted execution environment
    - Similar to PoW, far more energy efficient
    - Major criticism – requires trust in Intel, places power back in the hands of a central authority
  - Proof of Authority
    - Uses a set of “authorities” – nodes that are explicitly allowed to create new blocks and secure the blockchain
    - Replacement for PoW - Private blockchains only
    - Earn the right to become a validator/authority

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Consensus Mechanisms

- Consensus protocols are the key to Blockchain!
  - Blockchain consensus mechanisms are the nuts and bolts of validation.
  - Think Internet & TCP/IP – transmission of bytes of data across the Internet
- PoW is the only tried and true (9+ years in use). PoS is coming, rolling out now.
- The rest are concepts and development ideas that different developers are working on. Some are in a test trial phase.

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Mining a Block

203

Transaction Implications

- Transactions take time to 'confirm'
- Each transaction, once it's in an accepted block has a height
  - -The height of a block is the **number of blocks in the chain between it and the genesis block**
- Each increase in blockchain height is called a confirmation
- A transaction 5 blocks below the top of the chain is said to have '6 confirmations'
- Wait for 6 confirmations for anything of value

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Blockchain Forks

- Upgrades to the protocol can cause problems – but can be managed
- Blocks that are created have a version number
- New blocks using the new protocol use a different version number
- If the upgrade is backward compatible, it's a soft fork
- If the upgrade isn't backward compatible, it's a hard fork
- Hard forks are much harder and we try to avoid them

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Ethereum Tooling

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Overview

Browsers	Frameworks	KeyStore (Wallet)	Networks
• MIST • Status.im • MetaMask (to some extend)	• Truffle • Embark • DApp (yes, it's called that way!) • Populus • Etherlime • …	• In-Node (Geth) • MetaMask • MIST • Hardware Wallet • Paper? • …	• Main (1) • Ropsten (3) • Rinkeby (4) • Kovan (42) • Sokol (77) • Start your own! • …
Languages	**Consensus Algorithms**	**Blockchain Nodes**	**IDEs**
• Solidity • Vyper • Bamboo • …	• PoW • PoS • PoA • …	• Geth • Parity • Ganache • Kaleido • Ethereum on Azure • …	• Remix • Visual Studio Code (with Solidity Plugin) • Atom • Superblocks Lab

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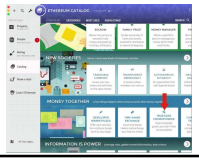
Browsers - MIST

- MIST
  - Is an Ethereum Browser which was built using electron
  - Runs a full "GETH" Node underneath
  - Including Keystore
  - And a chromium browser on top
  - Like Chrome with MetaMask but with a full local Ethereum node



Credit: Ethereum

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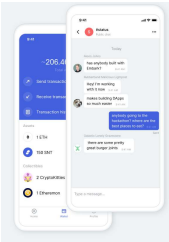
Browsers - Status.im

- Chat/Browser for Mobile
- Connects to a Blockchain node
- KeyStore integrated

- Can connect to Dapps
- Can "browse" Dapps like with MetaMask+Chrome on PC



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Browsers - MetaMask

- Browser Plugin
- Connects to a Blockchain (Infura most likely)
- KeyStore
- Intercepts Transactions
  - And shows confirmation window

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Frameworks - Truffle

- "A world class development environment, testing framework and asset pipeline for blockchains using the Ethereum Virtual Machine (EVM), aiming to make life as a developer easier."
- Lifecycle Management
- Unit Testing
- Scriptable Deployments
- + Truffle Boxes!
- Good for local development and teams

211

Frameworks - Embark

- "Embark is a framework that allows you to easily develop and deploy Decentralized Applications (DApps)."
- Test Driven Development
- Manage Different Chains
- Work with Decentralized Storage
- Work with Decentralized Communicatio

212

Frameworks - Populus

- Populus is a smart contract development framework for the Ethereum blockchain.
- Python based test environment
- Very similar to the previous frameworks

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Frameworks - Etherlime

- etherlime is an ethereum development and deployment framework based on ethers.js.
- allows for ultimate control by the developer
- adds verboseness in the deployment process

214

Networks

- There is the Main-Net
  - Network ID 1
- But new things might need tests on protocol level
  - Ropsten, Rinkeby, Kovan, Sokol
  - Faucets (free Ether)
  - Test-Net to try Smart Contracts (Beta Customers)
- Can start your own Blockchain based on the Ethereum Protocol (with a unique network ID)

215

Language - Solidity

- contract-oriented programming language
- initially proposed in August 2014 by Gavin Wood
- is designed around the ECMAScript syntax to make it familiar for existing web developers
- Support for
  - Complex member variables
  - arbitrarily hierarchical mappings and structs
  - inheritance, including multiple inheritance with C3 linearization
  - An application binary interface (ABI) facilitating multiple type-safe functions within a single contract

216

Language - Other

- Vyper (IDE: https://vyper.online/) :
  - Vyper is a smart contract development language built with the following goals:
  - **Security** - it should be possible and natural to build secure smart contracts in Vyper.
  - Language and compiler **simplicity** - the language and the compiler implementation should strive to be simple.
  - **Auditability** - Vyper code should be maximally human-readable
- Bamboo: a language for morphing smart contracts
  - state transition explicit and avoids reentrance problems by default

217

Consensus Algorithms

- Proof of Work
- Proof of Stake
- Proof of Authority
- Proof of …

- We talked about it.

- Ideally Nodes can "understand" more than one Consensus algorithm for Enterprise usage in private or consortium networks

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Blockchain Nodes

- Geth
  - Go-Ethereum
  - Written in GO
  - Keystore + Ethereum Node + Web3js Interface
- Parity
  - Rust
  - Web-Interface
- Ganache
  - Developer Node
  - In-Memory "private" blockchain
  - Only One Node possible
- Kaleido
  - full-stack platform
  - Made Radically Simple
  - RAFT, IBFT, POA

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IDEs

- Remix
  - Browser Based
  - Integrated Debugger
  - Integrated Blockchain (simulation)
  - Very Handy
- Local Development
  - Using VS Code or Atom

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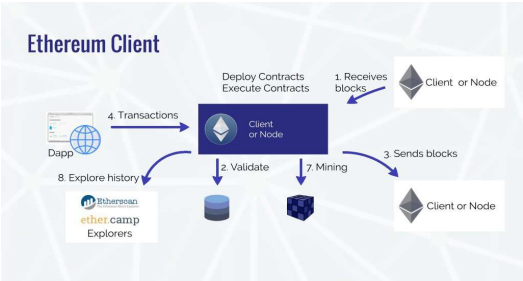
Go-Ethereum In-Depth

221

Ethereum Client



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Clients

- Go-Ethereum
  - Written in Go
- Parity
  - Rust
- Pantheon
  - Java
- CPP-Ethereum
  - C++

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Go-Ethereum

- Blockchain Node
- KeyStore
- Interactive JavaScript console
  - Might change
- Regular updates
  - But no update mechanism
- Several “Sync Modes”
- Several Consensus Protocols
- Create your own Private Network

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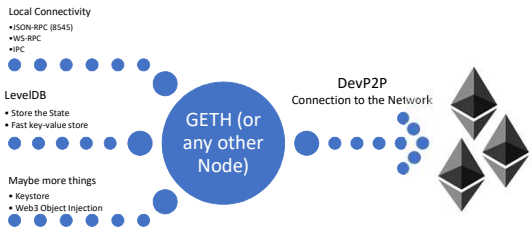
Client Flow



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Geth

Geth CLI : Usage

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Geth

geth [options] command [command options] [args..]

Configuration | API & Console | Misc

--identity	"MyTestNode"	Custom identity
--datadir	"/data-dir"	Directory for writing the chain data
--keystore	"/key-dir"	Keystore location
--networkid	"value"	Default=1 Live, Testnet=3, Private = User assigned
--testnet		Connect the node to the testnet (ROPSNET)
--fast	(use with --cache)	Fast synching through state downloads
--dev		Developer mode: private network; multiple debug flags

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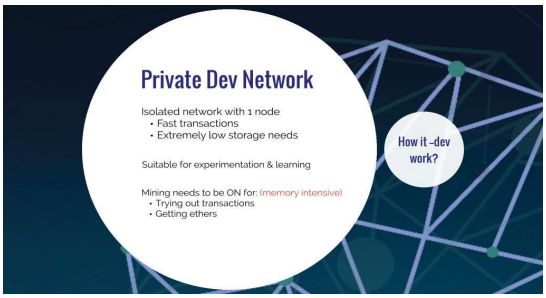
Private Networks



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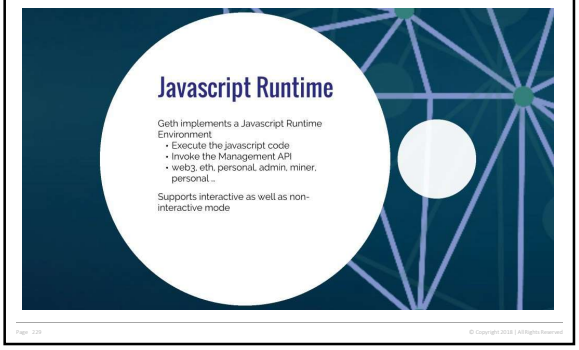
Javascript Runtime



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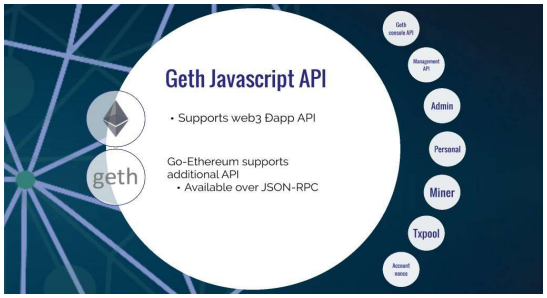
Geth Javascript



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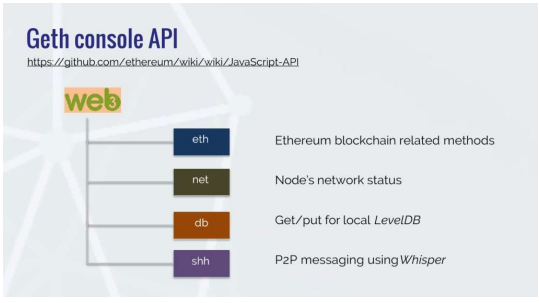
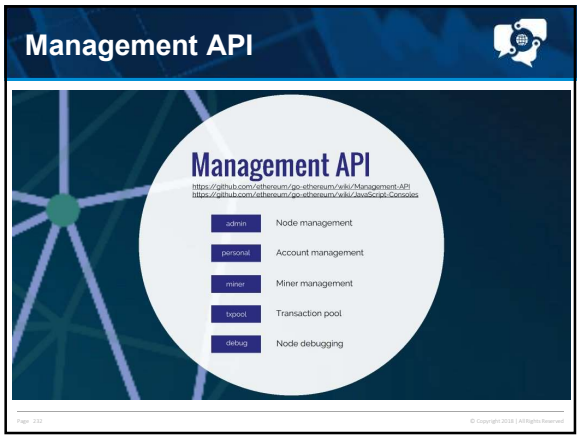
Geth Console API



231


Management API
Management API
https://github.com/ethereum/go-ethereum/wiki/Management-API
https://github.com/ethereum/go-ethereum/wiki/JavaScript-Consoles
admin
Node management
personal
Account management
miner
Miner management
txpool
Transaction pool
debug
Node debugging

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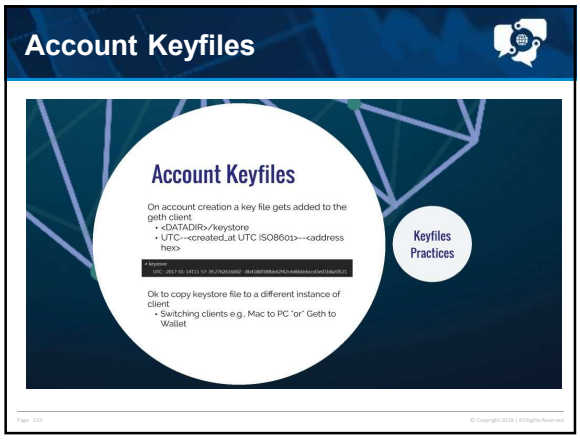
Account Keyfiles
Account Keyfiles
On account creation a key file gets added to the geth client
• <DATADIR>/keystore
• UTC--<created_at UTC ISO8601>---<address hex>
Ok to copy keystore file to a different instance of client
• Switching clients e.g., Mac to PC "or" Geth to Wallet
Keyfiles Practices

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Account Keyfiles
Keyfiles Practices
Good practices:
• Periodically backup all your key files
• Use strong passwords; DO NOT forget the passwords.
• If managing passwords in a file make sure they are hidden and
• accessible to only you

234

Miner

235

Truffle and Local Development

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Truffle Framework

- ❖Local Environment
- ❖Can be checked into GitHub
- ❖Unit Testing
  - ❖Using JavaScript and Solidity
- ❖Scripted Deployment & Migrations
- ❖Command Line Based

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Truffle Commands

- "truffle init"
  - Initialized an empty directory as truffle project
  - Will download the "truffle-init" repository which contains some smart contracts
  - And runs "npm install" which looks into package.json
- "truffle develop"
  - Opens developer console
  - From there are "test" or "migration" possible
  - On the Developer-Blockchain

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Truffle Commands

- "truffle migrate" or "truffle migrate --network abc"
  - Looks in the migrations folder for migration-scripts
  - Deploys to the "default" network or to "abc" network
    - Based on truffle.js config file in root directory
- "truffle test"
  - Runs the tests according to the "test/" directory
- "truffle compile"
  - Compiles the contracts
  - Generates so called contract artifacts – contain ABI, and meta-information
- That's all the magic you really need.
- Where is the HTML part?

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Truffle – HTML5

- Truffle *itself* is really *only* for Smart Contract Development
- Truffle is a npm package
- Any other npm package can be integrated.
- truffle-contract is an abstraction of web3.js
  - Can be used almost like web3.js
  - Uses Promises
  - And used in HTML/JS

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Truffle - HTML5

- Webpack or React or Vue or any other Web-Dev Framework can be used in combination with Truffle and Truffle-Contract
- Truffle has "ready to go" Templates
  - Calls it "Truffle Boxes"
- We can install a "ready to go" box via "truffle unbox"
  - A list is here: https://truffleframework.com/boxes

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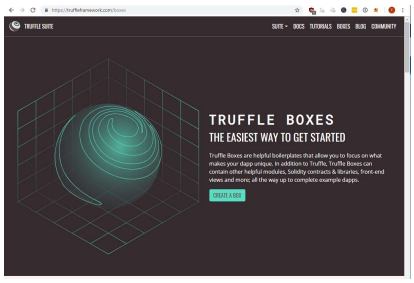
Truffle Boxes



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Truffle Boxes

- Truffle Boxes are *most likely* community created
- It's just a repository
- "truffle unbox" will
  - Download the repository
  - Run "npm install" to install all dependencies
- Virtually a boilerplate box for all modern Frontend Languages

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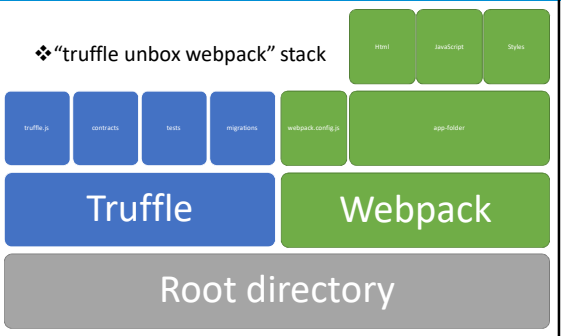
Truffle and Webpack

❖"truffle unbox webpack" stack



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Truffle Deployment/Migration

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Migrations

- ❖ Totally scriptable
- ❖ More than one network
  - ❖Maybe a developer blockchain
  - ❖Plus a Corporate Network
  - ❖Plus a Main Production Network
- ❖ No "upgradeable" contracts by default
  - ❖ Upgrade or migration plan in place?

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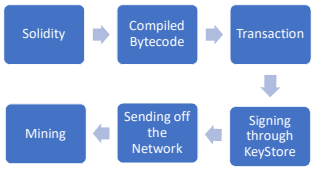
Components



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Solidity -> Compile

- Write your code in Solidity
- /contracts/ folder
- Truffle takes solc-js for compilation
  - Usually 1-2 version numbers behind
  - Comes pre-packaged
- As of writing: version 0.5.0 is newest, truffle comes with 0.4.24

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Compilation -> Bytecode

- Truffle produces “artifacts”
- Json-Files
- Contain the ABI
- Bytecode
- Plenty of Meta-Information
- /build/contracts/ folder

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Bytecode -> Transaction

- The Bytecode needs to be sent off using a transaction
- Transactions can only be started using EOAs
- EOA is managed by Private Key

- So: where does the Private Key come from for signing the transaction?

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KeyStore / Signature

- KeyStore can be built into a node offering web3 access through JSON RPC
  - Ganache/Geth for example
  - web3.eth.accounts array is filled
  - maybe "personal.unlockAccount(…)"

- Keys can also be generated using HD Wallet
  - Hierarchical Deterministic (HD) key creation
  - A "seed phrase" always leads to the same private keys

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HD Wallet

- Known as "mnemonic" or "seed phrase" used to initialize your wallet
- Same 12 words lead to the same private keys
  - Plural: Seed+Index => key
    - Seed+1 => Private Key1
    - Seed+2 => Private Key2
    - …

- Truffle can do that do
  - Don't publish your seed-phrase!
    - Also don't check it into your repository

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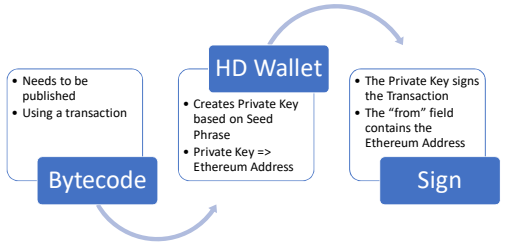
Publish using HD Wallet



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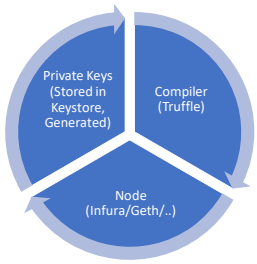
Components



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Truffle
Unit Testing

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Unit Testing

- Test all aspects of a software
- A Unit: smallest testable part of an application

- Smart Contract
  - That's a function
  - Write as simple as possible

256

Testing with Truffle

- Smart Contract testing
  - Not the "JavaScript" app
  - But Tests can be written in JavaScript

- Clean Room Environment
  - advanced snapshotting features to ensure your test files don't share state with each other.
  - re-deploy all of your migrations at the beginning of every test file to ensure you have a fresh set of contracts to test against

- Ganache or Truffle Develop during normal development and testing recommended (speed)

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Tests using JavaScript

- Mocha testing framework
- Chai for assertions

- Structurally, tests very similar to Mocha
  - If you know Mocha, Use contract() instead of describe()

- Contract Abstraction via artifacts.require()
- A web3 instance is available in each test file, configured to the correct provider.
  - So calling web3.eth.getBalance just works!

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Tests using JavaScript

- Very easy if you know *some* JavaScript
- Good for continuous integration
- Good when working in Teams
  - Avoid Regression Bugs
- Quite fast when working with Ganache/Truffle Develop

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Tests using JavaScript

```
var MetaCoin = artifacts.require("MetaCoin");

contract('MetaCoin', function(accounts) {
  it("should put 10000 MetaCoin in the first account", function() {
    return MetaCoin.deployed().then(function(instance) {
      return instance.getBalance.call(accounts[0]);
    }).then(function(balance) {
      assert.equal(balance.valueOf(), 10000, "10000 wasn't in the first account");
    });
  });
```

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Tests using Solidity

- Clean Room Environment
- Solidity tests shouldn't extend from any contract
  - makes your tests as minimal as possible
  - gives you complete control over the contracts you write.
- Don’t use your own assertion library.
  - Truffle provides an assertion library
- You should be able to run your Solidity tests against any Ethereum client.

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Tests using Solidity

```
import "truffle/Assert.sol";
import "truffle/DeployedAddresses.sol";
import "../contracts/MetaCoin.sol";

contract TestMetacoin {
  function testInitialBalanceUsingDeployedContract() {
    MetaCoin meta = MetaCoin(DeployedAddresses.MetaCoin());

    uint expected = 10000;

    Assert.equal(meta.getBalance(tx.origin), expected, "Owner should have 10000 MetaCoin initially");
  }

  function testInitialBalanceWithNewMetaCoin() {
    MetaCoin meta = new MetaCoin();

    uint expected = 10000;

    Assert.equal(meta.getBalance(tx.origin), expected, "Owner should have 10000 MetaCoin initially");
  }
}
```

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Security & Upgradeable Contracts

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Security Patterns

- Private Information and Randomness
- Re-Entrancy
  - Checks-Effects-Interactions Pattern
- Gas Limit and Loops
- Sending and Receiving Ether
- Callstack Depth
- tx.origin vs. msg.sender
- Underflows / Overflows
- General Recommendations

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Security Patterns

- Private Information and Randomness
  - ***Everything*** publicly visible, even local variables and state variables marked private.
  - random numbers in smart contracts is quite tricky
  - Randomness on Deterministic Systems hard to achieve
  - RANDAO
    - Smart Contract
    - Uses "many people" to generate randomness

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Security Patterns

- Re-Entrancy
  - The DAO attack
  - Contract A hands over control to Contract B
  - Contract B can "call back" to A
  - When does this become a problem?
    - If we can withdraw the same amount again
- Checks-Effects-Interactions Pattern
  - Update variable before calling external contract
  - "balance = 0" before "someAddress.call.value(…)(…)" not after
  - Check for return variables from low-level functions

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Security Patterns

- Gas Limit and Loops
  - Block gas limit limits the maximum runtime of smart contracts
  - Loops with "open end" quickly run out of gas
  - Avoid loops altogether
    - Unless you really know what you are doing
  - Never use loops on "scaling" variables
    - Such as arrays that grow with the number of users

267

Security Patterns

- Sending and Receiving Ether
  - You can never prevent the reception of ether
    - Set as coinbase or set as beneficiary on "selfdestruct(…)"
  - Fallback function is called by default (if no function is defined by caller). Transaction fails if no fallback function is called
  - addr.call.value(x)("") forwards all gas, letting the called contract potentially call back again. -> re-entrancy
  - Never rely on more than 2300 gas in a fallback function!

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Security Patterns

- Callstack Depth
  - Maximum callstack of 1024
  - Throws an exception
- Malicious actors can force Exception
- Be careful with low-level functions and always check the return value!

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Security Patterns

- tx.origin vs. msg.sender
  - Confusing difference between tx.origin and msg.sender
- Consider a Contract A and that contract calls another Contract B
  - In contract A is Tx.origin and msg.sender in both the same (address of EOA)
  - In contract B is tx.origin the address of the EOA and msg.sender the address of the calling contract A

270

Security Patterns

- Underflows / Overflows
- uint8(255) + uint8(1) == 0
- uint8(0) - uint8(1) == 255

- No warning
- Try to use require to limit the size of inputs to a reasonable range

271

Security Patterns

- General Recommendations
  - Take Warnings Seriously
  - Restrict the Amount of Ether
  - Keep it Small and Modular
  - Use the Checks-Effects-Interactions Pattern
  - Include a Fail-Safe Mode
  - Ask for Peer Review

272

Upgrades: Why Upgrade?

- An "unchangeable" ledger
  - Things can only be added
  - Immutability!

- Smart Contracts?
  - unchangeable logic
  - *immutable*
  - Looking at the logic now (which doesn't do anything bad) should guarantee that it doesn't do anything bad anytime in the future
  - Nice, but not *convenient* especially when bugs happen where contracts manage several M$.

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Ways around that

- Immutability stays
  - Have a migration path
  - Maybe means to release a new smart contract on a *new address* and then move all data over
  - Also tell users about the new address
  - Pause smart contracts?
- Make your Smart Contracts as *simple as possible* and *test everything*!

274

Ways around that

- Separate Logic from Data
  - Proxy-Delegate Pattern
  - Eternal Storage Pattern
  - https://zeppelinos.org/
- Governance?
  - Who is allowed to do that? Does every user have to agree to the upgrade? Or is there an authority?

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Proxy-Delegate Pattern

- Makes use of “delegatecall” low level function
- One Smart Contract as entry point
- Connects to another smart contract via an Address
- Relays the initial request
- More you don’t have to know
- A first functional version of this pattern was introduced in 2016.
- Removes the basic promise – Governance question:
  - Would you – as end-user – entrust all your savings a piece of code where the logic can be changed by a person?

276

Eternal Storage Pattern

- Idea: Keep contract storage after a smart contract upgrade.
- Moving storage is the most expensive operation on Ethereum
- slightly more complex syntax for storing data.

- Users might be able to choose which Version of Smart Contract they want to use
  - Let Users "upgrade" manually

- RocketPool uses this
  - Sidenote: Proof of Stake infrastructure service and pool

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ZeppelinOS

- Develop, deploy and operate any smart contract project securely
  - "ZeppelinOS is a development platform designed specifically for smart contracts projects. It allows for seamless upgrades, and provides economic incentives to create a healthy ecosystem of secure applications."
- Have upgradeable smart contracts
  - which follows the immutability rules guaranteed by the Ethereum blockchain
- Try to achieve decentralized governance
  - Not one person alone can upgrade a smart contract

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Smart Contracts Best Practices

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Best Practices

- The Ecosystem is very young
  - Many have made costly mistakes
- Good writeups of security best practices are available
  - ConsenSys does one at https://consensys.github.io/smart-contract-best-practices/
- Let's discuss this in more detail!
  - Don't make costly mistakes!

280

Prepare for failure

- There is no coding without errors
  - It's a wish to code error-free, so, how can we address this?
- Pause contracts when errors are discovered
  - Or have sanity checks
  - "Circuit breaker"
- Manage amount of money at risk
  - Rate limiting, maximum usage
- Have an "upgrade path" for bugfixes and improvements

281

Rollout strategy

- Test test test
  - Unit Testing
  - Alpha Testing
  - Beta Testing
- Bug bounties
- Rollout in phases
  - slowly, if possible

282

Simple and stupid

- The simpler the contract the better
- Modularize code, keep functions small
- Use libraries and tested code if possible
  - Don't try to re-invent the wheel
  - EthPM for example (truffle and zeppelinOS can do that)
- Clarity over performance
- **Only use the blockchain where the blockchain is needed!**

283

Stay up to date

- Checkout Niche News
  - Ethereum in a Week newsletter
  - Consensys newsletter
  - Reddit
  - …
- New Bugs discovered in the industry?
  - Make sure your contracts are safe then!
- Upgrade libraries and tooling
- Adopt new security best practices if possible

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Blockchain Specifics

- Attention at external contract calls
  - Might execute malicious code
  - Can change the control flow
- Public functions can be called by anyone, so prepare for that
- Private variables can be viewed by anyone easily
- Keep gas costs low and don't forget the block gas limit!

285

Simplicity vs. Complexity

- Ideally for a software developer:
  - Modular
  - code reuse
  - Upgradeable
- Blockchain Security sometimes not aligned with these ideals
  - Rigid vs. Upgradable
  - Monolithic vs. Modular
  - Duplication vs. Reuse

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Security Best Practices

- Be careful with external calls
- Mark untrusted contracts in your code clearly
- Checks-effects-interactions pattern
  - Avoid state changes after external calls
- Pull over Push Method
  - Also called "withdraw" method
  - Let a user "pull" his money out, rather than just sending it straight away
  - Can lead to dangerous DoS attacks
- Be careful with checking invariants concerning the balance
  - It is possible to forcefully send ether to a smart contract
  - Assert might break functionality completely

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Assert and Require

- Use Assert to check for invariants
  - Such as the cost per token
  - Use it as "circuit breaker"
  - Pause the contract if things fail
- Use Require to do input validation
- Keep this pattern to help with formal validation
  - "assert" should *never* fail if your code is correct

288

General Best Practices

- Use only assertions in modifiers
  - Code is executed before the function body
  - Check for invariants only, don't do input validation
  - Use modifiers only for error handling!
- Integer rounds always off!
  - Cuts off the decimal
  - 5/2 = 2

289

General Best Practices

- Keep fallback functions simple
  - Don't assume that there is more than 2300 gas available
  - That is usually just enough to emit an event
- Check the data-length in fallback functions
  - Are called when no other function matches
  - Throw an exception, or caller will not know they mistakenly called the fallback function
- Make your version pragma specific
  - ^0.4.25 can also be used for the nightly compiler

290

General Best Practices

- Be aware that the block timestamp can be manipulated by a miner
- Understand the inheritance graph if you use multiple inheritance
- **Read https://consensys.github.io/smart-contract-best-practices/known_attacks/ and understand known attacks**

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Blockchains for Data Storage

- Ethereum is not good at storing large amounts of data
  - Storage cost is extreme
    - $0.076/KB or $76,000/GB (Feb 2016)
    - More than $10M/GB in Nov 2017
  - Not meant for storing large data (pictures, videos…)
  - Data is redundantly distributed across all nodes
- Other Blockchain solutions are better for this
  - IPFS
  - SWARM

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IPFS and Swarm

- Peer to Peer
- File Content = Hash
- low-latency retrievalreliable, fault-tolerant operation, resistent to node's disconnections, intermittent availability
- zero-downtime
- censorship-resistant
- content-addressed block storage model, with content-addressed hyperlinks
- Beta (or even alpha)

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IPFS

- InterPlanetaryFileSystem
- Generic DHT
- proof of retrievability as part of mining
  - FileCoin
- already serves as a working solution for real-world businesses
- is supported by an enthusiastic user-base

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Swarm

- swarm's core storage component as an immutable content addressed chunkstore rather than a generic DHT
- swarm has deep integration with the Ethereum blockchain and the incentive system benefits from both smart contracts as well as the semi-stable peerpool
- Similar to BitTorrent

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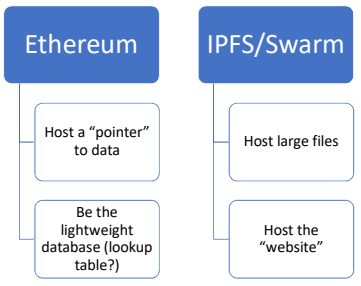
Architecture



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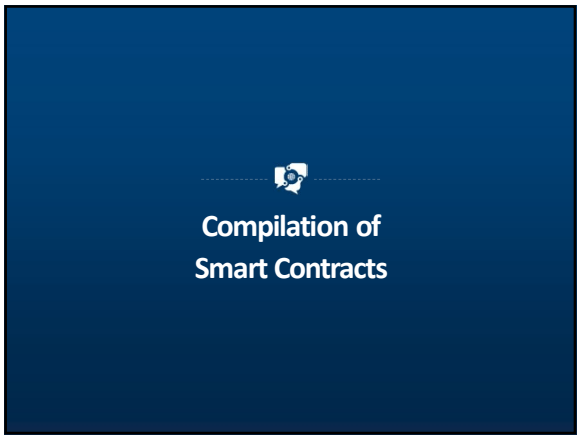

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Compilation

- Usually done within a Development Tool
  - Abstracted away from developer
  - Remix -> "deploy" will magically take the binary and put it in a transaction
  - Truffle -> "compile" or "migrate" will magically create the artifact and deploy it
- What really happens during compilation?

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Different Compilers

- There are different solidity compilers and versions
  - Old *compiled* solidity code is not "insecure"
  - New language features makes is harder to write buggy code
- NPM package: solcjs
  - The solc-js project is derived from the C++ *solc*
    - Uses the same source
- *Solc* is the c++ project
  - The comandline options of *solcjs* are not compatible with *solc* and tools (such as *geth*) expecting the behaviour of *solc* will not work with *solcjs*.

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Idea to reality

- 2016: Geth can compile Solidity code
  - web3.eth.compile.solidity(source_string, callback_func)
- 2017: Compiler Removed, but can be plugged in
  - But only solc (needs compilation)
  - Not solcjs (can't just do "npm install solcjs")
- 2018: Nobody uses geth to compile solidity anymore, better use a standalone compiler

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When using a compiler

- Large Project might need specific compiler version
  - Truffle comes "pre-packaged"
- Specific compiler options
- Maybe a custom compiler for low-level optimization?
  - Better not – "don't change the library": Upgrade-hell

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Compiler Output

- ABI Array
  - Compiler automatically creates Application Binary Interface
  - Needed for contract deployment
  - Needed for invoking contracts
- Bytecode / EVM Code / EWASM
  - Code that's deployed on the blockchain
  - Transaction field "data"

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Important?

- Is it important to know how to compile manually?
  - No
- Unless…
  - You want to do a deep-dive into the intrinsic details of the compiler and language
  - You need specific compiler options
  - Truffle Contract Management won't work for you
- Better…
  - Understand the bytecode / EVM Assembly or EWASM
  - Optimize from there

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Blockchain Use Cases

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Just a Few Use Cases

- Background checks: education credentials, criminal records
- Secure document storage: home deed, auto title
- Birth registries
- Land registries
- Financial services: securities clearing, syndicated loans
- Global supply chain: automotive recalls and counterfeit airbags
- Healthcare: EMRs, insurance claims, genome research
- Airlines: registration, re-booking, vouchers, loyalty
- Tokenized economy: Tech Coworking space 1 token = 1 seat
- Payment channels: Starbucks or for bandwidth consumption

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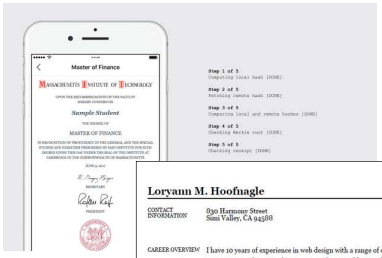
Background Checks

MIT Digital Certificates (diplomas); Criminal Records



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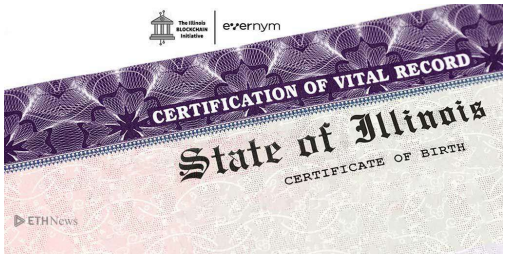
CAREER OVERVIEW I have 10 years of experience in web design with a range of clients including small private companies, medium-sized e-commerce shops, and large online magazines. My main focus is on design, usability and SEO optimization.

307

Birth Registry



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Global Supply Chain

- Automotive Industry Recalls and Counterfeit Airbags
- Business case: 30% global airbags sold and installed are counterfeit
- Solution: Single shared process for airbag registration and lookup

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Healthcare

- Electronic Medical Records (EMRs)
  - Digital health wallet
    - Identity credentials + EMR + health insurance + payment information
- Health insurance claims
  - Automated claims billing, validation, payment, and settlement
  - Multi-party value chain: patient, service provider, billing agent, insurance company, payor, government, collections
- Genomic research
  - Files too large (20-40 Gb) for centralized research repositories
  - Need secure validated access

Digital health wallet

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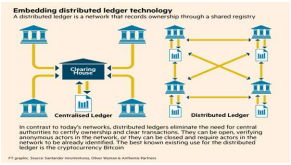
Financial Services

- Clearing and Settlement
- Issuance, Ownership, and Transfer of Financial Instruments
- Servicing of Instruments
- Payments and Remittance
- KYC/AML Compliance
- Regulatory Reporting
- Audit and QA
- Back-office Reconciliation



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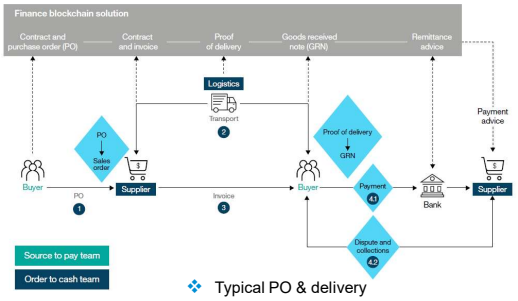
Financial Services - PO



- Typical PO & delivery

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Airlines

- Registration System (like SABRE)
- Cross-airline flight re-booking
- Loyalty programs
- Flight cancellation smart contract vouchers

Smart contracts automatically issue vouchers to customers when flights are delayed or cancelled

313

Real Estate Services

Blockchain and Home Purchases

- Save by eliminating transaction fees for buyer/seller agent, banks and any other intermediaries
- Minimize turnaround time
- Eliminate escrow as Blockchain is only a source of trust
- Eliminate manual process for requesting mortgages

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Blockchain and Political Systems

- Elections and Voting
- Liquid Democracy / Delegative Democracy
  - Voters can transitively delegate their votes
- Futarchy and Voting Prediction Markets
  - 2-tier voting for project area and approach
- Participatory Budgeting
  - Residents collectively decide how to spend their local government's budget
- Self-directed Public Finance
  - $500/$1000 personal bond offerings
- Virtual Democracy
  - Instant elections among machine learning models of real voters to address the challenge of ethical decision making

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Blockchain Adoption

One of the fastest-moving technology adoptions

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Blockchain Adoption

- Blockchain (distributed ledger technology) is being considered by more than half of the world's big corporations, according to a Juniper market research survey released Jul 2017
  - 57 percent of large corporations – defined as any company with more than 20,000 employees – were either actively considering or in the process of deploying blockchain
  - Two-thirds of companies surveyed by Juniper said that they expected the technology to be integrated into their systems by the end of 2018
- IDC: $2.1 billion estimated global blockchain spend 2018

https://www.cnbc.com/2017/07/31/blockchain-technology-considered-by-57-percent-of-big-corporations-study.html

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The Future of Blockchain

Transforming Society

- Blockchain technology is bringing us the Internet of value: a new platform to reshape the world of business
- It transcends all physical and geographical barriers and uses math and cryptography to enable transactions globally
- The uniqueness of blockchain lies in its capacity to store and retain person-to-person transactional history, so that chances of fraud, hacking, and third-party interference are greatly reduced

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Many Blockchains/Crypto currencies

- It's easy to create your own, and there are many.

- Each is separate and runs its own blockchain
- The value transferred in each blockchain is primarily in its own cryptocurrency

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Parallels to the Internet

Blockchains today have been likened to the Internet in 90s.

- Only faster growing WW investment occurring!
- Touching a larger scope of business and society
- Exploiting Web 3.0 with unlimited uses (IoT)

History doesn't repeat, but it rhymes: We expect similar...but

- Faster path to maturity – continued expansion
- Wider – Faster Adoption curve
- Evolution of protocol and applications touching the lives of people previously unreached by the Internet

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Parallels to the Internet

Just as the internet 1.0 revolutionized access to information, Blockchain is doing the same to multiple industrial verticals:

- Finance and Commerce first
  - It's what Blockchain's purpose is
  - It's where the money is
  - Greatest opportunity to reduce business cost
- Non-finance uses
  - Specialist Blockchains dedicated to one task
  - Typically tied to a cryptocurrency
  - Generalist Blockchains to be used as a 'platform'

Blockchain Technology is moving very fast – still a lot to learn and new opportunities on many levels, industries, services, and trade!!

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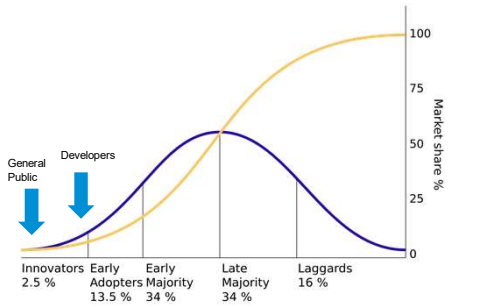
Where Are We Now?



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Investment Into the Sector

- Reid Hoffman (LinkedIn) Invested US$20M in Blockstream
- Sir Richard Branson backed BitPay (Exchange) in a US$30 Million
- Circle (Exchange) raised US$50 Million - led by Goldman Sachs
- NYSE led a US$75 Million Investment in Coinbase (Exchange)
- Large BaaS (Blockchain as a Service) investments by IBM, SAP, Cisco, AWS (2017 -2018)
- Mercedes Benz invests $110 million to explore blockchain use cases
- Blockchain investments are extending to the underdeveloped countries and underbanked areas of the world quickly, providing a way to do personal business, as well as commerce

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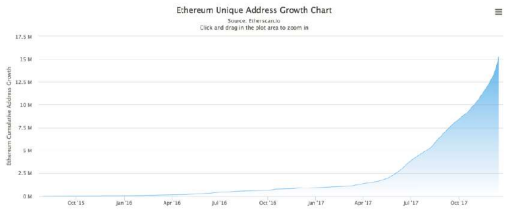
Growth in CryptoAddresses



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Wall Street Blockchain Investment Growing

BARCLAYS

Three blockchain startups selected for Barclays Accelerator, with one aiming to provide blockchain solutions for the insurance industry

citi

Citi wants "to [accelerate] emerging technologies that have the potential to transform financial services experiences for Citi's customers"

UBS

UBS is set to open a London-based research lab to explore the application of blockchain technology in the financial services industry

Sources: CoinDesk, Bank Innovation

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Web 3.0

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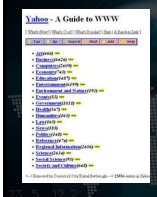
Internet Technology Progression

Internet 1.0
Static Information
WW Explosion of Information



Internet 2.0 Social Engagement
Twitter, Facebook, New Voice of People Worldwide

Internet 3.0 The Internet of Value. Communication, commerce, and participation at all levels, i.e. The Internet of Things (IoT)

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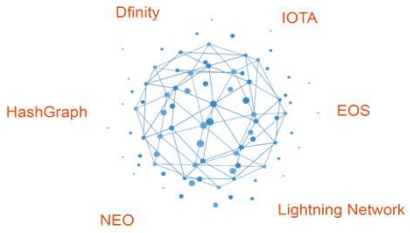
Blockchain – New 3.0 Solutions

Many new Blockchain networks are evolving to provide scalability and solve many of the current problems. New protocols such as Lightning's Off-Chain solution, and IOTA's parallel transactions are just two of the schemes being developed and tested.



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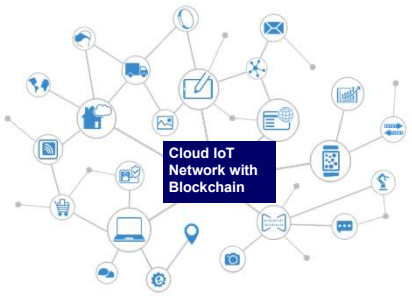
Blockchain – Future Internet 3.0



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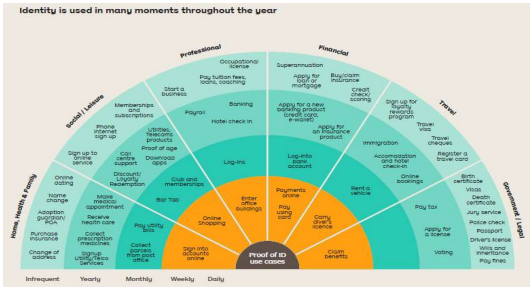
Digital Identity Touch Points using Blockchain



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Blockchain Implementation

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Top 5 Blockchain Platform Features

Summary of Features of top 5 Blockchain Platforms for Enterprises

	Ethereum	Hyperledger Fabric	R3 Corda	Ripple	Quorum
Industry-focus	Cross-industry	Cross-industry	Financial Services	Financial Services	Cross-industry
Governance	Ethereum developers	Linux Foundation	R3 Consortium	Ripple Labs	Ethereum developers & JP Morgan Chase
Ledger type	Permissionless	Permissioned	Permissioned	Permissioned	Permissioned
Cryptocurrency	Ether (ETH)	None	None	Ripple (XRP)	None
% providers with experience[1]	93%	93%	60%	33%	27%
% share of engagements[2]	52%	12%	13%	4%	10%
Coin Market Cap[3]	$91.5 B (18%)	Not applicable	Not Applicable	$43.9 B (9%)	Not Applicable
Consensus algorithm	Proof of Work (PoW)	Pluggable framework	Pluggable framework	Probabilistic voting	Majority voting
Smart contract functionality	Yes	Yes	Yes	No	Yes

1. Based on responses from 15 leading blockchain service providers
2. Based on a random sample of set of 50 enterprise blockchain engagements across multiple industries
3. Coinmarketcap.com as of Feb 20, 2018, 6:20 PM UTC

Source: HfS Research, 2018

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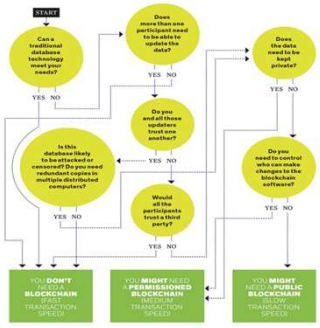
When to use Blockchain



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When to use Blockchain

- Database?
  - Centralized
  - Decentralized
- Secure network transfer?
  - # parties, frequency
  - Information
  - Money (value)
- Business process automation?
  - QA/Compliance/Audit
  - Always-available information
  - Data sovereignty

Use Case Example: **Factom: Health insurance claims billing**

- Automated claims billing, validation, payment, and settlement
- Multi-party value chain: patient, service provider, billing agent, insurance company, payor, government, collections

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When to use Blockchain

- Large Business Network
- Need for multiple ledgers
- Public Verification
- Coin / Token
- Audit / Review
- Can't be solved with a database
- Non-technical (human) problems / barriers
- Systems integration

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Requirements Definition

- Where would having a single shared set of trusted information help in value chain ecosystem?
  - Blockchain is a single shared database of information and transactions between parties in a value chain.
- What are obvious ways to deliver customer value?
  - Financial: What is the cost of transactions/information transfer now? What is the business case for moving to a blockchain solution?
  - QA Regulation/Compliance: audit-log demonstrates compliance; assures chain of custody.

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Next Steps

- Identify 2-3 Blockchain use cases that would address your business requirements
- Design and Implement Pilot Project
- Deployment Strategy
- Competitive Edge: lead blockchain single shared database and processes in your industry ecosystem
- Resources
  - Blockchain consultants, system integrators/vendors

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