Blockchain Technologies

Internet of Things A.Y. 18-19

Prof. Chiara Petrioli
Dept. of Computer Science
Sapienza University of Rome
Dr. Michele Martinelli
WSense

PART I

How many of you:

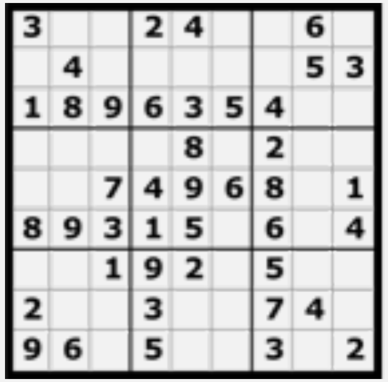
- Have heard of bitcoins?
- Own cryptocurrency?
- Feel you understand the underlying blockchain technology?

Block(chain) idea

1. Everyone
   tries to solve a puzzle

2. The **first one** to solve
   the puzzle **gets 1 coin**

3. The solution of **puzzle *i***
   defines puzzle *i+1*



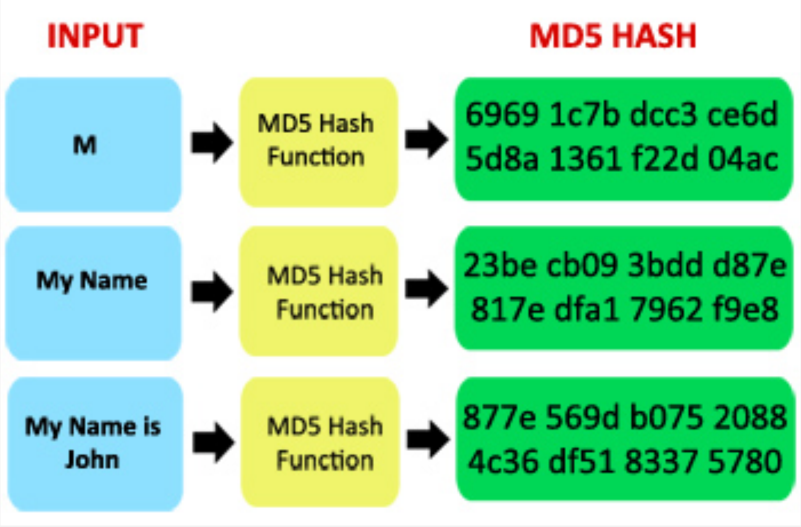
It's EASY to VERIFY the solution, not to find it!

Hash functions

Hashing is a process which you turn anything (as long as you can represent it as a string) into a fixed length of bit string

A cryptographic hash function is a special class of hash functions which has various properties making it ideal for cryptography.

1. **Deterministic**: no matter how many times you hash a particular input, you will always get the same result
2. **Quick Computation:** The hash function should be capable of returning the hash of an input quickly
3. **Pre-Image Resistance**: given H(A) it is infeasible to determine A, where A is the input and H(A) is the output hash.
4. **Small Changes In The Input Changes the Hash.**
5. **Puzzle Friendly**: For every output “Y”, if k is chosen from a distribution with high min-entropy it is infeasible to find an input x such that H(k|x) = Y.



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SHA256 hash functions

Here how you can try it in Python:

```
>>> import hashlib

>>> hashlib.sha256(“hello world”).hexdigest()
‘B94d27b9934d3e08a52e52d7da7dabfac484efe37a5380ee9088f7ace2efcde9’

>>> hashlib.sha256("helli world").hexdigest()
'bd6952606ca18ccc9ff86bb8874ce0c61d7aa4fb72363e323f9eb2d3e783a487'
```

The puzzle

I want to find a particular hash…
For example, I want two ZEROs at the end of the hash ("00")…
What string I have to use?

```
>>> import hashlib

>>> hashlib.sha256("hello world").hexdigest()
'B94d27b9934d3e08a52e52d7da7dabfac484efe37a5380ee9088f7ace2efcde9'

>>> hashlib.sha256("hello world 1").hexdigest()
'063dbf1d36387944a5f0ace625b4d3ee36b2daefd8bdaee5ede723637efb1cf4'

…

>>> hashlib.sha256("hello world 238").hexdigest()
'd622375f29c4b358674794610404bdd1f4e060a7244568b5549eed9754dfa400'
```

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The puzzle

…and 3 ZEROs at the end of the hash (“000”)…?

```
>>> import hashlib

>>> hashlib.sha256(“hello world 3198”).hexdigest()
‘838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000’
```

…and 6?

```
>>> hashlib.sha256(“hello world 28114982”).hexdigest()
3d28877e8af972f6732de4591245a87545b0221c26e446f09e98665a6d000000
```

It’s getting harder to find a solution, but easy to verify it!

The puzzle – python code

```
import hashlib

i=0
while True:
    res = hashlib.sha256("hello world "+str(i)).hexdigest()
    if res.endswith("000000"):
        print i
        print res
        break
    i += 1
```

The puzzle – create a chain

How can the puzzle “depends” on the previous one?

```
>>> hashlib.sha256(“hello world 3198”).hexdigest()
‘838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000’
```

The puzzle – create a chain

How can the puzzle "depends" on the previous one?

```
>>> hashlib.sha256("hello world 3198").hexdigest()
'838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000'
```

A new string!

```
>>> hashlib.sha256("
SECOND hello world + 838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000
  ").hexdigest()
'9b582a1b5fd41f36cc0a396d4747507148f3bdde58a4bff18891406a9158a72e'
```

But this hash doesn't end with "000"…

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The puzzle – create a chain

How can the puzzle “depends” on the previous one?

```
>>> hashlib.sha256("hello world 3198").hexdigest()
'838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000'
```

A new string!

```
>>> hashlib.sha256("
SECOND hello world + 838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000
   ").hexdigest()
'9b582a1b5fd41f36cc0a396d4747507148f3bdde58a4bff18891406a9158a72e'
```

But this hash doesn’t end with “000”… let’s do the puzzle again:

SECOND hello world +
838ee925a5eff45a3337363e9a2e993e02eddcc2edd90cdd4fec14b0c6e59000 + 1659
‘46eb8a72e26d849f9b755c39f0caa08013b61b4592f02ab446c4fa1b498d4000’

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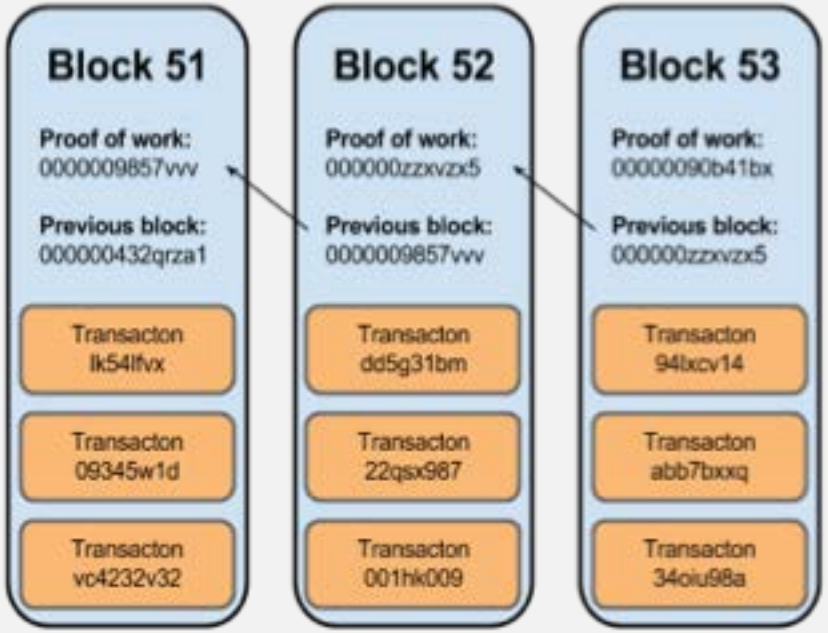
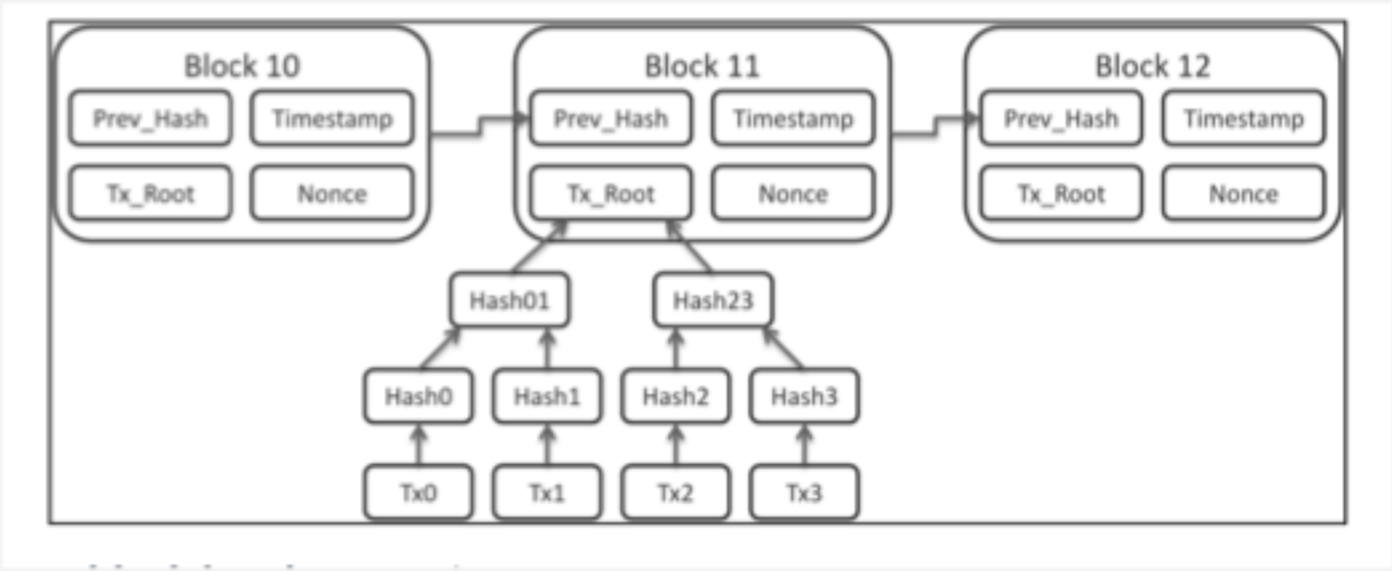
What is the Blockchain

The blockchain is basically a linked list which contains data and a hash pointer to the previous block, hence creating a persistent, ever-growing, "blockchain" that constantly updates to represent the latest state of the ledger.

What is a hash pointer? **A hash pointer is similar to a pointer, but instead of just containing the address of the previous block it contains the hash of the data inside the previous block**.





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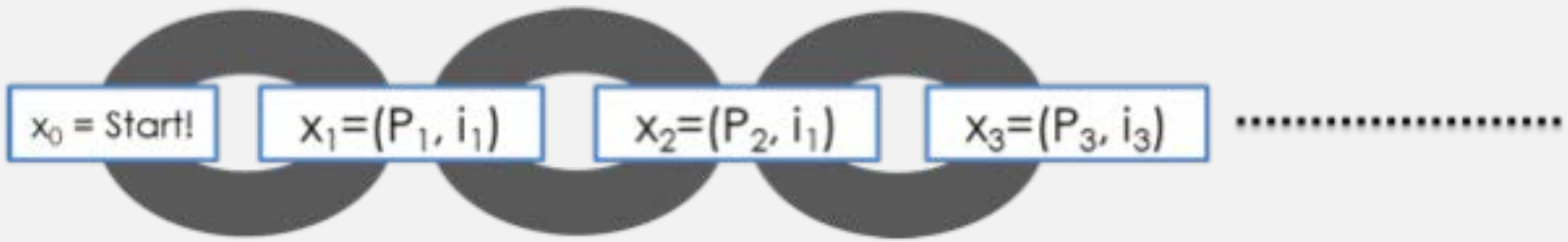
What is the Blockchain

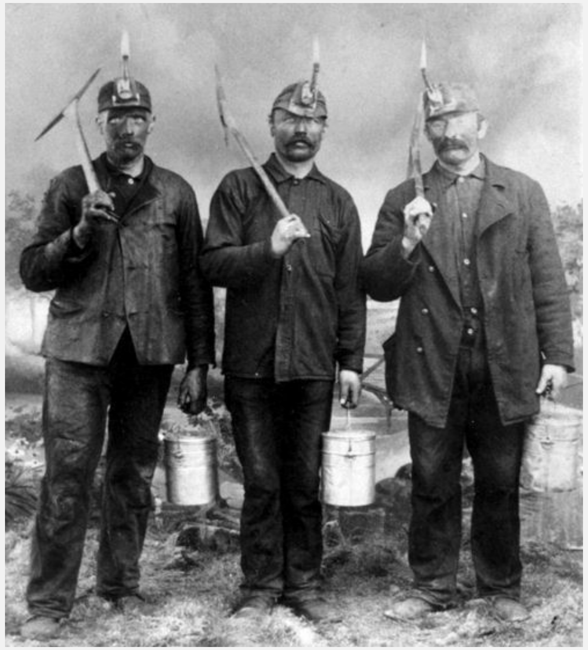
The blockchain is a decentralized, distributed and public digital ledger that is used to record information across many computers so that any involved record cannot be altered retroactively, without the alteration of all subsequent blocks.

Key concepts are:

- **Decentralization:** the information is not stored in a privileged central server but in all the individual computers of each participant
- **Immutability:** no participant can modified a transaction after it has been recorded on the ledger
- **Cryptography:** integrity and security of the information on the blockchain are ensured with cryptographic functions
- **Transparency:** participants know where the assets came from and how its ownership has changed over time



Proof of work (mining)



When you want to set a transaction this is what happens behind the scenes:

- Transactions are bundled together into what we call a block;
- Miners verify that transactions within each block are legitimate;
- miners solve a mathematical puzzle known as proof-of-work problem;
- A reward is given to the first miner who solves each blocks problem;
- Verified transactions are stored in the public blockchain

This “mathematical puzzle” has a key feature: **asymmetry**: hard on the requester side but easy to check for the network. 

All the network miners compete to be the first to find a solution for the mathematical problem that concerns the candidate block**, a problem that cannot be solved in other ways than through brute force** so that essentially requires a huge number of attempts.

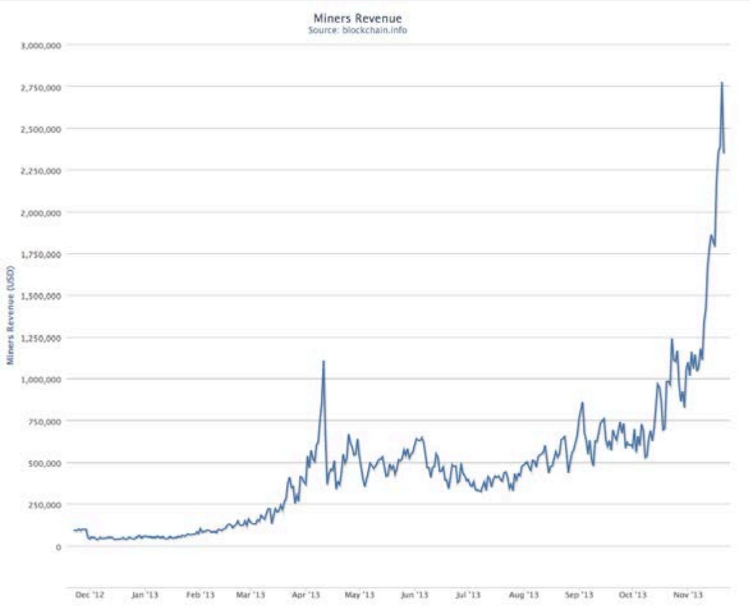
When a miner finally finds the right solution, he/she announces it to the whole network at the same time, receiving a cryptocurrency prize (the reward) provided by the protocol.

Reward

mining process is an operation of inverse hashing: it determines a number (nonce), so the cryptographic hash algorithm of block data results in less than a given threshold.

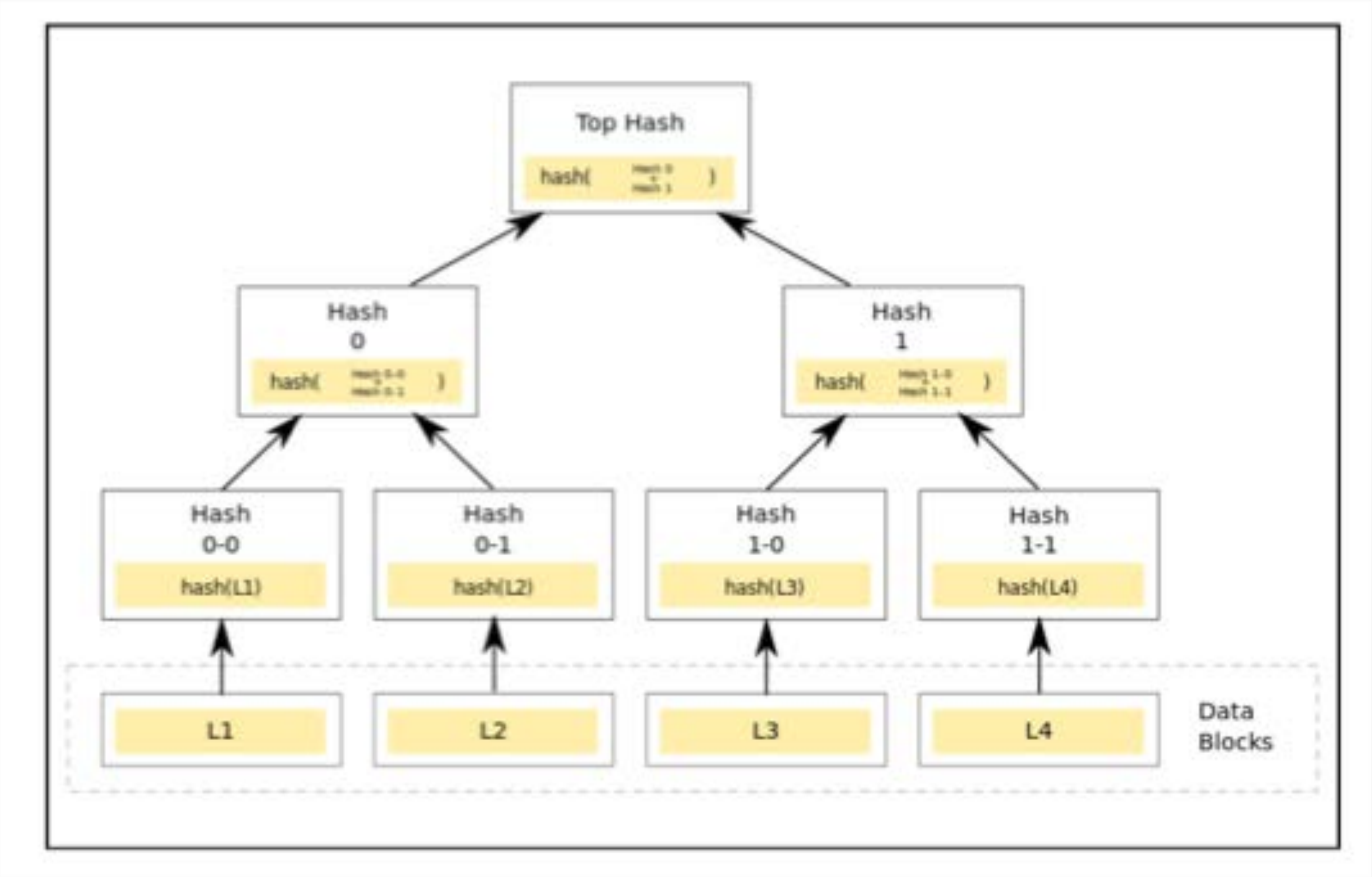
This threshold, called difficulty, is what determines the competitive nature of mining: more computing power is added to the network, the higher this parameter increases, increasing also the average number of calculations needed to create a new block.

This method also increases the cost of the block creation, pushing miners to improve the efficiency of their mining systems to maintain a positive economic balance.



Merkle Tree

A Merkle tree is a type of binary tree:
- each node is the hash of its two children
- a single root node, also formed from the hash of its two children, representing the "top" of the tree.



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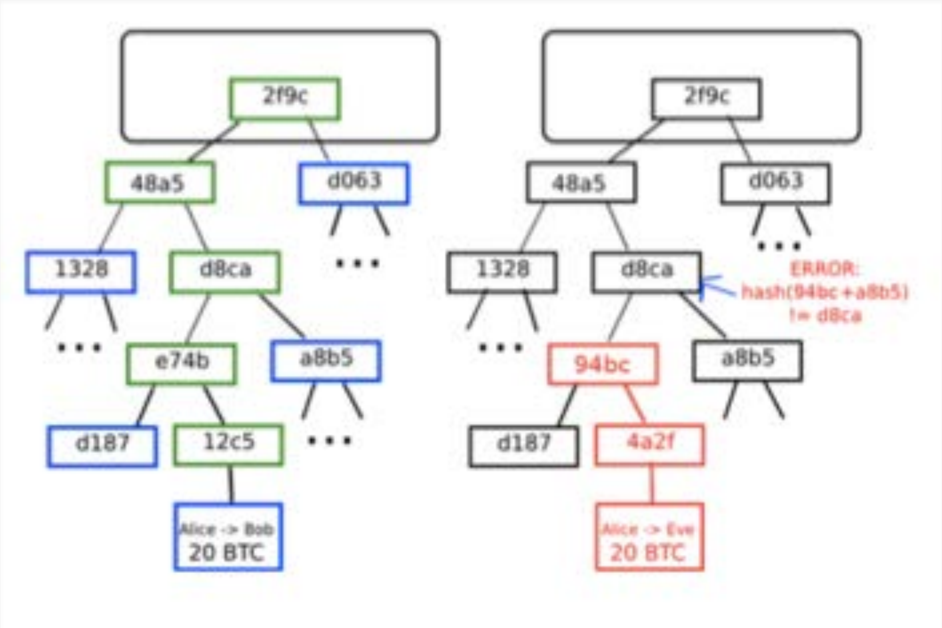
Scalability - Merkle Trees

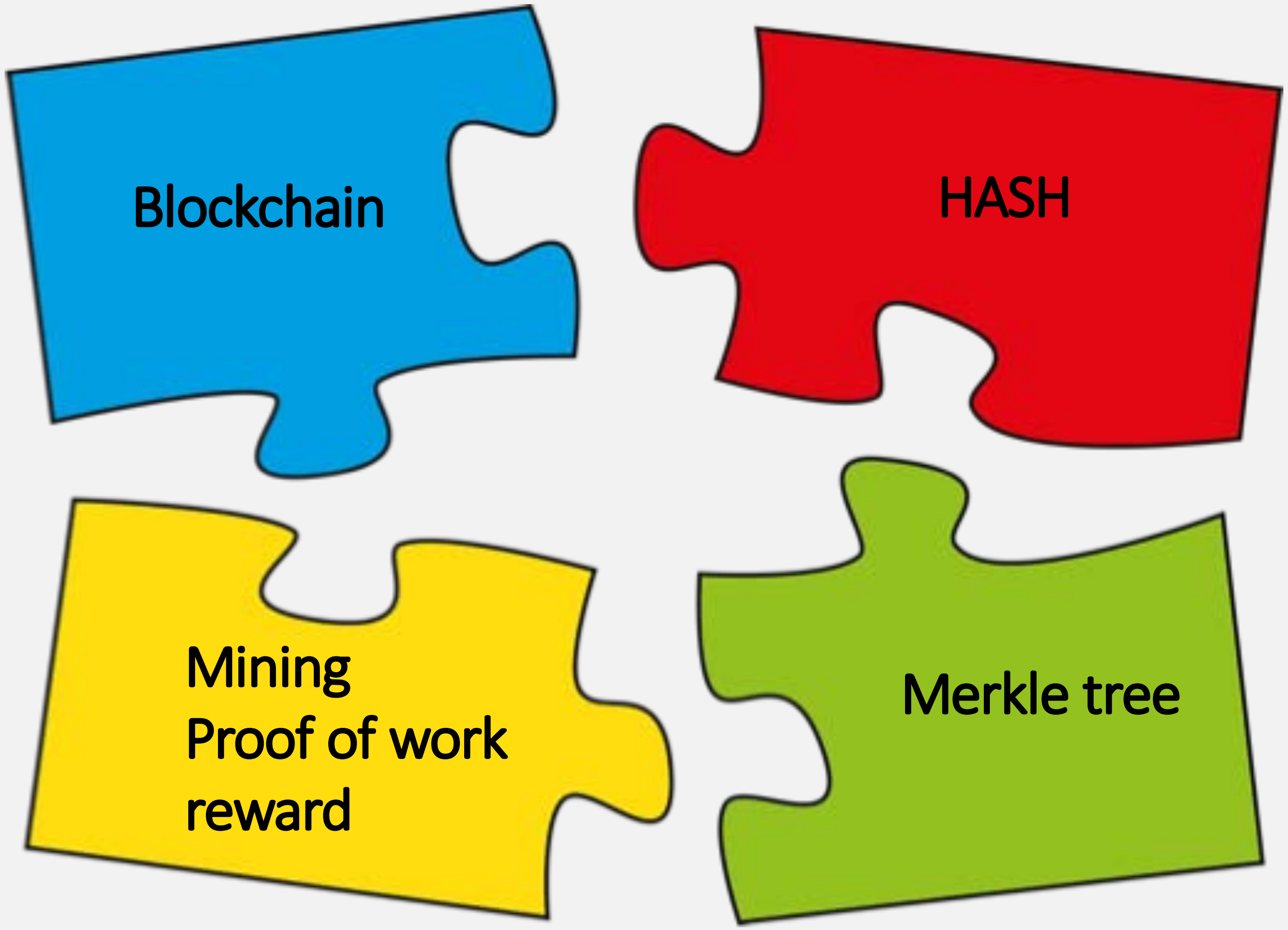
a node can download only the header of a block from one source, the small part of the tree relevant to them from another source, and still be assured that all of the data is correct.

if a malicious user attempts to swap in a fake transaction into the bottom of a Merkle tree, this change will cause a change in the node above, and then a change in the node above that, finally changing the root of the tree and therefore the hash of the block, causing the protocol to register it as a completely different block

"light nodes" downloads the block headers, verify the proof of work on the block headers, and then download only the "branches" associated with transactions that are relevant to them. This allows light nodes to determine with a strong guarantee of security what the status of any Bitcoin transaction, and their current balance is while downloading only a very small portion of the entire blockchain.



So much things… ☹



Be patient! Let's see a real case:
BITCOIN

Bitcoin

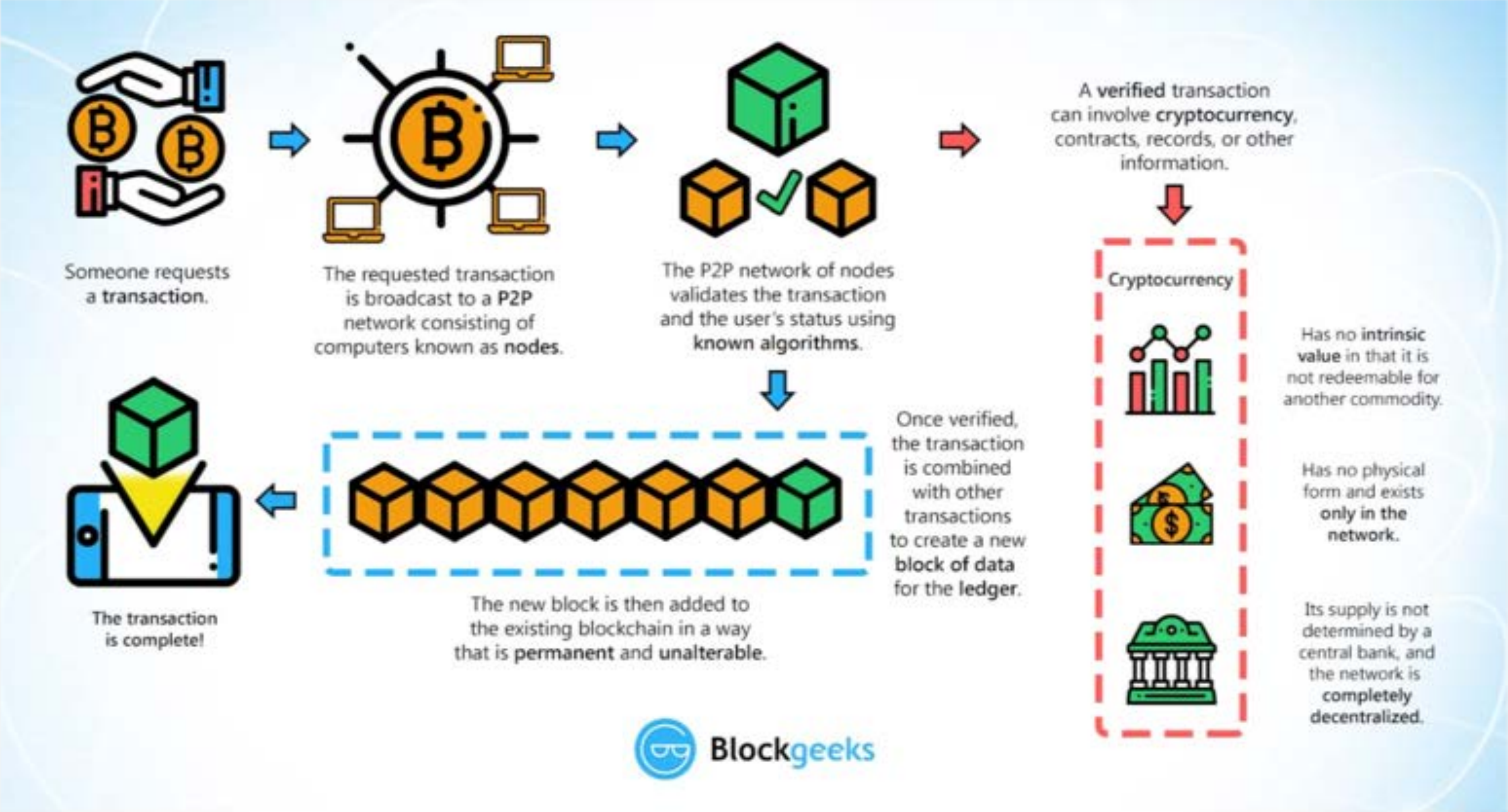
Blockchain technology was first introduced in a whitepaper entitled:
"Bitcoin: A Peer-to-Peer Electronic Cash System," by Satoshi Nakamoto in 2008.

Bitcoin is a collection of concepts and technologies creating a digital money ecosystem.

- A decentralized peer-to-peer network (the bitcoin protocol)
- A public transaction ledger (the blockchain) (roughly one block created every ten minutes)
- A decentralized mathematical and deterministic currency issuance (distributed mining)
- A decentralized transaction verification system (transaction script)

Bitcoin

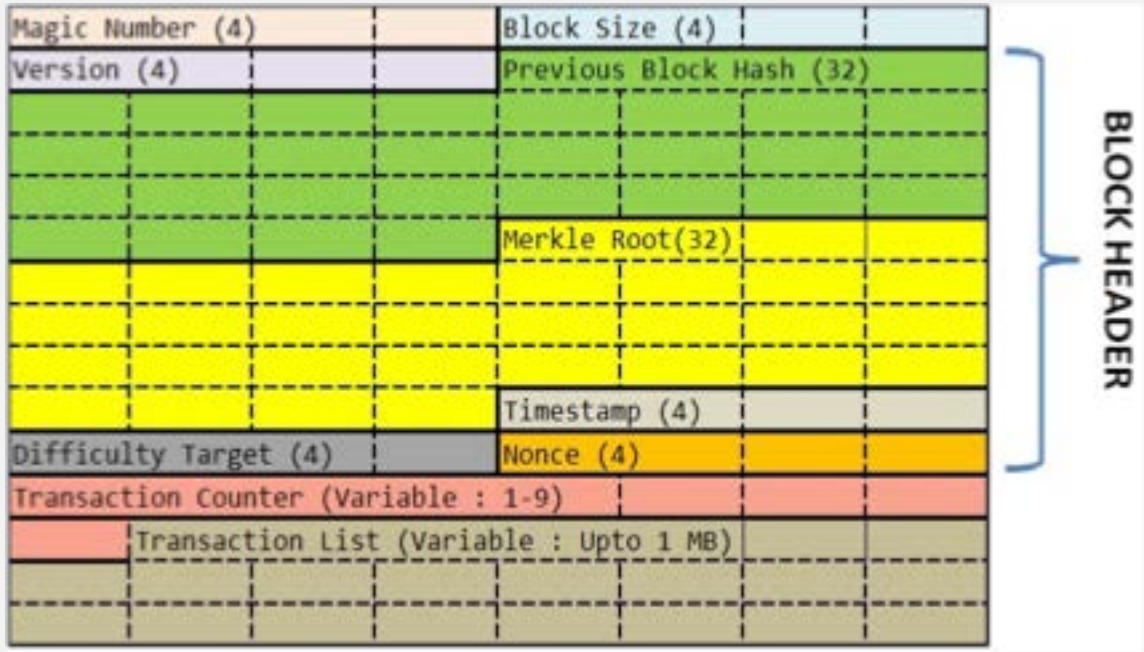
Satoshi Nakamoto: Bitcoin: A Peer-to-Peer Electronic Cash System, DATA



Blockchain

A block header contains:

Version: The block version number.
Time: the current timestamp.
The current difficult target.
Hash of the previous block.
Nonce.
The Merkle Root.



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difficulty

Mining is like a game, you solve the puzzle and you get rewards.

Setting difficulty makes that puzzle much harder to solve and hence more time-consuming.

the difficulty target is a 64-character string (which is the same as a SHA-256 output) which begins with a bunch of zeroes.

A number of zeroes increases as the difficulty level increases.
The difficulty level changes after every 2016th block to produce a block every 10 minutes.

The miner of every block is entitled to include a transaction giving themselves 12.5 BTC out of nowhere.
Additionally, there are "transaction fee".

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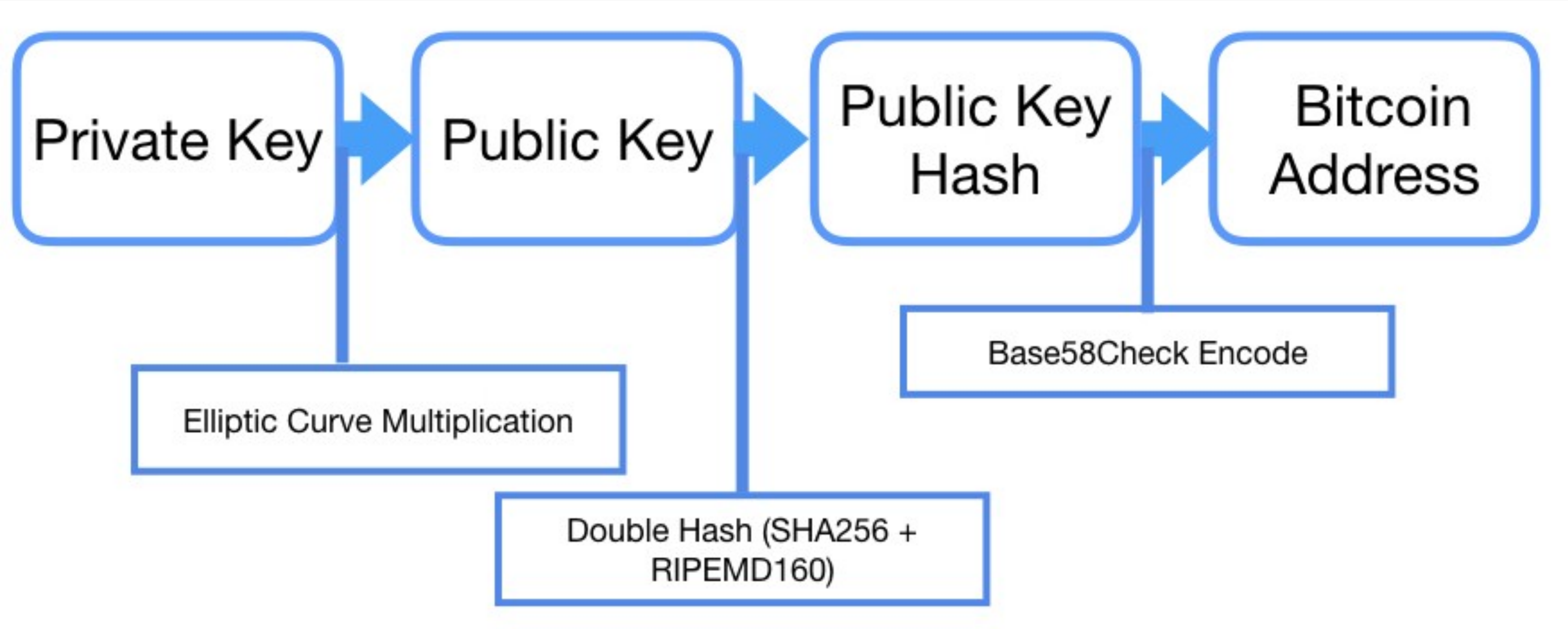
BTC Address


Private Key
Public Key
Public Key Hash
Bitcoin Address
Elliptic Curve Multiplication
Double Hash (SHA256 + RIPEMD160)
Base58Check Encode

BTC transaction

Transazione Ottieni informazioni su una transazione bitcoin

ac60220be92a9ae91adfac98594c34c4a3ea57112988fb86d6bcbdc6be7b82ca

bc1qdnjnjhv4h7drws852eq0caspmuzslccx48u38v → 38hm7FKkQDZgSFJCTc2xiqJT6fckEyt9m 0.13765206 BTC
bc1qdnjnjhv4h7drws852eq0caspmuzslccx48u38v 0.00125492 BTC

2 conferme 0.13890698 BTC

Sommario	
Dimensione	667 (byte)
Peso	1378
Orario di Ricezione	2019-05-22 20:59:16
Incluso nei Blocchi	577303 (2019-05-22 21:16:53 + 18 minuti)
conferme	2
Visualizza	Osserva il Grafico ad Albero

Input e Output	
Totale Input	0.14048818 BTC
Totale Output	0.13890698 BTC
tasse	0.0015812 BTC
Tariffa per byte	237.061 sat/B
Tariffa per unità di peso	114.746 sat/WU
Stima dei BTC scambiati	0.13765206 BTC
Script	Mostra gli script e la coinbase

Way more complex than this…

Crypto Puzzles – mining bitcoin

When the Bitcoin mining software wants to add a new block to the blockchain, this is the procedure it follows.

Whenever a new block arrives, all the contents of the blocks are first hashed.

If the hash is lesser than the difficulty target, then it is added to the blockchain and everyone in the community acknowledges the new block.

However, it is not as simple as that. You will have to be extremely lucky to get a new block just like that. This is where the nonce comes in.

The nonce is an arbitrary string which is concatenated with the hash of the block.

After that this concatenated string is hashed again and compared to the difficulty level. If it is not less than the difficulty level, then the nonce is changed and this keeps on repeating a million times until finally, the requirements are met. When that happens the block is added to the block chain.

Mining bitcoin 2009 - CPU

the first bitcoin miners used standard multi-core CPUs

If you had a couple computers lying around with decent specs you could have earned about five euro a day.

The difficulty of mining was so low then it was worth it for hobbyists and crypto nerds to participate.

Mining bitcoin 2010 - GPU

in October 2010 the code for mining bitcoin with GPUs was released to the general public.

Mining bitcoin 2011 - FPGA

mining difficulty continued to rise, and with it, the power requirements would soon become too steep for your average hobbyist to make any money.

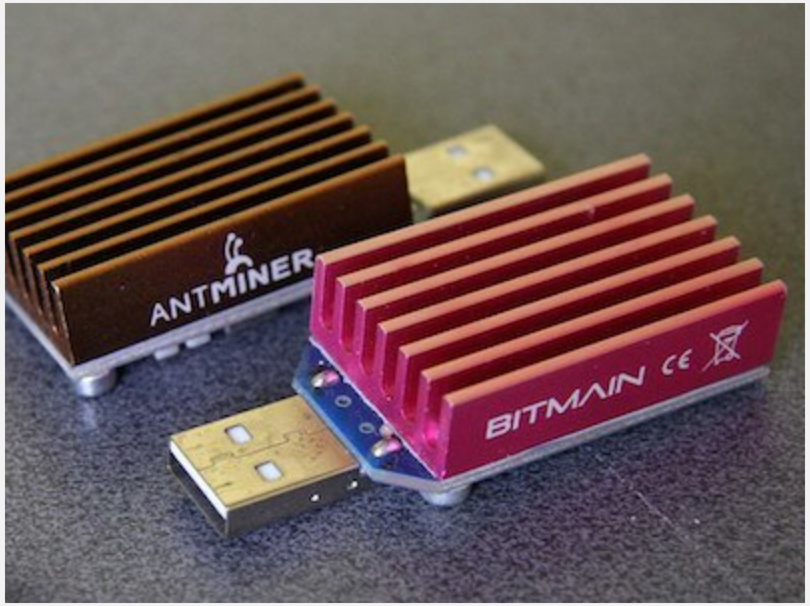
By June 2011 field-programmable gate arrays (FPGAs) were becoming all the rage.

The biggest draw to this hardware was the fact that it used three times less power than simple GPU setups to effectively accomplish the same task.

Mining bitcoin 2013 – cheap ASIC

Where FPGA requires tweaking after purchase (the field-programmable part of FPGA), an ASIC is created for a specific use, in this case mining cryptocurrency. This is why ASIC miners remain the standard.

330 Mh/s



1.8 Gh/s

Mining bitcoin 2013 – mining pool

Mining bitcoin now – expensive ASIC

14 Th/s

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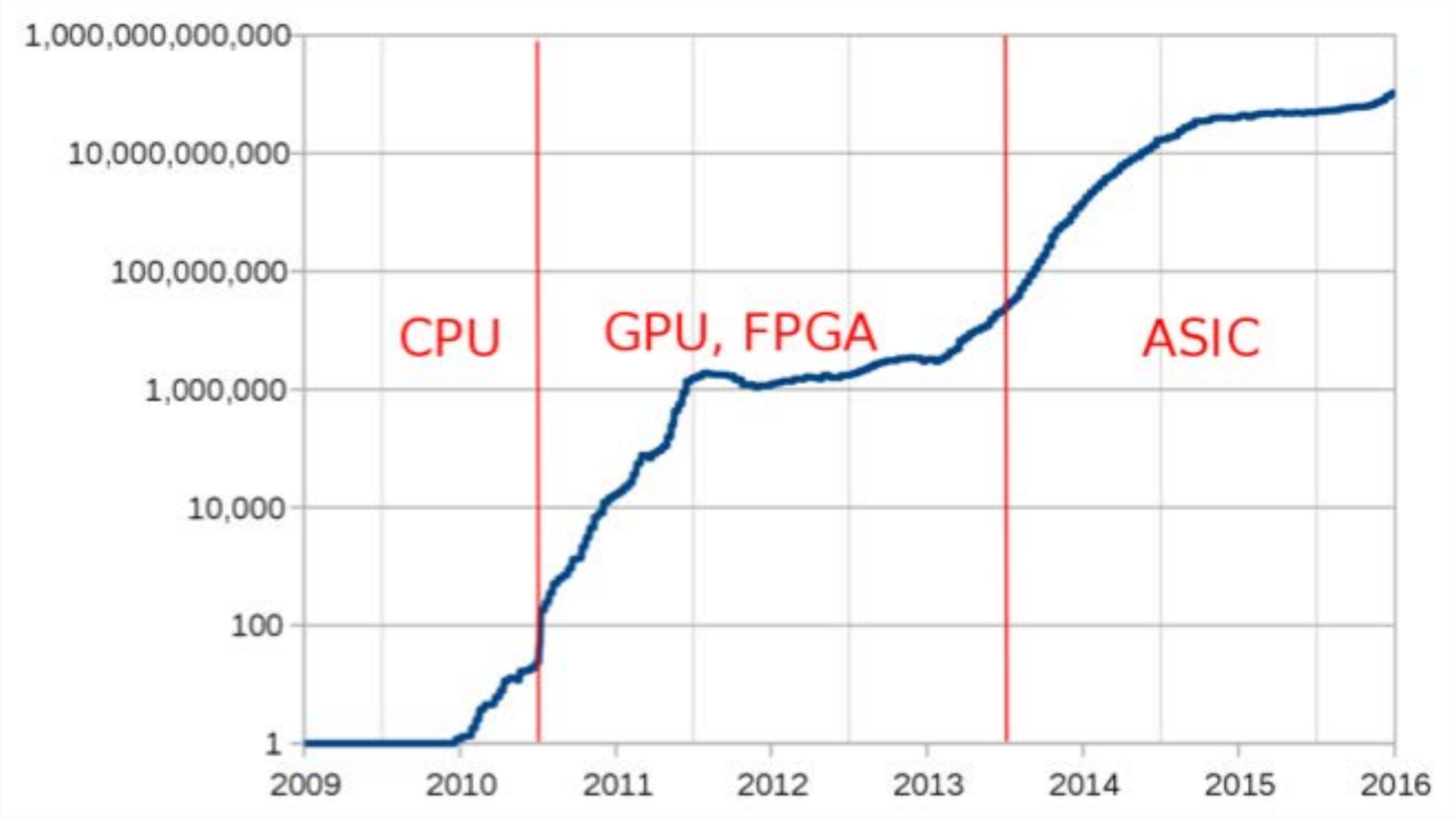
Mining bitcoin now

Mining bitcoin - difficulty



Bitcoin PIZZA

I'll pay 10,000 bitcoins for a couple of pizzas.. like maybe 2 large ones so I have some left over for the next day. I like having left over pizza to nibble on later. You can make the pizza yourself and bring it to my house or order it for me from a delivery place …

https://bitcointalk.org/index.php?topic=137.0

Eventually someone took him up on the offer and Hanyecz ended up eating a meal that, only some years later, would be worth $71 million.

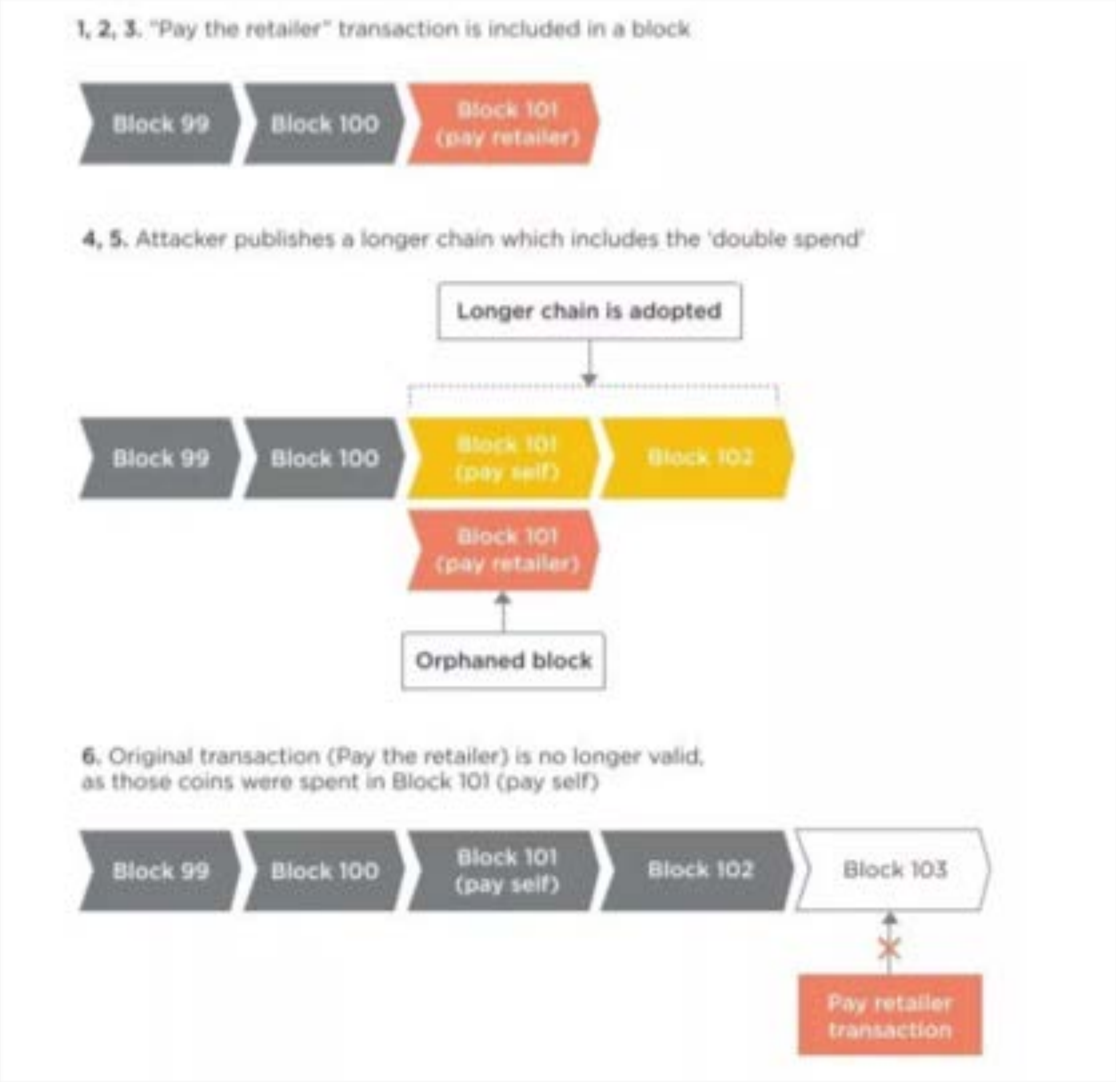
Every year, the crypto community celebrates 'Bitcoin Pizza Day' on May 22.

Double spending attack

Attacks the part lof the system not covered directly by cryptography: order of transactions.

Attacker strategy

- Send 100 BTC to a merchant/retailer in exchange for some product (Block 101-pay retailer);
- Wait for the delivery of the product
- Produce another transaction sending the same 100 BTC back to the attacker (Block 101, Pay self)
- Try to convince the network that this latter transaction was the one that came first.



Double spending attack

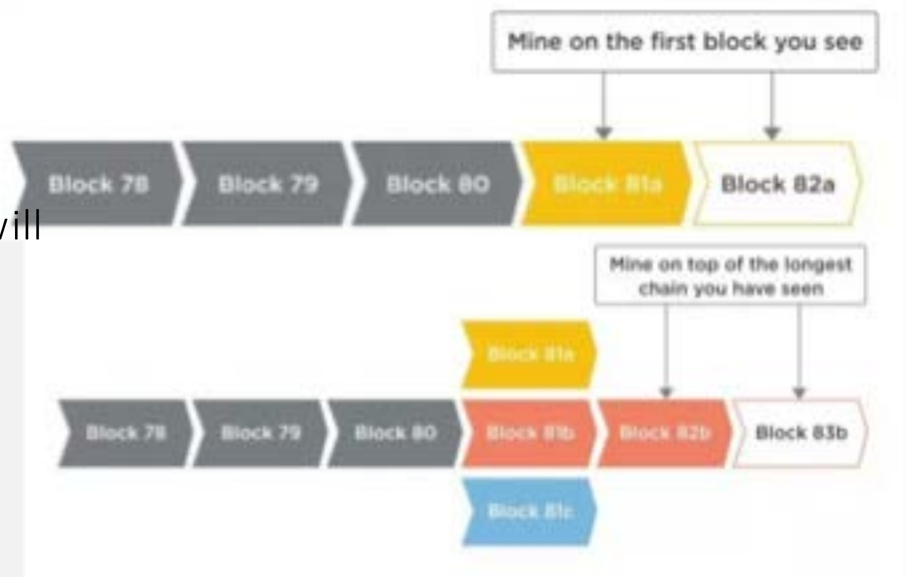
-The attacker creates another transaction sending the 100 BTC back to himself.

the transaction will not be processed as miners will notice that funds are already spent

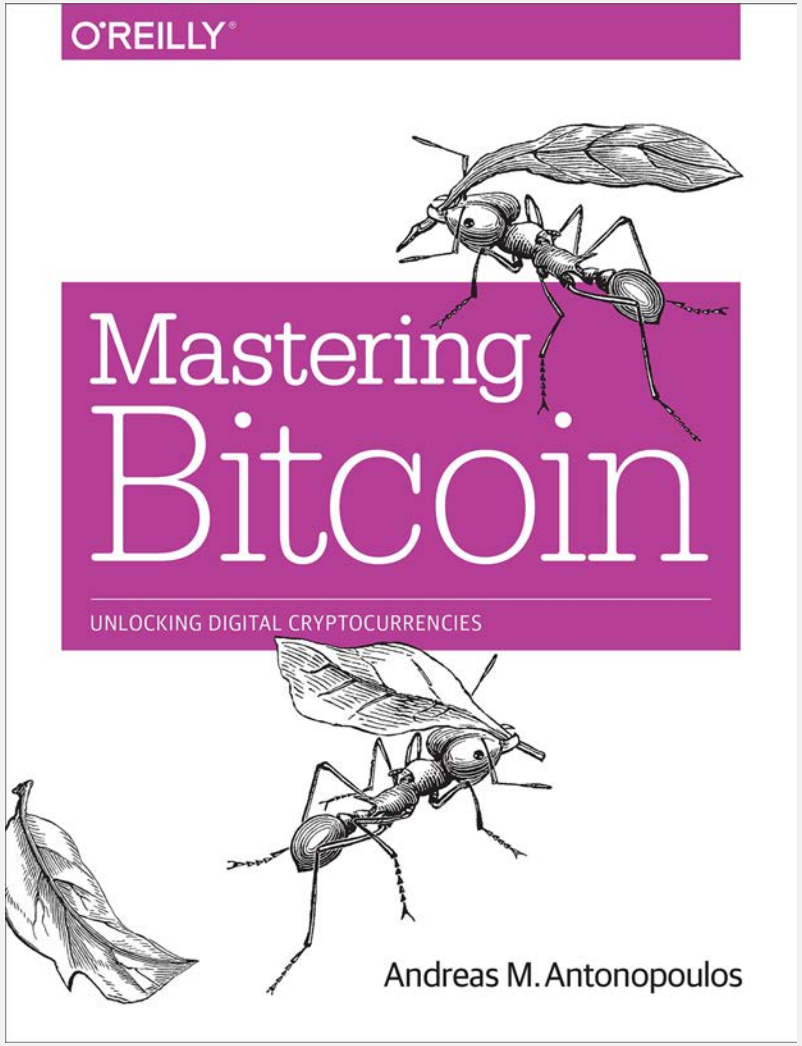
-the attacker creates a "fork" of the blockchain, by mining another version of block 270 pointing to the same block 269 as a parent but with the new transaction in place of the old one

-In case of a fork the longest blockchain is taken to be the truth: legitimate miners will work on the 275 chain while the attacker is working on the 270 chain.

- In order for the attacker to make his blockchain the longest, he would need to have more computational power than the rest of the network combined in order to catch up (hence, "51% attack").



For more infos…



https://github.com/bitcoinbook/bitcoinbook

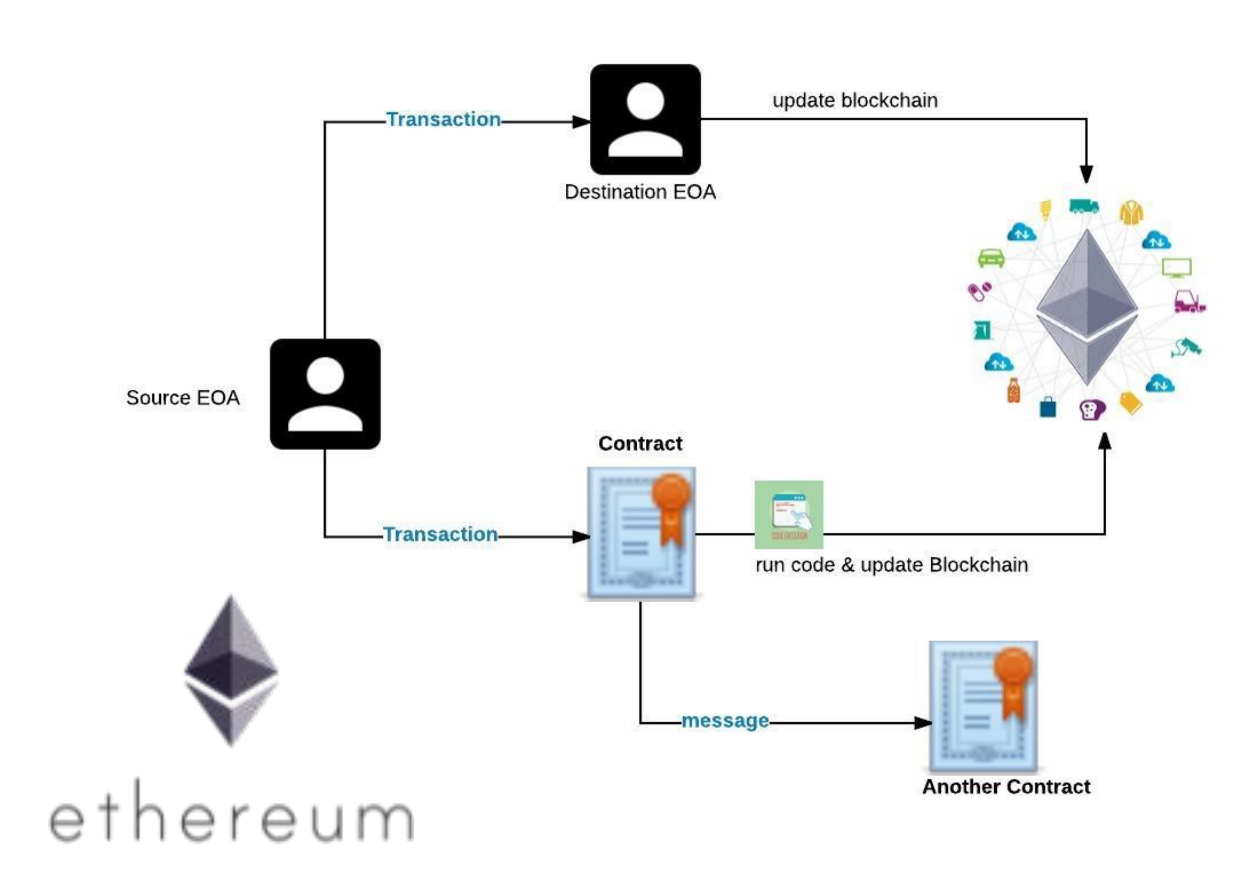
BlockChain + Smart Contracts: Ethereum

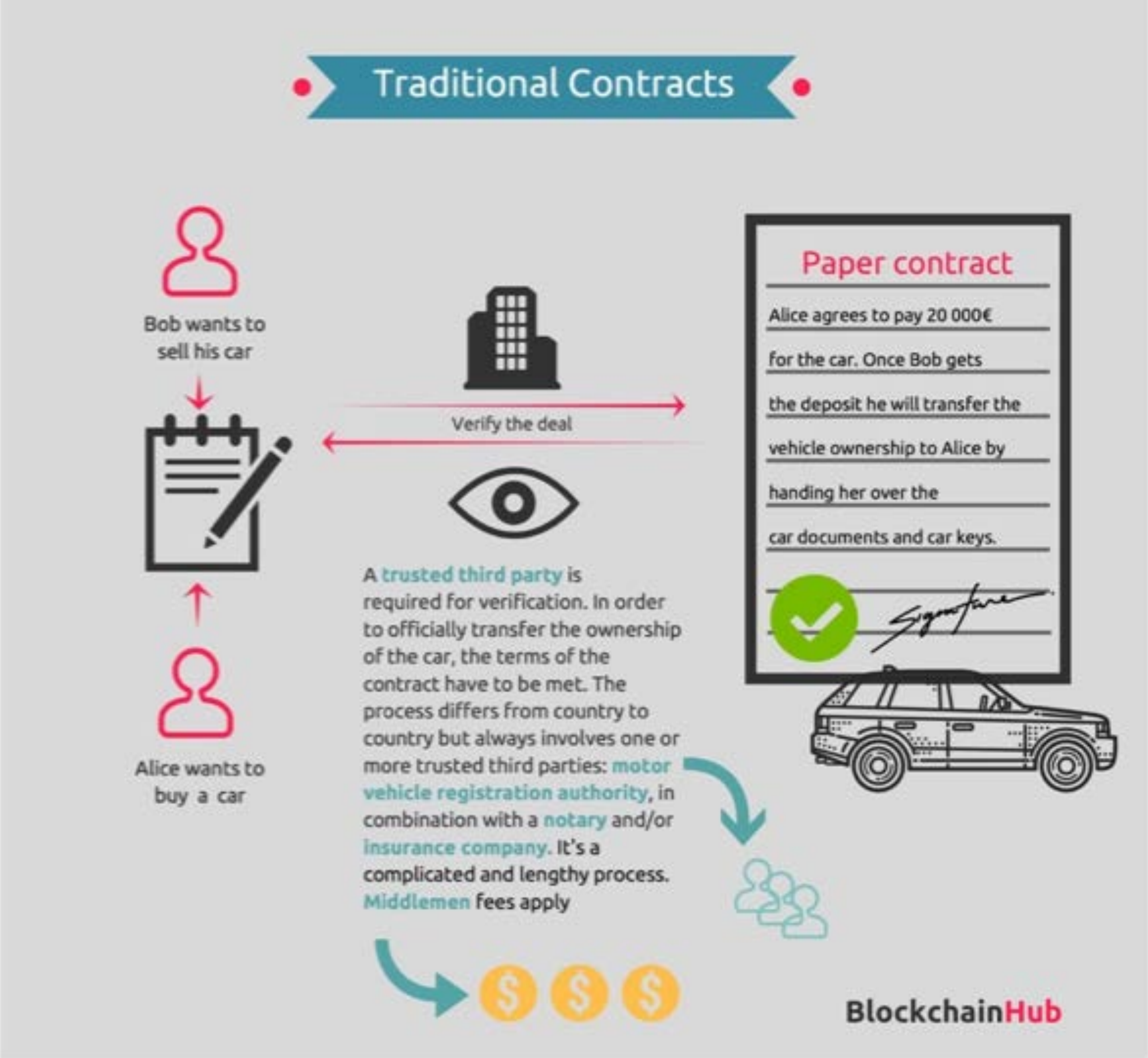
Ethereum is a blockchain with a built-in fully Turing-complete programming language that can be used to create «smart contracts»: a piece of code implementing arbitrary rules controlling the digital assets on the blockchain.

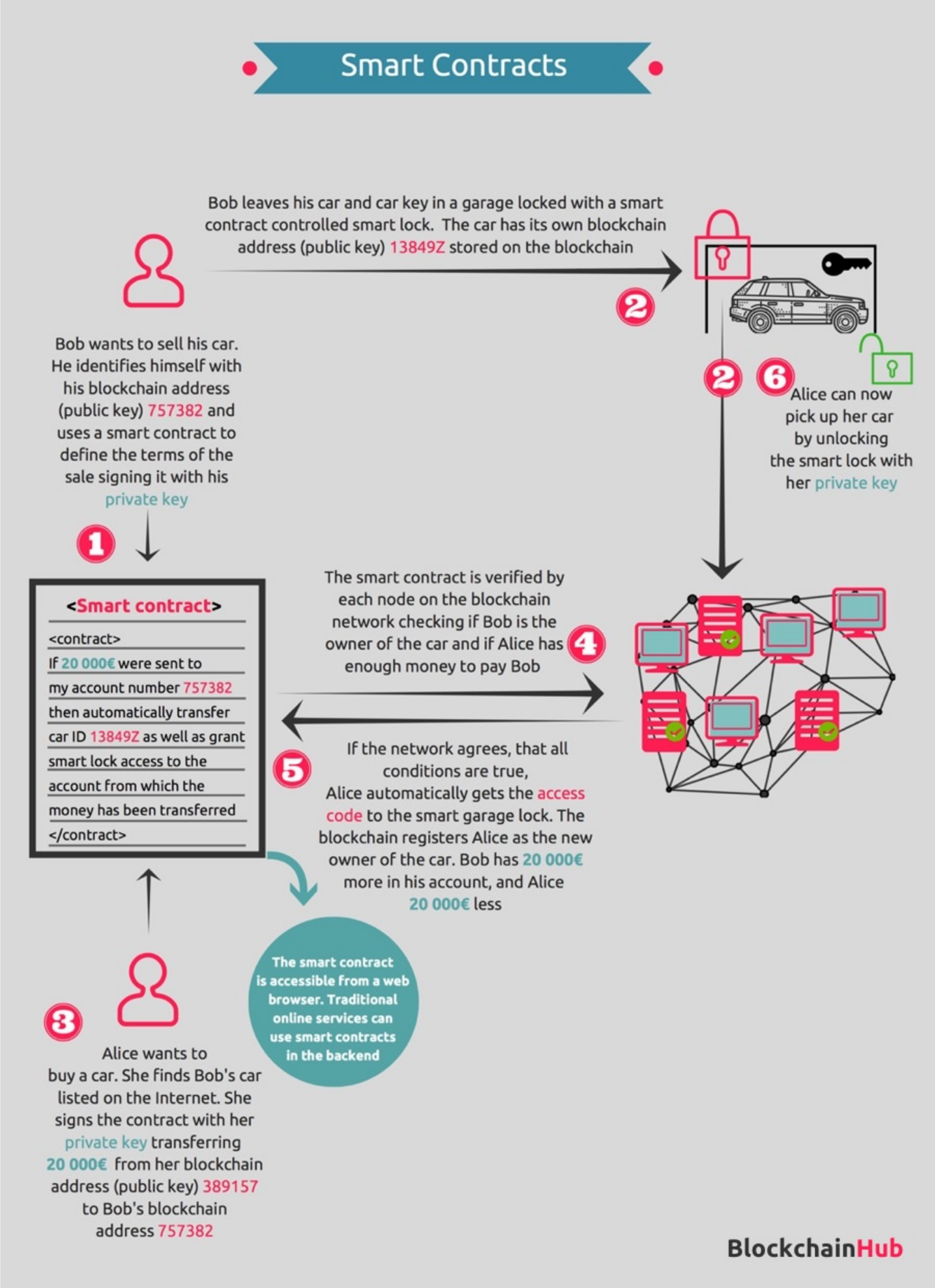
The structure of the ethereum blockchain is very similar to bitcoin's, in that it is a shared record of the entire transaction history. Every node on the network stores a copy of this history.

The big difference with ethereum is that **its nodes store the most recent state of each smart contract, in addition to all of the ether transactions.**

For each ethereum application, the network needs to keep track of the 'state', or the current information of all of these applications, including each user's balance, all the smart contract code and where it's all stored.




Traditional Contracts
Bob wants to sell his car
Alice wants to buy a car
Verify the deal
A trusted third party is required for verification. In order to officially transfer the ownership of the car, the terms of the contract have to be met. The process differs from country to country but always involves one or more trusted third parties: motor vehicle registration authority, in combination with a notary and/or insurance company. It's a complicated and lengthy process. Middlemen fees apply
Paper contract
Alice agrees to pay 20 000€
for the car. Once Bob gets
the deposit he will transfer the
vehicle ownership to Alice by
handing her over the
car documents and car keys.
Signature
BlockchainHub



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Ethereum

In Ethereum, the state is made up of objects called "accounts", with each account having a 20-byte address and state transitions being direct transfers of value and information between accounts.

An Ethereum account contains four fields:

The **nonce**, a counter used to make sure each transaction can only be processed once **(THIS IS NOT THE BLOCK NONCE!)**
The account's current **ether balance**

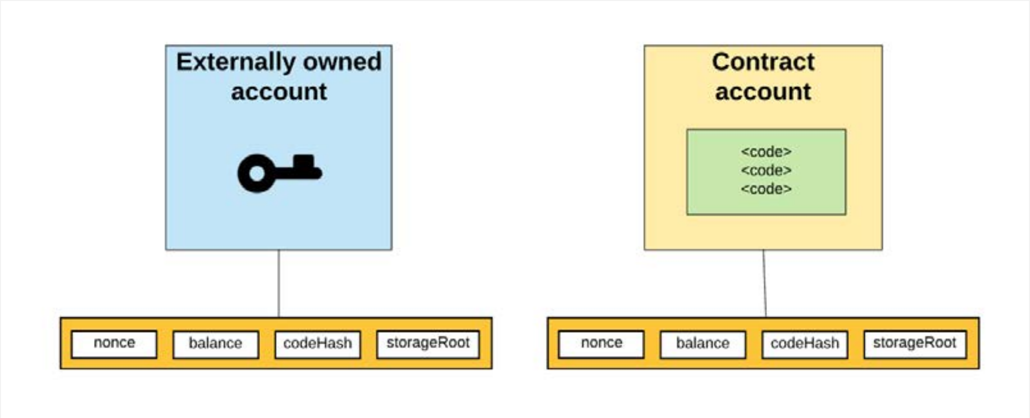
The account's **contract code**, if present
The account's **storage** (empty by default)

"Ether" is the main internal crypto-fuel of Ethereum, and is used to pay transaction fees.

In general, there are two types of accounts:

externally owned accounts, controlled by private keys: account has no code, and one can send messages from an externally owned account by creating and signing a transaction;

contract accounts, controlled by their contract code: every time the contract account receives a message its code activates, allowing it to read and write to internal storage and send other messages or create contracts in turn.



Ethereum contracts

"contracts" are like "autonomous agents" that live inside of the Ethereum execution environment
Always executing a specific piece of code when "poked" by a message or transaction
Have direct control over their own ether balance and their own key/value store to keep track of persistent variables.

The term "transaction" is used in Ethereum to refer to the signed data package that stores a message to be sent from an externally owned account.

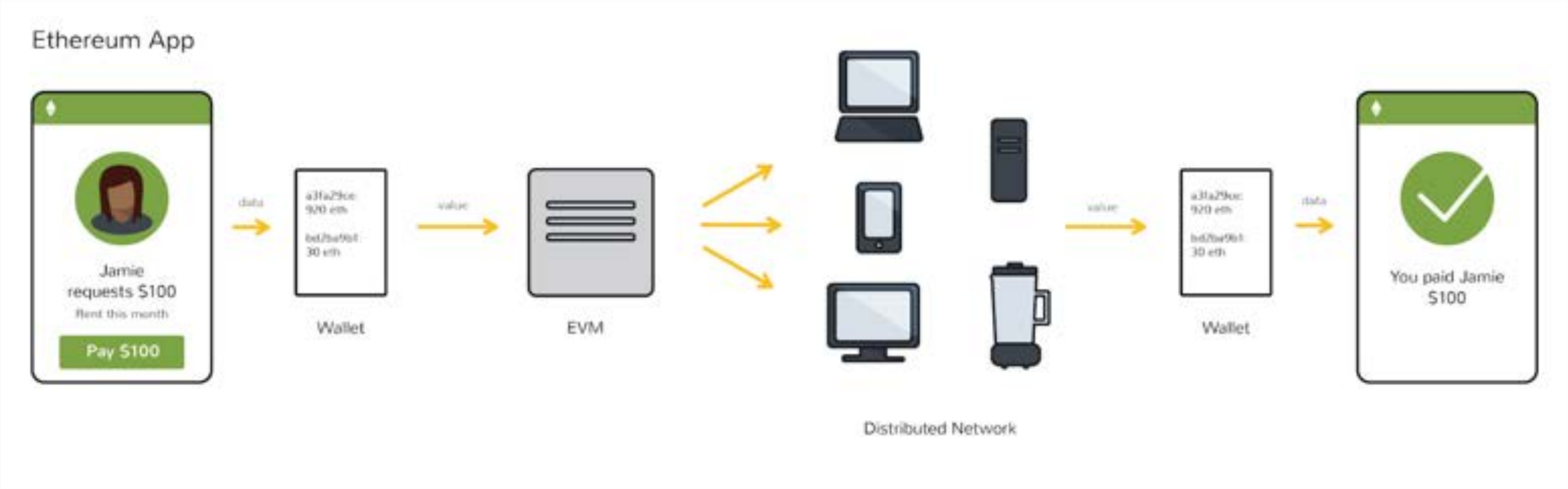
Transactions contain:
The recipient of the message
A signature identifying the sender
The **amount of ether to transfer** from the sender to the recipient
An optional **data field**
A **STARTGAS value**, representing the maximum number of computational steps the transaction execution is allowed to take
A **GASPRICE value**, representing the fee the sender pays per computational step

```
signedTransaction = {
    nonce: web3.toHex(0),
    gasPrice: web3.toHex(20000000000),
    gasLimit: web3.toHex(100000),
    to: '0x687422eEA2cB73B5d3e242bA5456b782919AFc85',
    value: web3.toHex(1000),
    data: '0xc0de',
    v: '0x1c',
    r: '0x668ed6500efd75df7cb9c9b9d8152292a75453ec2d11030b0eec42f6a7ace602',
    s: '0x3efcbbf4d53e0dfa4fde5c6d9a73221418652abc66dff7fddd78b81cc28b9fbf'
};
```

Ethereum

Contracts written in a smart contract-specific programming languages (Solidity and Serpent) are compiled into ‘bytecode’, which a feature called the ‘ethereum virtual machine’ (EVM) can read and execute.

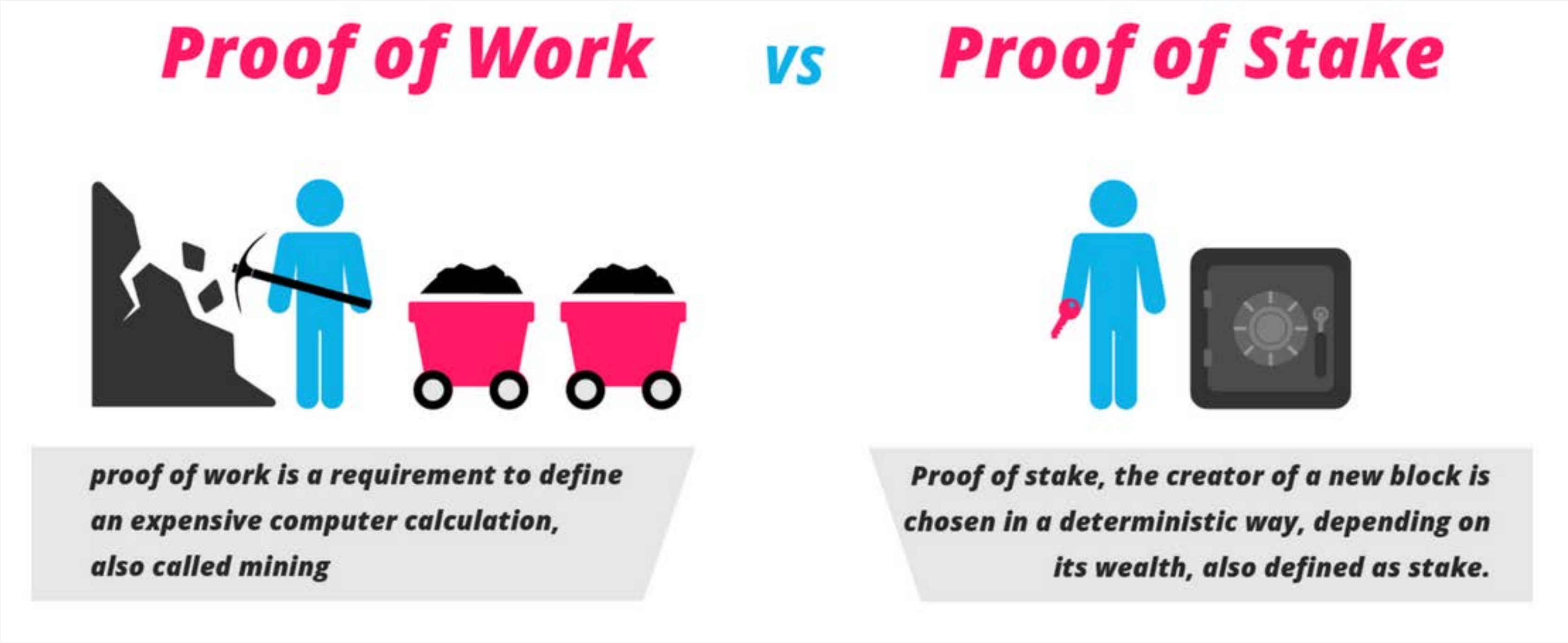
The goal here is for the network of miners and nodes to take responsibility for transferring the shift from state to state, rather than some authority such as PayPal or a bank.



Proof of stake

Unlike the proof-of-Work, where the algorithm rewards miners who solve mathematical problems with the goal of validating transactions and creating new blocks, with the proof of stake, **the creator of a new block is chosen in a deterministic way, depending on its wealth, also defined as stake.**

If Casper (the new proof of stake consensus protocol) will be implemented, there will exist a validator pool. Users can join this pool to be selected as the forger.



Let's play!

We will implement a simple (but working) blockchain in Python
tinyurl.com/y4sms6ls

Questions?