



A technical introduction to Blockchain technology

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Outline

- 1 Preliminary concepts
- 2 How does it work?
- 3 Blockchain by generations
- 4 Cardano: A scientific research-driven Blockchain
- 5 Cryptocurrency wallets
- 6 Why is it revolutionary?
- 7 Some conclusions

Outline

1 Preliminary concepts

- Consensus

- Proof of Work

- Proof of Stake

3 Blockchain by generations

- Preliminaries

- First Generation

- Second Generation

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5 Cryptocurrency wallets

6 Why is it revolutionary?

- The future will be decentralized

- Worldwide financial services

7 Some conclusions

What is a Blockchain?

- A **distributed cryptographic ledger** shared amongst all nodes participating in a network, over which every transaction is recorded.
- Blockchain serves as the **underlying** technology of several cryptocurrencies such as Bitcoin.
- The concept and its implementation was created in 2008/2009 and announced in a 9-page paper written by Satoshi Nakamoto.

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Ledger

The **foundation of accounting**, are as ancient as writing and money (Mesopotamia < 5000 B.C.).



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Cryptographic

The procedures and protocols to **append** new data to the ledger implies the use of cryptographic techniques.

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Distributed

Not a single entity is the owner of the data, but it is **replicated** in every participant of the network.

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Bitcoin

was the first and most popular *peer-to-peer value exchange* network.

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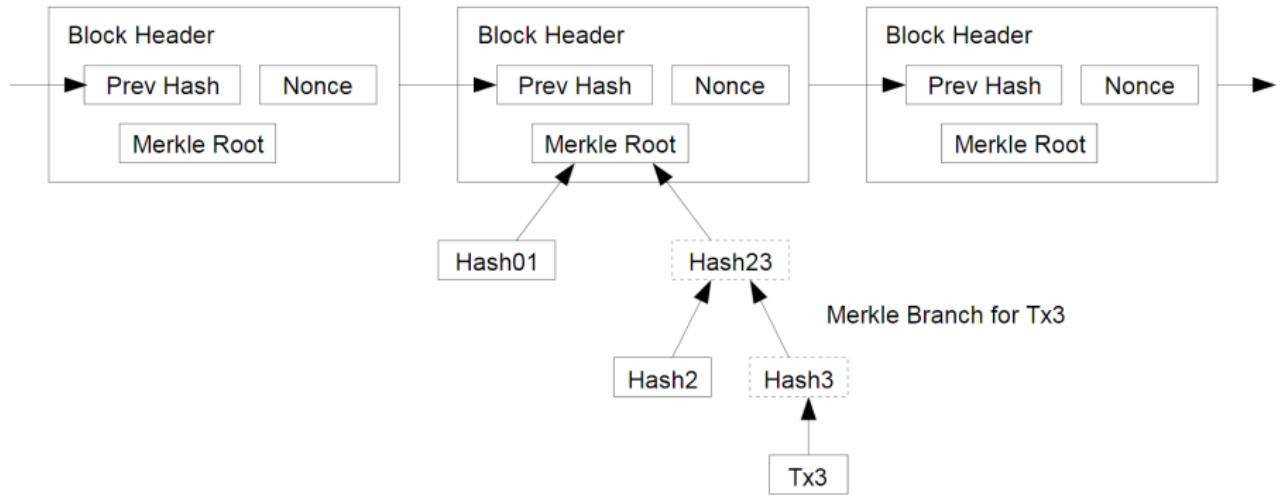
is a pseudonym of an anonymous individual or group that developed the idea of Blockchain and Bitcoin.

What is a Blockchain?

Now we know, but... how does it look like?

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What is a Blockchain?

Cool! But why?

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Cool! But why?

- **Suppress** the necessity of trusted third-party (i.e. financial institutions and banks).
- Move **trust** from central authorities to decentralized secure protocol.
- Create an economical system not driven by central institutions.
- **Empower** people.
- Enable almost **immediate** transactions.
- Offer **lower fees** than traditional banking.
- Let people become their own bank.

A bit more background

- Since Bitcoin appearance in 2009, several other cryptocurrencies emerged.
- Currently most of them are based in some kind of Blockchain.
- Blockchain provides a **reliable** infrastructure that provides at least 2 out of the 3 properties of CIA triad: **integrity** and **availability**.

Integrity

By the use of asymmetric cryptography the integrity of the data is guaranteed.

Availability

As a decentralized network, there is no single point of failure.

Confidentiality

It seems that some implementations could provide it as well (e.g. ZCash).

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“ We can see it as an Internet-native way to store and exchange value ”

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How does it work?

“It is all about consensus”

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"It is all about consensus"

- Blockchain concept is in continuous **evolution** and new protocols are continuously created to improve the current flaws.
- Earliest implementations (which includes Bitcoin and Ethereum) are using a system called *Proof of Work (PoW)* to **validate** the transactions.
- Validation is required in order to **append** a new block of transactions to the chain; preventing things such as double spend.
- The process of block validation is known as **mining**.
- Lately a new system called *Proof of Stake (PoS)* was developed to address PoW flaws.

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- Nodes are motivated to maintain the network with a **reward** coming from transaction fees.
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Transaction work-flow

- ① Clients **create** and **sign** transactions (TX) using their private key, then they **broadcast** TX to the network.
- ② Network nodes (miners) receive transactions and store them in the so called **mempool**.
- ③ Miners **prioritize** transactions based on fees, **validate** and **put** them in a block.
- ④ Once successfully created and **verified** by the network, the block is finally **appended** to the chain.

But how does it work under the hood?

Proof of Work: The Bitcoin case

Block creation (mining)

Participants of a Blockchain network put computational **resources** to validate transactions by **solving** the so called **cryptographic puzzles**.

Proof of Work: The Bitcoin case

Block creation (mining)

Participants of a Blockchain network put computational **resources** to validate transactions by **solving** the so called **cryptographic puzzles**.

- Block creation consists in finding a **nonce** (number) for the block that **satisfies** a property of the block's hash (a number of leading zeros) known as **difficulty**.
- This is a trial and error procedure (a kind of brute-force).
- The first node that finds a successful solution **announces** it to the network.
- The rest of the nodes can **easily verify** that the solution (and hence the block) is valid.
- If a node acts **dishonestly**, the rest of nodes will discard the block.

Proof of Work: The Bitcoin case

Drawbacks

- Huge energy consumption.
- Susceptible to a 51% attack.
- Democratization of the network (hardware, electricity price, . . .)

Proof of Stake

Given the aforementioned problems that PoW presents, the new Proof of Stake (PoS) model was developed.

Block creation (forging)

Participants of the network **stake** an amount of currency they hold (a kind of deposit) to be able to forge and **send** a block to the network.

Proof of Stake

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Participants of the network **stake** an amount of currency they hold (a kind of deposit) to be able to forge and **send** a block to the network.

- The next block creator (called forger) will be chosen randomly following certain criteria.
- The forger **verifies** transactions, **forges** a new block and **sends** it to the network.
- As in PoW, new block is added to the chain and forger receives transaction fees (and its stake back).
- If the forger acts **dishonestly**, the rest of nodes will discard the block and forger will **lose** the **stake**.

Proof of Stake

Pros

- A way more **energy** efficient: there are no computational resources required.
- More democratization and hence **decentralization**.
- **Security**: Purchasing more than half of the coins is likely more costly than acquiring 51% of PoW hashing power.

Several proposals have been presented, studied and even implemented but PoS still faces some **challenges** that must be addressed.

Proof of Stake

“ Not so *trivial* ”

Recursive Formula for Reach & Margin

$$[\rho(w1), \mu(w1)] = [\rho(w) + 1, \mu(w) + 1]$$

$$[\rho(w0), \mu(w0)] = \begin{cases} [\rho(w) - 1, 0] & \rho(w) > \mu(w) = 0 \\ [0, \mu(w) - 1] & \rho(w) = 0 \\ [\rho(w) - 1, \mu(w) - 1] & \text{otherwise} \end{cases}$$

it is possible for the adversary to compensate for the margin, by sacrificing reach

reach never drops below 0

reach and margin decrement

Forkable strings are rare!

partition string in equal segments

$$w = 0101\dots \quad \dots \quad \dots \quad 0101$$

$$(\rho \geq \delta\sqrt{n}) \wedge (\mu \geq -\delta\sqrt{n})$$

$$-\delta\sqrt{n} \leq \mu \leq \rho < \delta\sqrt{n}$$

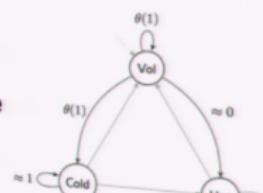
$$\mu < -\delta\sqrt{n}$$

$$\text{density is } 2^{-\Omega(\sqrt{n})}$$

Hot

Volatile

Cold



$$\text{error is } 2^{-\sqrt{n}}$$

Ouroboros: A Provably Secure Proof-of-Stake Blockchain Protocol

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Definition

Turing Completeness

A programming language is said to be Turing Complete (TC) if can be used to simulate a Turing Machine and hence to **solve any** mathematical/computational problem.

A TC-language has some important properties:

- conditional branching;
- infinite **looping** ability;
- [...]

First Generation: Bitcoin

Bitcoin was the first implementation of the Blockchain and is considered the **first generation** of Blockchain.

- Bitcoin has a programming language called **Script** used to “encode” the transactions, and to **control** how the payee of a TX can access the funds.
- But, Script is **not** a **TC-language** (has no loops)...
- ... so Bitcoin can be **merely** used as a **store of value** and **exchange of value** network.



For its nature, it is usually called digital gold.

Current implementation presents **scalability** issues (≈ 7 TPS)

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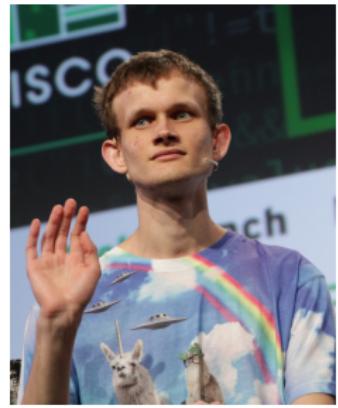
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Second Generation: Ethereum

Ethereum, which is considered a **second generation Blockchain**, was released in 2015 after two years of research and development.

- Co-founded by Vitalik Buterin, a young cryptocurrency researcher/programmer.
- Features a **TC-complete** programming language called **Solidity** (and experimental Vyper).
- An **abstraction** of the 1st gen. that allows **not only** exchange “money” but the execution of any program.
- These programs are called **Smart Contracts**.
- Users pay fees for contract (program) execution.



Vitalik Buterin

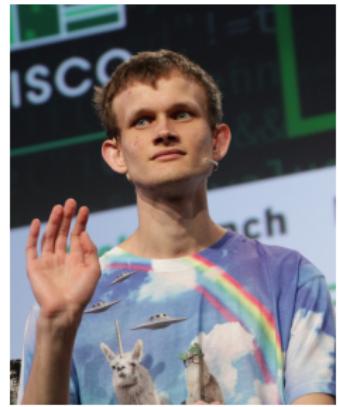
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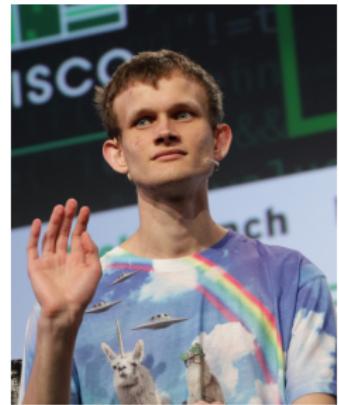
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Smart Contracts

"A smart contract is a set of promises, specified in digital form, including protocols within which the parties perform on these promises."

Nick Szabo, 1996

Example: ICO

When participating in an Initial Coin Offer (ICO) a user **sends funds** (an investment) to a Smart Contract.

The contract **encodes the rules** of the agreement: usually a number of tokens proportional to the investment will be sent back to the user (which represents his investment in the project).

No third party is involved.

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Third Generation

The 3rd generation of Blockchain is mainly focused to address two of the main issues of the 2nd generation:

- Scalability
- Security

Scalability

A 3rd generation of Blockchain should be able to scale to several thousands of TPS.

Network usage (**bandwidth**) and **data storage** should scale efficiently.

Security

Smart contracts should be able to be verified using **Formal Verification**.

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Cardano

is a 3rd generation Blockchain focused to address limitations of 2nd generation Blockchains.



Charles Hoskinson,
co-founder of Cardano
and former co-founder of Ethereum

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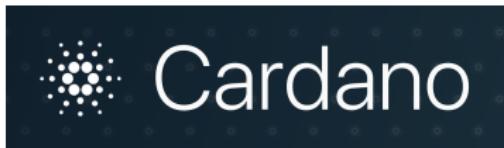
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Cardano



- Born in 2015 as an effort to **change the way** cryptocurrencies are designed and developed.
- Developed together by IOHK company and several universities.
- **Scientific** research model and **peer review**.
- The Blockchain for ADA cryptocurrency.
- Considered a **3rd generation** Blockchain.
- Different approach: **How to scale** instead of how many TPS.
- Current development roadmap planned at least until 2020.
- ADA was launched to trade in October 2017.

Cardano

Key features

- Proof of Stake (Ouroboros consensus algorithm)
- Sustainable ecosystem
- Strongly focused on scalability
- Interoperability with other Blockchains
- Smart contracts
- Treasury
- Based on epochs and quorums
- Parallelize transactions amongst quorums will allow to scale
- Reduces network pressure by using RINA

Cardano

Aims to **solve** 3 main problems of current cryptocurrencies:

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Scalability

PoS and parallelization of epochs → Δ TPS (Transactions per second)

Split network in subnets (RINA) → ∇ Bandwidth

Pruning, compression, partitioning → ∇ Storage

Cardano

Aims to **solve** 3 main problems of current cryptocurrencies:

- Scalability
- Interoperability
- Sustainability

Interoperability

Allow different cryptocurrencies to **talk each other**.

Allows **metadata** into TX → Better integration with banks/governments.

Cardano

Aims to **solve** 3 main problems of current cryptocurrencies:

- Scalability
- Interoperability
- Sustainability

Sustainability (Treasury)

The **treasury** is a special wallet not controlled by anyone that receives a small percentage of every transaction.

It promotes **continuous improvement** of the system by funding the most voted improvement proposals.

It will keep Cardano sustainable.

Powered by smart contracts.

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What is a cryptocurrency?

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Cryptocurrency

A **digital asset** (or currency) that relies on cryptography to work and runs over a decentralized network, **typically** backed by a Blockchain.

Crypto in crypto-currency does **not** mean that all information in the Blockchain is **encrypted** and secret...

- Bitcoin Blockchain is not confidential at all as transaction details are public.
- ... But can be **challenging** to trace and **relate** transactions.

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Cryptocurrency

A **digital asset** (or currency) that relies on cryptography to work and runs over a decentralized network, **typically** backed by a Blockchain.

Crypto comes from the use of cryptographic techniques used by the protocol such as:

- Public-key (asymmetrical) cryptography
- Cryptographic hashes (e.g. SHA-256 Bitcoin)
- ... (*probably more*)

What is a cryptocurrency [wallet](#)?

What is a cryptocurrency **wallet**?

What is **not** a wallet...

A software or physical device where your coins are **stored inside**.

What is a wallet indeed...

The term wallet can refer to 2 things:

- Ⓐ a software that allows to interact with a Blockchain (a light client);
- Ⓑ a store for your addresses and its **private keys**;

where usually $A \supset B$.

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Type of wallets

Some different kind of wallets exist:

By type

| Type | Example |
|------------------|--|
| Software wallets | Electrum |
| Hardware wallets | Ledger |
| Paper wallets | walletgenerator.net |
| Brain wallets | keybase.io/warp |

By storage mode

- Hot storage
- Cold storage

Hierarchical Deterministic Wallets (HD)

- Introduced by BIP32 (2012), provides a way to generate **several** addresses from a **single** master key using key-derivation-functions.
- The whole wallet is generated from a seed (12 words) and is the only thing the user needs to back up.

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Key notes

- Address **reuse** is **discouraged** as compromises **privacy** and security
⇒ HD wallets allow zero-address reuse.
- The user does not need to **trust anyone** but himself to safely store his funds.
- But the **lost** of the key/seed results in the **inability** to access the funds (unlike traditional banking).

Bitkey

Bitkey is a [Linux live](#) distribution that includes a set of tools and wallets for some of the most popular cryptocurrencies.

It can run in 2 modes:

- Hot online: Interact with the Blockchain from a secure environment.
- Cold offline: This is the most secure way of operating as it starts as an [air-gapped](#) system where private key is **never** exposed.

As a side project has not received updates in a while, but a recent fork provided by @estevaocm on [GitHub](#) includes many interesting tools such as:

- QR-code scanning through webcam :) – A very convenient way to import and export TX and addresses.
- Support for several [other](#) cryptocurrency [wallets](#) other than Bitcoin (Ethereum, Litecoin,...) —more are being constantly added.

Outline

1 Preliminary concepts

- Consensus

- Proof of Work

- Proof of Stake

3 Blockchain by generations

- Preliminaries

- First Generation

- Second Generation

- Third Generation

4 Cardano: A scientific research-driven Blockchain

5 Cryptocurrency wallets

6 Why is it revolutionary?

- The future will be decentralized

- Worldwide financial services

7 Some conclusions

The future will be decentralized

Since its creation, Internet has been **mostly centralized**¹, which implies that it is:

- Easy to **watch/monitor**
- Easy to **censor**
- Easy to **attack**
- **Fragile** to failure

During the years more distributed and P2P protocols has been deployed, although **client-server** model is the most common yet.

¹ARPANET hosts file is a great example.

The future will be decentralized

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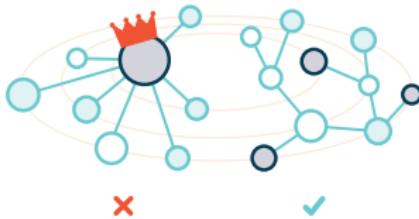
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But the appearance of new P2P systems can drive Internet to a new state

¹ARPANET hosts file is a great example.

The future will be decentralized



A nice example

IPFS (Inter Planetary File System)

Another example

Steemit is a blogging/social media website built on top of a Blockchain.

Steemit has proven to be able to run an entire social network in a Blockchain.

All blog entries are stored in the Blockchain.

The future will be decentralized

The future of the Internet?

Decentralization provides

- censorship resistance
- freedom of Internet
- democratization
- more privacy



Worldwide financial services

- >50% of world's population (2-3 billion people) does **not have access** to formal, or any kind of financial services at all.
- People **sending money** to their families in developing or third world countries pay **very high** fees.
- Access to **loans** for those unbanked collectives is difficult and they pay **extraordinary high** interests (>100% in some cases).

Worldwide financial services

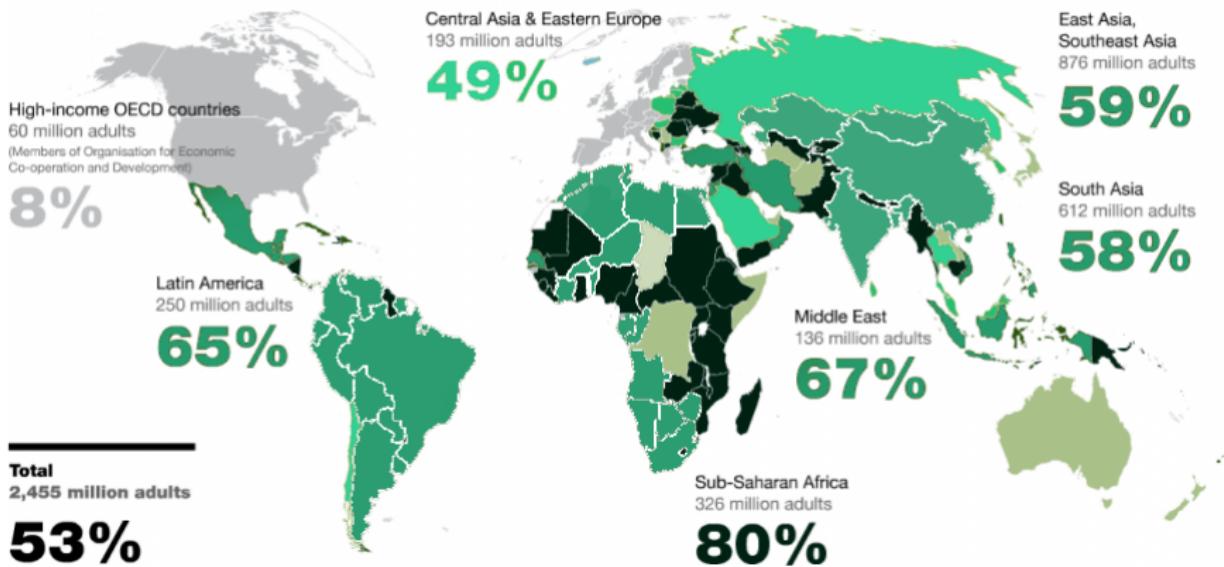
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Blockchain and Smart Contracts could provide the infrastructure to **tackle** such a serious problem.

Worldwide financial services

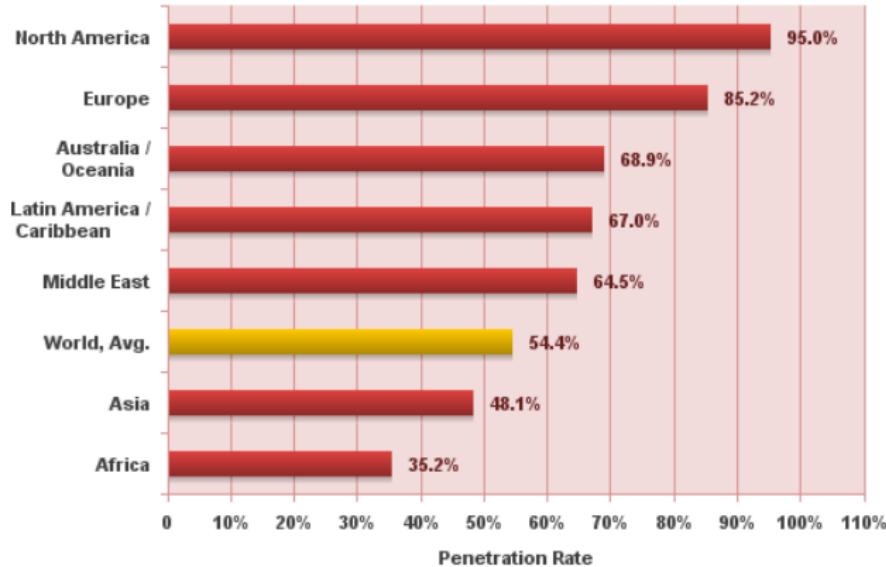


Estimates used to calculate regional averages



Percentage of **unbanked** people (Source: ethichub.com)

Worldwide financial services



But...

only 54.4% of world's population have access to Internet

(Source: Internet World Stats 2018)

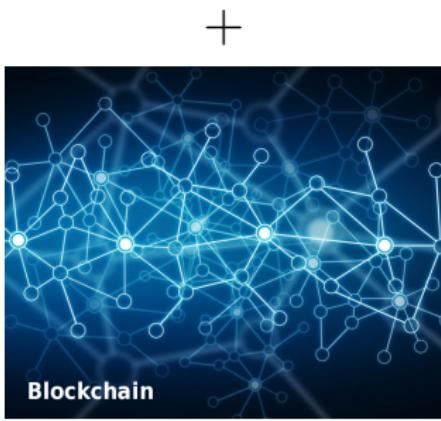
Technology to the rescue again

- **Starlink** is a project of SpaceX and co-financed by Google that aims to provide a global Internet connection using a constellation of satellites.
- Recently the first two satellites of what aims to conform a worldwide-available hi-speed Internet network have been launched.
- In near future, it could **potentially provide** Internet access to hundreds of millions of people that are offline nowadays.



Technology to the rescue again

- The combination of all these could **empower people**, bringing financial services everywhere.
- Everyone could become its own bank.
- Think about yourself being able to crediting third world population.
- It could flip the whole system.



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Some conclusions

As a result of all these, one can think:

- Wow! Technology is always awesome and has power to change the world.
- Traditional financial model is becoming out-dated...
- ...but for now, Blockchain ecosystem is probably not yet mature enough to drive world's economy.
- The future is going to be more decentralized.
- Awesome things could happen, but only time will tell.

Thanks for your time!

Questions?

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Slides code available on GitHub:



github.com/gerardbosch/blockchain-presentation

Updated PDF available online:



gerardbosch.github.io/blockchain-presentation