



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

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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

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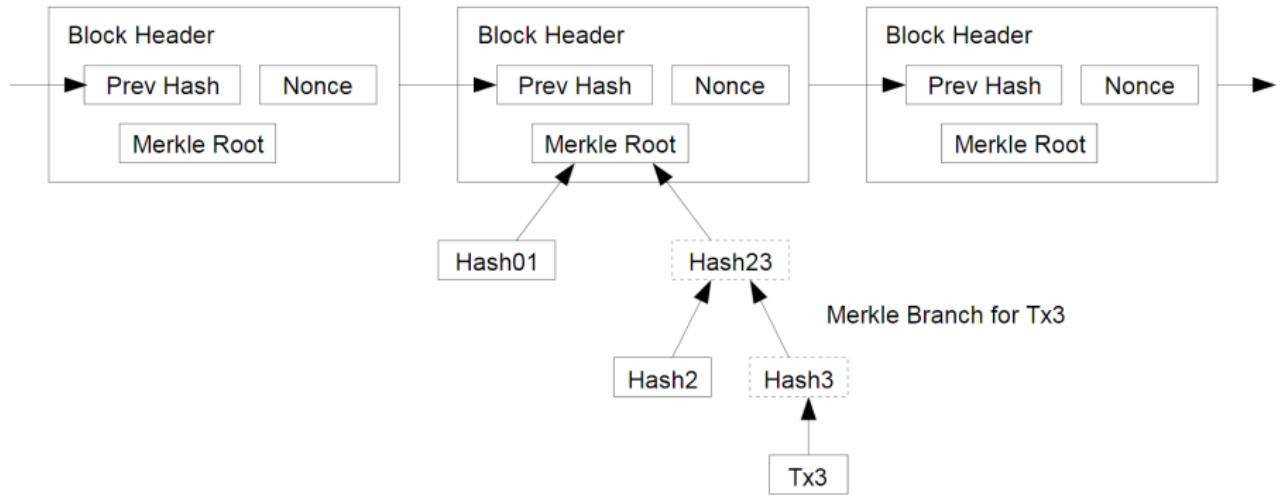
is a pseudonym of an anonymous individual or group that developed the idea of Blockchain and Bitcoin.

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”

How does it work?

"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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How does it work?

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- Nodes are motivated to maintain the network with a **reward** coming from transaction fees.
- Hence, **consensus** is achieved through these systems (PoW/PoS).

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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.

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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.

- 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

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

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

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

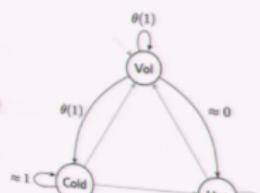
$$\mu < -\delta\sqrt{n}$$

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

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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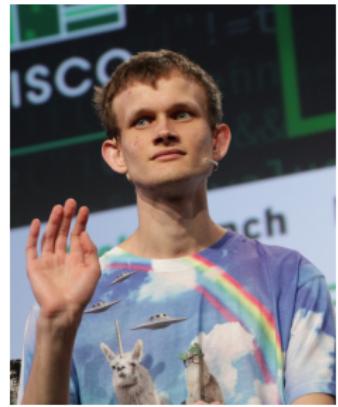
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Second Generation: Ethereum

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

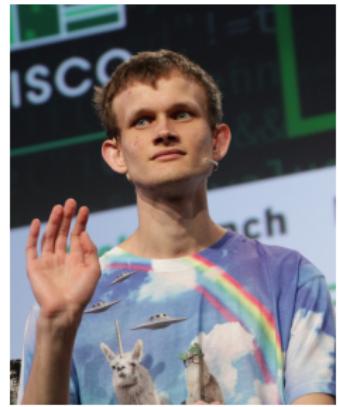
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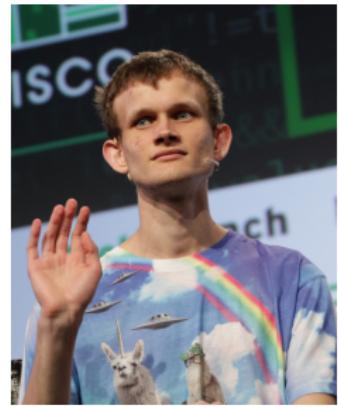
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Smart Contracts

"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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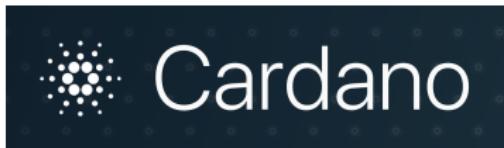
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Cardano



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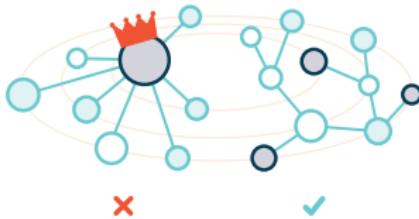
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During the years more distributed and P2P protocols has been deployed, although **client-server** model is the most common yet.

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

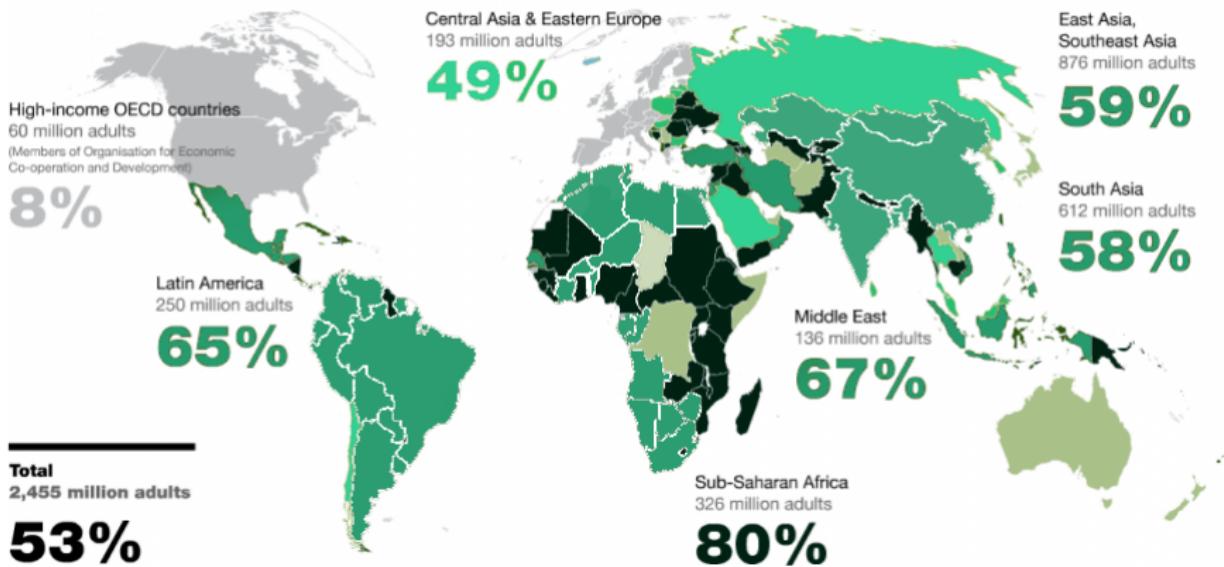
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Blockchain and Smart Contracts could provide the infrastructure to **tackle** such a serious problem.

Worldwide financial services

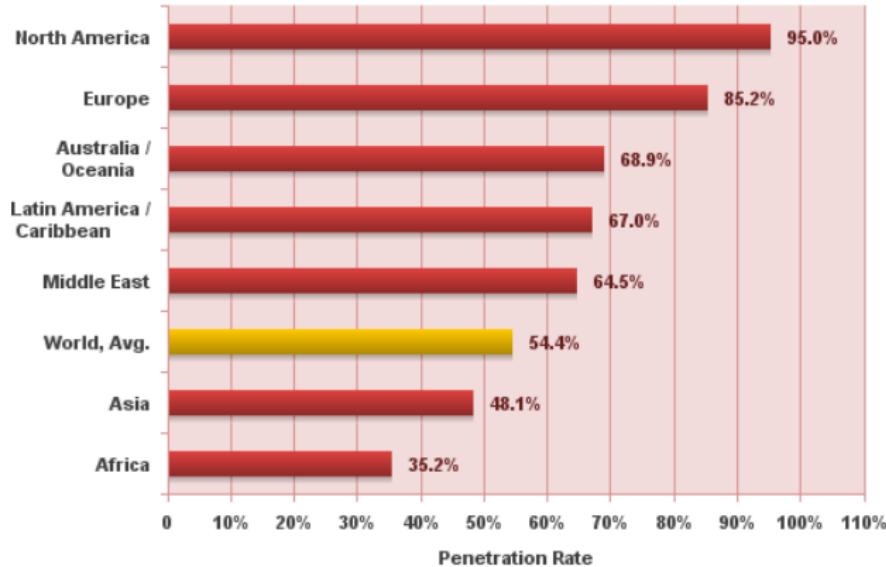


Estimates used to calculate regional averages



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

Worldwide financial services



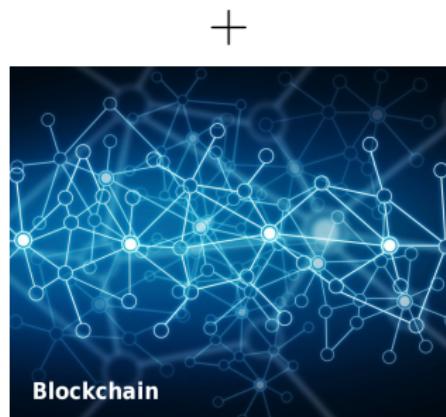
But...

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

(Source: Internet World Stats 2018)

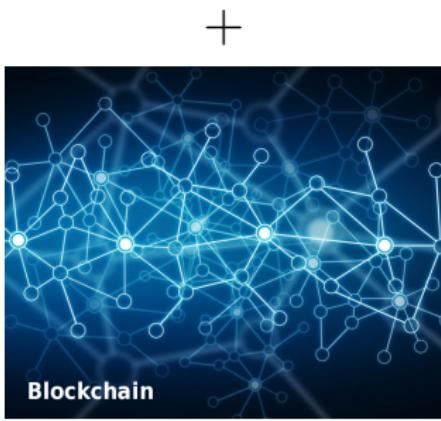
Technology to the rescue again

- **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