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National Technical University of Athens 2012

What is bitcoin?

- **Digital currency**
- For real **online payments**
- **Replacement** (?) for **€** and **$**

History

- **Wei Dai**, 1998: “Bmoney” (cypherpunks)
- **Satoshi Nakamoto**, 2009: ”Bitcoin: A Peer-to-Peer Electronic Cash System"
- 2009: bitcoind **open source client** in C++

Problem: Online payments

- A trusted authority is required
- Payments with **credit cards**
- **e.g. Visa, MasterCard**
- Or services such as **PayPal**
- **No anonymity**
- **Cost** for the services
- Can’t make very small transactions

Problem

- **People dislike central control**
- **€** and **$** are **centrally controlled**
- Government control of the economy may be undesired
- **Centrally controlled inflation**

Many people do not trust their government for managing the economy.

Problem

- We could use **gold** – objective value
- Hard to use
- **Slow**
- Inconvenient
- Dangerous

Solution

- A digital currency: **bitcoin**
- **Peer-to-peer** network

Advantages

- **Fast** payments (< 10’)
- **No** central authority
- **Free market** exchange rates
- **Secure** transactions
- **Anonymity**

Disadvantages?
From a government perspective…

- People are going to use **bitcoin** anyway
  - bitcoin is a fundamentally **good** idea
  - hard to illegalize
- Hard to track
  - People don't want to be tracked by governments
- Bad things can happen
  - Fraud
  - Money laundering
  - Illegal transactions (drugs, guns, …)
- Can a government…
  - Ensure safety and security?
  - Avoid fraud?
  - Maintain a growing economy for the nation?

Purpose of this talk

- Present bitcoin as it is today
- Illustrate what it is from the point of its creators and users
  - What problems it solves and how
- Discuss with you how the government fits into this scheme
  - In an evolving crypto-economy
  - What can a government do?

From a government perspective…

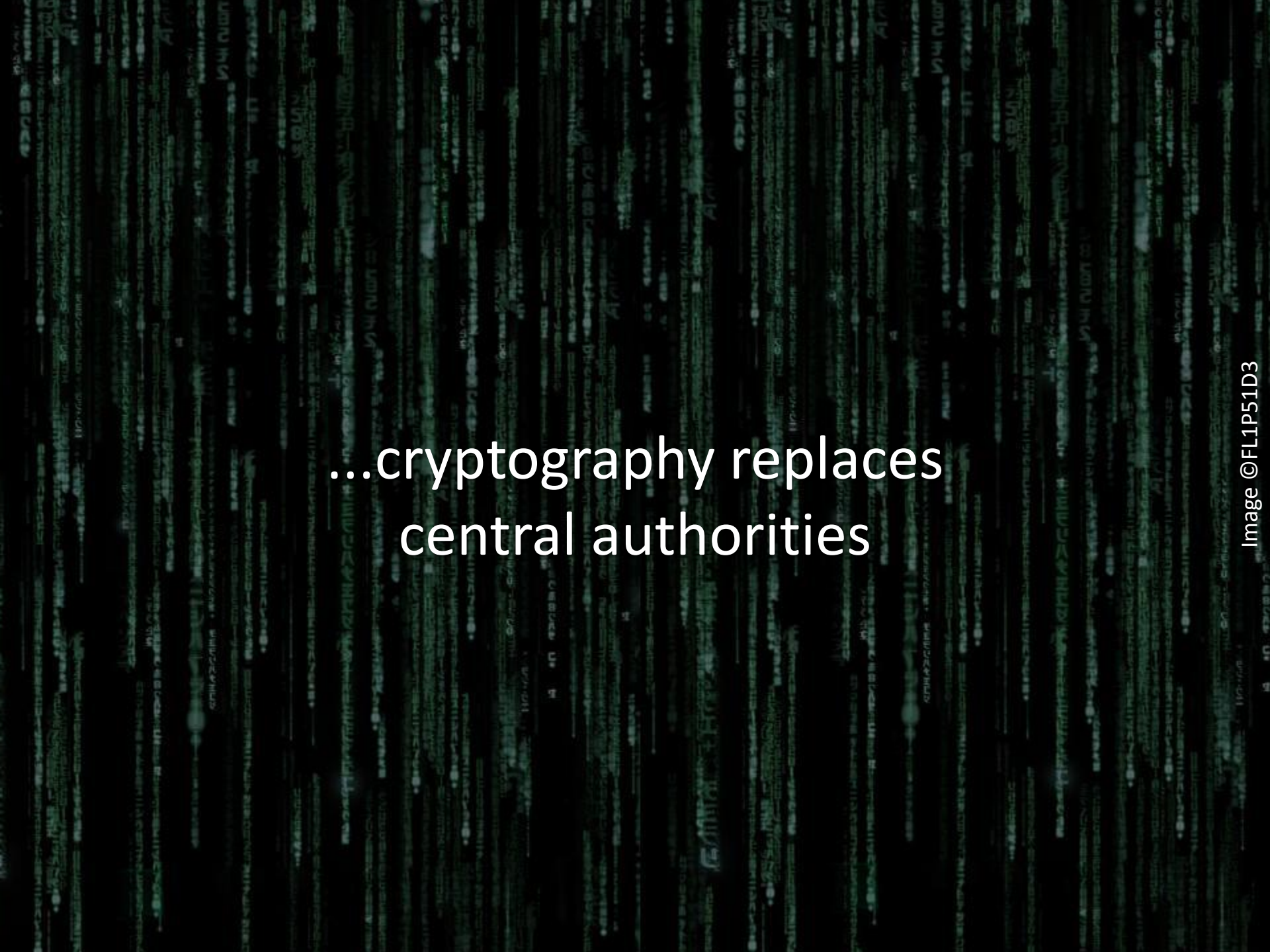
- bitcoin creators & users **don't like governments**
- Bitcoin is inherently an economy based on **anarchy**
- Many governments don't like bitcoin
  - China made it illegal in 2009
- But a government needs to know **what bitcoin is**
- It **cannot be ignored**
- It cannot be easily illegalized
- bitcoin creates problems for the government?
- We need to discuss how to solve them

The basic idea

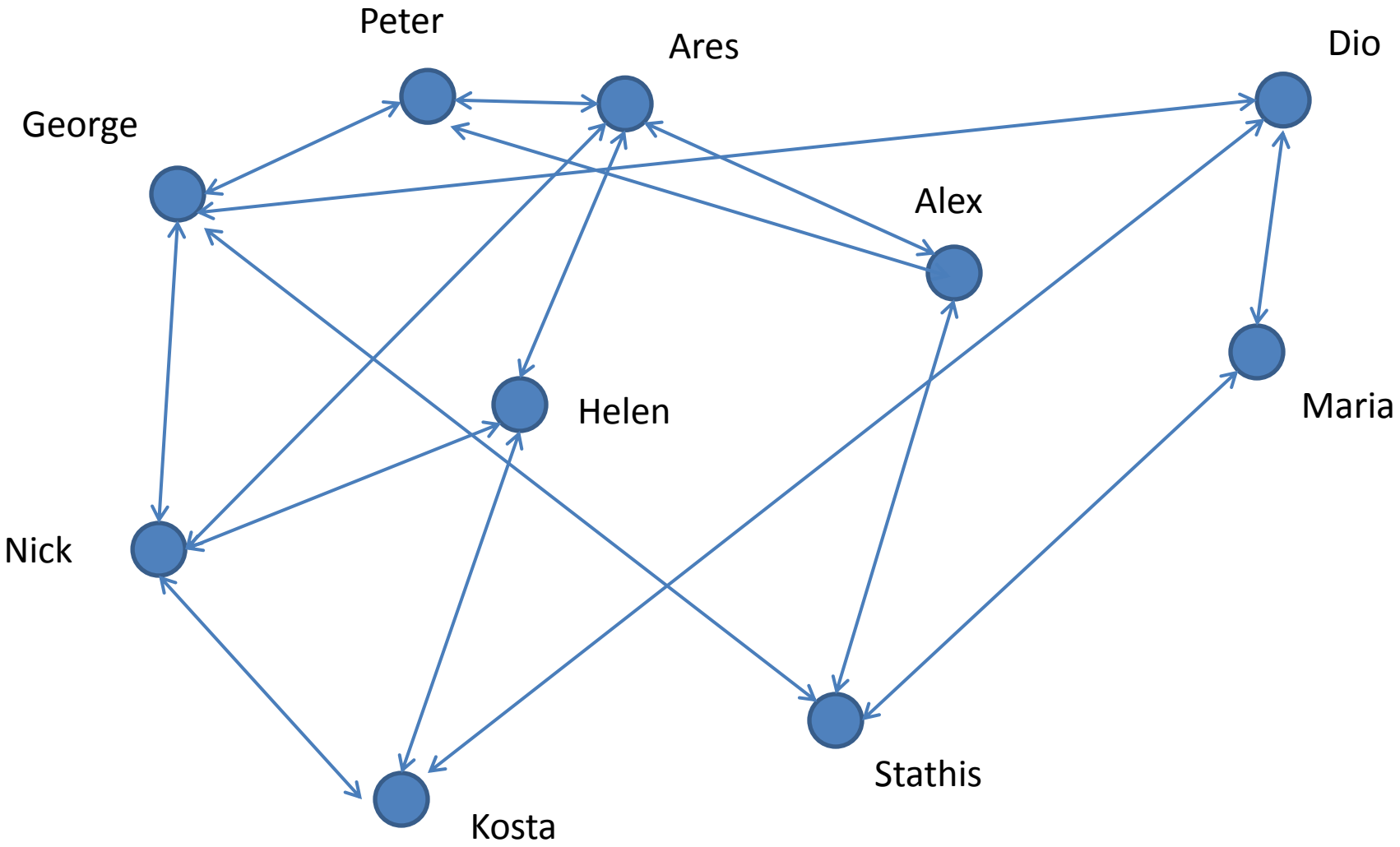
- Modern currencies **$** and **€**
- They're **virtual** – no **real** value
- They can be **any object**
  - …providing it cannot be cloned
- We agree, as a nation, to make a piece of **paper** into a **currency**

This doesn't inherently require a central authority!

...cryptography replaces central authorities



The bitcoin peer-to-peer network



Authentication

- Every **node** has a **private/public key**
- This ensures that **whoever** has the money, **it's them who make payments**
- **Public key** is **broadcasted** to the network
- Private key is stored locally on the node

Bob **Alice**

Has 12BTC **Has 0BTC**

m ← "Send 12BTC to Alice"
h ← H (m)
s ← $sign_{SB}$(h)

Has 0BTC

$verify_{PB}$(h)
Has 12BTC

Validity

- How do we ensure that the coin came from a **valid source** and is not **self-made?**

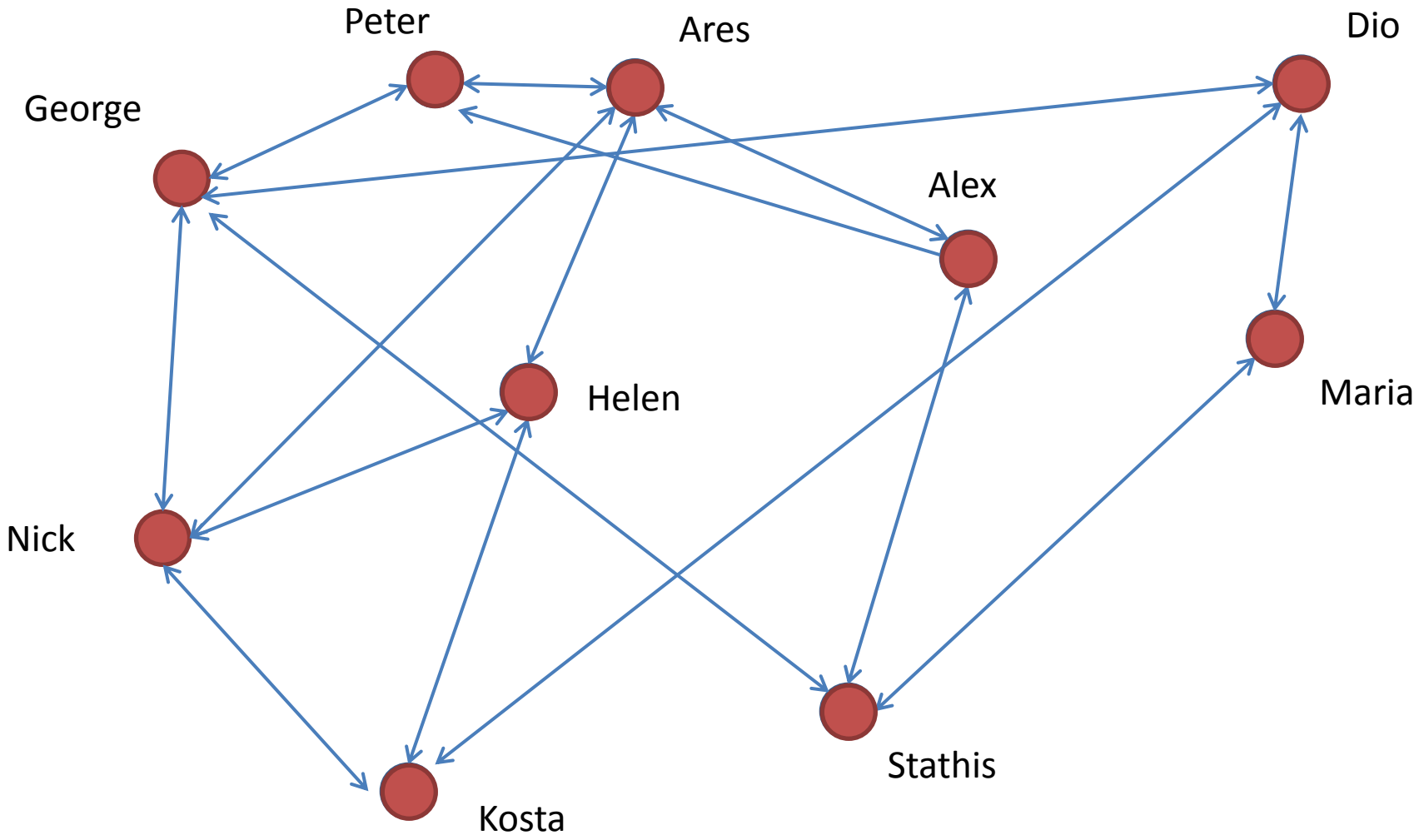
Who has what

- The network stores **collectively** who has how much money
- **Everyone** knows how rich Bob is
- **Everyone** knows how rich Alice is

- Therefore: Bob cannot send money he doesn't have
- To **give** money, I have to have **received** it

Broadcasting

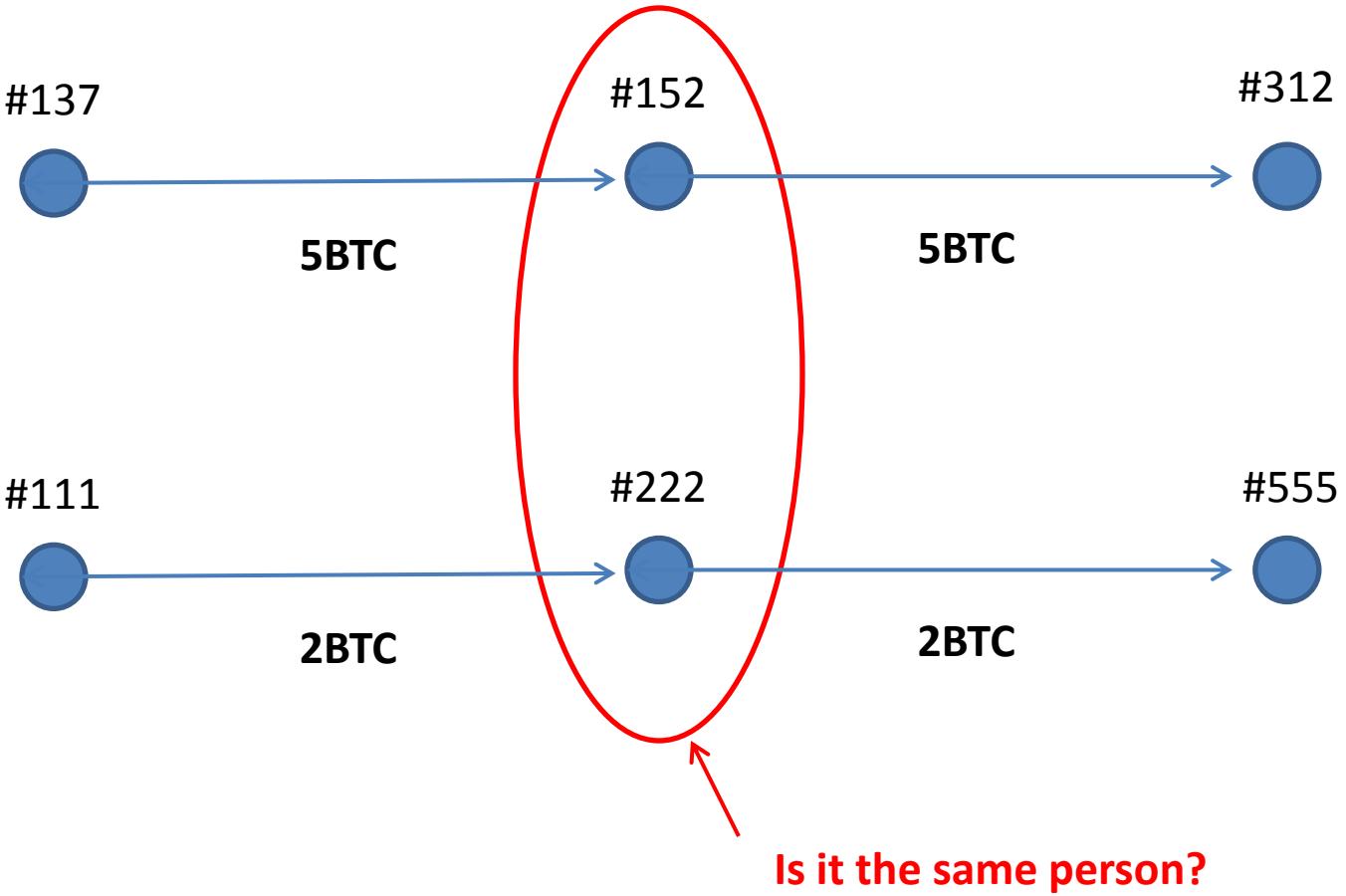
- Every transaction is **published** to the network
- Whenever I send or receive money, I communicate it to my neighbors


Peter
Ares
Dio
George
Alex
Helen
Maria
Nick
Stathis
Kosta

Anonymity

- For **every transaction** the participants use a **new private key**
- The nodes **don’t have names** – only keys

Anonymity


#137
#152
#312
5BTC
5BTC
#111
#222
#555
2BTC
2BTC
Is it the same person?

Bob

Uses the key with which he **received** the money
PB, SB

m1 ← "12BTC to PA"
h1 ← H(m1)

s1 ← $sign_{SB}$(h1)

Alice

Generates a **new** key for this transaction
PA, SA

ver_{PB}(s1)

m2 ← "12BTC to PC"
h2 ← H(m2)

s2 ← $sign_{SA}$(h2)

Charlie

Generates a **new** key for this transaction
PC, SC

ver_{PA}(s2)

Currency

- The measure according to which financial values are expressed or valuated.

- **A chain of digital signatures.**

Currency = Chain of digital signatures

…

$coin1 \leftarrow sign_{S0}(H(coin0 \,||\, P1))$

$coin2 \leftarrow sign_{S1}(H(coin1 \,||\, P2))$

$coin3 \leftarrow sign_{S2}(H(coin2 \,||\, P3))$

…

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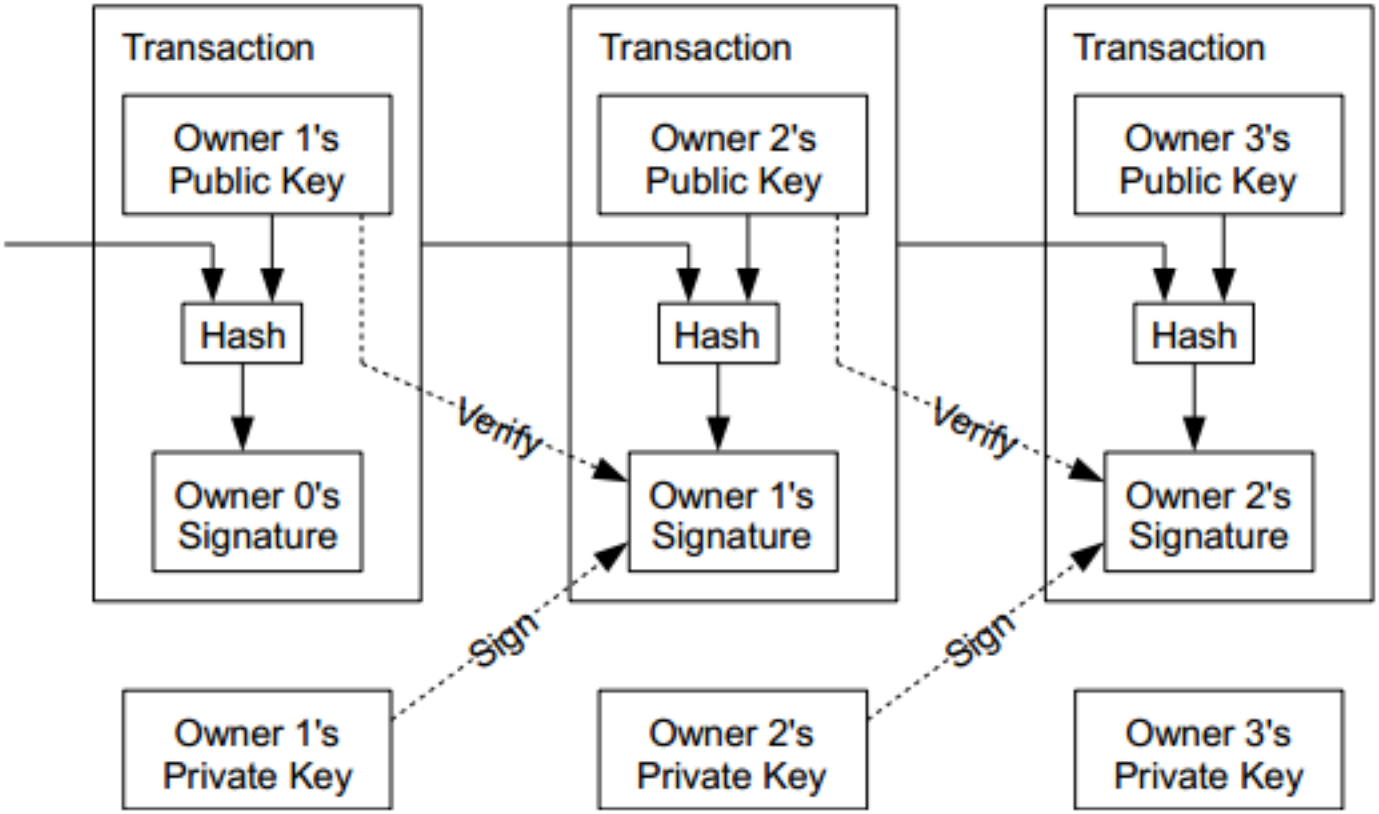

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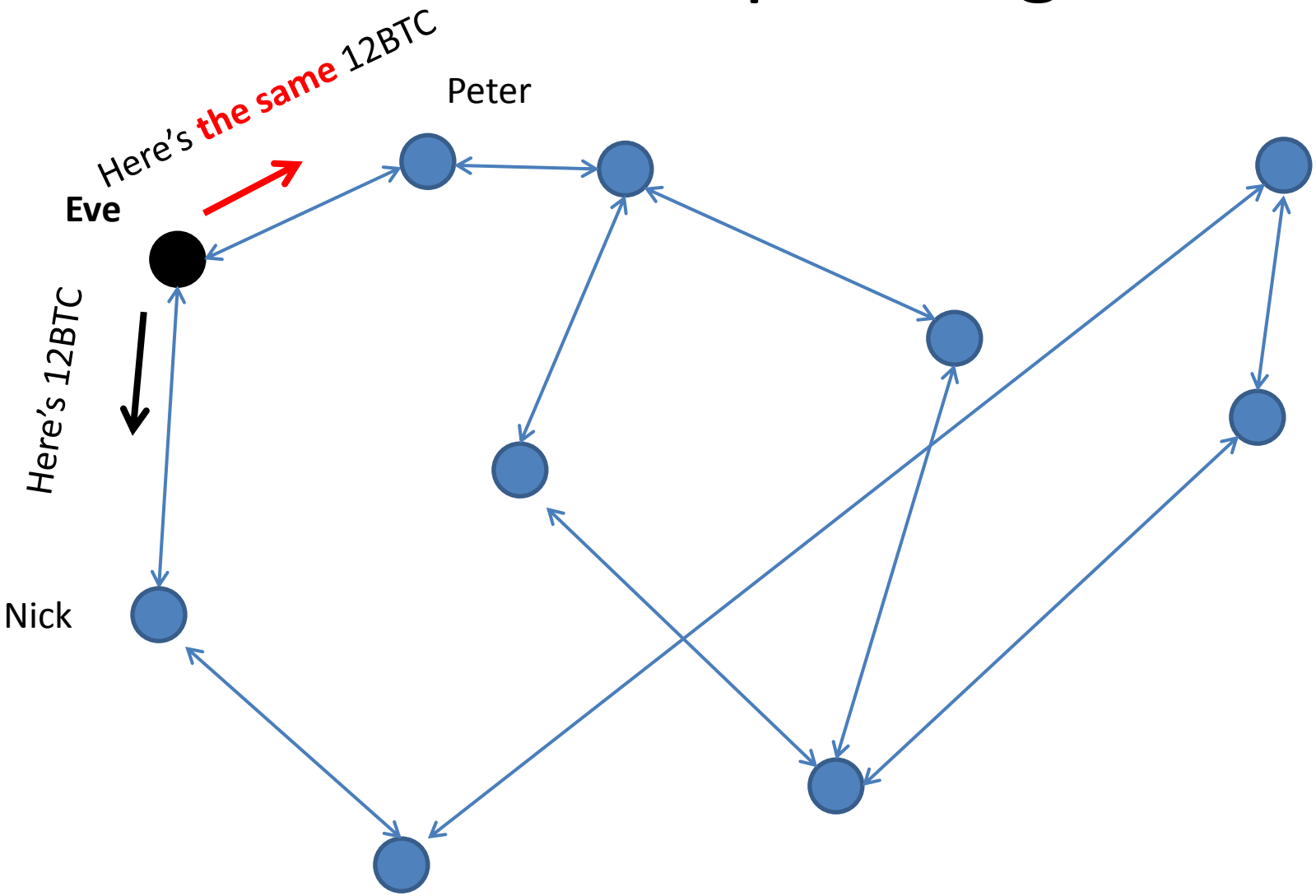
Double spending



Double spending

- Undesired
- How can we avoid it?

Valid transactions

=

Transactions that have **not** been acted out >= **twice**?

This would mean I can cancel a transaction I don't like!

Cancelling a transaction

- Bob pays 1BTC to Alice for a cup of coffee
- Alice delivers the cup of coffee to Bob
- Bob pays the same 1BTC to Charlie
- Charlie rejects the transfer
- The network considers both transactions invalid
- Alice loses her money
- Bob loses his money too – but he doesn’t care

We need a better way to prevent double spending!

The arrow of time

- **Valid** is the **first** transaction in the chain
- **Later** transactions are **invalid**

The arrow of time

- **When** did a transaction take place?
- I cannot trust a signature
- The date may be **forged**

Blocks

- Recent transactions are accumulated into a **block**
- Calculate **the hash** of each block
- Every new block includes the **hash** of its previous block
- Every block is published
- Every next block is in the **future** with respect to its previous block
  - Otherwise **it could not have known** its hash

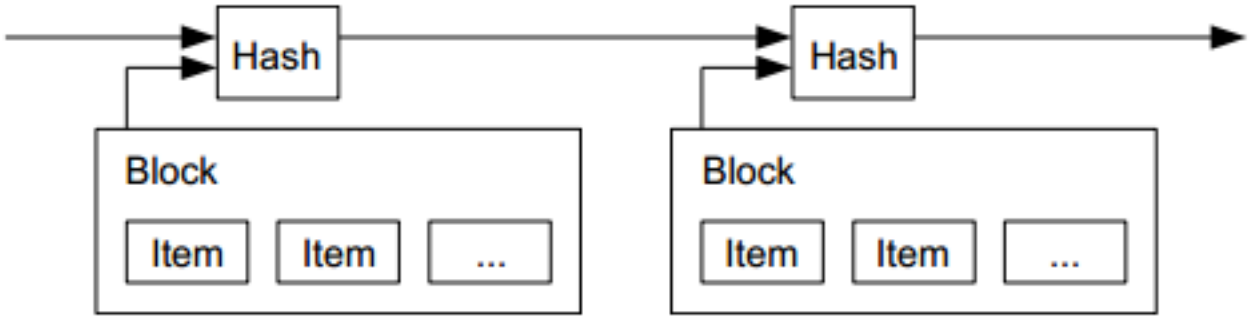


Image ©Satoshi Nakamoto

Proof of work

- We cannot just publish blocks
  - We'd need a trusted party
- Blocks are calculated at the node level and broadcasted
- We introduce an **artificial difficulty** to block generation
- It's **hard** to generate a block

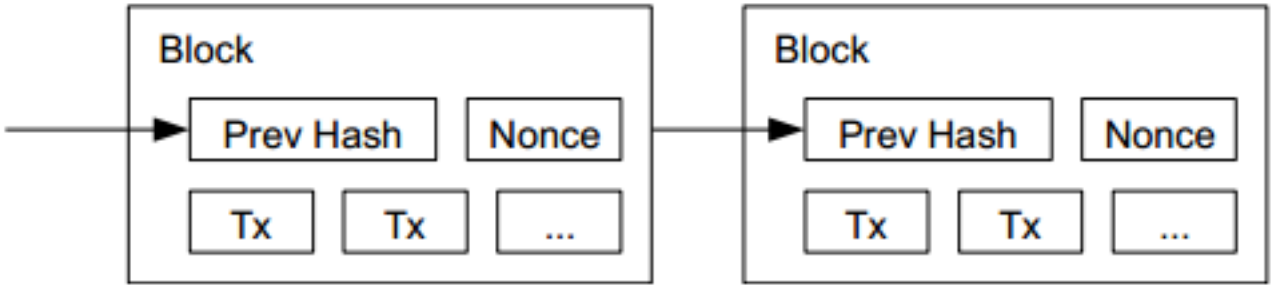


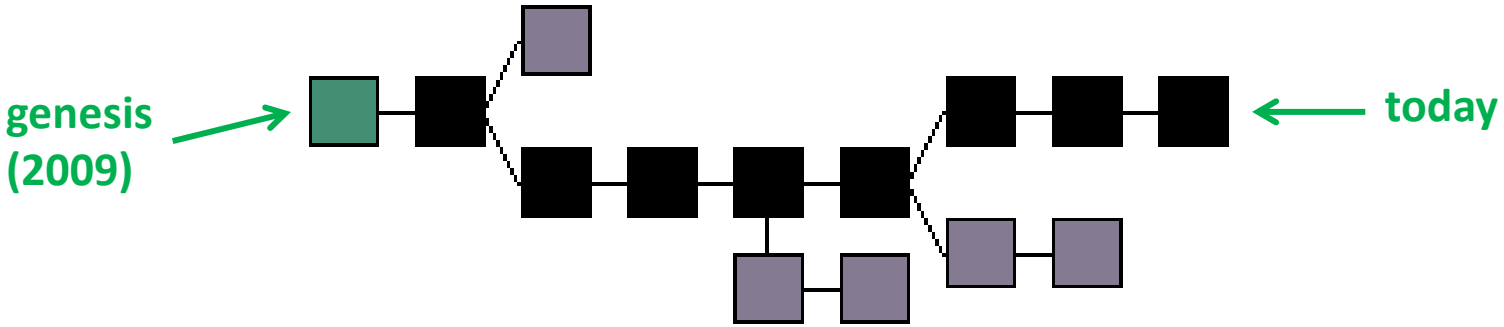
Image ©Satoshi Nakamoto

```
nonce ← 000000
while H( block || nonce ) ≠ “000000”:
    nonce ← nonce + 1

broadcast( block )
```

Proof of work

- Each block **validates** the transactions it includes
- A block chain is generated
- Every valid block inherits from genesis



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Proof of work

- All nodes try to generate the block
- The first node to do so publishes
- The next block continues from there

Transaction validation

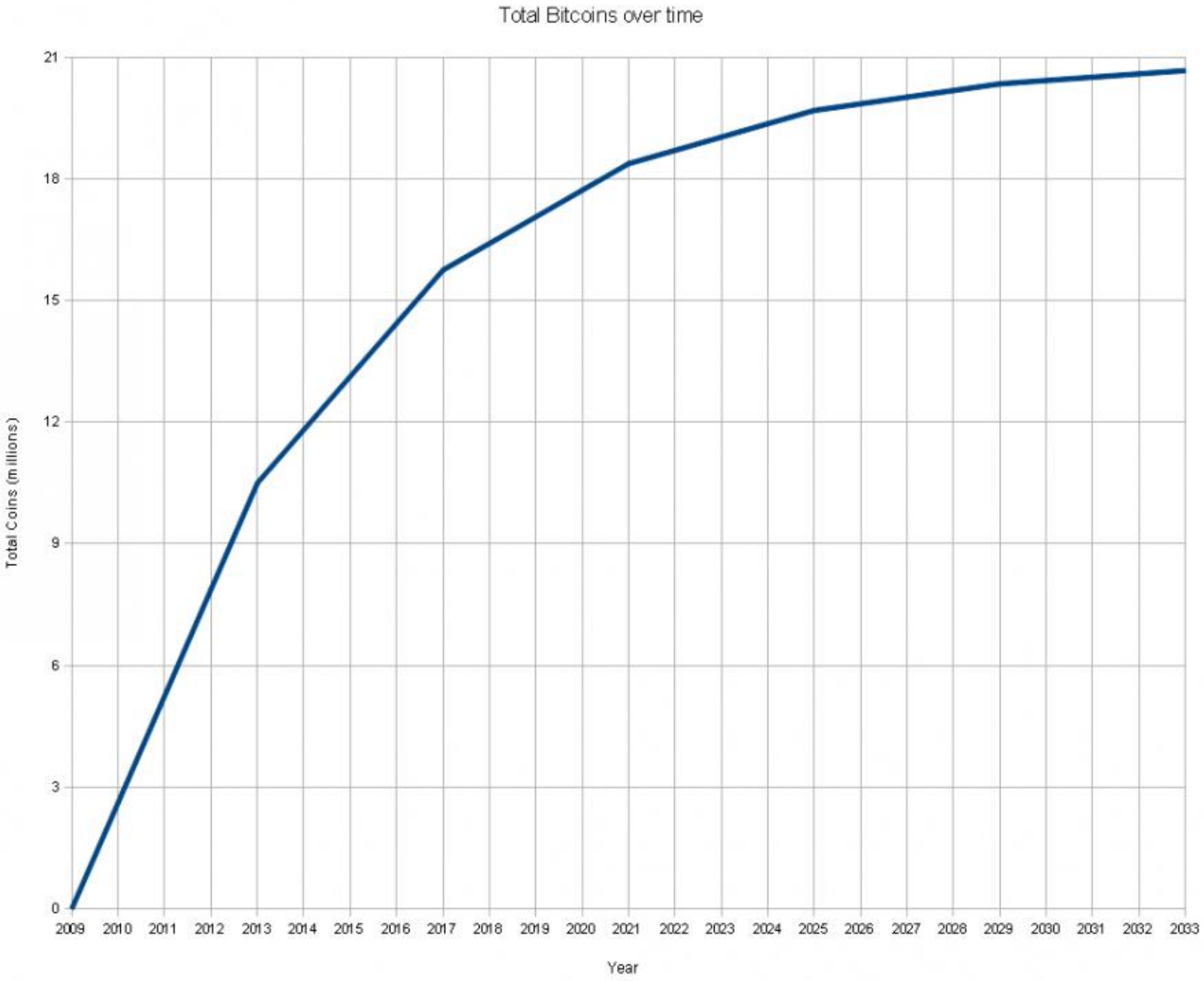
- A transaction is **validated** when included in the next block
- It becomes **exponentially difficult** to construct fraudulent blocks as time passes
- Every next block **secures** all previous blocks
- A transaction change incurs a change in all the next blocks

Transaction validation

- An adversary would need the **majority** of the network CPU to alter the chain
- Altering becomes **exponentially** harder as a transaction becomes validated by more and more blocks

Bitcoin mining

- Block generation = bitcoin earnings for the lucky CPU
- Controlled, **mathematically predictable inflation**



Technical details

- Digital signatures
  - Based on Elgamal (DSA)
  - Using elliptic curves
- Hash function
  - SHA256(SHA256(_))
- Work function
  - SHA256(_)

Bitcoin today

25 March 2012:

- 172,000 blocks
- 1BTC = 3.40€
- 8,642,700 BTC in circulation
- **~29,000,000€ in value**
- Network hashing frequency: > 10THz

bitcoin.org
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