Blockchain technology and Bitcoin

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CONFETI
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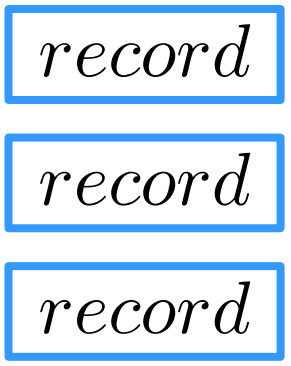
Blockchain

- list of records



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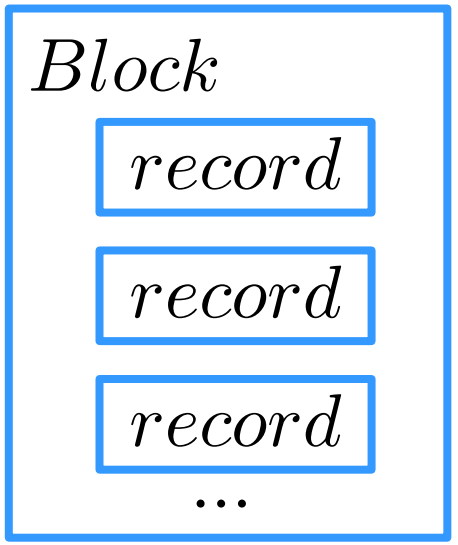
Blockchain

- list of records
- grouped in blocks



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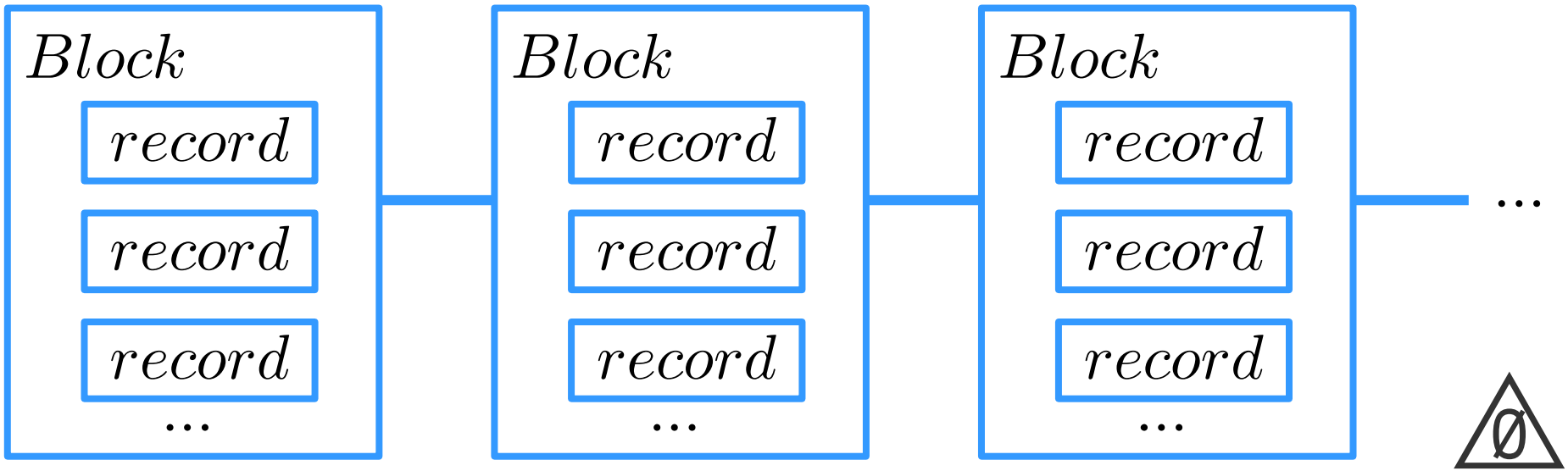
Blockchain

- list of records
- grouped in blocks
- linked in a chain

→

ledger

- add to chain
- can't modify old blocks



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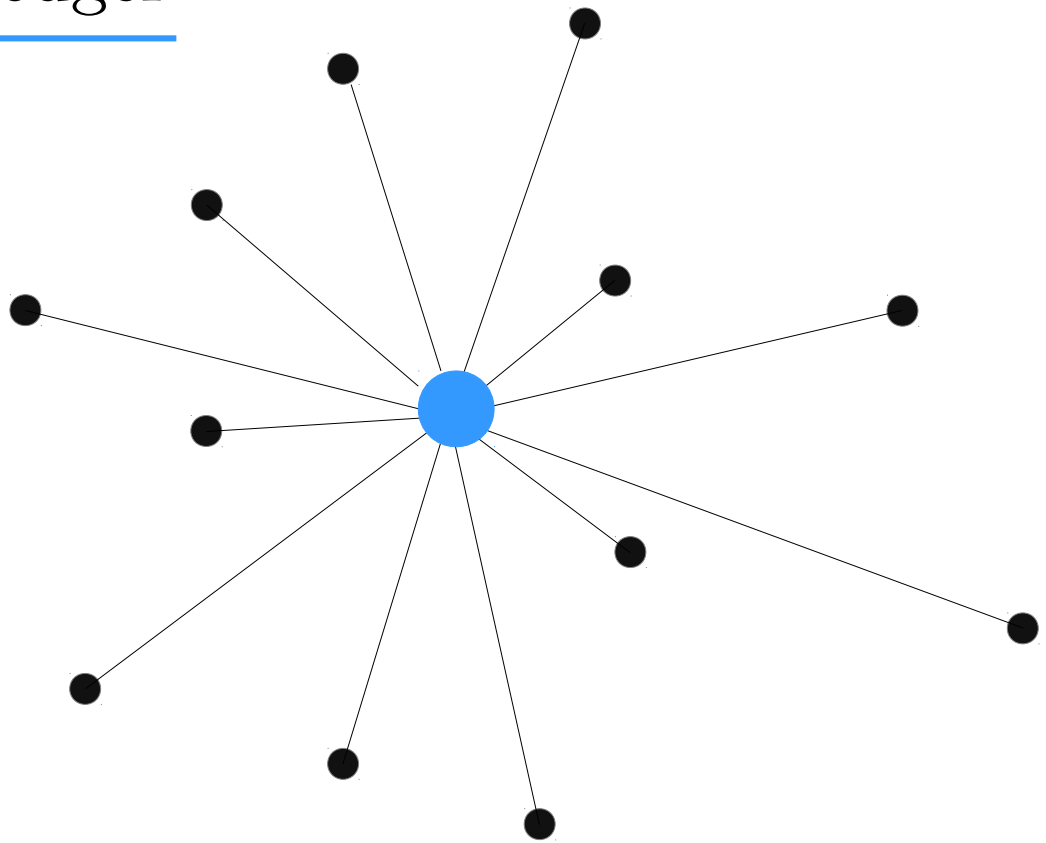
Blockchain

Centralized Ledger



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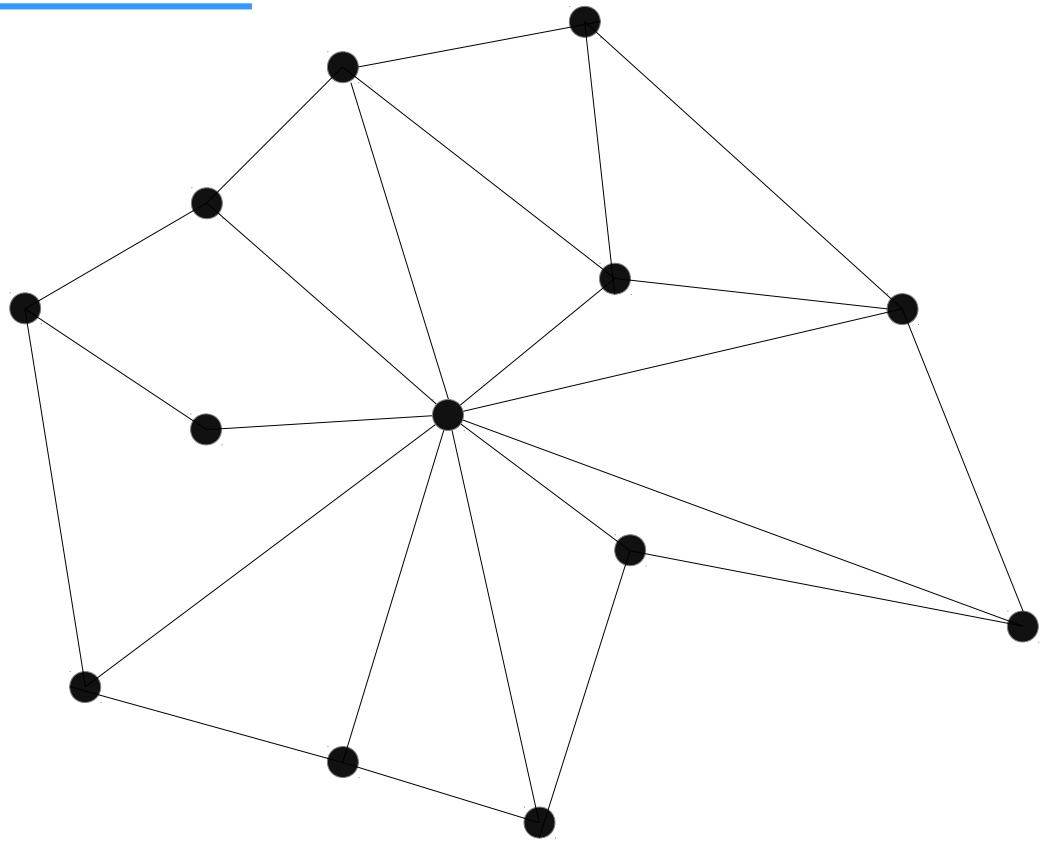
Blockchain

Decentralized Ledger

Distributed



reduce, track down errors, corruption...

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Public Blockchain: Bitcoin

‘Original Blockchain’

- cryptocurrency
  - ⟶ blockchain keeps track of wealth
- open source (Ex. Litecoin)
- trustless
- secured by miners
- whitepaper: bitcoin.org/bitcoin.pdf

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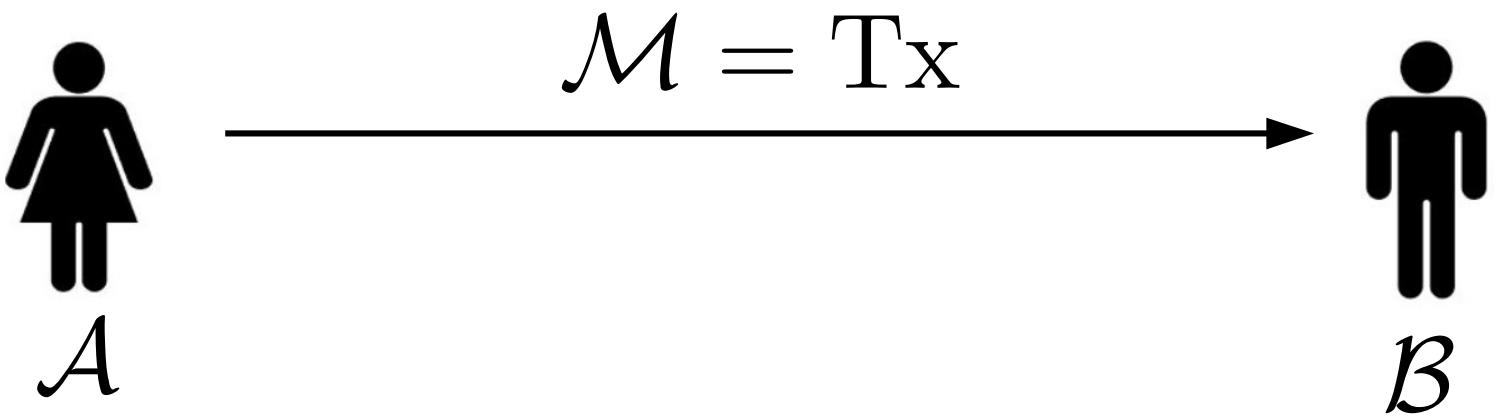
Bitcoin Transactions



How do you prove $\mathcal{A}$lice sent the $\mathcal{M}$essage to $\mathcal{B}$ob ?

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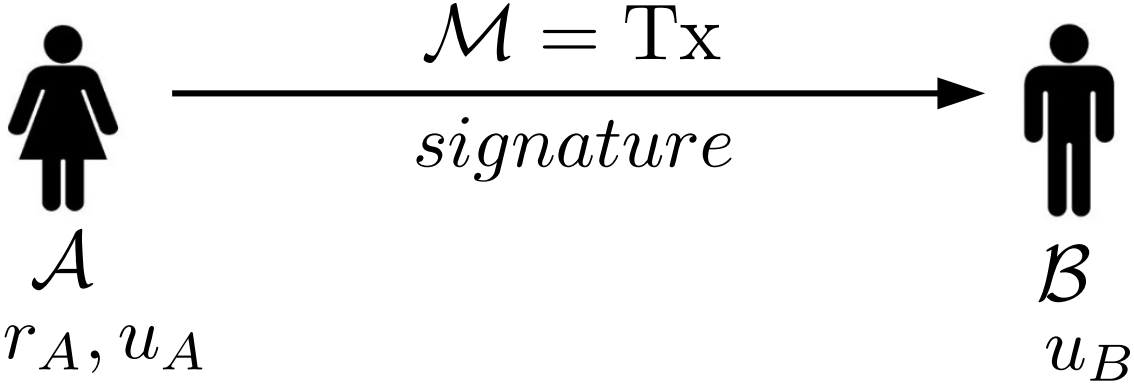
Bitcoin Transactions

Cryptographic Signature

Signature

- public and private key pair generated
- only $\mathcal{A}$ knows private key, r_A
- public key, u_A, known by everyone

$$sig : r_A, \mathcal{M} \rightarrow signature$$



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Bitcoin Transactions

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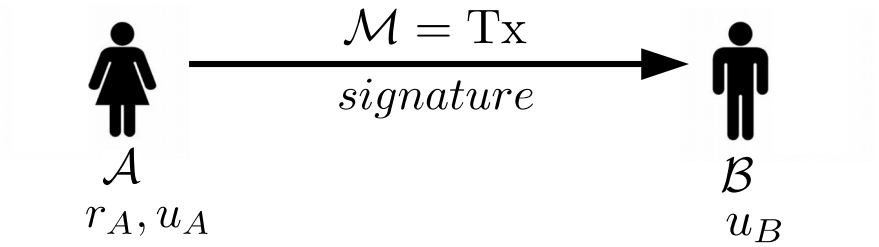

Verification

$$check : u_A, \mathcal{M}, signature \rightarrow Yes/No$$

The $\mathcal{M}$essage can be verified by $\mathcal{B}$ob or anyone else

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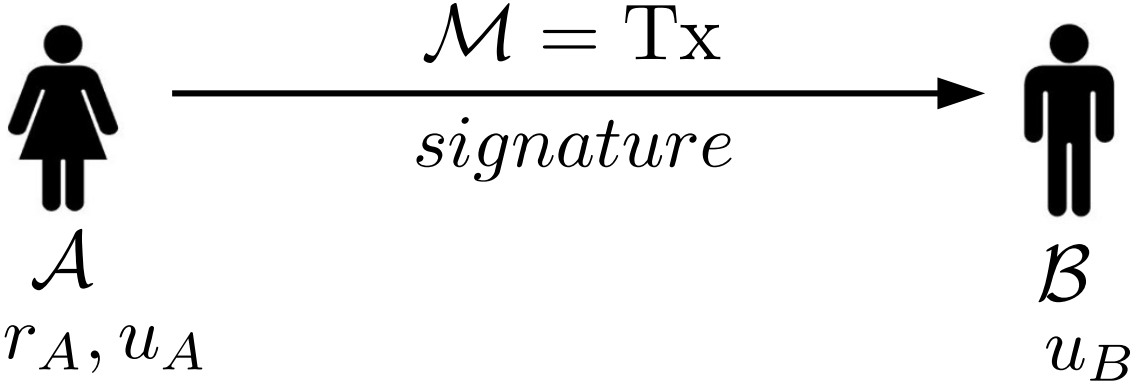
Bitcoin Transactions

Overview

- participants in the network identified by public keys
  - ⟶ $\sim$ anonymity
- access to private key means access to funds
  - ⟶ $\sim$ access to 'wallet'
- transaction broadcasted and added to the ledger



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Bitcoin Mining

No central authority

Who keeps track of which transactions are valid?
double spending?
why?

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Bitcoin Mining

Cryptographic Hash Function (H)

- maps any input to fixed size output

$H(\text{a}) = \text{ca978112ca1bbdcafac231b39a23dc4da786eff8147c4e72b9807785afee48bb}$

$H(\text{“Bible”}) = \text{47f63b8cd8470051acd3a3c0bd5c77c4aa9574d79cf5bfb3e576facabbc11491}$

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Bitcoin Mining

Cryptographic Hash Function (H)

- maps any input to fixed size output
- not invertible

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Bitcoin Mining

Cryptographic Hash Function (H)

- maps any input to fixed size output
- not invertible
- not 'continuous'

$H(\text{bank}) = 4381\text{dc2ab14285160c808659aee005d51255add7264b318d07c7417292c7442c}$

$H(\text{Bank}) = 676\text{c471bc8dc3d1324133cf087c20aa0137fc02348811e4162c79e560298fb11}$

$H(\text{the bank}) = \text{b3d0b18e01647cc301a5dc022784fd1e5b85475a4dbb14140b983dbf1c5a7be1}$

$H(\text{thebank}) = \text{fc4cb9f881175d7b5ac02906947f288b9998bd9354ea06ddf13fc21fa5c12c4d}$

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Bitcoin Mining

Cryptographic Hash Function (H)

- maps any input to fixed size output
- not invertible
- not 'continuous'
- no collisions

$$x \neq y \implies H(x) \neq H(y)$$

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Bitcoin Mining

How does mining work?

- anyone in the network can add block
- hash of the block must start with a certain number of 0's
  - ⟶ determined by a difficulty parameter
  - ⟶ $H(Block) = 00000....ab142a1...$
- blocks contain:
  - ⟶ hash of last block
  - ⟶ valid transactions

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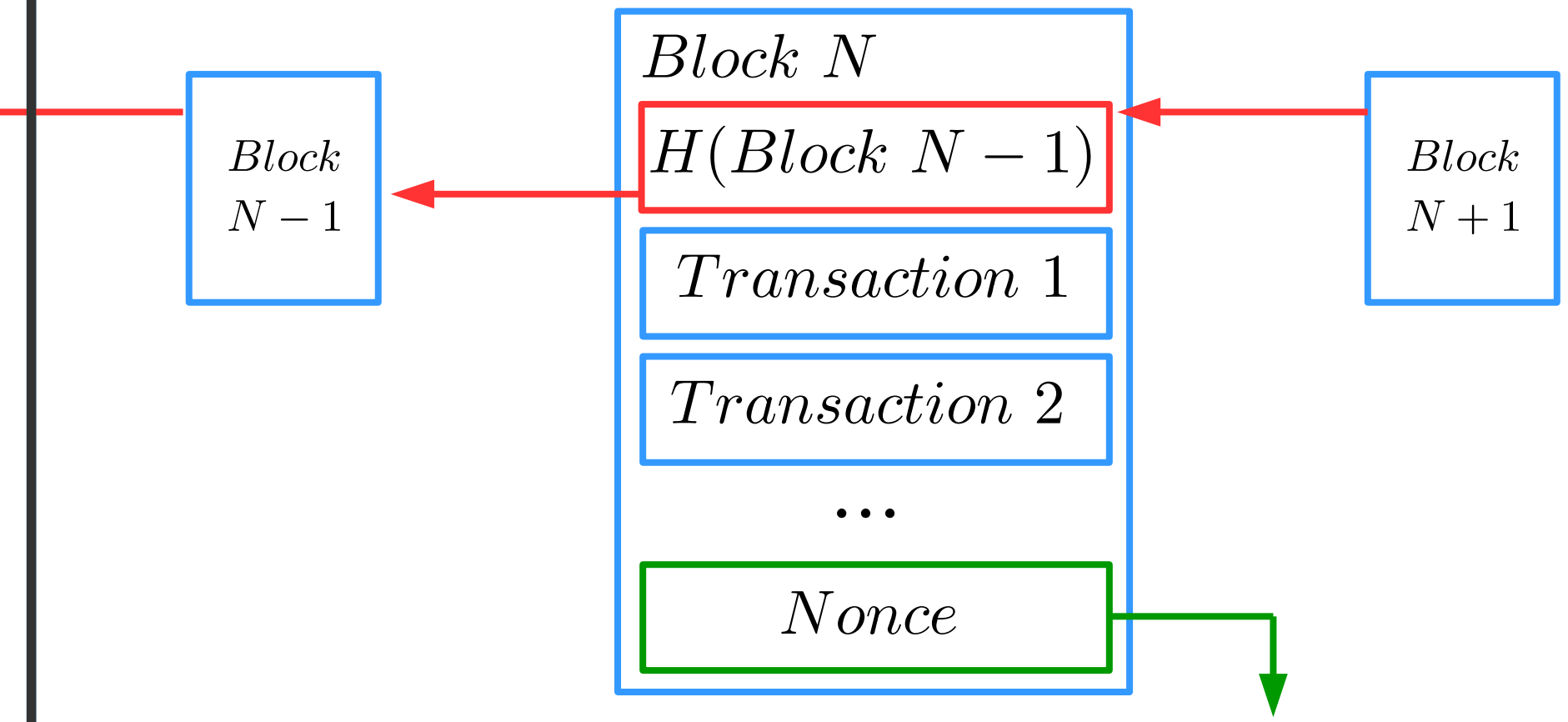
Bitcoin Mining

How does mining work?



picked so hash has correct amount of 0's

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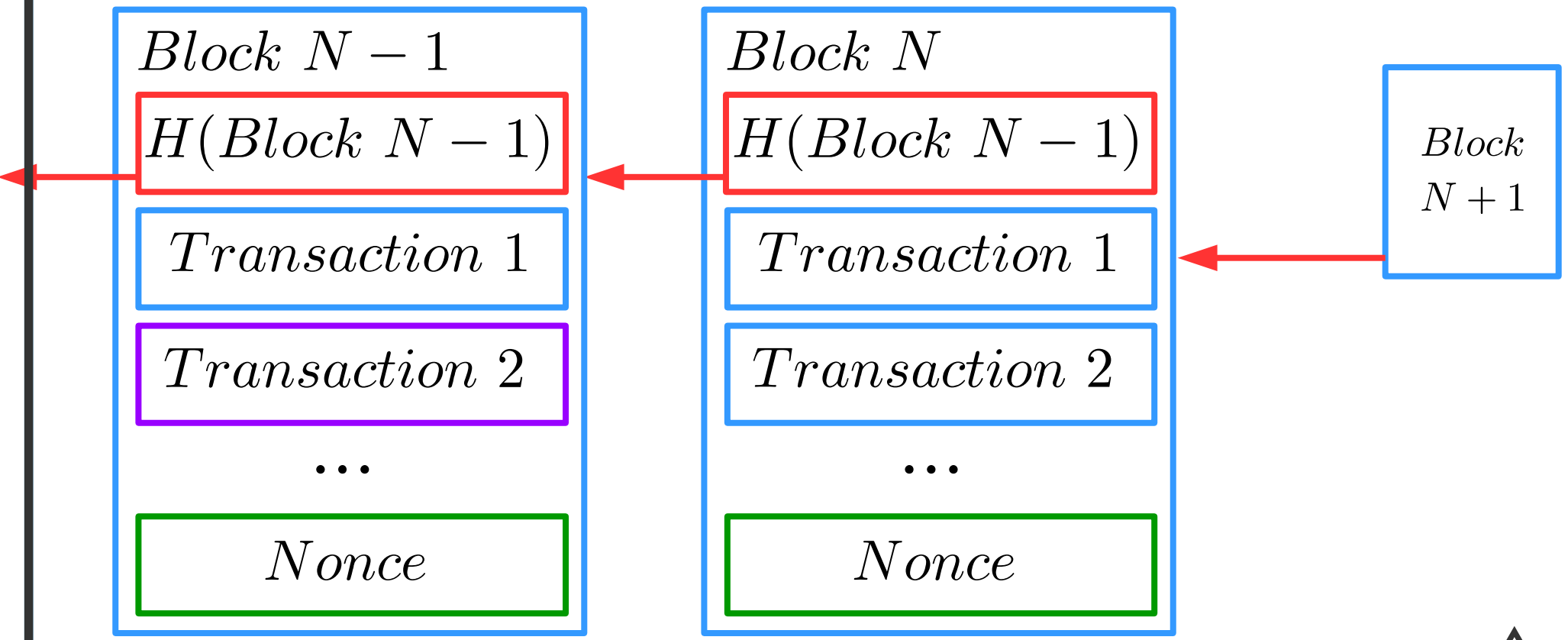
Bitcoin Mining

What if someone cheats?



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Bitcoin Mining

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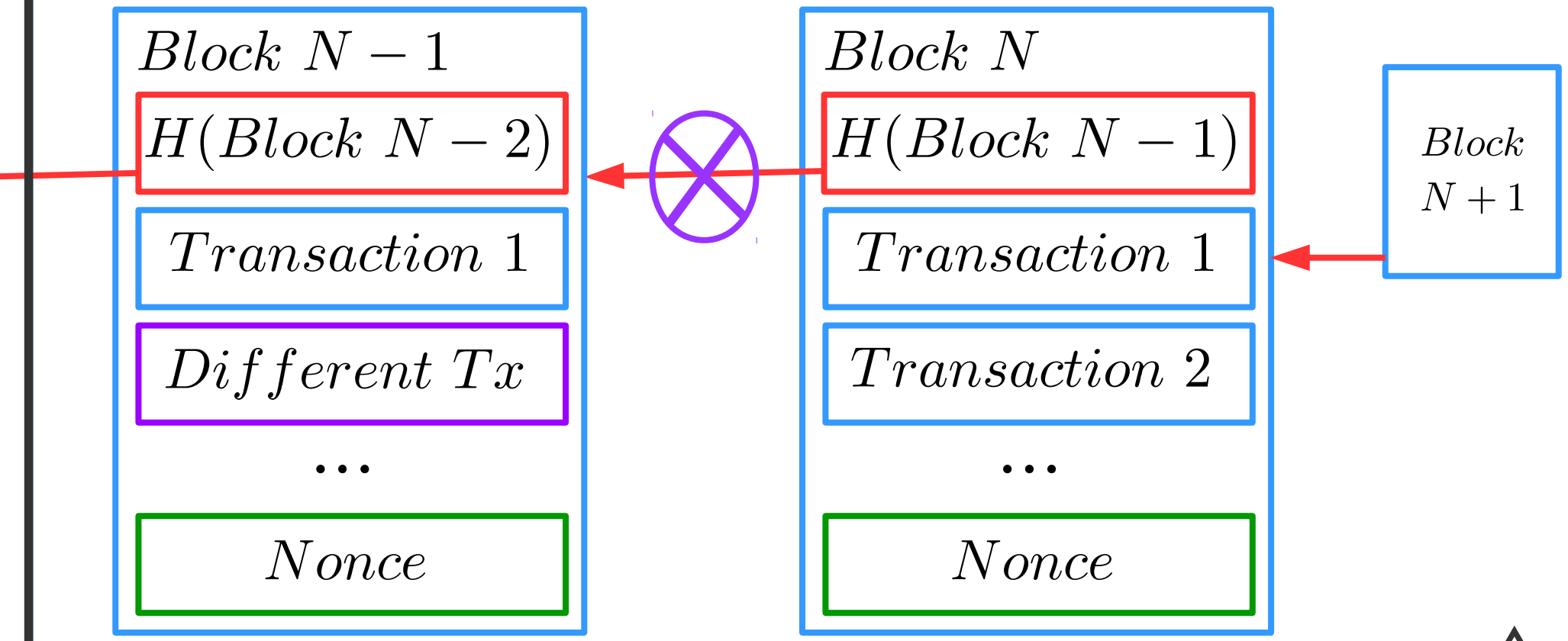

Error gets propagated

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Bitcoin Mining

Overview

- miners add 1 MB blocks respecting current difficulty
- network accept valid blocks by adding blocks on the chain
  - → add blocks to longest valid chain (most work)
- blocks can only be added not modified
- new block is added every 10 minutes (on average)
  - → difficulty readjusted every 2 weeks
- miners are rewarded for adding blocks
  - → current reward: 12.5 BTC + fees
  - → first transaction in the block
  - → total number of bitcoins is capped ($\sim$ 21 million coins)

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Bitcoin Mining

Consumption

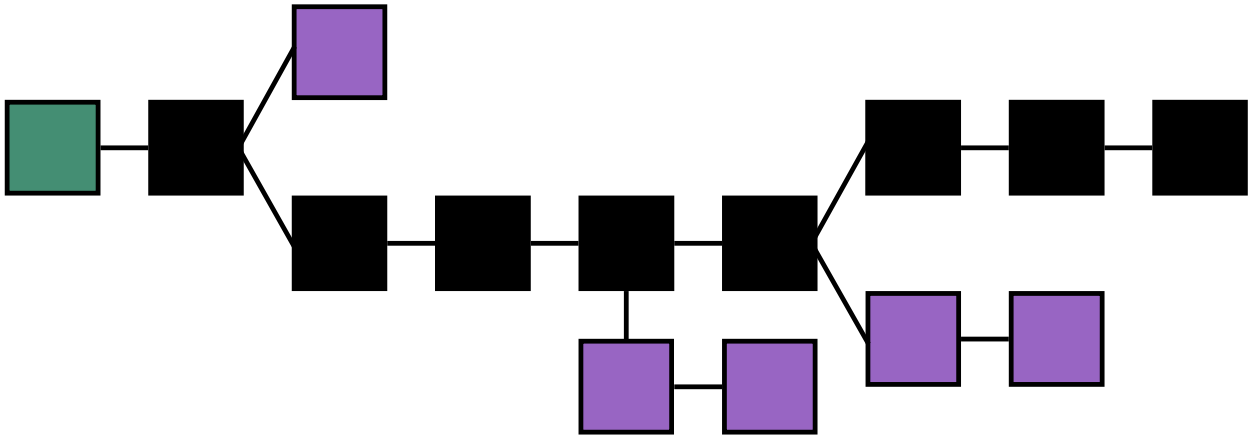
- in the beginning, mining could be done on a PC
- now, there are 'BTC mining farms'
- hashing electricity consumption
  - → 0.09% of world's power
  - → as much electricity as Syria
  - → enough to power 1,740,000 US households
  - → 1 tx ∼ powering 7 houses for a day
- Proposal for a fully decentralized blockchain and proof-of-work algorithm for solving NP-complete problems - arXiv:1708.09419v2

source: https://digiconomist.net/bitcoin-energy-consumption

Bitcoin Mining

Longest Valid Chain

- longest chain will have the most valid transactions
- 51 % attack



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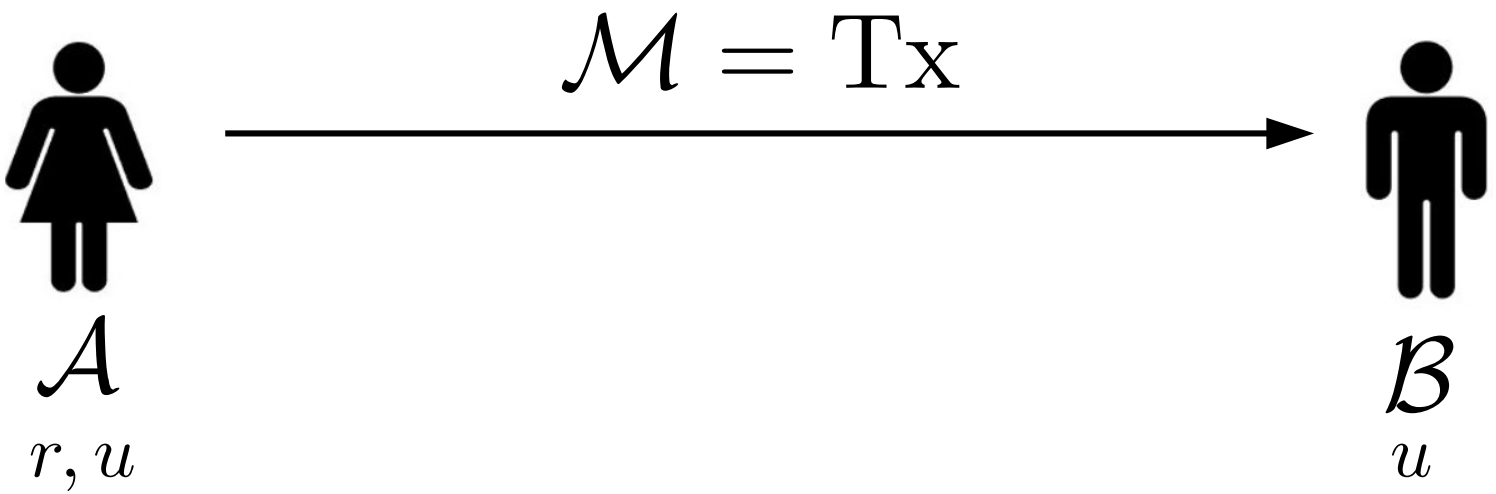

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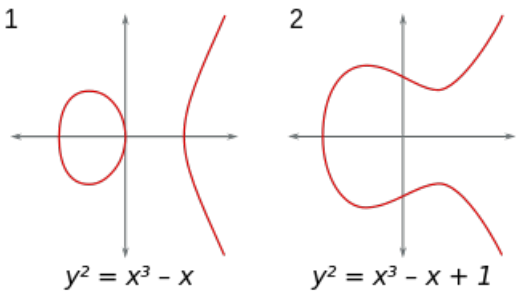
Quantum Computers

Transactions

- public-key cryptography - elliptic curves
- discrete-log problem



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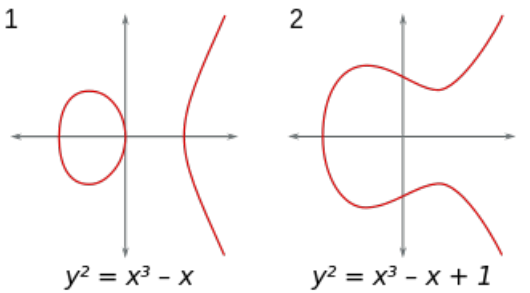

$$\text{Find } k, \text{ such that } b^k = a$$

$$a, b \in G$$

$$G \text{ is a group}$$

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Quantum Computers

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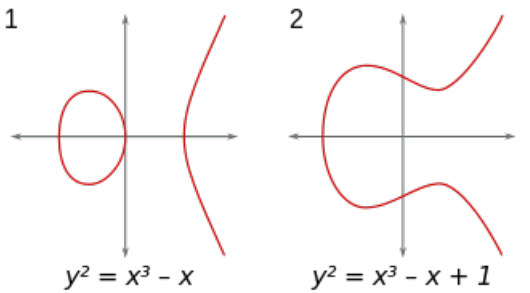
- discrete-log problem

  → Inefficient classically



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Quantum Computers

Transactions

- public-key cryptography - elliptic curves
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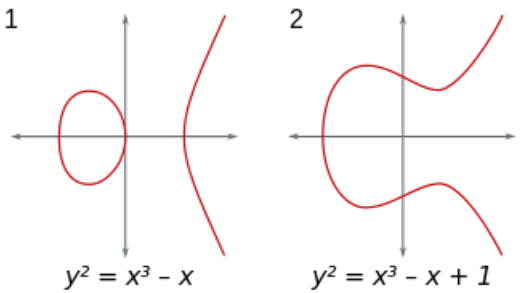
  - ⟶ Inefficient classically
- quantum computer: Shor's algorithm
  - ⟶ Efficient
- private key can be found from public key
  - ⟶ Funds are not secure



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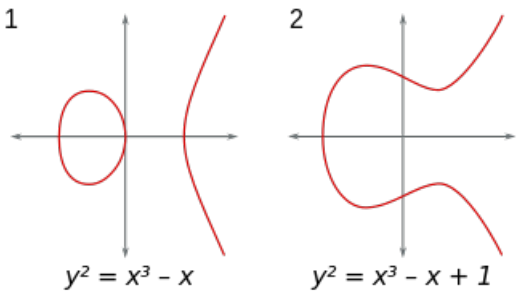
Quantum Computers

Transactions

- public-key cryptography - elliptic curves
- discrete-log problem
  - → Inefficient classically
- quantum computer: Shor's algorithm
  - → Efficient
- private key can be found from public key
  - → Funds are not secure
- a lot of the encrypted communication breaks
  - → ways to fix this



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Quantum Computers

Mining

- Classically: trial and error
  → $O(2^d)$
- Quantum: Grover's Algorithm
  → $O(2^{d/2})$
- better at mining than the rest of the network
  → $d \sim 60$
- eventually everyone has a quantum computer
  → difficulty readjusted

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Forking and Bitcoin Cash

Disagreement about the future

- issue: not enough transactions/block
  - ⟶ scaling problem
- Bitcoin: segwit
  - ⟶ restructure blocks
- Bitcoin Cash: Larger blocks

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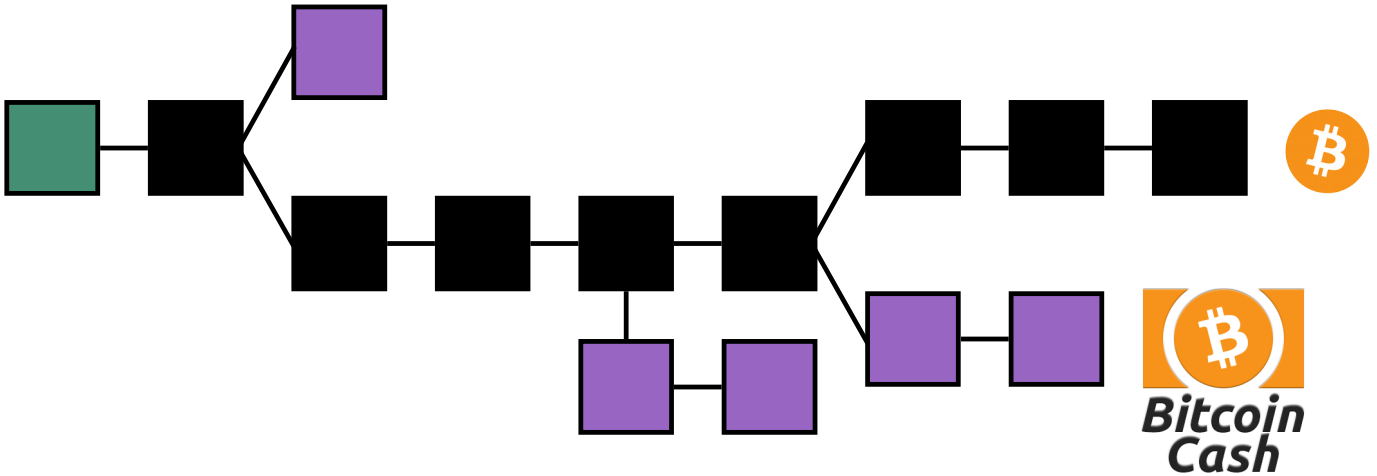
Forking and Bitcoin Cash

Resolution of the conflict

- fork the ledger
- same past, different future
- different miners agree to work on different chains



1 MB blocks

8 MB blocks

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Other Ideas

Cryptocurrencies

- Bitcoin is first, is it best?
- Ethereum: smart contracts
- Iota: tangle
- Quantum Resistant Ledger: ‘resistant’ to quantum computers

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Other Ideas

Smart Contracts

- decentralized applications - dApps
- Ex. Pear: decentralized journal
  - → https://github.com/ricott1/Pear

PEAR

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