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Norwegian University of Science and Technology

Bitcoin, Blockchains and Smart Contracts

Understanding the Crypto in Cryptocurrencies

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Outline

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Bitcoin origins

- Online proposal by Satoshi Nakamoto late 2008
- First Bitcoin blocks formed 2009
- Protocol defined by implementation in software
- No central authority
- Not linked to any fiat currency

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Interfacing with the Bitcoin blockchain

Several alternative methods to view and interact with the Bitcoin blockchain:

- Make a bitcoin node: install Bitcoin Core
- Toolkit: libbitcoin-explorer

  `https://github.com/libbitcoin/libbitcoin-explorer`
- Blockchain explorers
  - https://btc.bitaps.com
  - https://blockstream.info
  - https://www.blockchair.com
- Bitcoin testnet

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Digital signatures

- A digital signature is a bit string which authenticates a message
  - Private signing key is used to generate each signature
  - Public verification key is used to verify each signature
- Bitcoin uses a modern, efficient, standardised signature scheme (ECDSA with a specific curve)
- Bitcoin signatures are 512 bits in length
- Bitcoin addresses are public signature verification keys
- A typical Bitcoin address:

`1HnhWpkMHMjgt167kvgcPyurMmsCQ2WPgg`

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Bitcoin transactions

- Bitcoin transactions (payments) transfer value from one or more *input addresses* to one or more *output* addresses
- Each output specifies:
  - The address whose signing key will be used later to authorise spending of the output
  - The value of this output
- Each input specifies:
  - an output of an *earlier* transaction with its value
  - a signature of the current transaction by the owner of that input

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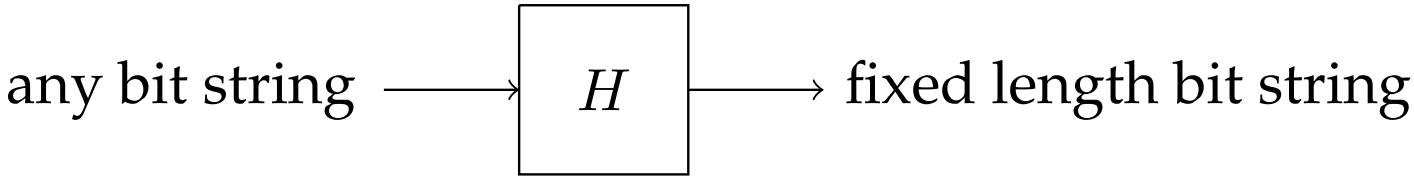
Valid transactions in Bitcoin

- A transaction that spends an already spent output is invalid (no double spending)
- The sum of input values to a transaction must not exceed the sum of output values
- Transactions are exchanged on the Bitcoin peer-to-peer network
- A set of transactions is sometimes hashed together into a *Merkle root*

Hash functions



- Example SHA-256: output looks like a random 256 bit string (64 hex digits)
- SHA-256 hash of an Ubuntu image (around 2GB file):

```
574870693753941 8ee5707bd538c4f5e
abae485d17aa49fb13ce2c9b70532433
```

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Hash collisions

— A collision for H is a pair or two messages $m_1 \neq m_2$ such that

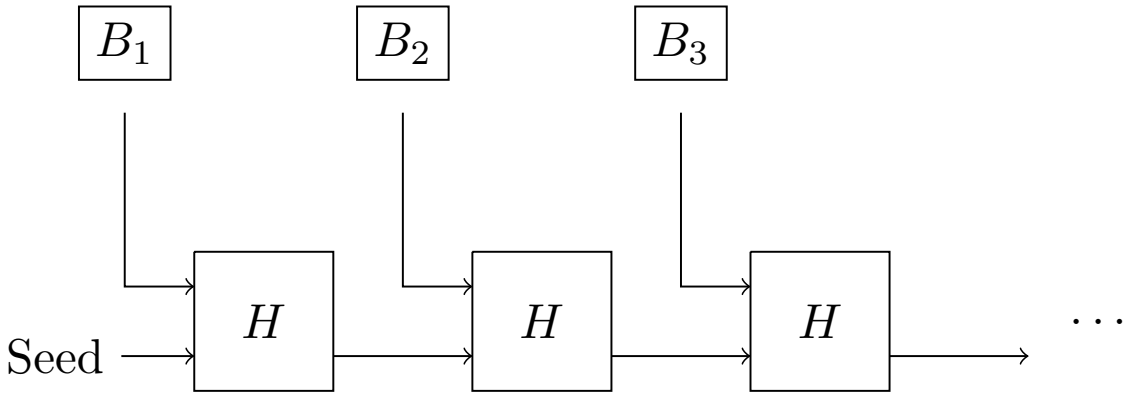
$$H(m_1) = H(m_2).$$

— Collisions must *exist*

Fact

For a good hash function collisions are too hard to find

Hash chains



— Sequence of hashes. Each new hash input includes the previous hash.

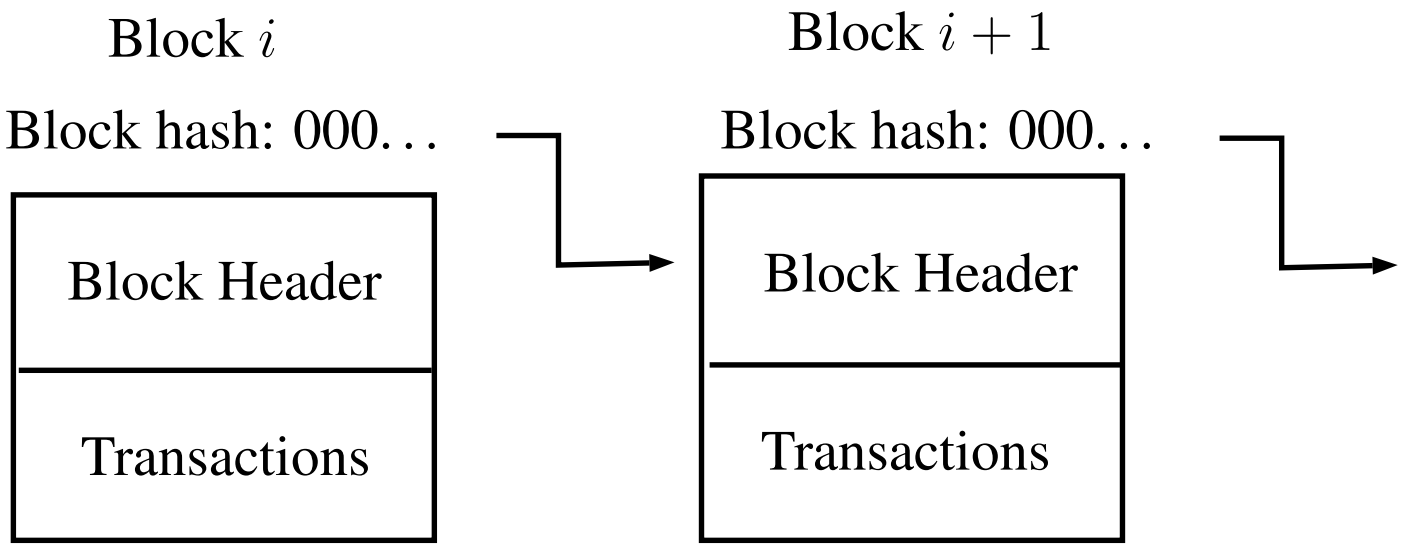
— Cannot change (add, delete nodes) without finding a collision

— Used in cryptography for a long time (micropayments, timestamping, . . .)

Bitcoin blocks

- A Bitcoin block consists of an 80-byte header and a set of transactions
- Each header includes the hash of the previous block header
- The Bitcoin blockchain started with block number 0, known as the *genesis block*

Chained blocks



Fact

The Bitcoin blockchain is a hashchain of blocks

Mining

- A block is valid if it has a hash with enough zero bits at the start
- The number of zero bits at the start of a valid block is defined by the current *difficulty*
- A *miner* attempts to construct a valid block by changing variables in the block until there are enough zero bits in the hash
- This is a *cryptographic puzzle* or *proof of work*. Only known way to solve the puzzle is by trial and error

Question

How many trials do we expect to need to construct a block with hash starting with 32 zero bits?

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Mining costs and rewards

- A *block reward* is given for each block mined until 21 000 000 bitcoins mined (around year 2040)
- When Bitcoin started the block reward was 50 Bitcoins, but it halves every 4 years
- Transactions include fees paid to miner

Fact

Consensus is built by the community accepting that the longest valid chain is the correct blockchain

DIY mining

AntMiner S9 ~13.0TH/s @ 0.098W/GH 16nm ASIC Bitcoin Miner

by Bitmain

20 customer reviews | 69 answered questions

Price: $515.00 + $189.82 Shipping & Import Fees Deposit to Finland Details

Free Amazon tech support included

- Bitcoin Mining Hash Rate: 13.0TH/s ±5%
- Power Consumption: 1273W ±10% (Power supply not included)
- Built-in web management portal - No separate host computer or software required
- Most Power Efficient Bitcoin Miner: 0.098 J/GH ±7%
- Power supply sold separately - AntMiner APW3++ power supply recommended if you have 220v+. EVGA SuperNova 1600 G2 recommended if you only have 110-120v power.

› See more product details

Used & new (11) from $399.00

Today all effective mining is done in *mining pools* – a huge industry

Industrial scale mining

NHO-toppens bønn til regjeringen: – Rydd opp i dette uhellet

Fjerning av strømrabatt for kryptosentre rammer hele datasenternæringen – ikke bare de som driver med utvinning av Bitcoin, hevder NHO-topp.

NHO frykter at store aktører ikke vil bygge datasentre i Norge når staten skiller på pris etter hva man bruker datasentrene til. Her fra datalagring i fjellhallen Green Mountain i Rennesøy. Illustrasjonsfoto.
FOTO: SEBASTIAN WINUM STORVIK/NRK

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How much electricity does mining use?

- Bitcoin miner profits depend on:
  - capital cost of equipment
  - cost of electricity
  - value of Bitcoin
- Mining reward available per day for Bitcoin is $12.5 \times 144 \times$ Value of 1 Bitcoin:
  - $\approx$ \$6.3 million today
  - $\approx$ \$35 million December 2017
- Often estimated that Bitcoin energy consumption is similar to a small country:
  https://digiconomist.net/bitcoin-energy-consumption

Bitcoin as a global immutable ledger

- The Bitcoin blockchain contains many messages hidden in Bitcoin addresses or transactions
- Easy to add your own message
- Available as a notary service for around $1 per document

Question

Can this feature make it illegal to run a Bitcoin node?

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How anonymous is Bitcoin?

- Bitcoin addresses provide *pseudonymity*
- New addresses can be generated for every transaction
- Transaction inputs and outputs are public and *linkable*
- Some transactions, such as those with exchanges, are not permitted to be anonymous

Fact

Bitcoin transactions provide only weak anonymity

Monero and Zcash

- Some newer cryptocurrencies use cryptography to provide stronger anonymity, usually at a computational and/or storage cost
- Ring signatures:
  - someone from a user-defined set of signed the transaction
  - used in Monero
- Zero knowledge proofs:
  - provide proof that transaction is valid without revealing details
  - used in Zcash
- Zcash has been approved by financial regulators in New York (NYFDS)

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Smart contracts

- A set of formal conditions which trigger a payment when they are satisfied
- Bitcoin has a built-in scripting language
  - Powerful but limited language
  - Used in every transaction
  - Script must return TRUE in order to spend transaction output
- Developed further in Ethereum
  - Turing complete language
  - Contains both users accounts and contract accounts
  - Basis for many blockchain applications today
- Most large companies, such as IBM, are interested in using smart contracts in commercial applications

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Altcoins

- Hundreds of Bitcoin alternatives deployed today
- Commercial applications today typically using closed (*permissioned*) blockchains
- Other consensus mechanisms are being widely explored
  - Proof of stake
  - Sortition (see Algorand)
  - Byzantine agreement protocols

Conclusion

- Commonly stated that we are still at the start of the blockchain era
- Many different opinions on the likely impact of blockchains
- According to Meiklejohn top challenges are:
  - **Interoperability**: in a world of multiple ledgers, how should they be classified or standardised to allow interoperation?
  - **Cost-effectiveness**: can we avoid proof-of-work puzzles with their huge power costs?
  - **Privacy**: long-term privacy, selective privacy and anonymity all remain problematic
  - **Scalability**:
    - how to limit the size of blockchains?
    - can we split into realms of interest (sharding) to avoid checking all transactions?

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More information

- Mastering Bitcoin by Andreas M. Antonopoulos
  https://github.com/bitcoinbook/bitcoinbook
- Technical details of Bitcoin: en.bitcoin.it
- Software and wallets for Bitcoin: bitcoin.org
- Original Bitcoin paper of Satoshi Nakamoto:
  https://bitcoin.org/en/bitcoin-paper
- IBM Blockchain Blog
  https://www.ibm.com/blogs/blockchain/

Thanks for listening

Questions?