The Blockchain &
The Internet of Things

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- The blockchain
- Blockchains for the Internet of Things

The problem of distributed trust

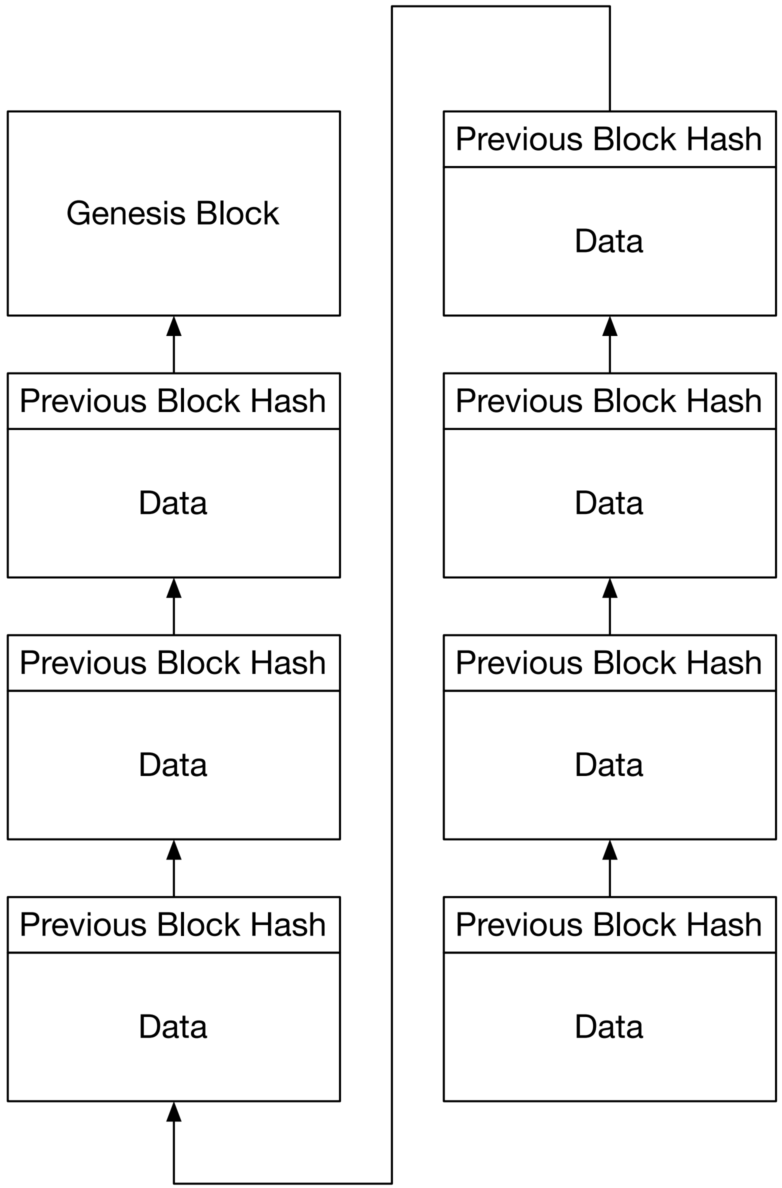
- We have touched upon this before
- How do you establish trust in something important shared with faceless strangers?
- You can choose to put your trust in an authority
    - like MobilePay, PayPal, eBay, etc
- or you can do something else

Requirements for public trust

- **Transparency**
  - all is public—no special privileges required except participation
- **Verifiability**
  - everybody can check and verify what takes place
- **Integrity & Immutability**
  - once committed, records cannot be changed
- **Consistency**
  - all will have the same records (eventually)

The blockchain

- A linked list of blocks containing data and a (crypto) hash value of the previous block (e.g., SHA256)
- Each hash validates the previous block, and thus the whole chain of blocks can be verified from the newest back to the genesis block
- Once it exists, a block cannot be modified without detection as that would invalidate the next and thus all subsequent blocks



What use is an immutable list?

Previous Block Hash
Transaction
Transaction
Transaction

- **It can be used to represent a *ledger,* i.e., a series of financial (or other) transactions collected in a block**
  - a transaction might be 'Bob paid Alice B100'
- **To defend against fraud, a transaction should be cryptographically signed by the issuer**
  - i.e., $(\text{Bob paid Alice B100})_{\text{signed by Bob}}$ where Bob's public key is known by all
- **Once bundled up in a published block, the information cannot be modified**

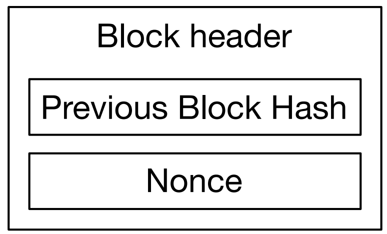
Fraud prevention

- Does Bob even have B100?
- This can be checked by transversing all prior transactions, looking for Bob
- All Bob's previous financial transactions are public, so doing a sum of all transactions adding to or subtract-ing from to Bob's account will yield Bob's net worth

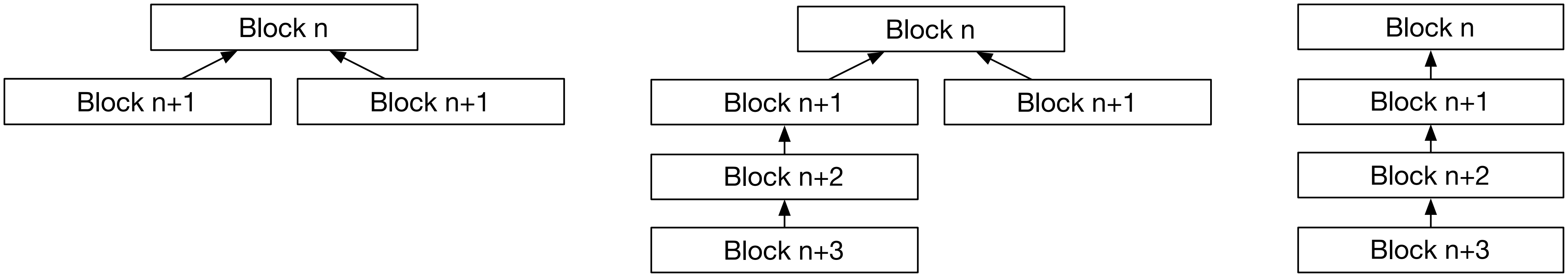
- Sounds like hard work! Who should do this and why?

Mining

- **Miners gather transactions, verify, and bundle them**
  - in return for a small transaction fee from the payer
  - as well as the *block reward* for creating and publishing the completed block
- **Before they can publish the transactions in a block, they have to perform a computational heavy task, so that it becomes infeasible to recreate (parts of) the blockchain for fraudulent purposes**
- **This is most often a Proof-of-Work, consisting of generating a nonce (a number) so that the hash of the block header satisfy some requirement:**
  - SHA256(block header) < some slowly decreasing target threshold



Forking



- Two miners may well create each a valid block at approximate the same time, but *there can be only one*
- The network prefers the more difficult, i.e., longer, chain, so if a fork happens, the longer of the forks will be accepted as the consensus chain
- Thus, the miners race to complete new blocks in order to protect already generated blocks and their rewards

The cost of doing Proof-of-Work

- **In the most popular blockchain, Bitcoin, the difficulty of the PoW has been steadily increasing to match the rising computation power of the miners**
- **The miners currently earn 12,5 bitcoin per block, approximately (14/11/2017) equivalent to 500.000 kr**
    - thus, that is the upper bound cost of electricity spent to generate the block, ignoring other expenses
- **Current estimates put the electricity cost of a single transaction (*not* block) at 215 KWh**
    - an average Danish family uses 5.200 KWh per year, so that is **2 weeks worth of electricity** (!)

Alternatives to Proof-of-Work

- **Proof-of-Stake**
  - defer block creation to those, who have most to lose (have most at stake), if consensus is not reached
  - not widely adopted, seems to be a hard problem to solve
- **Proof-of-Space**
  - defer block creation to those, who can prove that they hold a specific (large) data structure/file—trades CPU cycles for disk space
- **Regardless, if a cryptocurrency is traded at a certain value, it will be worth spending up to that amount in resources to generate it**

Smart contracts

- **Apart from transactions (a simple form of code), the data in a block could also be used to store executable code, known as *smart contracts***
  - takes input from the blockchain, and generates output to the blockchain
  - the smart contracts run on all peers when triggered by a transaction pointing to it
- **The code is as public as the blockchain, and bugs and vulnerabilities are thus also visible to all**
  - however, in contrast to open source software, a faulty smart contract is not easy to withdraw, as it resides in an immutable block
  - Ethereum especially has suffered from time to time because of this

Does it scale?

- **Not very well**
  - Bitcoin (Core) blocks cannot (currently) be bigger than 1 MB
  - Estimates put transactions per second for Bitcoin around 3-4
  - Ethereum clocks in around 25 TPS
- **There are other systems that scale considerably better**
  - though shouldn't they then be the dominant ones?
- **Still, a private rather than public blockchain, might be made to scale better as PoW requirements may be different between trusted participants**
  - but they might as well use other, more classic and *far* faster, methods to handle their transactions

Is it P2P?

- **Well, yes…**
  - no central authority
  - all can, in principle, perform all actions, though some actions are *very* resource heavy
- **But not particularly well designed P2P**
  - (ignoring mining, which is often *grotesquely* energy inefficient, and which because of economy of scale has become quite centralised with giant mining server farms wherever in the world electricity is cheap)
  - every peer stores all the state
  - every peer performs all the smart contracts
  - if they defer these actions to other, more capable peers, how is this different from trusting a central authority?

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So, what use might it be?

- **Well…**
- **Use cases**
  - decentralised architecture for IoT (sounds good, but why build it on blockchains?)
  - micropayment infrastructure for microservices (performing sensor readings, doing calculations, storing data)
  - direct access to manufacturing equipment
  - energy trading (from one home to another)
  - logistics tracking (containers from origin to destination)
- **Many if not all of these can be solved today using common PKI (public-key infrastructure) methods**

So, is it a good idea?

- **At this point, it seems as a grossly inefficient solution searching for a problem**
- **Having an immutable, public accessible record is a great idea for some use cases**
  - not everything should be public—and other methods can be used to ensure immutability
- **There are already, rock solid, cryptographic methods to do secure transactions with strangers**
  - PKI for many purposes—a signed transaction is also immutable
  - Secure Multiparty Computations for the truly cautious ones
- **Hype and speculation are not evidence of usefulness**
  - actual, useful work is proof of usefulness