BLOCKCHAIN AND DISTRIBUTED LEDGER TECHNOLOGIES

Lecture 2 – Introduction to the Bitcoin Blockchain

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LEARNING OUTCOUMES

After this lecture students shall

- **know**
  - what Bitcoin is
  - the historical importance and development
  - about the protocol steps and special roles in Bitcoin
  - the concepts of double spending detection and avoidance
  - mining and consensus

- **can describe**
  - a full way of a Bitcoin transaction
  - evolution steps and major types of BC/DLT systems

- **Can set up** a full Bitcoin node and operate a transaction

BITCOIN INTRODUCTION

*"A purely **peer-to-peer** version **of electronic cash** would allow **online payments** to be sent **directly from one party** to another **without going through a financial institution**. **Digital signatures** provide part of the solution, but the main benefits are lost if a trusted third party is still required to **prevent double-spending**.*
[…]
***The network timestamps transactions by hashing** them into an ongoing chain of hash-based **proof-of-work**, forming a record that **cannot be changed** without redoing the proof-of-work.*

*The **longest chain** not only serves as proof of the sequence of events witnessed, but **proof that it came from the largest pool** of CPU power. As **long as a majority of CPU power is controlled** by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. […]"*

Source: Satoshi Nakamoto: Bitcoin: A Peer-to-Peer Electronic Cash System, 2008

BASIC CONCEPTS

- **identity**
  the Bitcoin address for every user

- **privacy**
  anonymity of the identities in the Bitcoin network is given that only transactions are made public

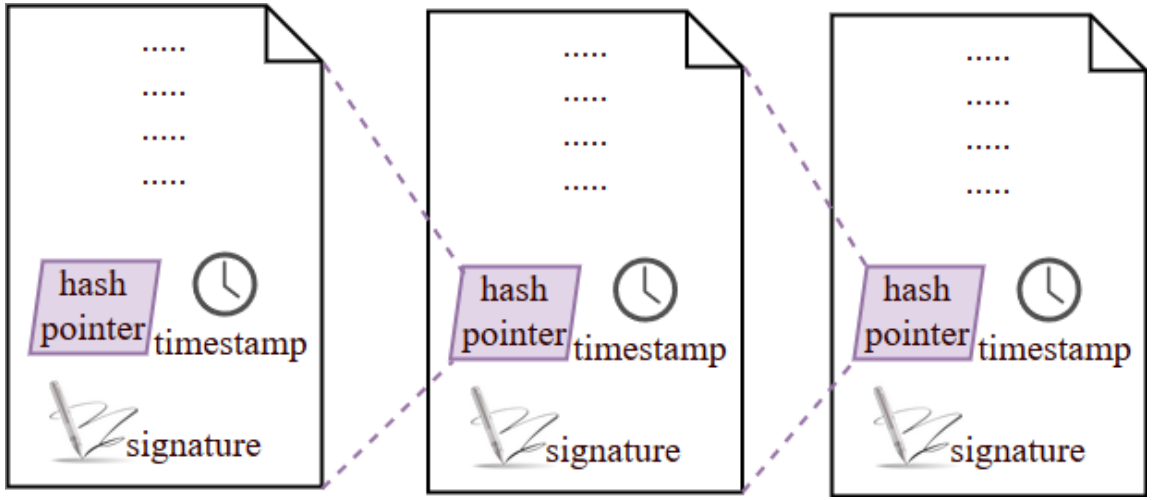
- **block building and consensus**
  the process of validate new blocks and adding them to the Bitcoin blockchain by using individual CPU time and electricity (to solve mathematical puzzles)

Record transactions in a ledger

- timestamp a document (= bring into an order with other documents) and to issue the „certificate“ of it
- goal:
  give the time of when a document came into existence

By doing so, to accurately convey the order of creation of documents

- required: a document‘s timestamp shouldn‘t be changed after the fact
- The certificate of a document ensures the integrity of the contents of the previous document



A document‘s certificate signs the three data elements

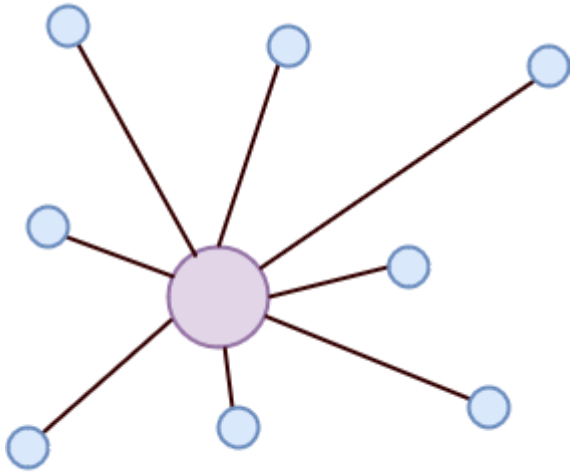
- hash pointer to previous document‘s certificate,
- current timestamp and
- document data together.

Sources/ Further reading:

Haber, S., Stornetta, W.: Secure names for bitstrings. CCS, (1997)

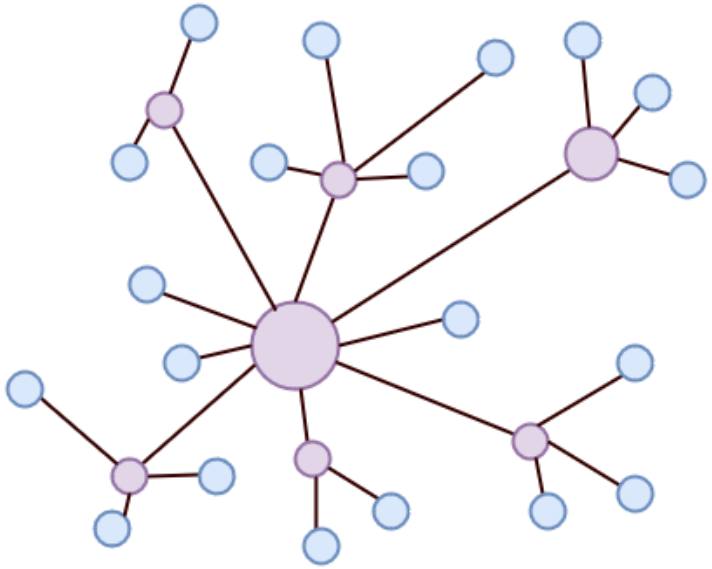
TYPES OF NETWORK

Three Kinds of Network



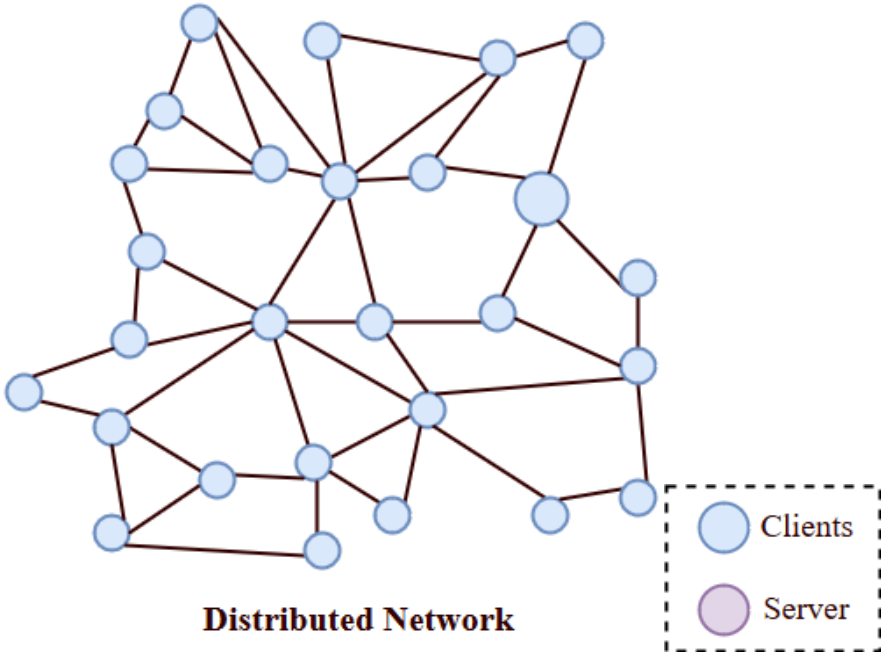
Centralized Network

In a centralized network, individual clients request services and recources from centralized servers.



Decentralized Network

In a decentralized network, local servers offer services and resources for individual clients nearby.



Distributed Network

In a distributed (or P2P) network, interconnected nodes („peers“) share resources each other without the use of a centralized administrative system.

DECENTRALIZATION IN BLOCKCHAIN

- **Logical (de)centralization**: Do the systems interface and data structure look like a single huge object or like an amorpous swarm? If both, providers and users of the system, cut in half, will both halfes be able to fully operate as independet units?
- **Political (de)centralization**: By how many individuals or organizations, that ultimately controll the computers, is the system made up of?
- **Architectural (de)centralization:** If the system is breaking down, how many physical computers can it tolerate at any single time? And of how many physical computers is the system made up at all?

➡ Blockchains should be

- Politically decentralized – no one controls them
- Architectural decentralized – no infrastructural central point of failure
- Logically centralized – one commonly agreed state; system behaving like a single computer

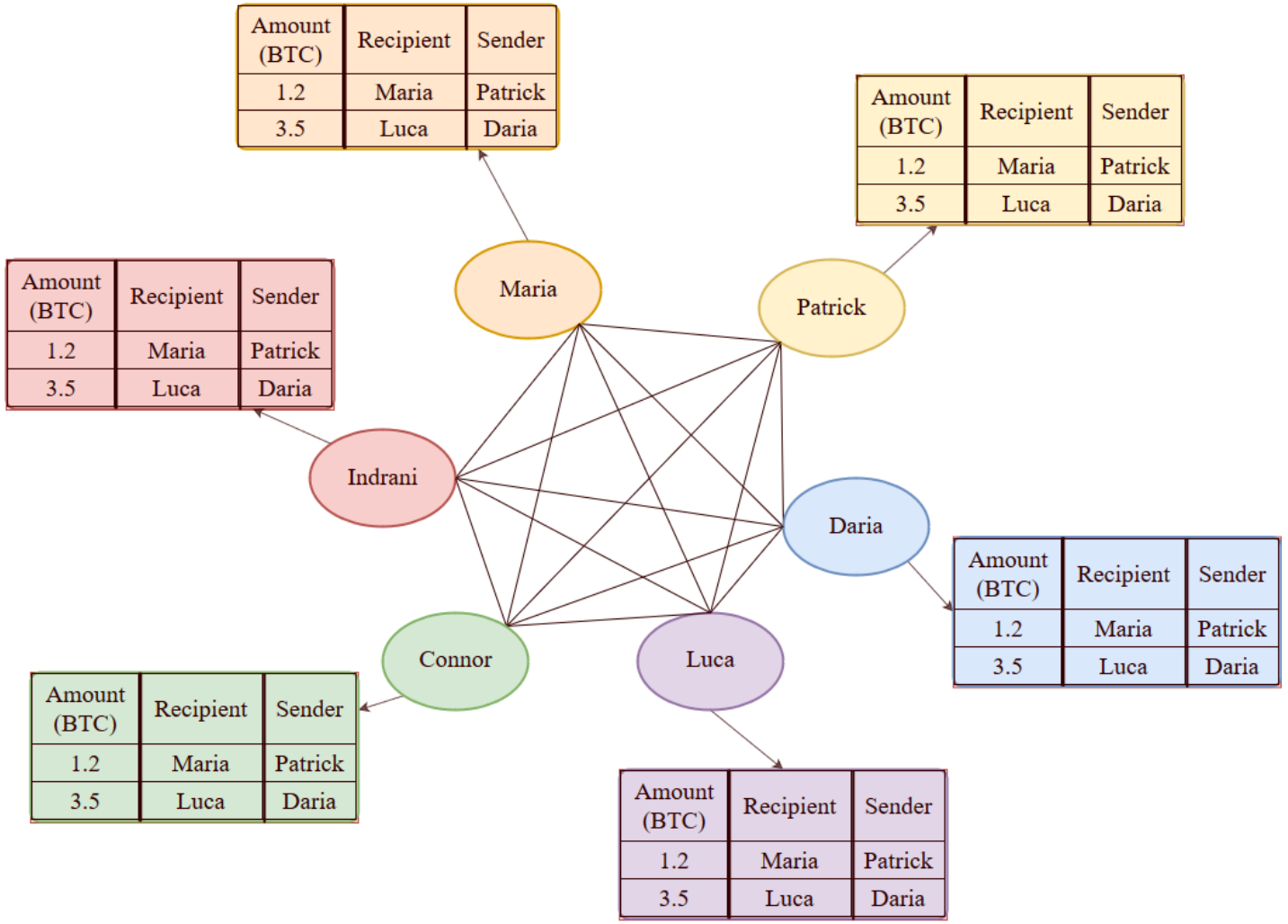
The system must prevent participants from any kind of **cheating**

- The assumption: it is a cyberspace that uncertain number of anonymous people do economic activities

- **How** can we **store all the information** and keep the integrity of the ledger of transactions?

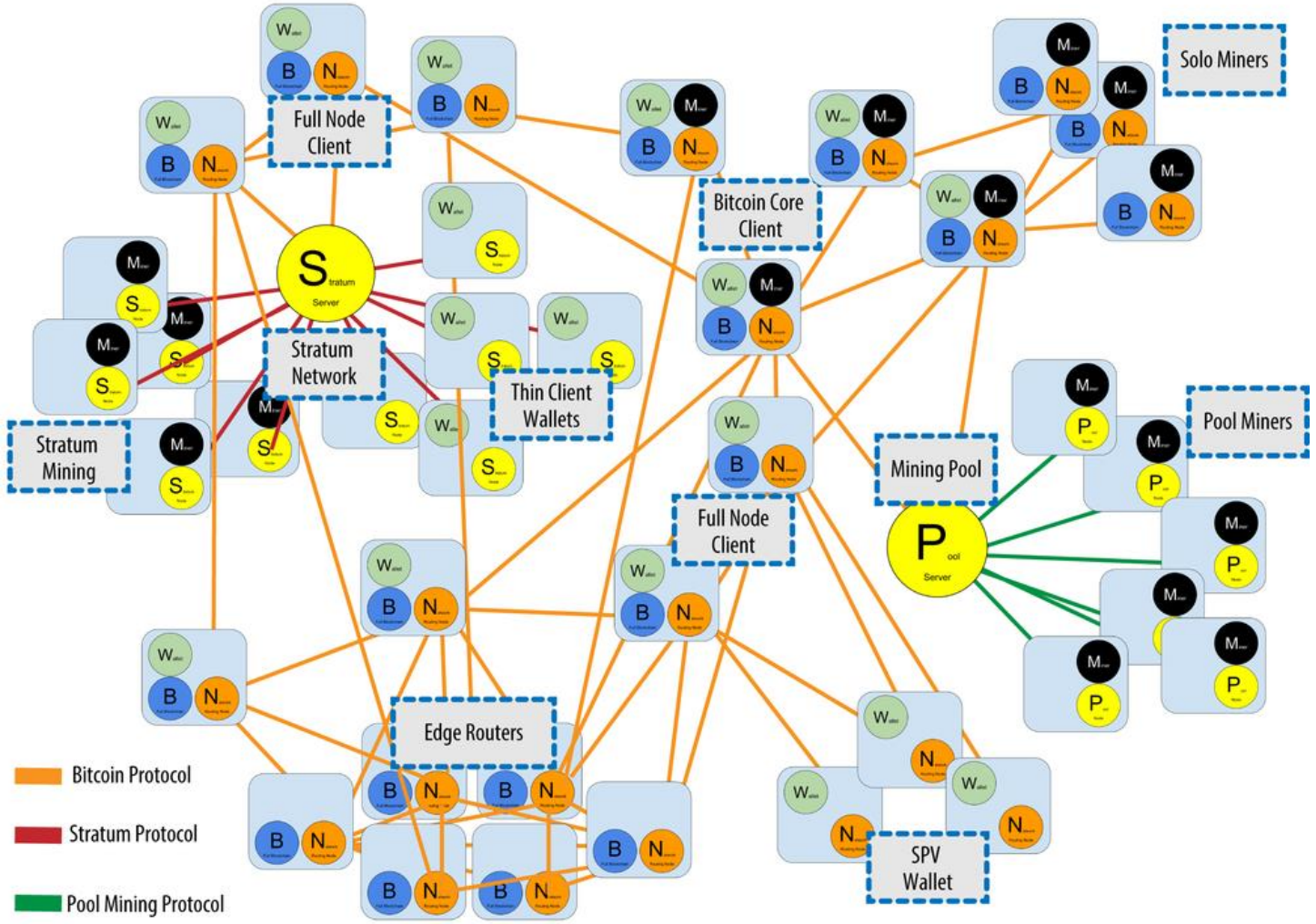
➡ Simple but smart answer: Let **everyone keep the ledger**.
Hard part: Make sure everyone has the exactly the same ledger at any given time.

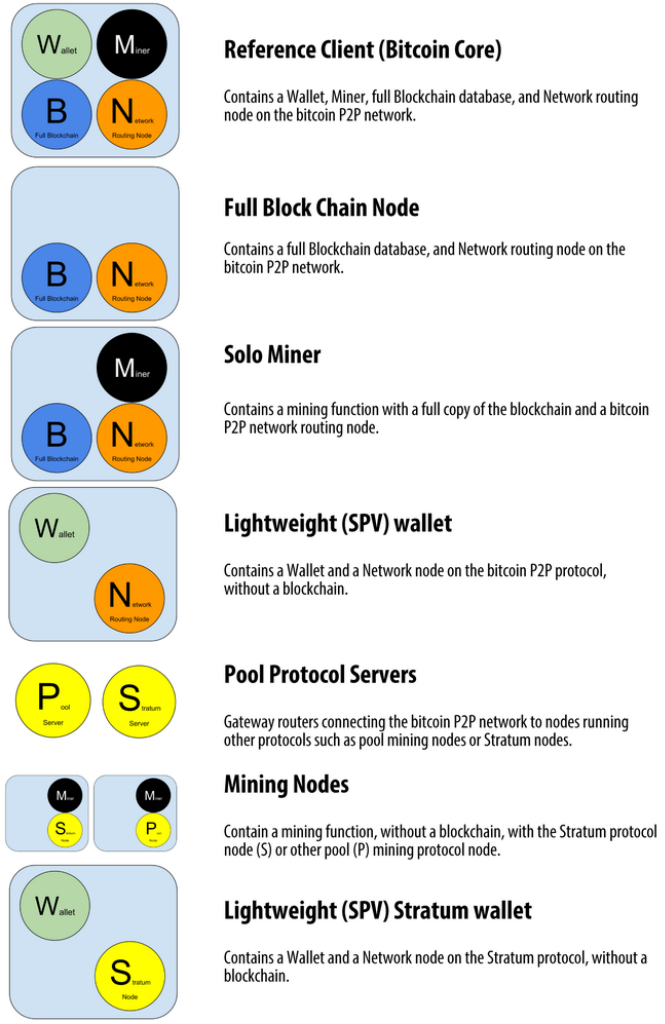
DISTRIBUTED LEDGERS



➡ Everyone stores the ledger!

THE BITCOIN NETWORK ROLES OVERVIEW

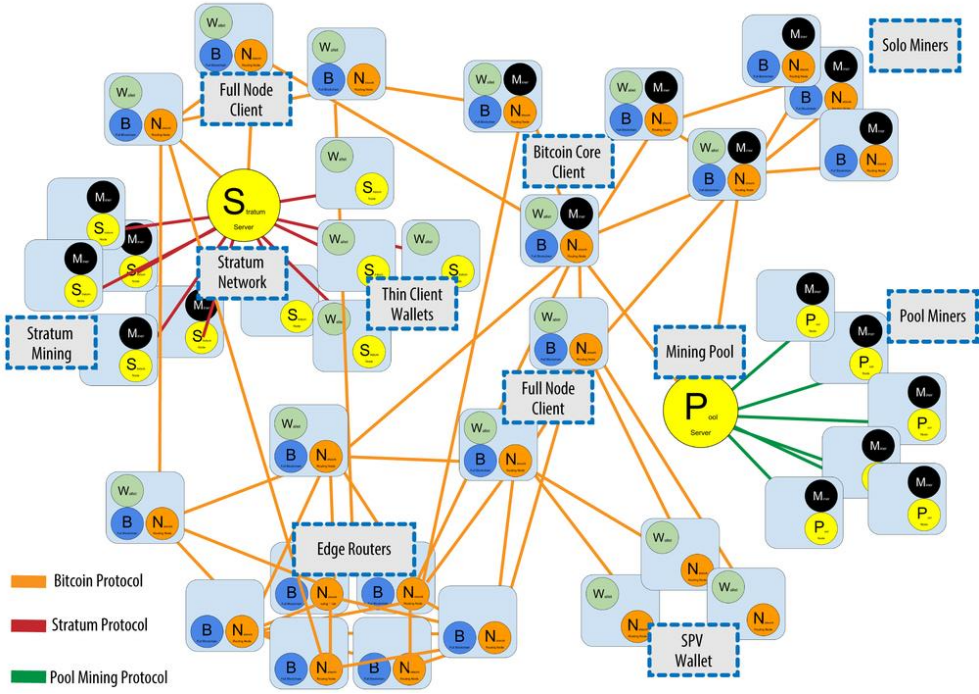




source: [Mastering Bitcoin by Andreas M. Antonopoulos](), O'Reilly (2015)

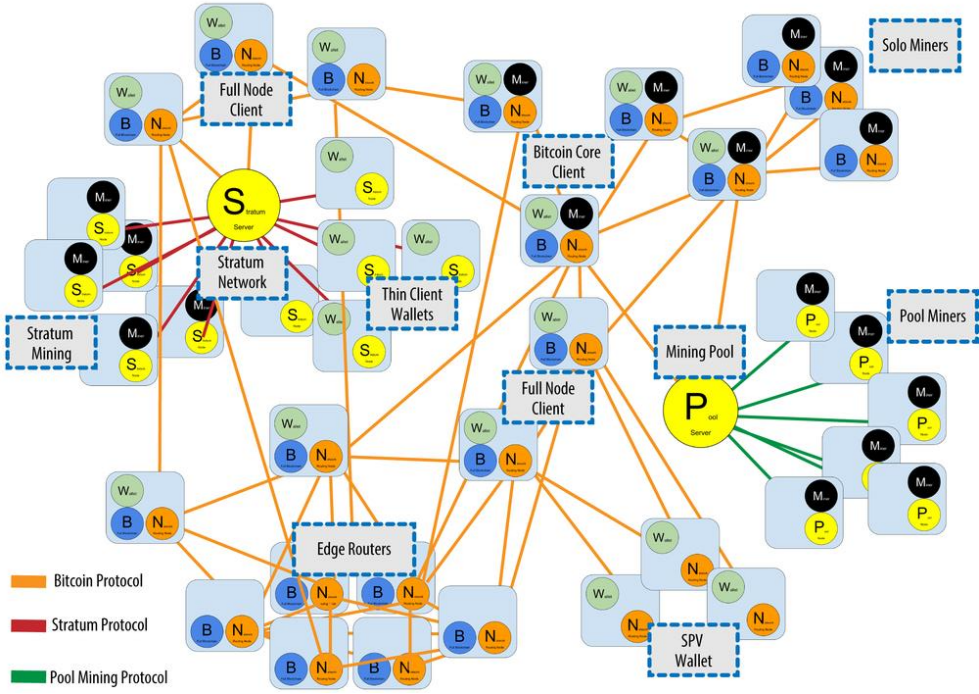
THE BITCOIN NETWORK ROLES NODES

- **Nodes**
  - any computer (or enddevice) that connects to the Bitcoin network with a collection of services: routing, blockchain database, mining, and wallet
  - validate, propagate transactions,
  - discover and maintain connections to peers
  - **Full Nodes:** storing the complete, up-to-date Bitcoin blockchain
  - **Light Nodes:** storing only parts of the Bitcoin blockchain and perform simplified payment verification (SPV) only



THE BITCOIN NETWORK ROLES WALLET

- **Wallets**
  - a collection of private keys of an Bitcoin network address to manage those keys and make transactions and store transactions from and to this address
  - Light wallets do not carry a copy of the blockchain but perform simple payment verifications (SPV):
    - only downloads block-header, 1000 times smaller than transactions
    - search for block containing transactions and looking for the single transaction in Merkle tree
    - if block is older than 6 blocktimes, it counts as confirmed



THE BITCOIN NETWORK ROLES MINERS

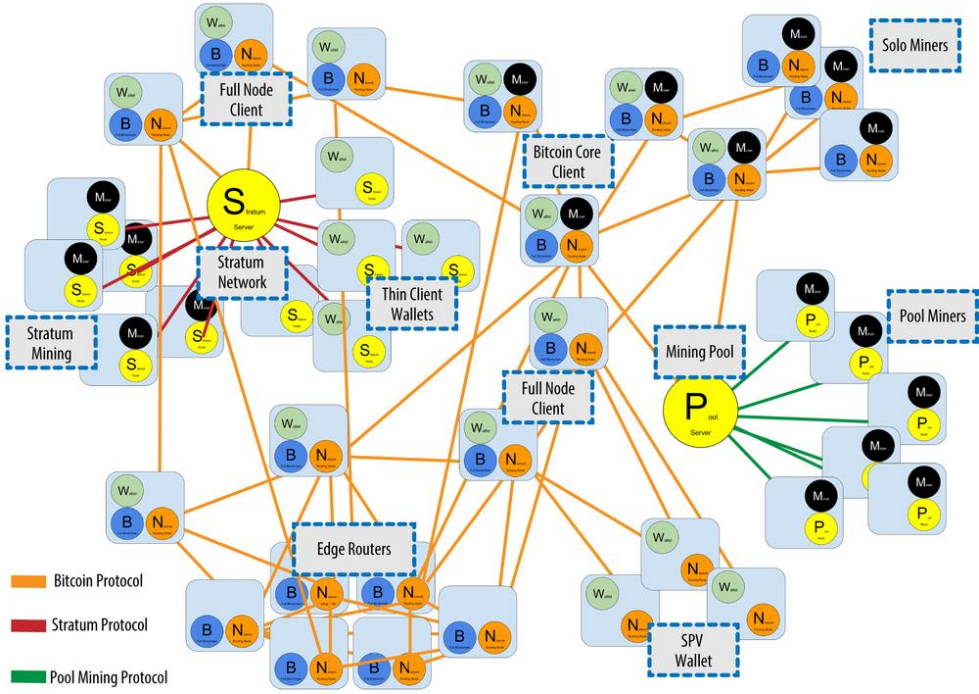
- **Miners**
  - full node that uses CPU time to solve the proof-of-work-puzzle
  - Create blocks using collected valid transactions and solve puzzles as „**Proof-of-Work**“ mechanism
  - Verify incoming transactions by checking signatures and confirming the existance of the valid bitcoins
  - Find a valid nonce (number used once) to create a valid block header with a defined number of leading zeroes (= difficulty) satisfying the following equation

$$H(nonce||prev_{hash}||transaction||transaction||\ ...\ ||transaction) < target$$

  - Equation for difficulty:

$$difficulty = difficulty * \frac{two_{weeks}}{time\ to\ mine\ prev\ 2016\ blocks}$$

→ the faster miners become, the less time is needed per block, the higher the difficulty



INCENTIVES FOR MINING

- PoW is computation intensive and consumes a lot of energy
- for motivation, the miners achieves incentive = Block reward + transaction fees

  Block reward currently is 12.5 BTC.

  The block reward halfes every 210.000 blocks.

→ amount of total Bitcoin emitted is limited to 21.000.000

→ mining is the only way to (temporarily still) increase number of Bitcoins

Reward-Drop ETA date: **30 May 2020 09:16:12**

The Bitcoin block mining reward halves every 210,000 blocks, the coin reward will decrease from 12.5 to 6.25 coins.

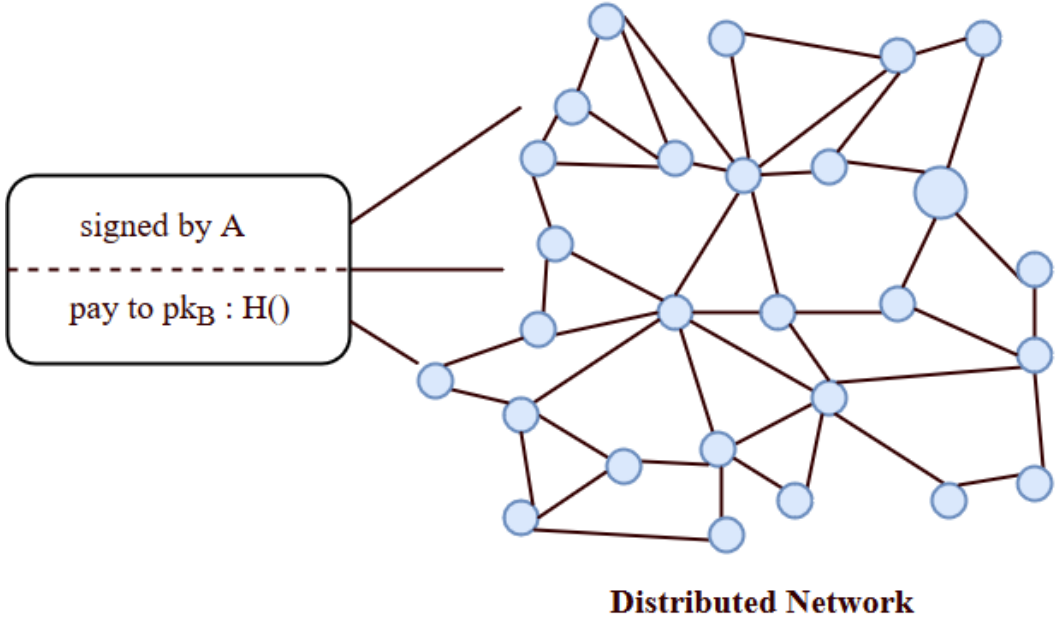
Total Bitcoins in circulation:	16,971,963
Total Bitcoins to ever be produced:	21,000,000
Percentage of total Bitcoins mined:	80.82%
Total Bitcoins left to mine:	4,028,038
Total Bitcoins left to mine until next blockhalf:	1,403,038
Bitcoin price (USD):	$6,904.00
Market capitalization (USD):	$117,174,429,100.00
Bitcoins generated per day:	1,800
Bitcoin inflation rate per annum:	3.95%

http://www.bitcoinblockhalf.com/

DISTRIBUTED CONSENSUS PROTOCOL IN BITCOIN (1/2)

Definition: There are n nodes that each have an input value. Some of these nodes are faulty or malicious. A **distributed consensus protocol** has the following two properties:

- It must terminate with all honest nodes in agreement on the value
- The value must have been generated by an honest node



Broadcasting a transaction:
In order to pay B, A broadcasts the transaction to the entire Bitcoin peer-to-peer network.

DISTRIBUTED CONSENSUS PROTOCOL IN BITCOIN (2/2)

The nodes in the system must agree on exactly

- which transactions were on broadcast and
- the order in which these transactions happened.

→ This results a single, global ledger for the system.

Problems:

- Imperfections in the network, such as latency and node crashing
- Deliberate attempts by some nodes to disturb the process

DECENTRALIZATION IN BLOCKCHAIN (REPEATED)

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THE BITCOIN NETWORK ROLES NODES

GLOBAL BITCOIN NODES DISTRIBUTION

Reachable nodes as of Wed Apr 11 2018 22:48:35 GMT+0200.

11033 NODES

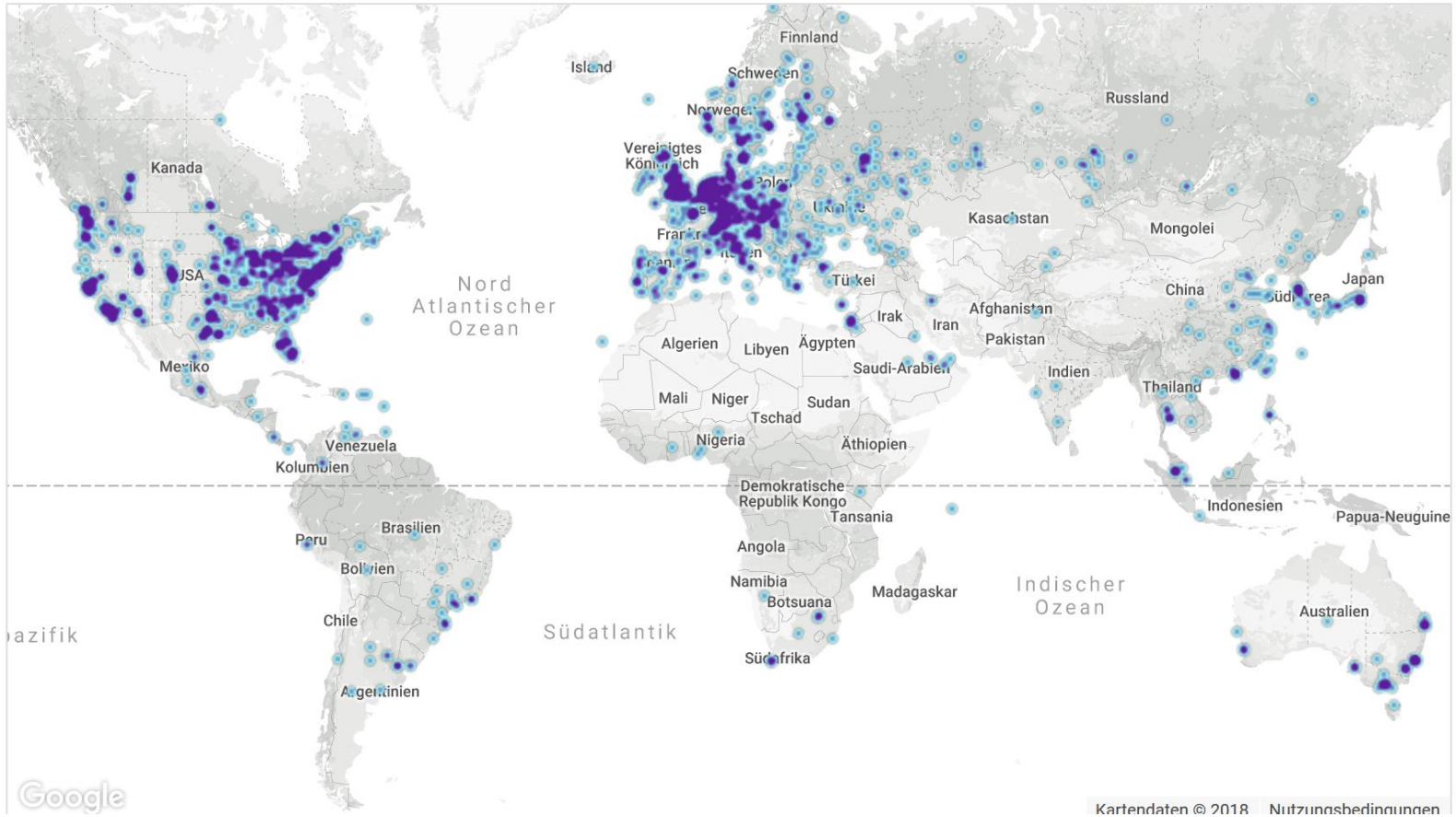
24-hour charts »

Top 10 countries with their respective number of reachable nodes are as follow.

RANK	COUNTRY	NODES
1	United States	2637 (23.90%)
2	Germany	2017 (18.28%)
3	China	1076 (9.75%)
4	France	668 (6.05%)
5	Netherlands	499 (4.52%)
6	United Kingdom	398 (3.61%)
7	Canada	390 (3.53%)
8	Russian Federation	360 (3.26%)
9	n/a	324 (2.94%)
10	Singapore	236 (2.14%)

More (104) »

https://bitnodes.earn.com/



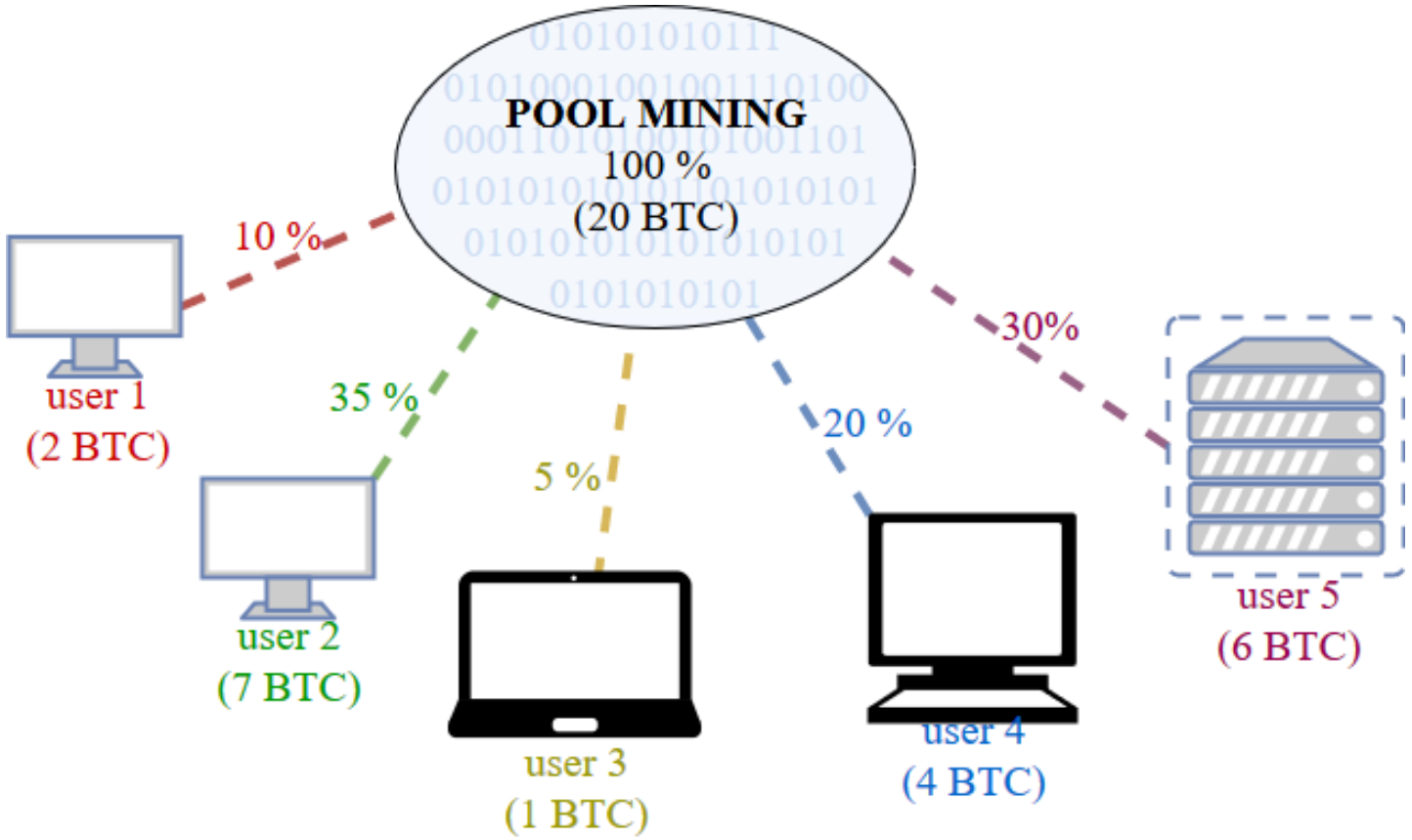
MINING POOLS

Pros

- Allows individual miners to participate
- Easy to upgrade software changes

Cons

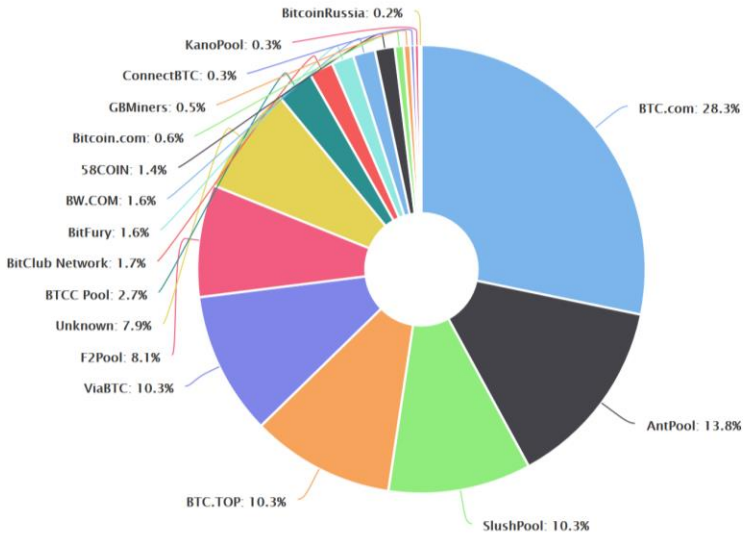
- Pool manager must be trusted
- Centralized
- Enables a multitude of attacks



THE BITCOIN NETWORK ROLES MINERS

https://investoon.com/charts/mining-map/btc, 11.4.2018

https://blockchain.info/de/pools
11.4.2018



REAL WORLD MINING (4/4)

Quick facts

- Today's network hashrate: 7,257,882 TH/s
- Mining Reward / yr = (1 yr / 10 mins) * 12.5 = 657k BTC / yr
- Assume constant price of $4000

Suppose you want to start mining today.

- Antminer S9: Costs $3000, 14 TH/s
- % of network hashrate = (14 TH/s) / (7,257,882 TH/s) = 0.000192893%

Expected Annual Reward

- 0.000192893% * 657k /yr ≈ 1.27 BTC / yr ≈ $5080/yr

Solo mining

- 1 block mined per 571853 blocks

⇒ 12.5 BTC every 3972 days

⇒ $50000 once every 10.9 years

Mining with mining pool

- Assume pool has ⅙ network hashrate
  - Pool finds every 6th block ≈ 1 per hour
- $5080 / 8760 hrs/yr

≈ $0.58 every hour

Paradox:

- The more secure Bitcoin gets, the greater the appeal for mining pools

IDENTITY IN BITCOIN

- **Identity pairs**
  - Email: address and passwords
  - House: address and keys
  - Bitcoins: public key and private key

- **Identity pairs in the context of currencies**
  - public key for receiving money
  - private key for redeeming money

IDENTITY: PUBLIC AND PRIVATE KEY GENERATION

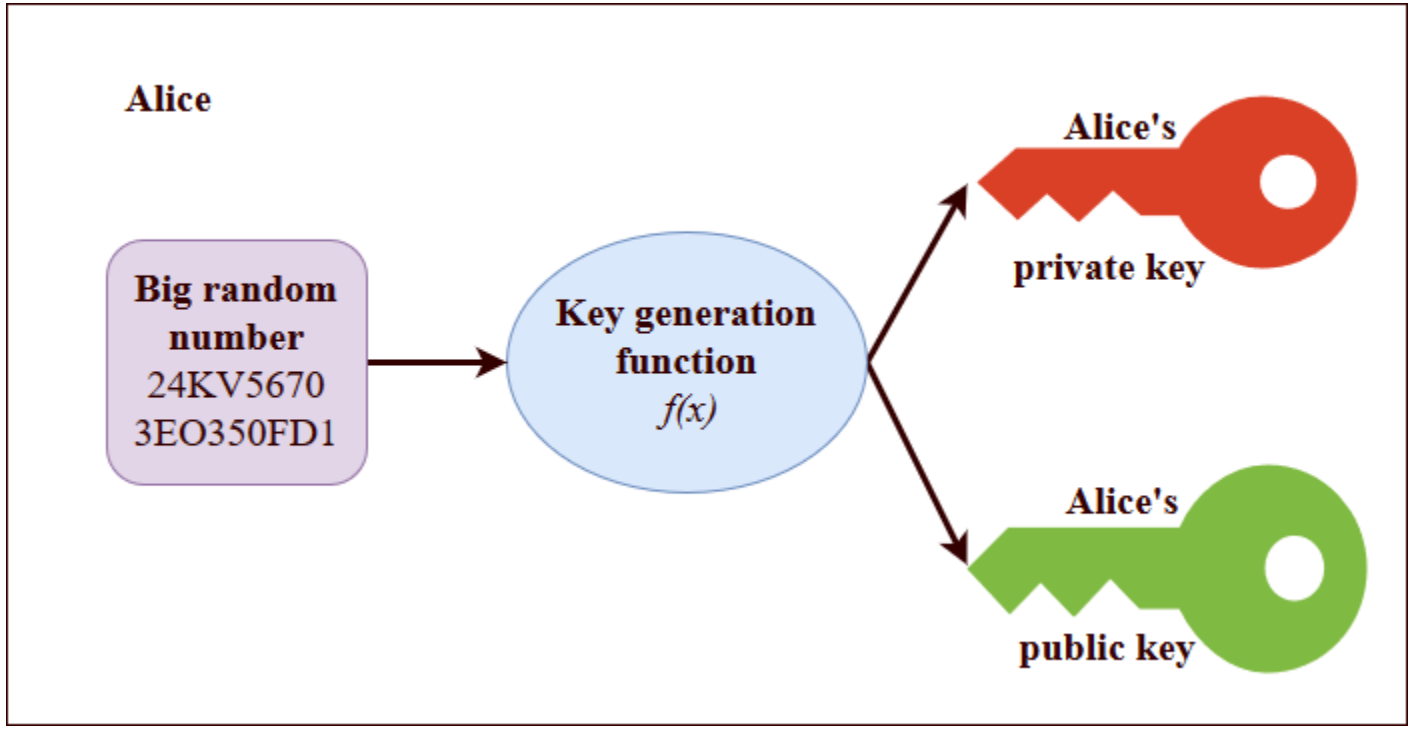
Key Management:

Normal practice is to generate new keys for every transaction you make

Why?

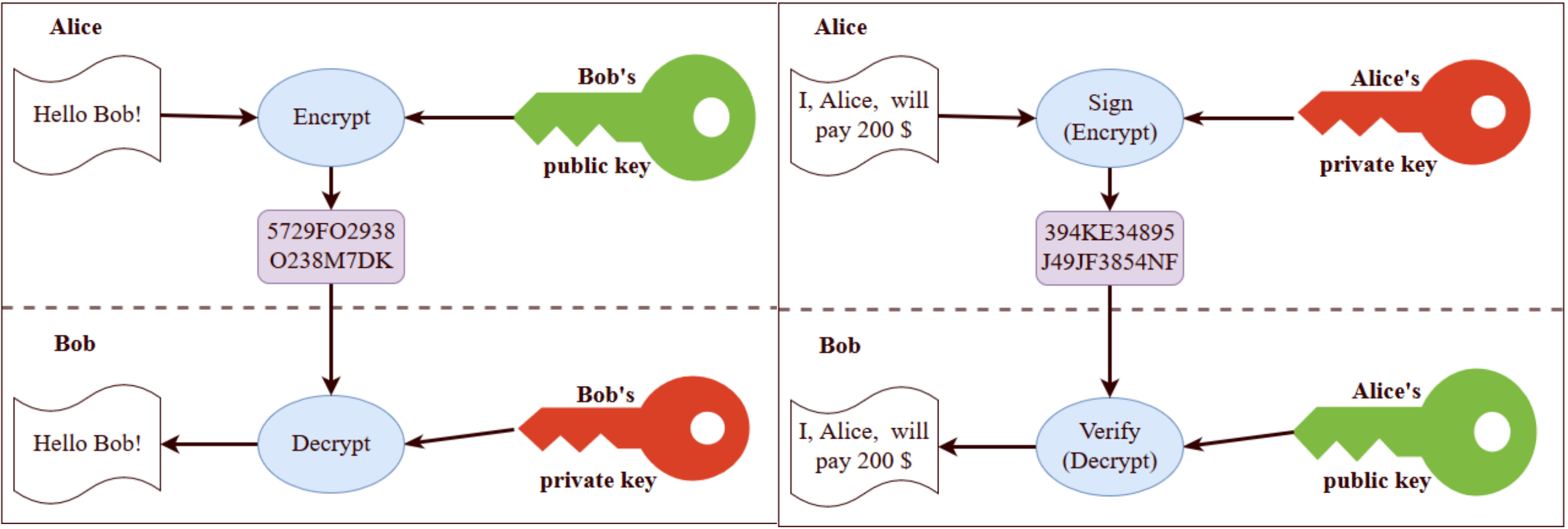
- Privacy
  - Someone shouldn't be able to determine how much bitcoin you own
- Easier to tell who sent you a transaction

Wallet software will do legwork of combining funds from different keys



Public key for receiving

Private key for redeeming



"What if someone guesses my private key?!"

- Bitcoin is hidden in the large amount of public keys
- 2^{160}

  (1,461,501,637,330,902,918,203,684,832,716,283,019,655,932,542,97)

  possible addresses
- Practically impossible for anyone to overlap
  - For reference:
    - Grains of sand on earth: 2^{63}
    - With 2^{63} earths, each with 2^{63} grains of sand: 2^{126} total grains of sand
    - 2^{126} is only 0.0000000058% of 2^{160}
  - Population of world: 7.5 billion in April 2017
    - Every person could have about 2^{127} addresses all to themselves

TRANSACTIONS: VALIDITY

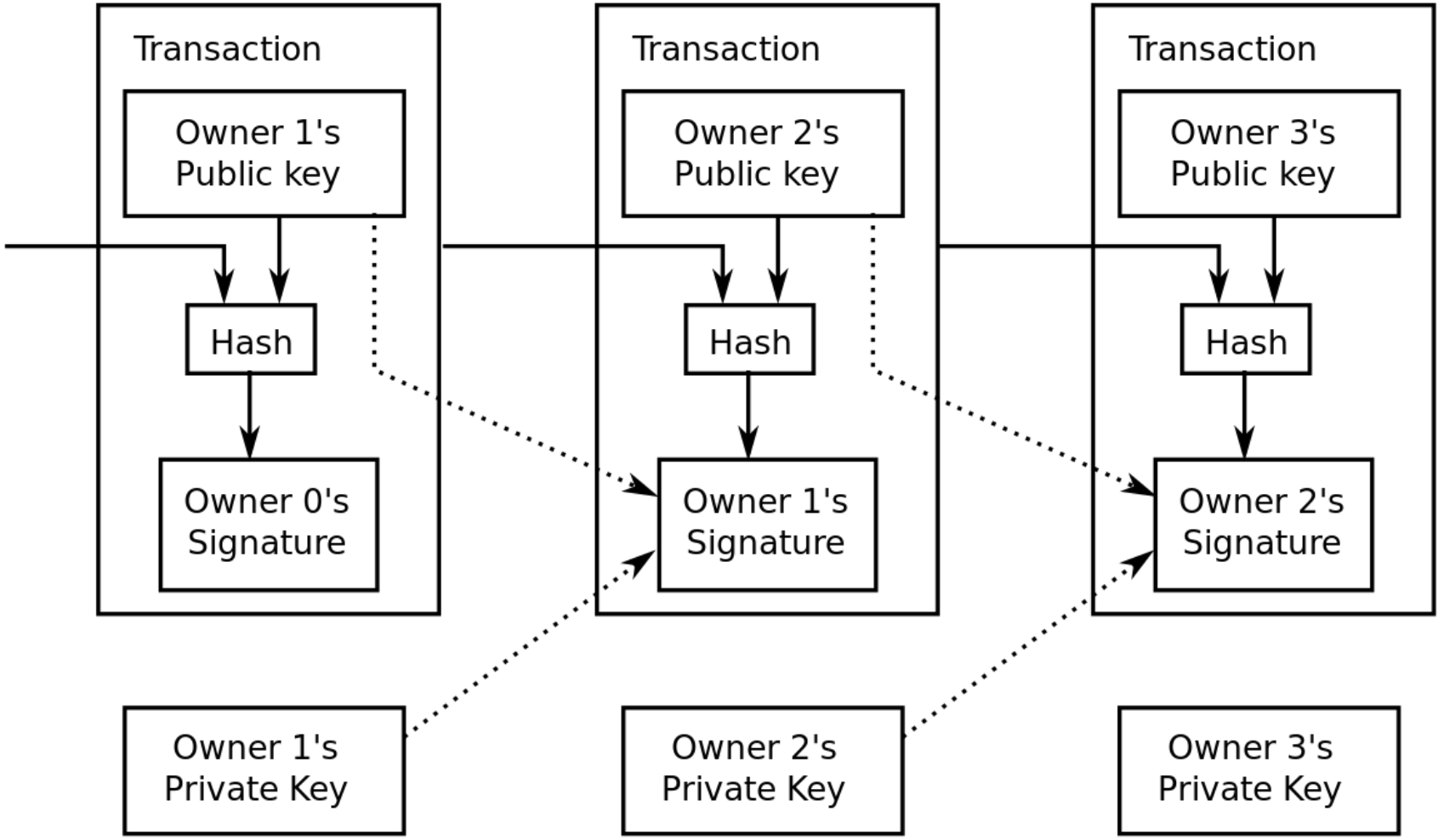
A **transaction** must be **valid**, if all the conditions below are satisfied:

- signature
- funds available
- no other transactions using the same fund

Unspent transaction output (UTXO) model

- to ensure the funds are used only once

TRANSACTIONS (1/2)

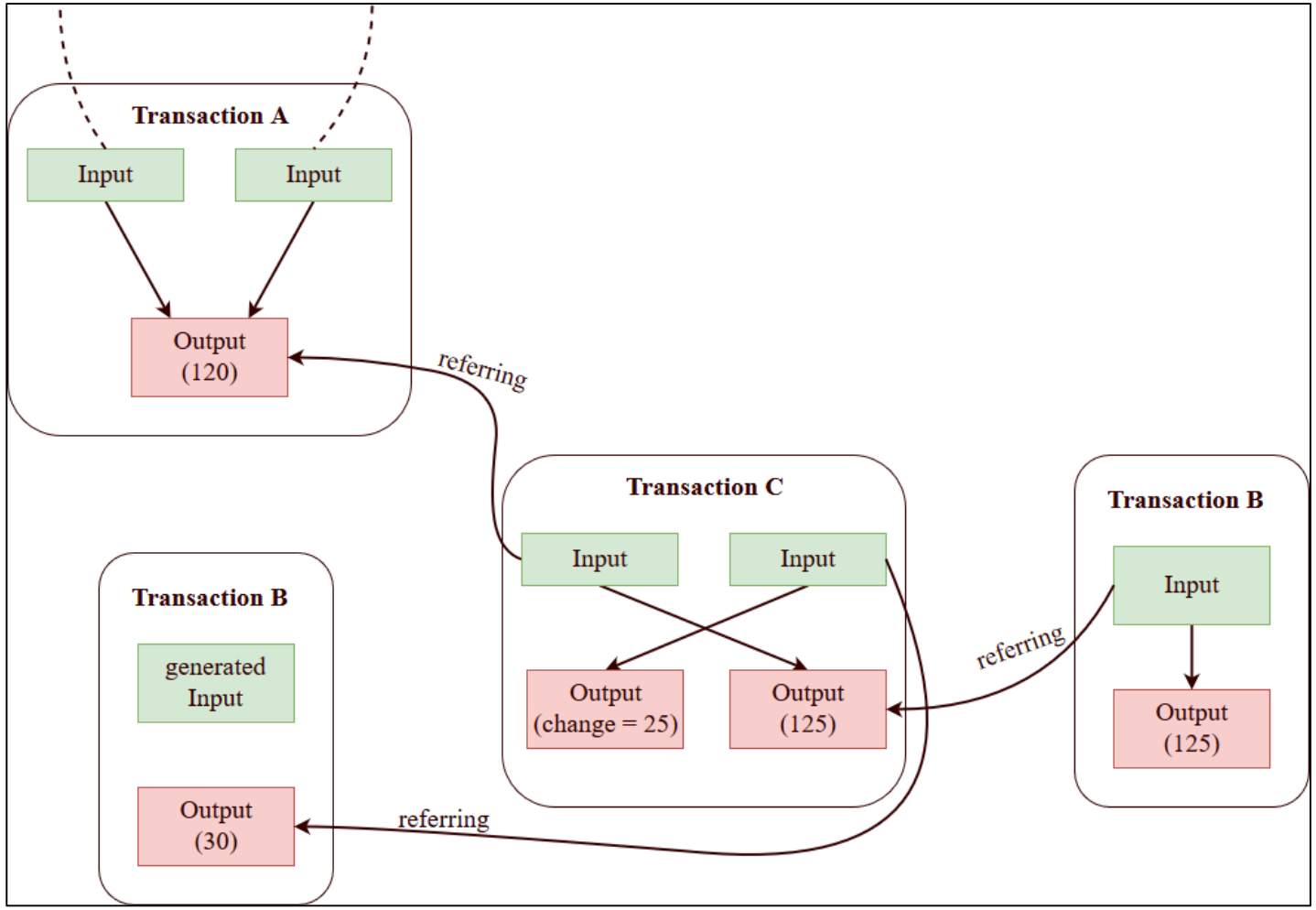


TRANSACTIONS (2/2)

	version	01 00 00 00
	input count	01
Input	**previous output hash (reversed)**	jd 23 i7 jr 85 e9 2m 19
Input	**previous output index**	00 00 00 00
Input	**script length**	
Input	**scriptSig**	script containing signature
Input	**sequence**	ff ff ff ff
	output count	01
Output	**value**	A5 00 00 00 00 00
Output	**script length**	
Output	**scriptPubKey**	script containing destination address
	block lock time	00 00 00 00

TRANSACTION: UTXO

- Instead of keeping all your cash in one chest, each received payment goes into a new piggy bank
- Every time you need to make a transaction, you break one or more piggy banks
- All bitcoins have a „serial number“, the reference number when using UTXOs as inputs for other transactions.



POTENTIAL ATTACKS (1/2)

Sybil attack

- A malicious adversary creates just copies of nodes, all controlled by the same party
  → Bitcoin‘s Solution: Implicit consensus (by randomness) for a block creation

Denial of service attack

- A denies transactions from B‘s address

51% attack

Bitcoin‘s solution → PoW (Bitcoin assumes an honest majority)

POTENTIAL ATTACKS (2/2)

Double-spending attack

- Alice creates two transactions: one to Bob, the other to herself
- Bitcoin‘s solution → make sure to wait for ***n*** confirmation.
    - **Confirmation:** The number of blocks created on top of the block a txn is in.

$$confirmations = block_{depth} - 1$$