

Lecture 3 - Centralized and Decentralized Cryptocurrencies

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April 14, 2016

Note: This lecture is based on Princeton University's BTC-Tech: Bitcoin and Cryptocurrency Technologies Spring 2015 course.

Centralization vs. Decentralization

Centralized Banking

- Centralize: to concentrate under a single authority
- Centralized banking means there is a single institution that manages supply, inflation, and interest.
- Cryptocurrency has to satisfy:
 - Mathematically complex (to avoid fraud and hacker attacks)
 - Decentralized but with *adequate consumer safeguards and protection*
 - Preserve user anonymity without being a conduit for tax evasion, money laundering, etc.

Advantages to Centralization

- Automation:
 - Easily manage a large number of keys e.g. Mastercard Europe
 - Maintain secure infrastructure and improve operations/efficiency
- Centralized Monitoring:
 - Record everything that happens easily; brings transparency
- Centralized Policy
- Easily update and track keys
- Easily update cryptographic schemes - swap out algorithms

CentralizedCoin

- I can generate coins, and give them unique ID's. I also sign these coins.
- I can pass them to anyone else - I sign the transaction; recipient can prove it's valid because it has my signature.
 - Recipient can sign to pass to someone else.
- Chain of hash pointers can be used to follow it back. = verify

- Double Spending Problem
- Only I can write on the chain - everything has to pass through me
- This is centralized; how do you trust me?

Centralized Cryptocurrencies

- E-Gold (1996)
 - Operated by Gold and Silver Reserve inc
 - Let users open an account denominated in gold; could make instant transfers
 - Grew to 5 million accounts; processing over 2 billion a year
 - "e-Gold Special Purpose Trust" - actually held the gold; could see gold bars with serial numbers per acct.
 - Hackers used flaws in Microsoft Windows OS's and phishing to compromise millions of e-gold accounts
 - People thought it was *anonymous*, but really it was *pseudonymous*. Law enforcement identified many.
 - Ponzi schemes via. eBay
 - Patriot Act, after Sept 11, made operating a money transmitter business without a state money transmitter license a federal crime.
 - Taken down 2007-2013; inability to provide reliable user identification and cut off illegal activity
 - PayPal has done a better job, but still has to deal with the same problems.
 - KYC - process of verifying clients' identity
- DigiCash by Chaum 1990
 - Store money as data on your computer
 - Transfer anonymously
 - Lacked decentralization; the company's servers were used
 - Went bankrupt in 1998
- Can be shut down by gov. at any time

Decentralized Cryptocurrencies

- Decentralization is not all or nothing
 - Partially decentralized - SMTP (email)
- Bitcoin and Decentralization
- How does Bitcoin deal with decentralization?
 1. Who maintains ledger of transactions?
 2. Who determines which transactions are valid/invalid?
 3. Who creates new coins
 4. Who chooses when rules change

Distributed Consensus (Solves 1 and 2)

- Paxos - Method for consensus
- All good nodes agree on the same value (proposed by a good node)
 - A good node is one that is being honest
- How it works:
 - All nodes have a sequence of blocks of transactions they have reached consensus on; order is important
 - Each node has a set of outstanding transactions - this solves the problem where not all nodes are aware of all transactions.
 - Each transaction is broadcast to all
 - Doesn't matter if transactions are left out - they get included in the next block.
 - A random node gets to broadcast its block per round
 - Other nodes accept only if valid, and show through including block in hash for next block.
 - Paxos is a Two Phase Commit (2PC): Coordinator suggests value to all nodes, Coordinator (on receiving enough yes's), says value is final - Update. (Problem of falling coordinator is solve by everyone being able).
 - Two phases are called *Voting Phase* and *Commit Phase*.
- Consensus without identity - Block Chain
 - Bitcoin nodes don't have identity; pseudonymity vs. anonymity
 - Implicit Consensus: Random node picks next block in the chain, and other nodes vote by extending or ignoring.
 - Works because difficult (impossible) to subvert.
 - "Zero confirmation transaction" is a bad idea.
 - The more confirmations, the better the choice. Bitcoin uses 6.
- Incentives: Solves 3
 - Can't penalize, but can reward nodes for working correctly.
 - Incentive 1: Block Reward (25 BTC, halves every 4 years). (Solves 3)
 - 21 million max - block reward is how new coins are created; run out in 2140.
 - Incentive 2: Transaction Fee
 - Incentive to have your transaction verified
 - Remaining problems:
 - How to pick random node
 - How to avoid free-for-all rewards
- The Solution: Proof of work:
 - Select nodes in proportion to computational power
 - Give example of leading 0's
 - Difficult to compute
 - Puzzle Friendliness: No solving strategy for finding $H(k|x) = y$ is better than trying random values of x.
 - Motivation to subvert the process (picking a hopefully honest node), so reward honest nodes
 - Use bitcoins to incentivize honest nodes - mining. Reward only if it becomes legitimate transaction

- Every 210,000 blocks (4 years), block reward is cut in half. Geometric sum - 21 million bitcoins
- Nonce published as part of the block.
- Proof of work details
 - Mining: Hash function with nonce appended to beginning (ex: 0's)
 - HashCash - with SHA-256 (used twice)
 - Less than some value
 - Items used: version, prevBlockHash, merkleRoot, timestamp, bits, nonce
 - Selecting nodes based on processing power/proportional
 - Hash puzzles - to make blocks, it needs to find a nonce where

$$H(\text{nonce} || \text{prev_hash} || \text{tx} || \text{tx} || \dots || \text{tx}) < \text{target}$$
 - Nonce: Random number that is only used once
 - Hash puzzle properties: difficult, parameterizable cost (10 minutes variable target), trivial to verify
 - 10 minutes: reduce inefficiency from having many blocks
 - $$\text{meantime to next block} = \frac{10 \text{ minutes}}{\text{fraction of hash power}}$$
 - proof of stake - proportion to ownership of currency (used in other cryptocurrencies)
 - <http://www.righto.com/2014/09/mining-bitcoin-with-pencil-and-paper.html>
- The miner gains if reward > cost
 - reward = block reward + tx fees
 - mining cost = hardware cost + operating costs
- Aspects of decentralization in Bitcoin
 - Peer to peer network, open to anyone, low barrier for entry
 - Mining is open to everyone
 - Updates to software - core developers trusted by the community who have a lot of power (Solve Problem 4)
- New Problems from being Decentralized and Attacks:
 - Byzantine Generals: How to make a safe decision while communicating with other parties over an insecure network
 - Work is hard, but easy to check if it's been done.
 - Blockchain is important because it is a way of representing the truth, without any one gate-keeper.
 - Give example then consider: Must wait 10 minutes to give message, and must embed all past messages in your own.
 - <http://www.dugcampbell.com/byzantine-generals-problem/>
 - Implicit Consensus:
 - Byzantine Generals
 - Chosen node chooses what the next block is; voting is by what is extended by the others
 - Fischer-Lynch-Paterson: consensus impossible with a single faulty node.
 - solved with 6 blocks
 - Can't penalize those who try to double spend, since there's no way to tell
 - Blocks have a tendency to extend the block they hear about first
 - Orphan Block
 - Latency, not all nodes connected, internet connection, malicious nodes

- Attacks:
- Stealing - even if Alice gets to decide the next block, she can't steal because she has to create a valid transaction; can't forge signatures
- Denial of Service - even if Alice never validates Bob's transactions, an honest node will eventually do so.
- Double Spend - DRAW DIAGRAM
Say Alice pays Bob, and an honest node broadcasts this. Bob accepts that he's been paid. Alice then gets to broadcast her own transaction. She then makes a block with the *prevBlock* hash as the one before her payment to Bob. Only one of these blocks will be accepted.
- Sybil attack
Can't gain more power by having more accounts
Satoshi's original paper had 1 cpu = 1 vote
- Zero-confirmation transaction
Bob gives Alice product before transaction has been verified
6 blocks; double spend probability goes down exponentially
Never a 100% guarantee
- Solves the problem of not trusting a central authority - Problem 4
- 51% attacker
 1. CANNOT Steal Bitcoin
 2. CANNOT change block reward
 3. Suppress transactions
 4. Destroy confidence in Bitcoin

Changing the rules

- Two types of changes - soft forks; hard forks
Soft forks are forward compatible; new rules are subset of old rules. Only applied if over 51% agree.
Hard forks are backward compatible; old rules are subset of new rules. Everyone needs to upgrade to new.

Source: http://people.dsv.su.se/~matei/courses/IK2001_SJE/Chaum90.pdf
 Source: <http://blog.koehntopp.de/uploads/Chaum.BlindSigForPayment.1982.PDF>