Bitcoin

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Bitcoin

- Network of bitcoin peers (servers) run by volunteers
- Peers are not trusted: may be greedy or corrupt
- Each peer knows about all bitcoins and transactions
- Transaction (sender -> receiver):
  - sender sends transaction info to some peers
  - peers check that bitcoin hasn't already been spent
  - peers flood transaction to all other peers
  - receiver checks that lots of peers have seen transaction
Purses

• Instead of discrete coins, aggregate into purse
• Purse
  – Controlled by a public key (only owner can spend)
  – Aggregate value = sum over history of in/outs
  – Peers check remaining balance > transfer
  – Peers only accept valid transfers
• Newly minted coins go into a single purse
Block Chain

• Block
  – Hash of previous block (no undo)
  – Set of transaction (transfer)
  – Assignment of newly minted coins to purse
  – Nonce st SHA of block < threshold

• Transaction
  – ID of source of funds (unspent transaction)
  – Amount to be transferred
  – Public key of new owner
  – Signed by owner of source of funds
Example

• 0.1 Bitcoin owned by Jialin (who received it in payment from Ellis)
• T7: pub(Jialin), hash(T6), 0.1 BT, sig(Ellis)
• Jialin buys a hamburger from Doug
• Doug gives Jialin a public key (bitcoin "address")
  – Perhaps create a new address just for this purchase
• Jialin creates a new transaction and signs it
• T8: pub(Doug), hash(T7), 0.1 BT, sig(Jialin)
Example

• T8: pub(Doug), hash(T7), 0.1 BT, sig(Jialin)
• Jialin sends T8 to bitcoin peers; peers flood
• Honest peers verify that
  – hash(T7) contains enough value
  – T8's sig() corresponds to T7's pub()
• Peer finds valid nonce for block containing T8
• Broadcasts nonce to other peers
• Next block will contain hash of block with T8
Double Spending

Suppose Jialin creates two transactions spending the same bitcoin balance
  – Jialin->Doug, Jialin->Tom

How long should Doug wait before giving Jialin the hamburger?

Until Doug sees Jialin flood the transaction to many peers?
Double Spending

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– not in the chain, Jialin might flood conflicting xaction

Until Doug sees one peer with chain containing xaction?
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– maybe that peer is corrupt, in league with Jialin

Until Doug sees lots of peers with chain containing xaction?
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Until Doug sees one peer with chain containing xaction?
  – maybe that peer is corrupt, in league with Jialin

Until Doug sees lots of peers with chain containing xaction?
  – risky -- some other chain may win
  – perhaps that chain won't have transaction

Until Doug sees chain with multiple blocks after transaction?
  – slim chance attacker can catch up
Reward

• Solution is broadcast to every replica; what keeps replicas from stealing the solution?
• Every replica works on a slightly different puzzle
• Ellis works on:
  – SHA(previous hash, mint coin and give it to Ellis, set of transactions, nonce) < target
• Jialin works on:
  – SHA(previous hash, mint coin and give it to Jialin, set of transactions, nonce) < target
When Nonce is Found

Replicas have a choice:

– Ignore the answer and continue to try to find another one
– Take the answer as a given and work on the next puzzle.

Which should it choose?

– If more than half of the computational power chooses (b), replica should choose (b)
Who Wins?

• If two nodes find the nonce at about the same time, who wins?
• Depends on solution to the next puzzle!
• Everyone has an incentive to work on chain that others will work on
  – If next solution uses A’s solution, A wins
  – If next solution uses B’s solution, B wins
• In practice, choose the nonce that is less likely (smaller)
Who Wins?

- Replicas have an incentive to prevent others from announcing their solutions
- DoS attacks
  - flood replica with traffic so TCP connections fail
- BGP prefix hijacking
  - Internet is shortest path routing, without security
  - Announce your network has shorter path to target replica, then don’t deliver the traffic
Mining Groups

• Reward is (very) sporadic: if 1M replicas search for hash, each will win once every few decades.
• Pool resources: pay nodes to look for solutions
• If Doug is a coordinator, ask replicas to:
  – SHA(previous hash, mint coin for Doug, msg, nonce)
• Why would anyone do this for Doug?
  – Small reward for incremental proof of work
  – Ex: hand out 0.001 bitcoin for nonces with 60 zeros
Serial Numbers Revisited

• Proof of work solves how we create new coins
  – Every 10 minutes, another reward

• What about inflation?
  – Reward decreases by 2x every few years
  – Increasing number of coins in circulation
  – Fixed total number of coins (93% of total already mined)

• Do miners stop working when reward stops?
Theory of Money

• Why do bitcoins have value?

• Why does gold?

• Why does cash?

• Why does Facebook or Google stock?
Who Wins?

- Bitcoin founder(s) performed early mining
  - Reserved 1M Bitcoins for their own use = $2B
  - But haven’t spent them (bitcoin log is public)
  - Is it possible for them to sell?
  - Backlog equal to 18 months of mining (!)
Transaction Reward

• When a replica receives a request what should it do?
  – Ignore it?
  – Add it to the next batch?
  – Forward it?
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• Transactions can have multiple outputs
  – Main payment to recipient
  – Side payment to the winning miner
Private Exchanges

• Bitcoin
  – can only perform a few operations per second
  – performs operations slowly (minutes to confirm)
  – No accountability if seller reneges

• Private exchanges/escrow
  – Both parties trust exchange
  – Execute operations on internal account record
  – Exports internal account to cash or public bitcoin

• How is this different from a bank?
Bitcoin and Other Cryptocurrencies

• Bitcoin is not the only electronic cash standard

• Zerocoin
  – Better anonymity (money laundering)

• Ethereum
  – Better scripting (create new types of coins)

• Ripple
  – Public blockchain, but with stable price
Bitcoin Discussion

• Where does value of a Bitcoin come from?
• How long will SHA-256 last?
• How do we make changes to the protocol?
• Is Bitcoin anonymous? Linkability
• Is Bitcoin ethical? Ransomware
• Private exchanges and security
• Non-reversible (vs. credit cards)
• Attacks: mining monopolies, BGP route hijacks, ...