TOPIC: 6.857

DATE: 4/1/19

FILE UNDER:

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Admin: Pset #4 out today. (6.857 coin!)

Today: E-cash & bitcoin

Representing value: bits vs. atoms

Gold atoms: unforgeable & scarce

"ownable"

transferable (multiple times one after another)

decentralized

divisible & combinable

anonymous

Bits: Easy to generate bits (dig. sigs?)

Easy to copy
⇒ double spending!!

Need "accounts" to prevent/detect double-spending

accounts may be centralized or decentralized (bitcoin)

transferable (≈ checks)

divisible & combinable

not as anonymous (PK = identity)

Electronic Checks

With TTP (trusted-third party = bank):

Bank has PK_B, SK_B

User has PK_u, SK_u

certificate on PK_u (signed by B)

Check = cert on PK_u signed by B

("Pay PK_v $100, date, serial #)

signed by u

Bank processes check once (ser # prevents replay = double spending)

Usual problem: overdraft

Privacy: Bank & Merchant know xact details

Bank maintains transaction history of accts

Coins vs Checks

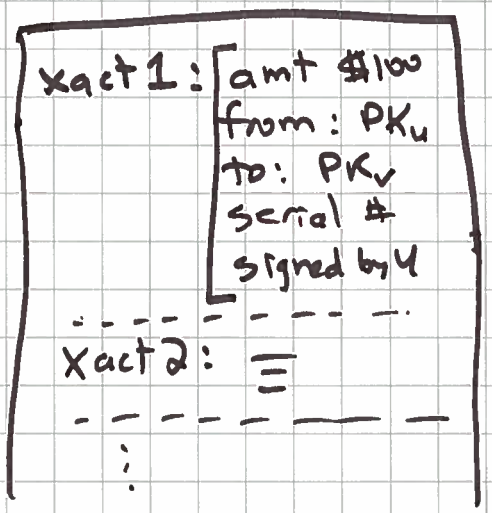
Coin: bit string signed by bank ≡ coin
"blindly"

bank can recognize coin when deposited

Checks: Replace bank B by "public ledger"
(append-only log of xacts)

IDs are just PKs, not more
(¬anonymous, pseudonymous)

ledger =



ledger = entire state of system!

where do accts get value?

Anyone can check that xact is valid

Public Ledger:

Centralized or decentralized?

Who can read?
write? (create xact
add to ledger)

[Decentralized public ledger is key
Bitcoin contribution

Bitcoin (Nakamoto 2009)

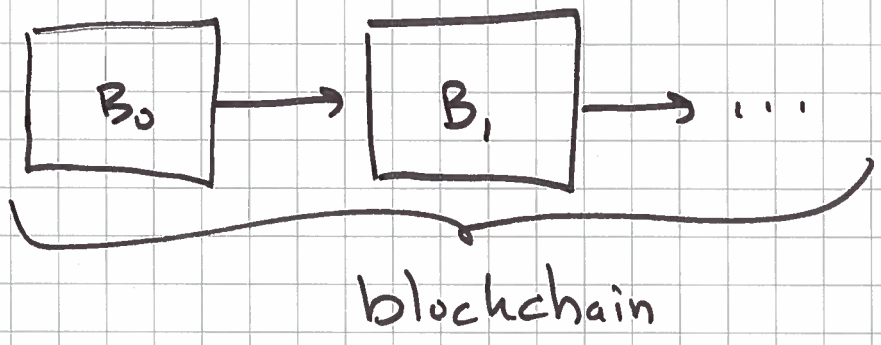
Public ledger records all transactions

Decentralized maintenance of ledger

based on POW to validate blocks

put on the "blockchain" (ledger)

Uses bitcoin to incentivize maintenance



Block chain

Each block contains:

- hash of previous block (∴ "chain")
- PK of creator (≈ "miner") (really H(PK))
- nonce (for puzzle - see later)
- Transactions:
  1. coinbase = fee to creator = 12.5 ₿
  2. Merkle tree of transactions
     - Each transaction has
       - inputs: block & output # where created (or coinbase) with sigs
       - outputs: PKs (actually hashes) of recipients, with amounts
     - Value(inputs) ≥ Value(outputs)
     - Inputs not previously spent
     - Input sigs valid
     - Change ⇒ miner as xact fee

Communications Network

- Anyone (with bitcoins) can propose a transaction for inclusion in public ledger.
- Transaction is only valid if it is on ledger.
- Blocks distributed to other nodes via a "gossip" protocol.
- New blocks posted about 1 / ten-minutes.
- If network partitioned, can be lack of consensus as to what is current state of blockchain.
- Even if no partition, several nodes may propose what should be "next" block on blockchain.

Bitcoin provides a distributed consensus protocol (perhaps its biggest contribution)

Consensus Protocol

Consensus via race to solve block puzzle first

"nonce" is solution to puzzle if

$$H(\text{block}) \leq 2^{256-d}$$

↑ includes block header, nonce, H(PK(miner)), Merkle root of xacts

$d \approx 74.5$ now (e.g. start with 74 "0" bits)

Takes about 2^d tries to find a good nonce.

d adjusted so soln found about every 10 minutes

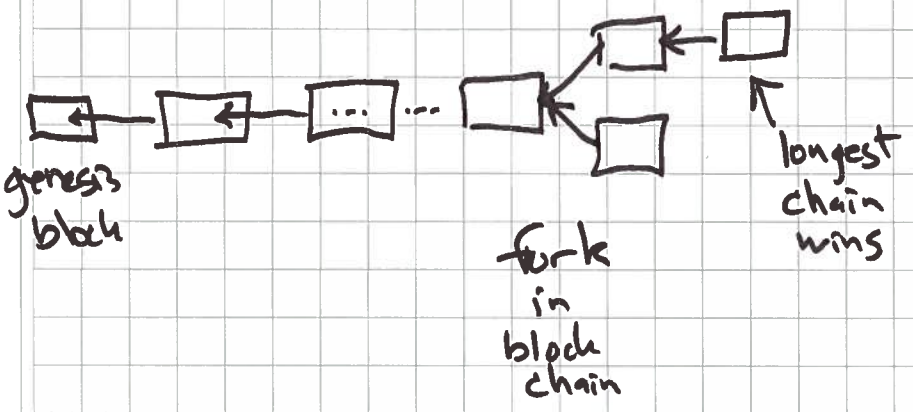
"POW" = proof of work

Prob (good guys find soln first)

= % of hash power owned by good guys

Once a solution is found, it is broadcast.

All other nodes work to extend longest blockchain



Hash power & 51% attack

Let p = prob honest node finds next block

q = " " malicious " " " "

q_z = " " miner will overtake main chain if it starts z nodes behind

$$= \begin{cases} 1 & \text{if } q \geq p \\ \left(\frac{q}{p}\right)^z & \text{if } q < p \end{cases}$$

e.g. $\left(\frac{0.49}{0.51}\right)^{144} = 0.003148$

"wait 6 blocks" (one hour) to "confirm payment received"

Mining Pools

Many miners combine forces to even out variance in payments.

Maker "pay to" for coinbase = mining pool operator

Can show "POW" for "almost solns" to pool operator

Reward split among pool miners according to work done

Bitcoin (In)efficiency

- Ledger getting big (197GB)
- Electricity use 500 kWh/transaction
  total ≈ Bangladesh
  0.25% of all electricity
- Time to "settle"
  one hour?
  more?
  (Latency)
- Throughput
  VISA 5000/sec
  Bitcoin 5/sec

Variations & Extensions

"side chains"

"smart contracts"

"anonymity & Zcash"

algorand (Micali) - not POW

"Proof of stake" (more generally)

Probabilistic payments?

memory-hard POW