Lecture 23 – Cryptocurrency

Stephen Checkoway
University of Illinois at Chicago
CS 487– Fall 2017
Slides from Miller's ECE 422

The Times 03/Jan/2009 *Chancellor on brink of second bailout for banks.*

Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
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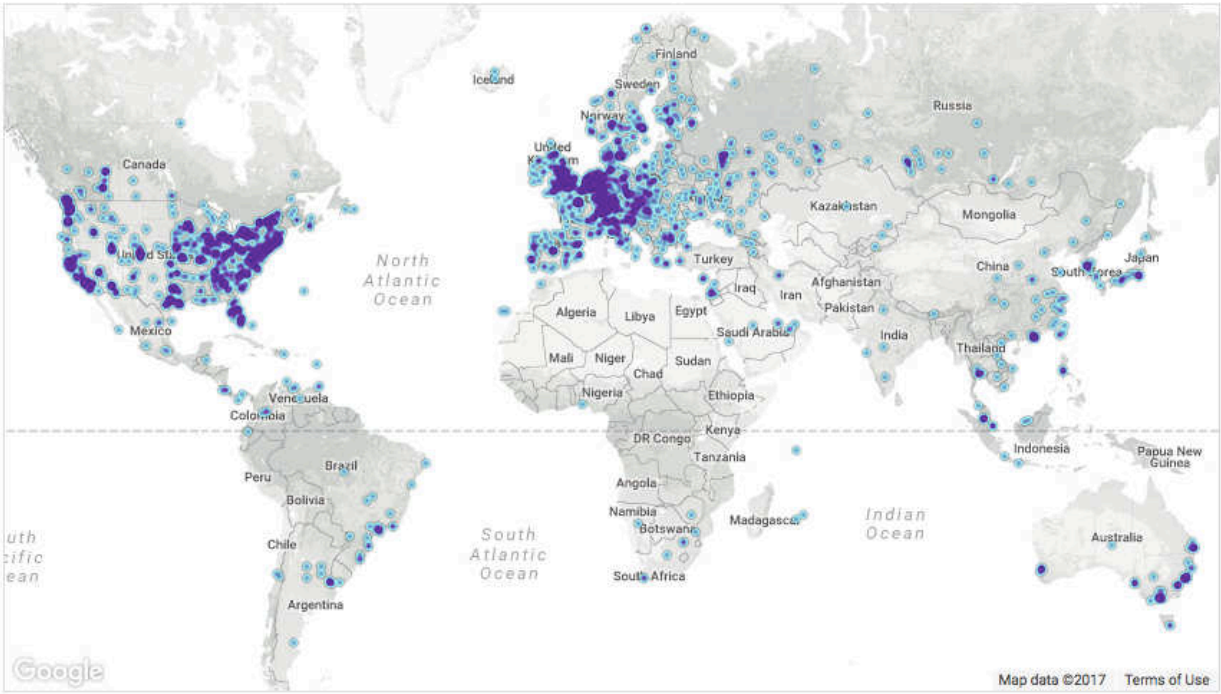
www.bitcoin.org

Abstract. 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. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of

```
bitcoin-0.1.0.rar
bitcoin-0.1.0.tgz
```

≈11,000 reachable nodes (Nov, 2017)

RANK	COUNTRY	NODES
1	United States	3068 (27.83%)
2	Germany	1854 (16.82%)
3	France	767 (6.96%)
4	China	719 (6.52%)
5	Netherlands	531 (4.82%)
6	Canada	448 (4.06%)
7	United Kingdom	437 (3.96%)
8	n/a	378 (3.43%)
9	Russian Federation	354 (3.21%)
10	Singapore	220 (2.00%)



https://bitnodes.earn.com/

Just kidding.
That was from March

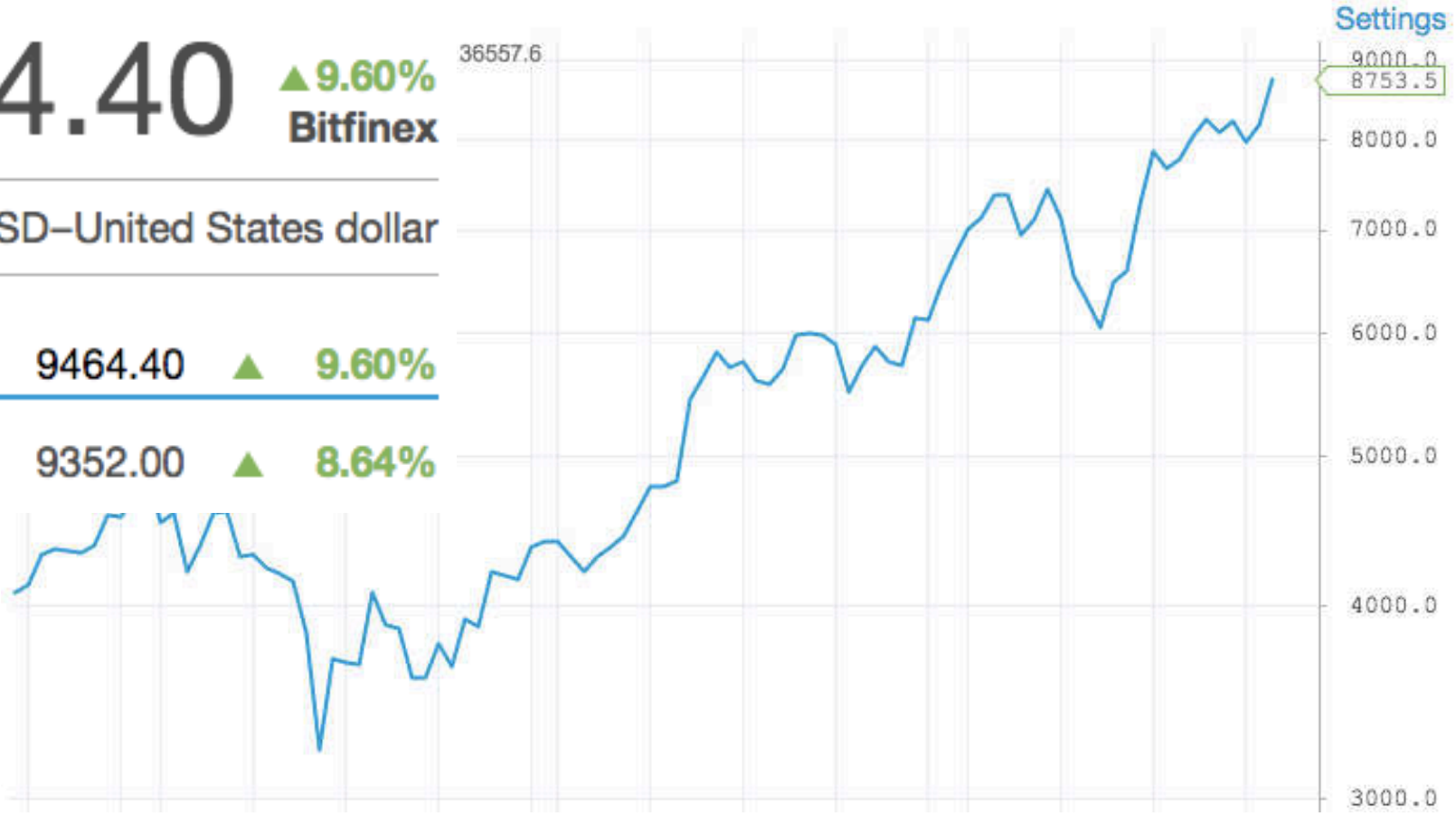
source: blockchain.info

$9,464.40

▲9.60%
Bitfinex

Currency	USD–United States dollar

Bitfinex	9464.40	▲	9.60%
Bitstamp	9352.00	▲	8.64%

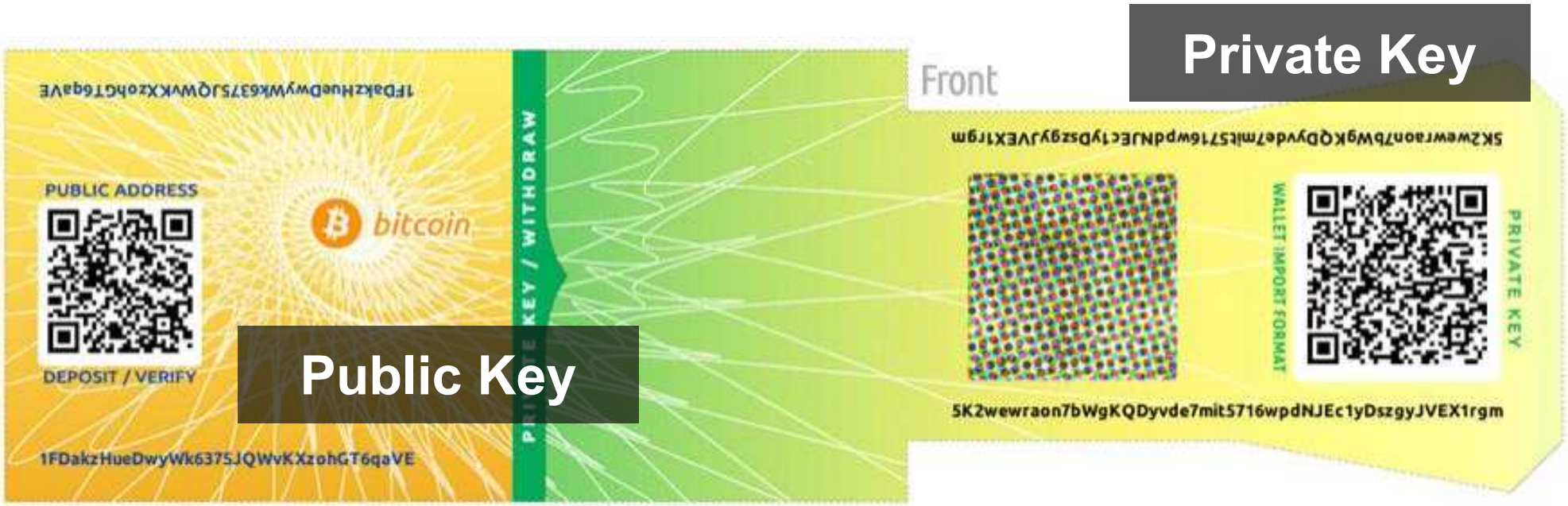


Bitcoin Market Cap
$156.6B

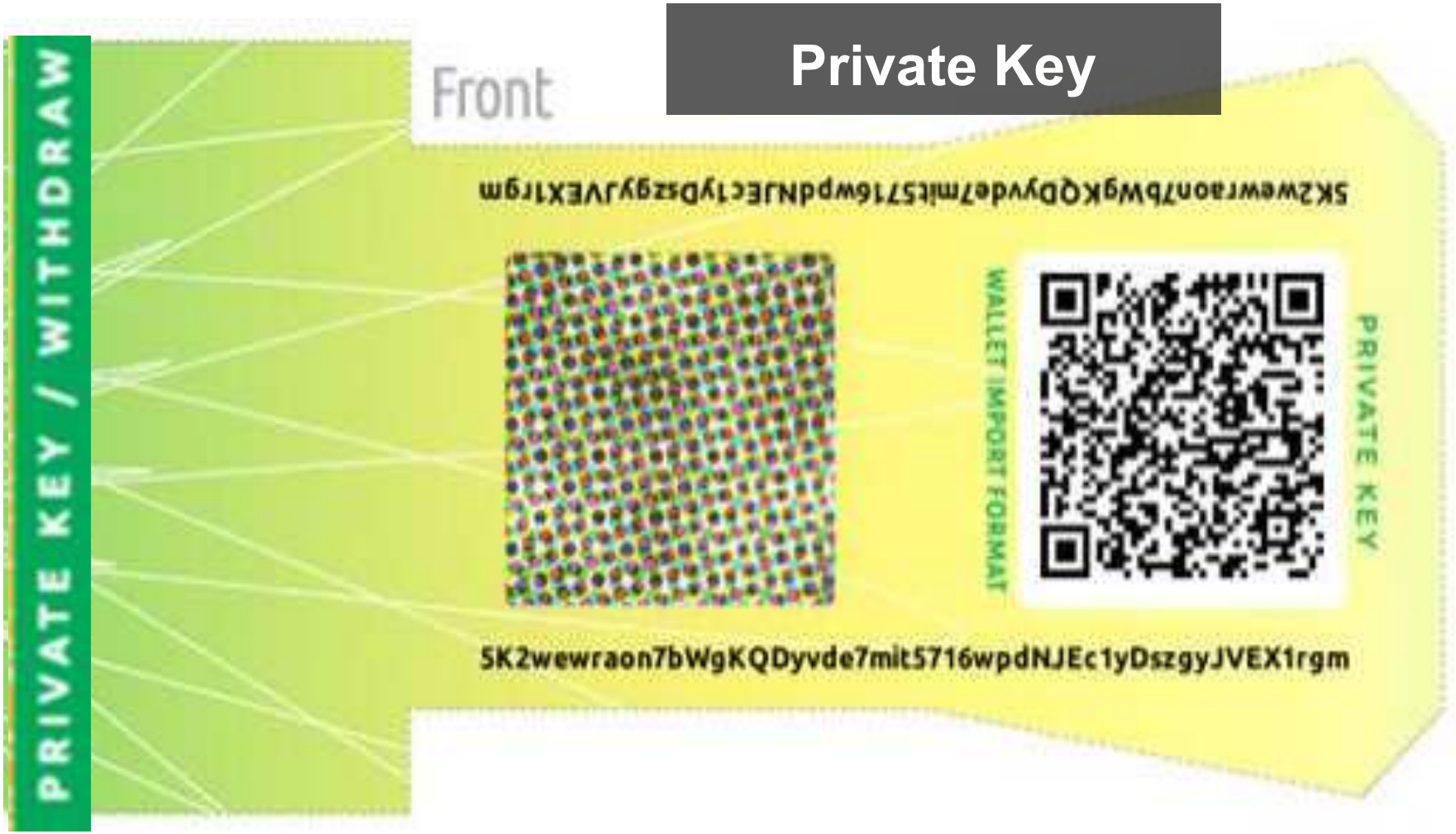
24-hour Transaction Volume
$2.1B

Bitcoin Money Supply
16.70M

Bitcoin Paper Wallet



Private Key

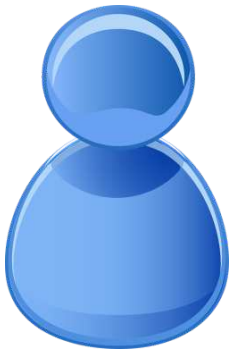

PRIVATE KEY / WITHDRAW
Front
5K2wewraon7bWgKQDyvde7mit5716wpdNJEc1yDszgyJVEX1rgm
WALLET IMPORT FORMAT
PRIVATE KEY
5K2wewraon7bWgKQDyvde7mit5716wpdNJEc1yDszgyJVEX1rgm


PUBLIC ADDRESS
bitcoin
DEPOSIT / VERIFY
1FDakzHueDwyWk637SJQWvKXzohGT6qaVE

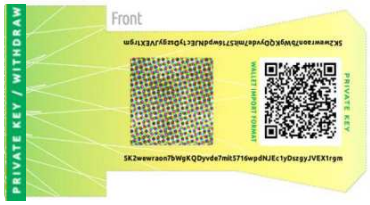
Public Key

Alice and Bob are only identified by public keys

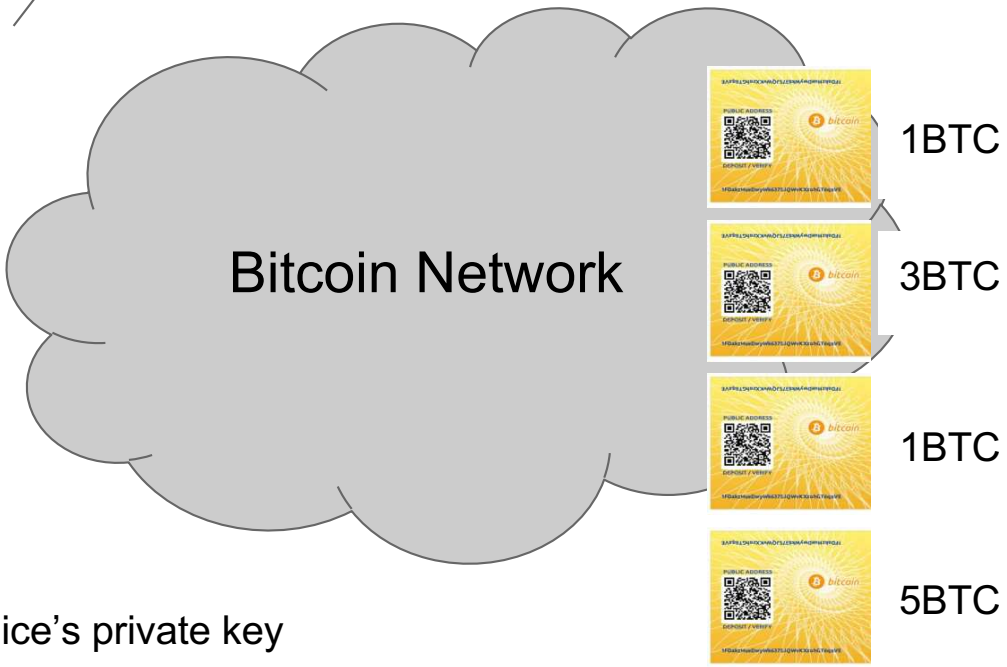
Transfer 10 Bitcoins from me to Bob.



Alice

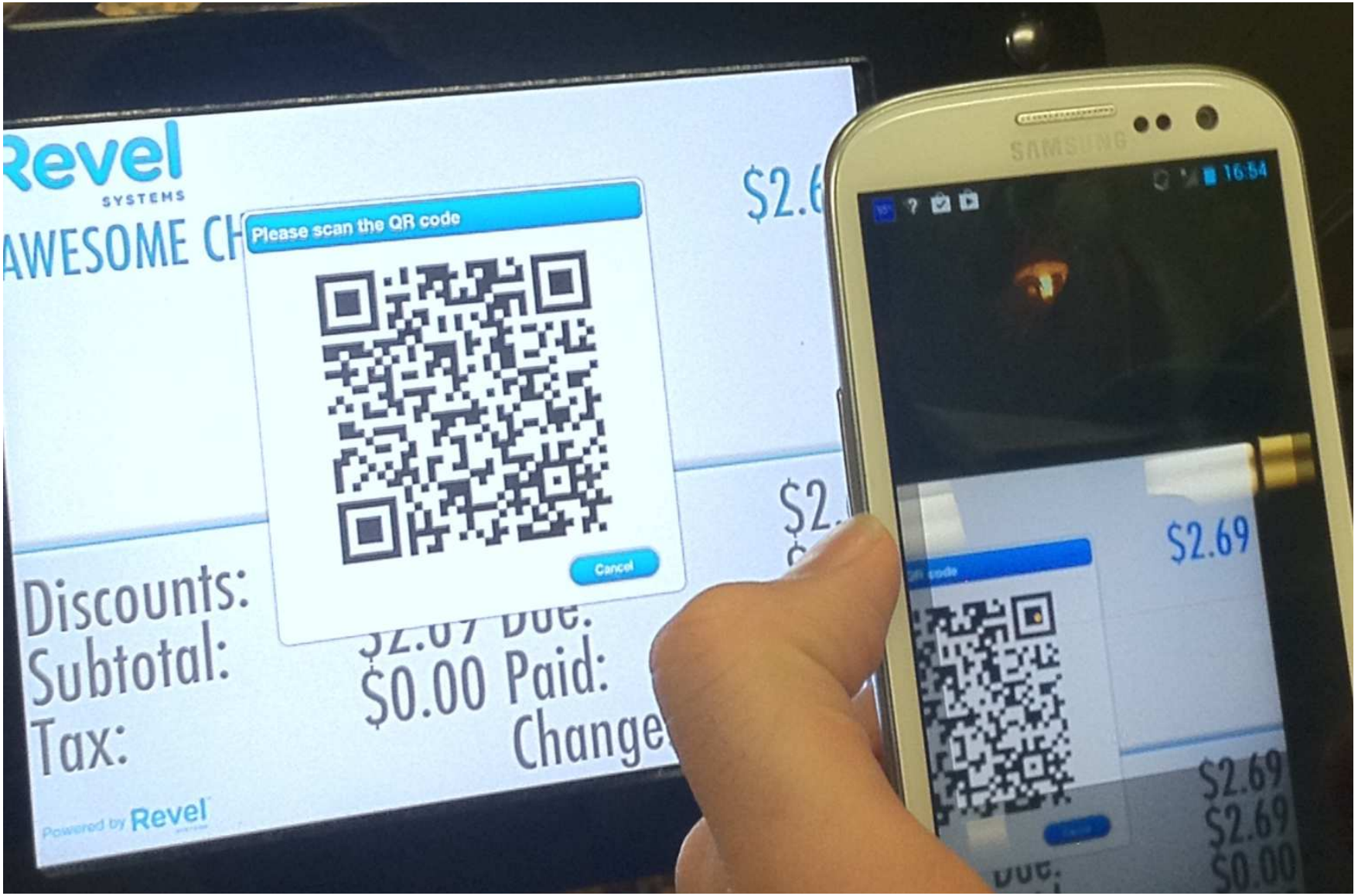


Signed with Alice's private key



LATEST BLOCKS

Height	Age	Transactions	Total Sent
496234	16 minutes	2356	5,709.20 BTC
496233	19 minutes	2750	6,188.44 BTC
496232	21 minutes	2119	4,374.67 BTC
496231	23 minutes	2532	6,900.23 BTC


Revel
SYSTEMS
AWESOME CH
Please scan the QR code
Cancel
$2.6
Discounts:
Subtotal:
Tax:
$0.00 Paid:
Powered by Revel
SAMSUNG
16:54
$2.69
$2.69
$2.69
$0.00


HI MOM SEND

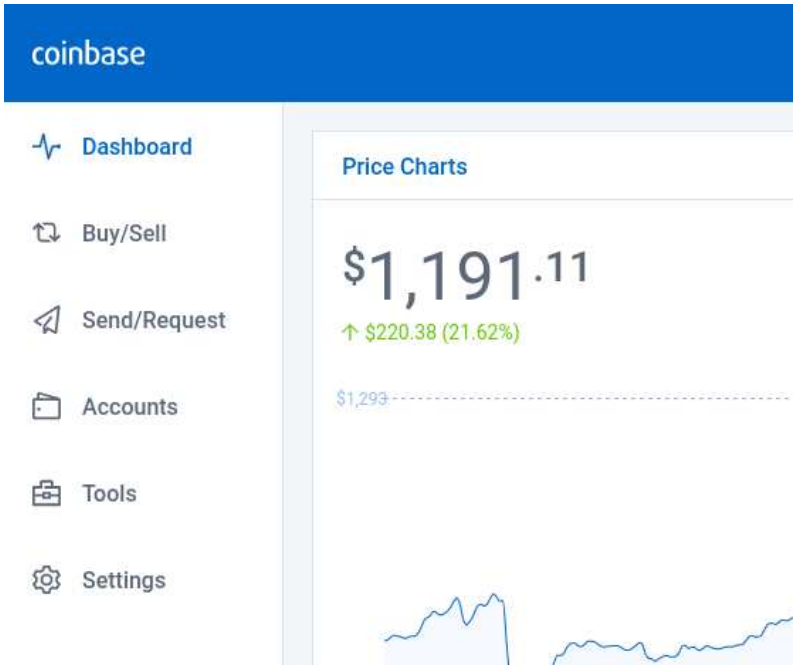

TREZOR
Confirm sending
0.0469 BTC
to
1NuuZ753n7h3ZnCQJ
CT2HVKTFfQjhpXhcw
Cancel
Confirm

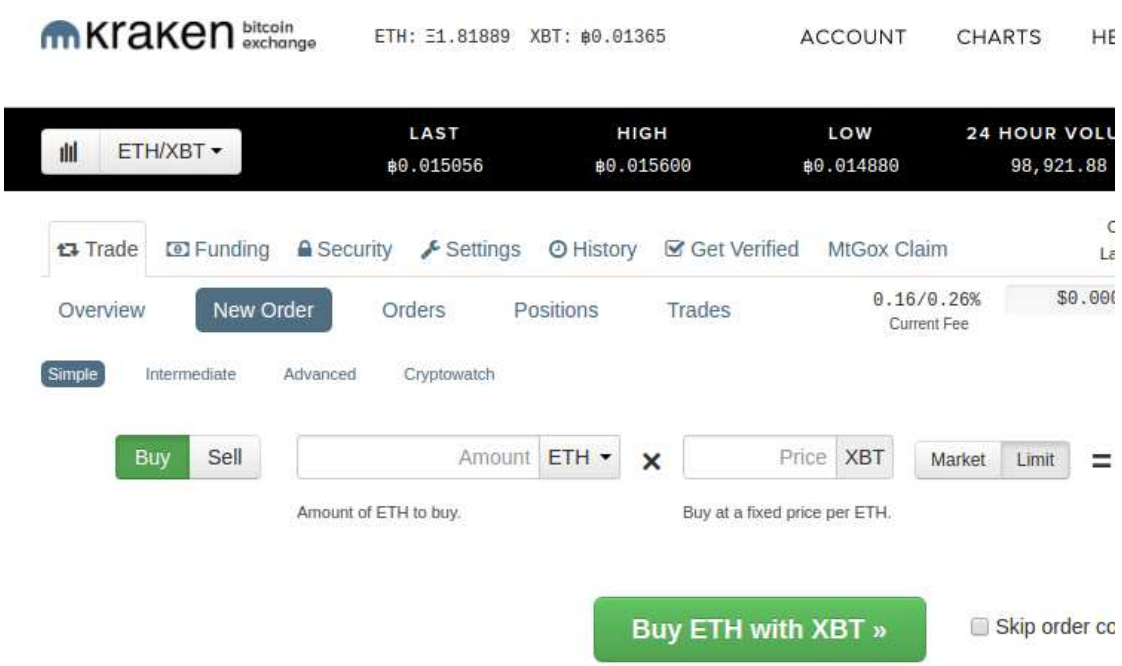
ATMs

Bitcoin is the first and largest of ***hundreds*** of cryptocurrencies

#	Name	Market Cap	Price
1	Bitcoin	$158,904,206,299	$9513.62
2	Ethereum	$43,854,960,273	$456.96
3	Bitcoin Cash	$26,961,401,198	$1602.60
4	Ripple	$9,675,917,364	$0.250523
5	Bitcoin Gold	$5,675,398,231	$340.39
6	Dash	$4,801,721,337	$622.62
7	Litecoin	$4,616,401,352	$85.48
8	Monero	$2,513,605,641	$163.19
9	NEO	$2,512,646,500	$38.66
10	IOTA	$2,222,893,210	$0.799737
11	Ethereum Classic	$2,168,465,125	$22.17
12	NEM	$1,954,071,000	$0.217119
13	EOS	$1,310,607,703	$2.62
14	Qtum	$1,106,200,781	$15.01
15	Cardano	$1,027,194,237	$0.039619
16	Zcash	$921,864,283	$340.71

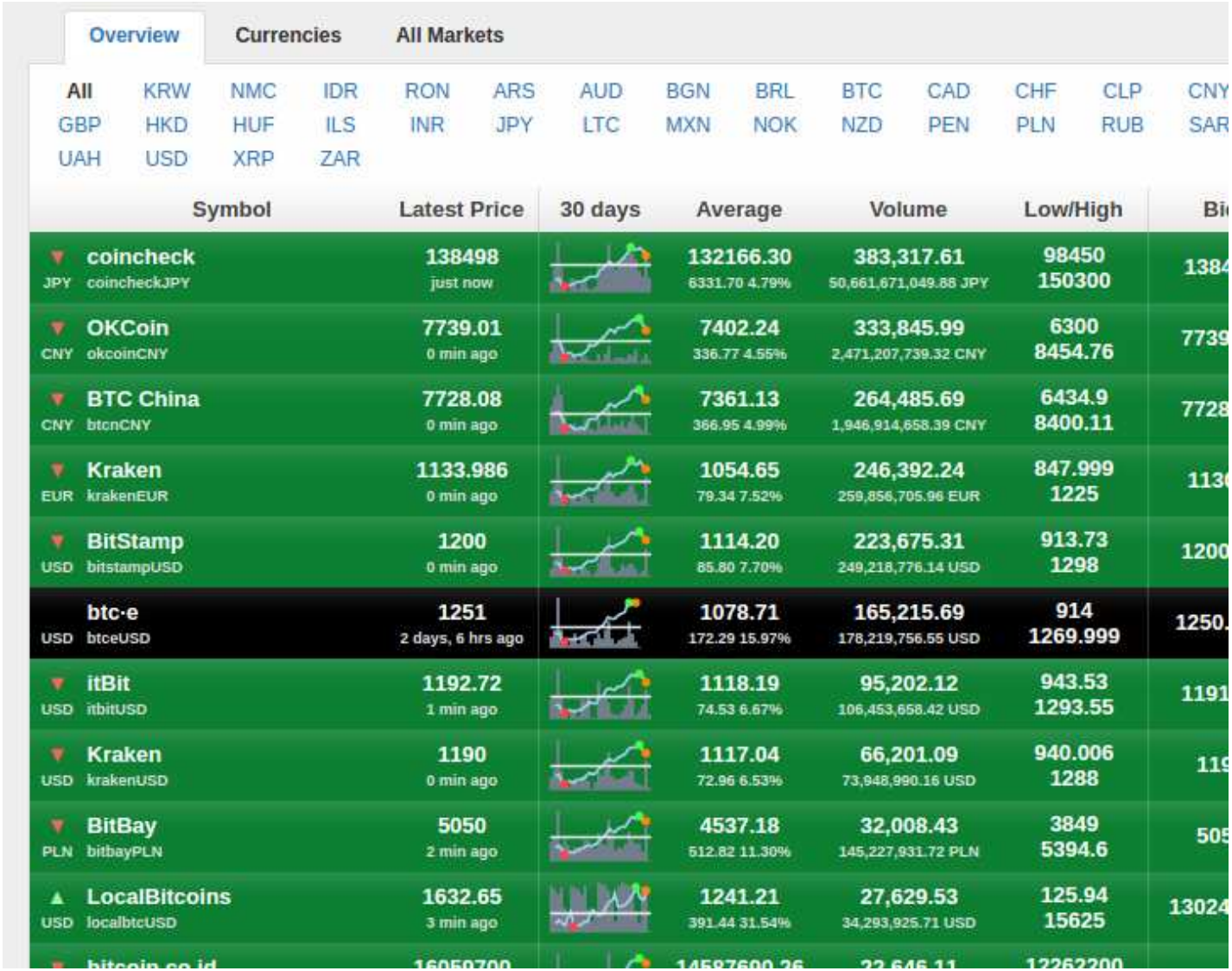
Bitcoin exchanges





Beware the middleman: Empirical analysis of Bitcoin-exchange risk
Tyler Moore and Nicolas Christin, Financial Crypto 2013

Exchanges



Overview | Currencies | All Markets

All KRW NMC IDR RON ARS AUD BGN BRL BTC CAD CHF CLP CNY
GBP HKD HUF ILS INR JPY LTC MXN NOK NZD PEN PLN RUB SAR
UAH USD XRP ZAR

Symbol	Latest Price	30 days	Average	Volume	Low/High	Bi
coincheck JPY coincheckJPY	138498 just now		132166.30 6331.70 4.79%	383,317.61 50,661,671,049.88 JPY	98450 150300	1384
OKCoin CNY okcoinCNY	7739.01 0 min ago		7402.24 336.77 4.55%	333,845.99 2,471,207,739.32 CNY	6300 8454.76	7739
BTC China CNY btcnCNY	7728.08 0 min ago		7361.13 366.95 4.99%	264,485.69 1,946,914,658.39 CNY	6434.9 8400.11	7728
Kraken EUR krakenEUR	1133.986 0 min ago		1054.65 79.34 7.52%	246,392.24 259,856,705.96 EUR	847.999 1225	113
BitStamp USD bitstampUSD	1200 0 min ago		1114.20 85.80 7.70%	223,675.31 249,218,776.14 USD	913.73 1298	1200
btc-e USD btceUSD	1251 2 days, 6 hrs ago		1078.71 172.29 15.97%	165,215.69 178,219,756.55 USD	914 1269.999	1250.
itBit USD itbitUSD	1192.72 1 min ago		1118.19 74.53 6.67%	95,202.12 106,453,658.42 USD	943.53 1293.55	1191
Kraken USD krakenUSD	1190 0 min ago		1117.04 72.96 6.53%	66,201.09 73,948,990.16 USD	940.006 1288	119
BitBay PLN bitbayPLN	5050 2 min ago		4537.18 512.82 11.30%	32,008.43 145,227,931.72 PLN	3849 5394.6	505
LocalBitcoins USD localbtcUSD	1632.65 3 min ago		1241.21 391.44 31.54%	27,629.53 34,293,925.71 USD	125.94 15625	13024
bitcoin.co.id	16059700		14587600.26	22,646.11	12262200	

What are the security goals?

- Transactions are “valid”.

  Alice can’t spend more money than she has

- Transactions are “authorized”

  Alice can’t spend Bob’s money

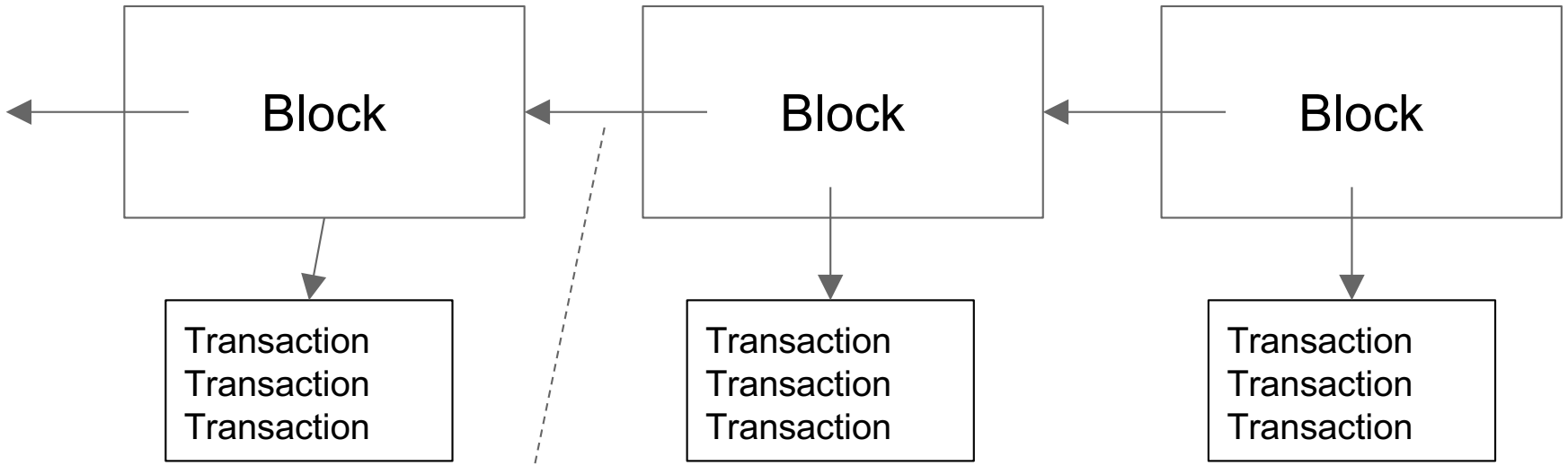
- The service is “available”

  Alice can’t prevent Bob from spending his own money

- Transactions are consistent, permanent

  Alice can’t send Bob money, and then take it back!

Blockchain Data Structure

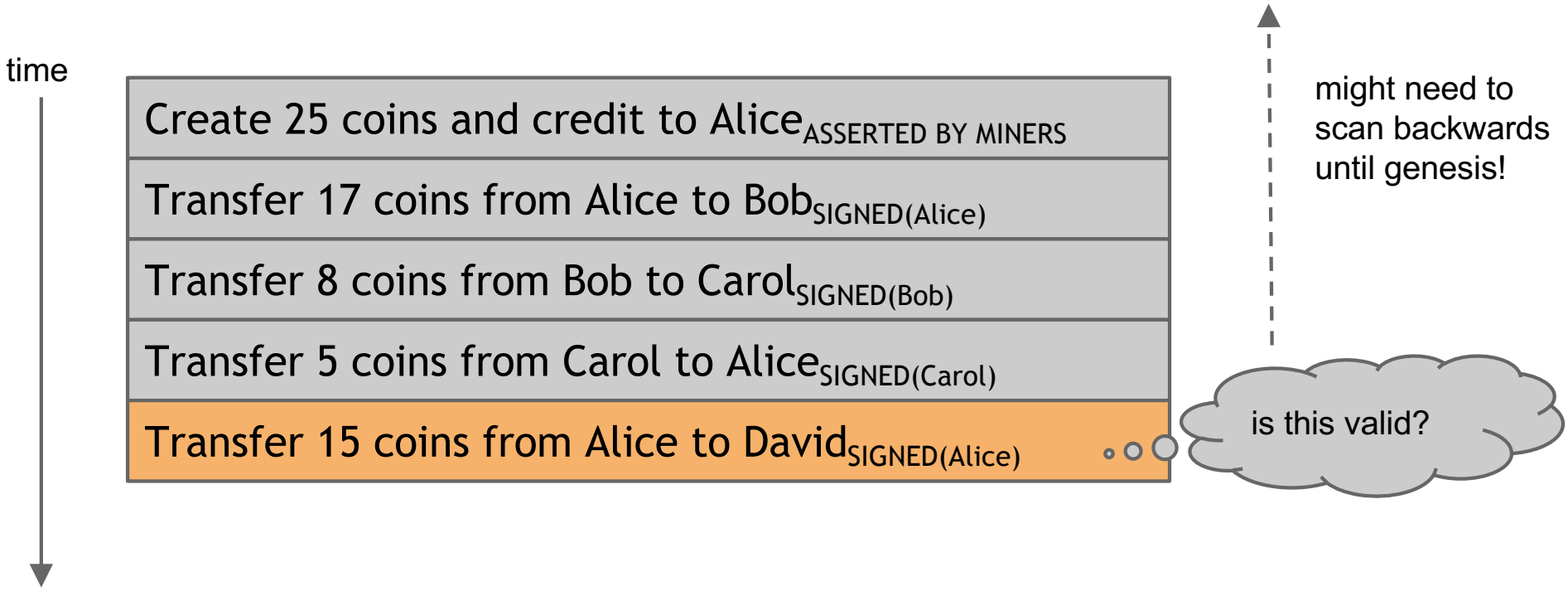


Each “arrow” is actually a SHA2 ***hash***

The hash of the most recent “block” is a hash of ALL of the transactions

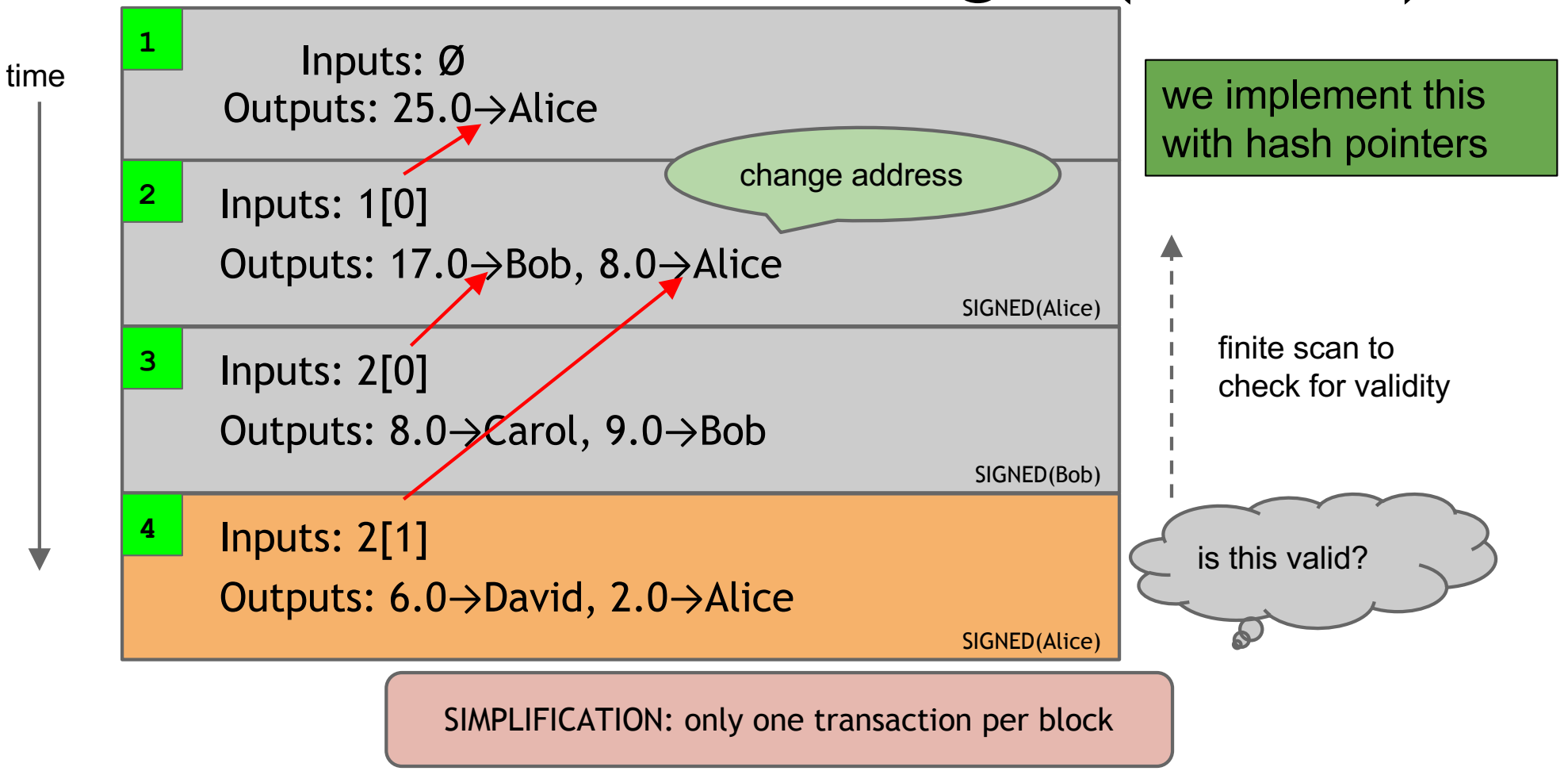
One block every 10 minutes

An account-based ledger (*not* Bitcoin)

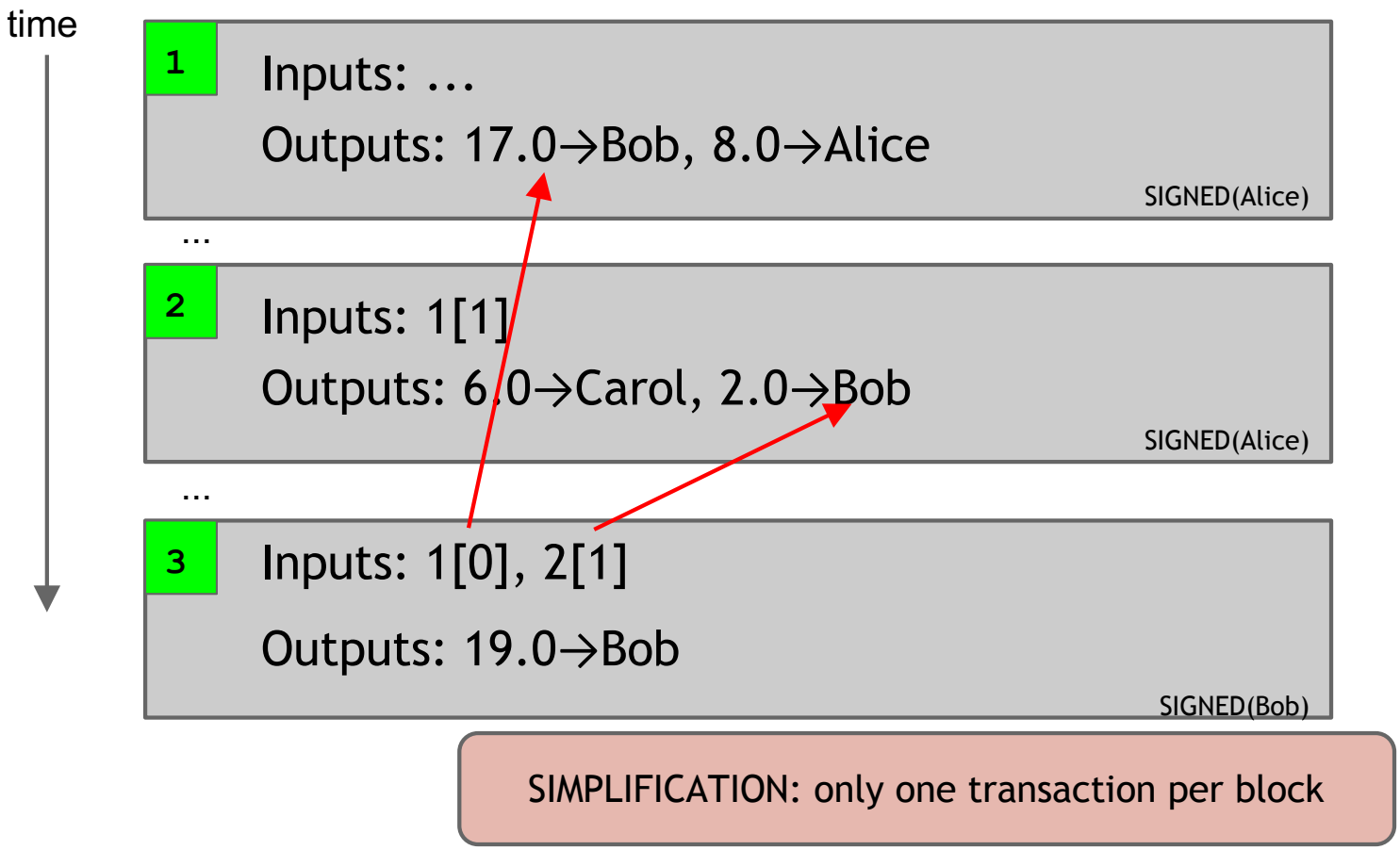


SIMPLIFICATION: only one transaction per block

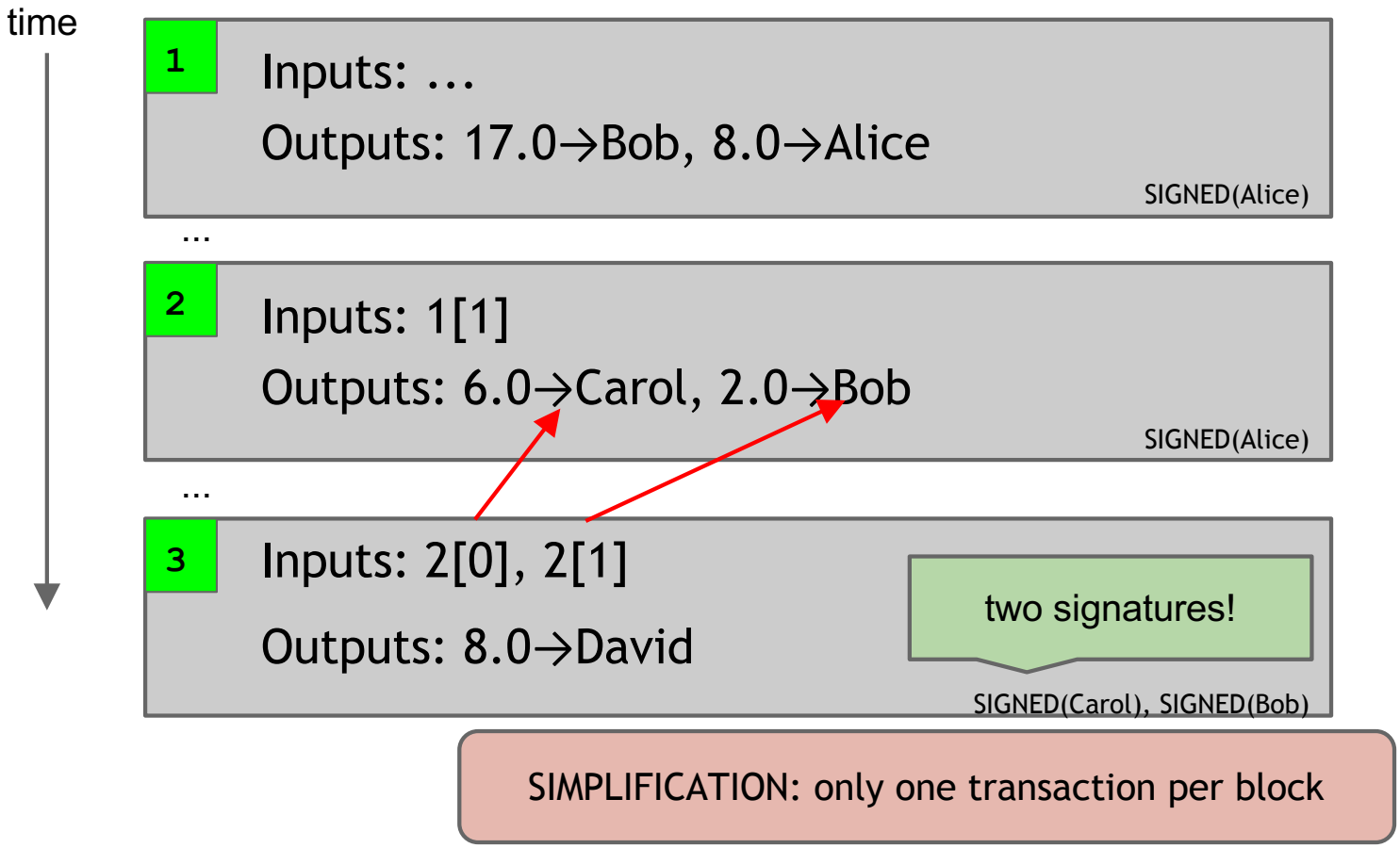
A transaction-based ledger (Bitcoin)



Merging value



Joint payments

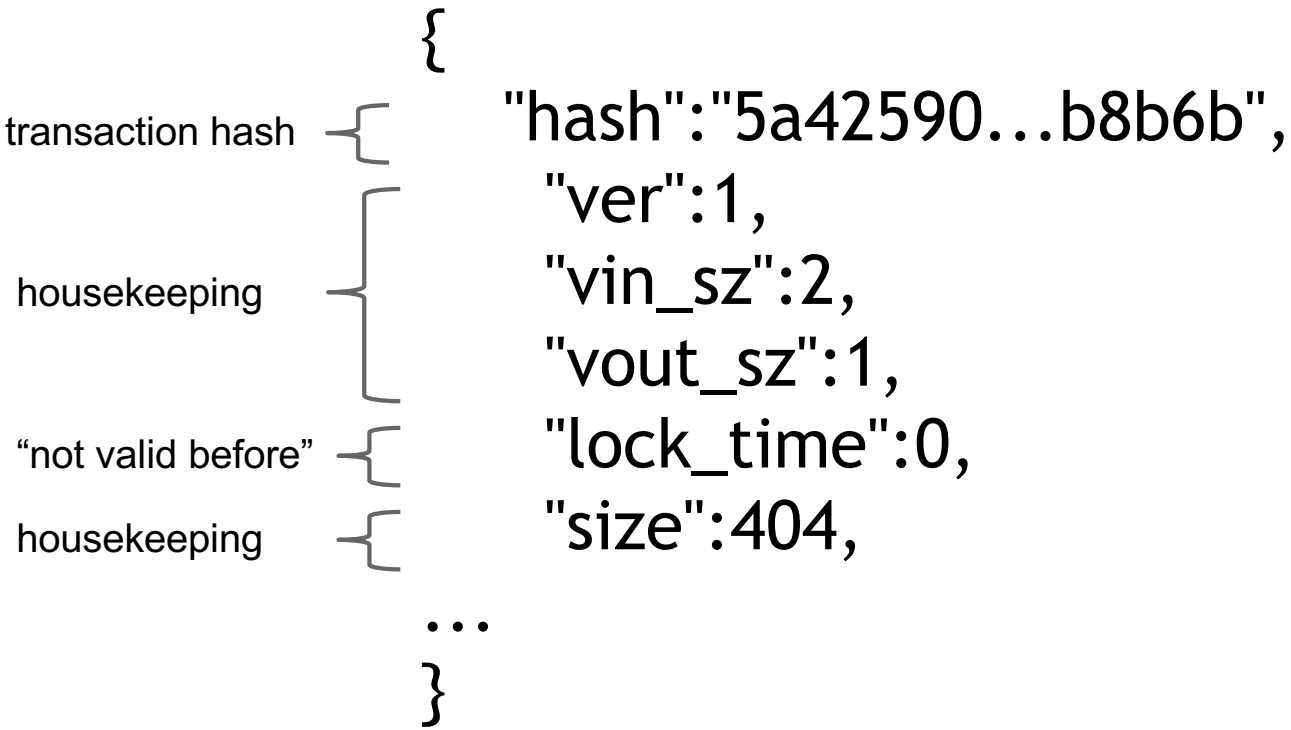


The real deal: a Bitcoin transaction

1. metadata
2. input(s)
3. output(s)


```
{
  "hash":"5a42590fbe0a90ee8e8747244d6c84f0db1a3a24e8f1b95b10c9e050990b8b6b",
  "ver":1,
  "vin_sz":2,
  "vout_sz":1,
  "lock_time":0,
  "size":404,
  "in":[
   {
    "prev_out":{
     "hash":"3be4ac9728a0823cf5e2deb2e86fc0bd2aa503a91d307b42ba76117d79280260",
     "n":0
    },
     "scriptSig":"30440..."
   },
   {
    "prev_out":{
     "hash":"7508e6ab259b4df0fd5147bab0c949d81473db4518f81afc5c3f52f91ff6b34e",
     "n":0
    },
    "scriptSig":"3f3a4ce81...."
   }
  ],
  "out":[
   {
    "value":"10.12287097",
    "scriptPubKey":"OP_DUP OP_HASH160 69e02e18b5705a05dd6b28ed517716c894b3d42e OP_EQUALVERIFY OP_CHECKSIG"
   }
  ]
}
```

The real deal: 1. transaction metadata



The real deal: 2. transaction inputs

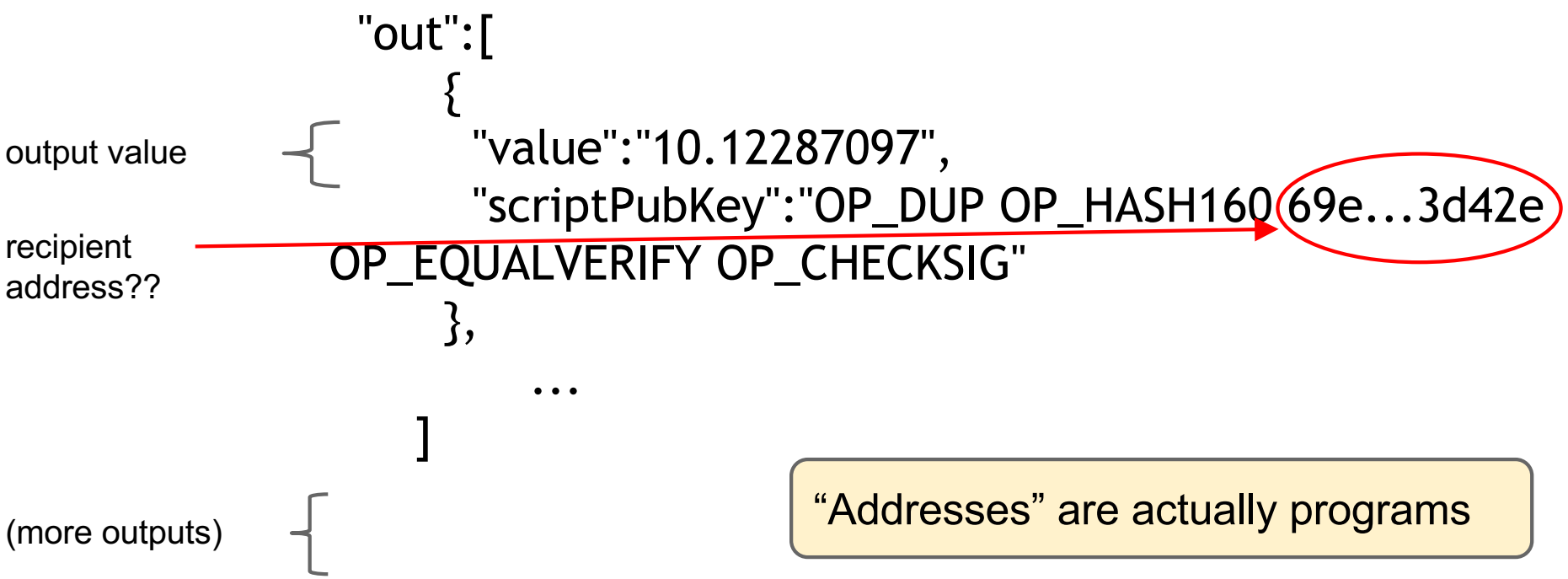
previous transaction

signature

(more inputs)

```
"in":[
  {
    "prev_out":{
      "hash":"3be4...80260",
      "n":0
    },
"scriptSig":"30440....3f3a4ce81"
  },
...
],
```

The real deal: 3. transaction outputs



"Addresses" are actually programs

Bitcoin Mining

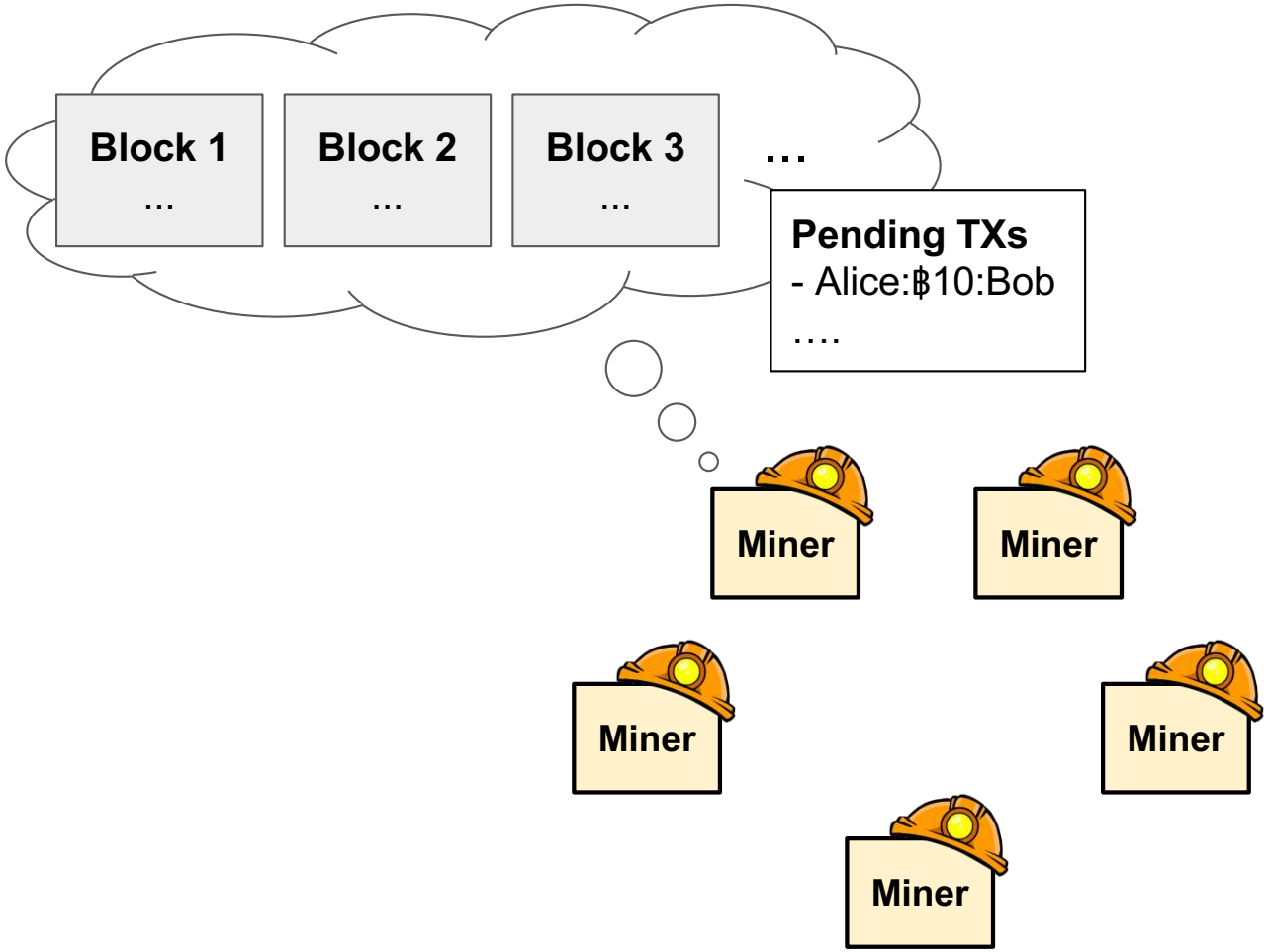
How do we commit new transactions?

Why not have 1 trusted “transaction authority”?
What happens if it’s compromised?

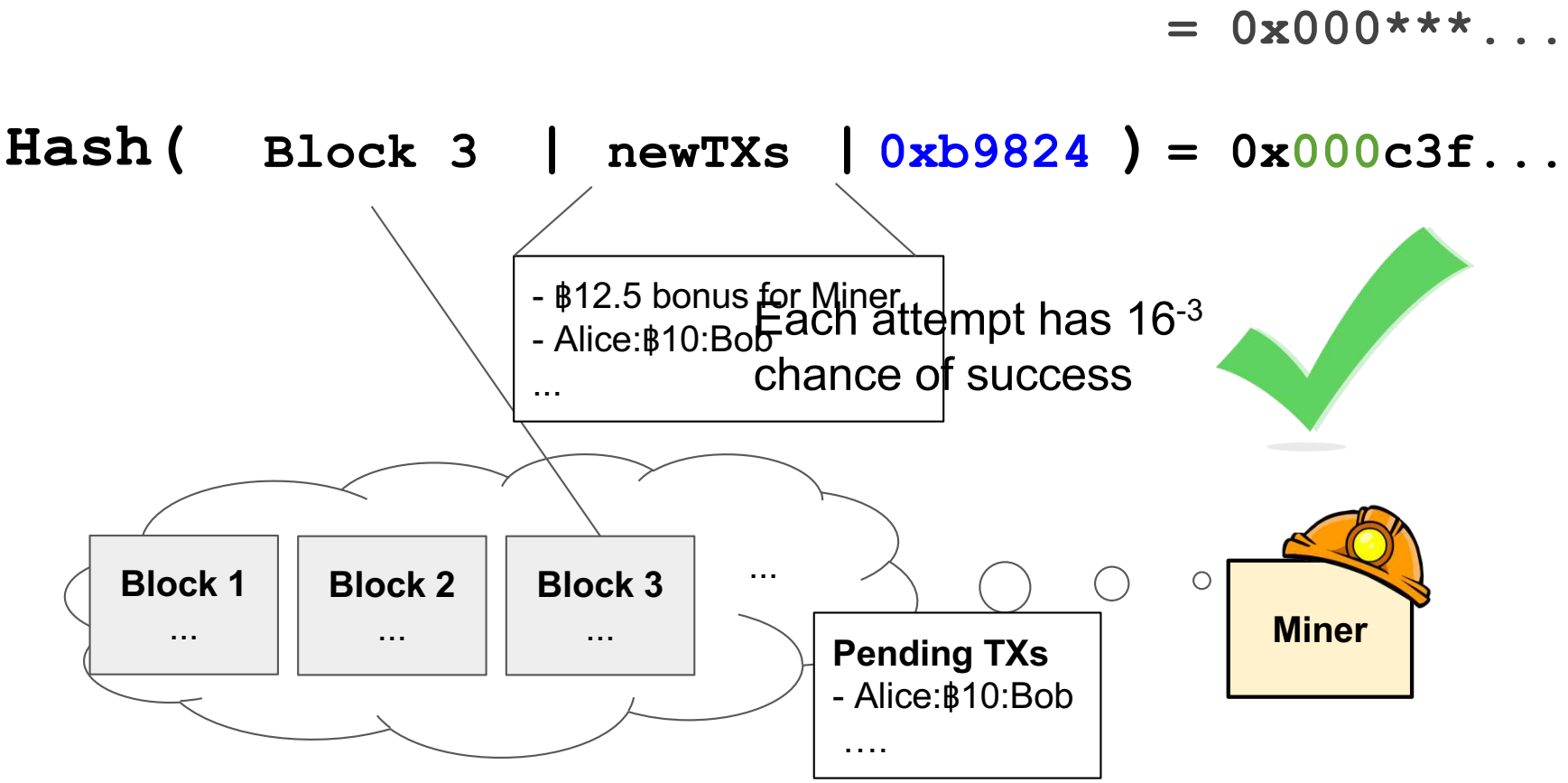
Why not sample/count based on IP addresses?

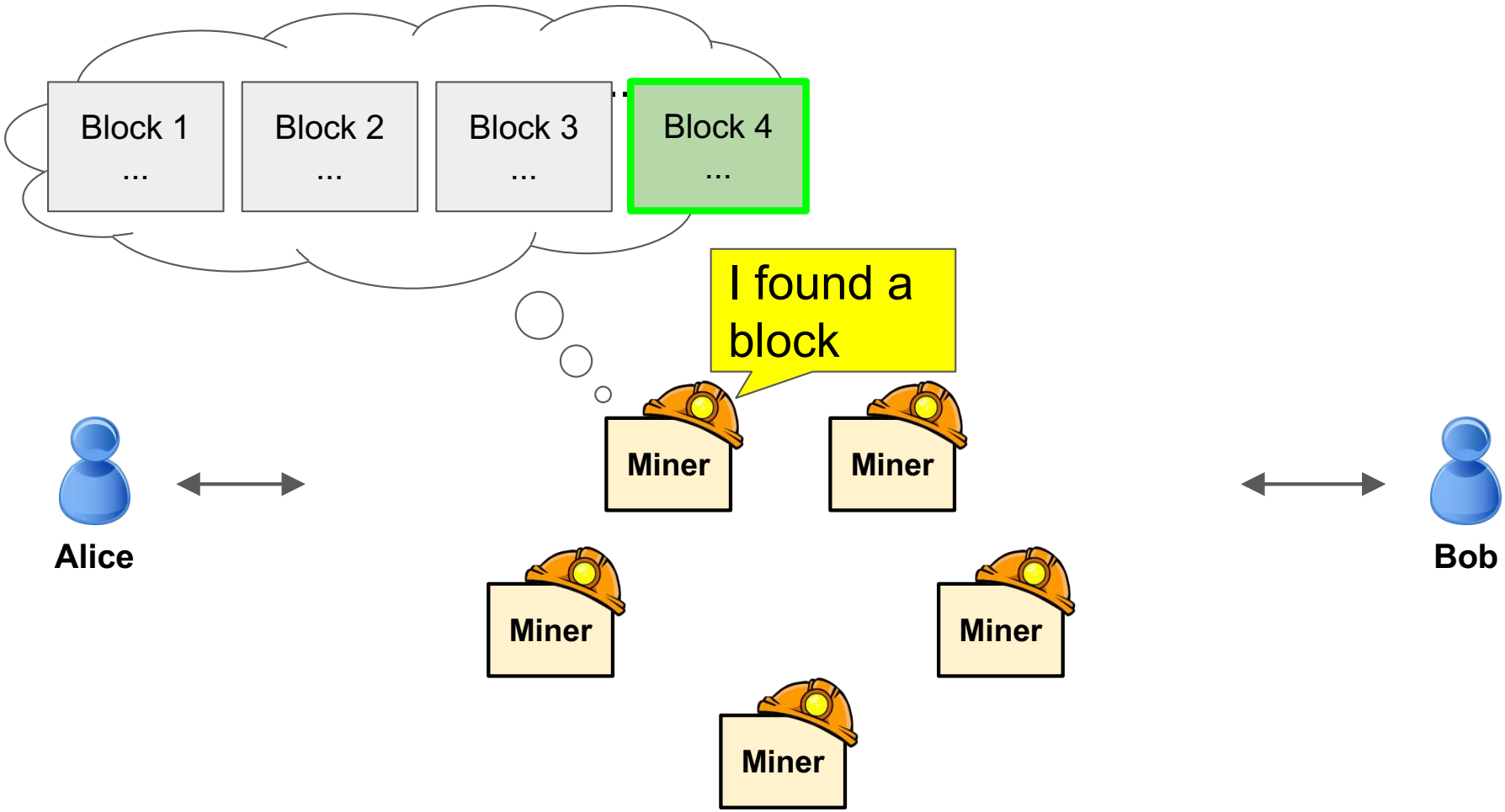
Mining Bitcoins in 6 easy steps

1. Join the network, listen for transactions
    a. Validate all proposed transactions
2. Listen for new blocks, maintain block chain
    a. When a new block is proposed, validate it
3. Assemble a new valid block
4. Find the nonce to make your block valid
5. Hope everybody accepts your new block
6. Profit!


Block 1
...
Block 2
...
Block 3
...
...
Pending TXs
- Alice:฿10:Bob
....
Miner
Miner
Miner
Miner
Miner

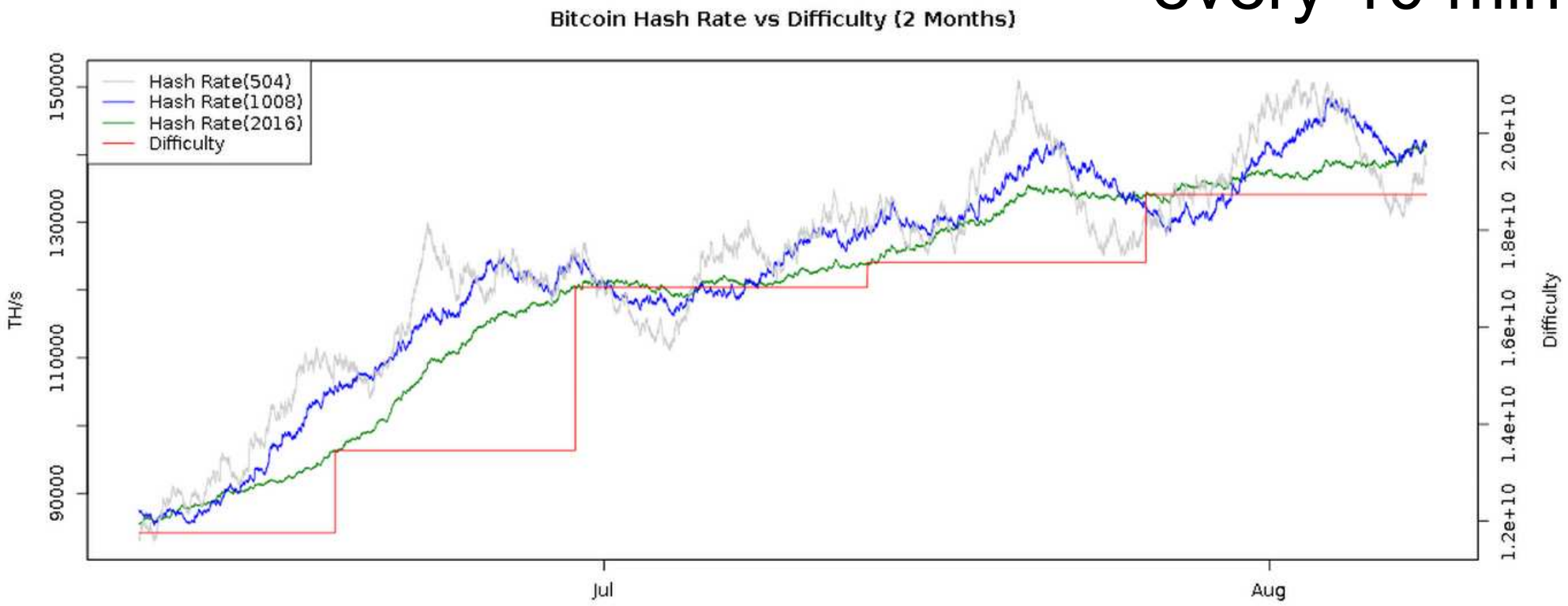
Miners commit new transactions by solving puzzles




Block 1
...
Block 2
...
Block 3
...
Block 4
...
I found a block
Miner
Miner
Miner
Miner
Miner
Alice
Bob

Mining difficulty adjusts over time

One block every 10 min



bitcoinwisdom.com

Evolution of mining

CPU

GPU

FPGA

ASIC

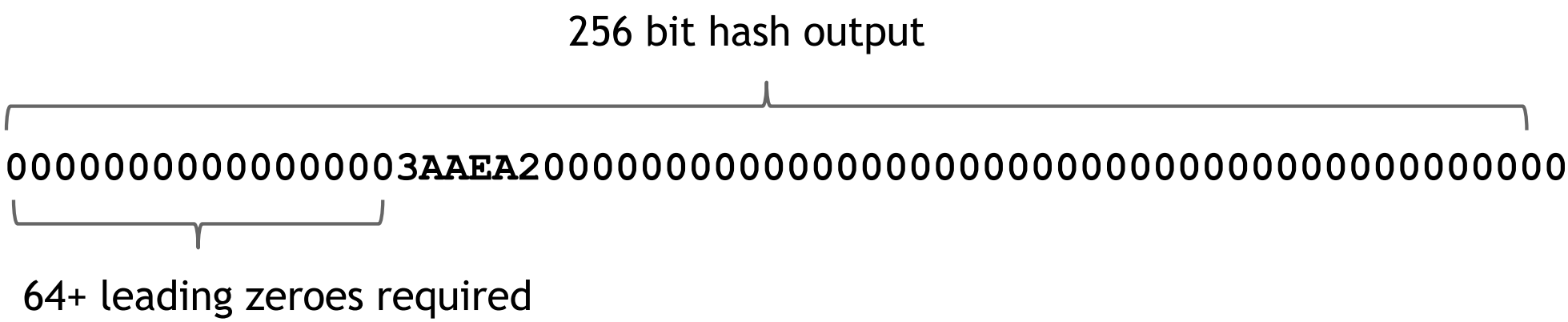
gold pan

sluice box

placer mining

pit mining

Mining difficulty “target” (2016-04-24)

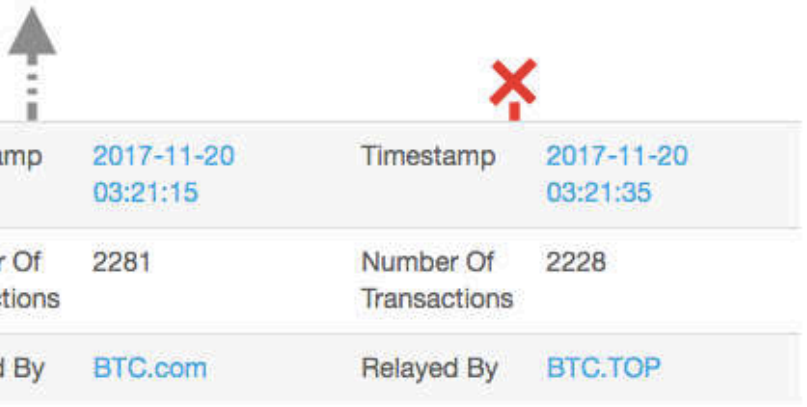


Current difficulty = 2^{68}

What happens if 2 blocks found at the same time?

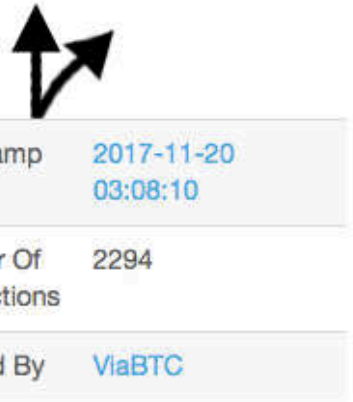
Miners use longest chain

Two valid blocks produced

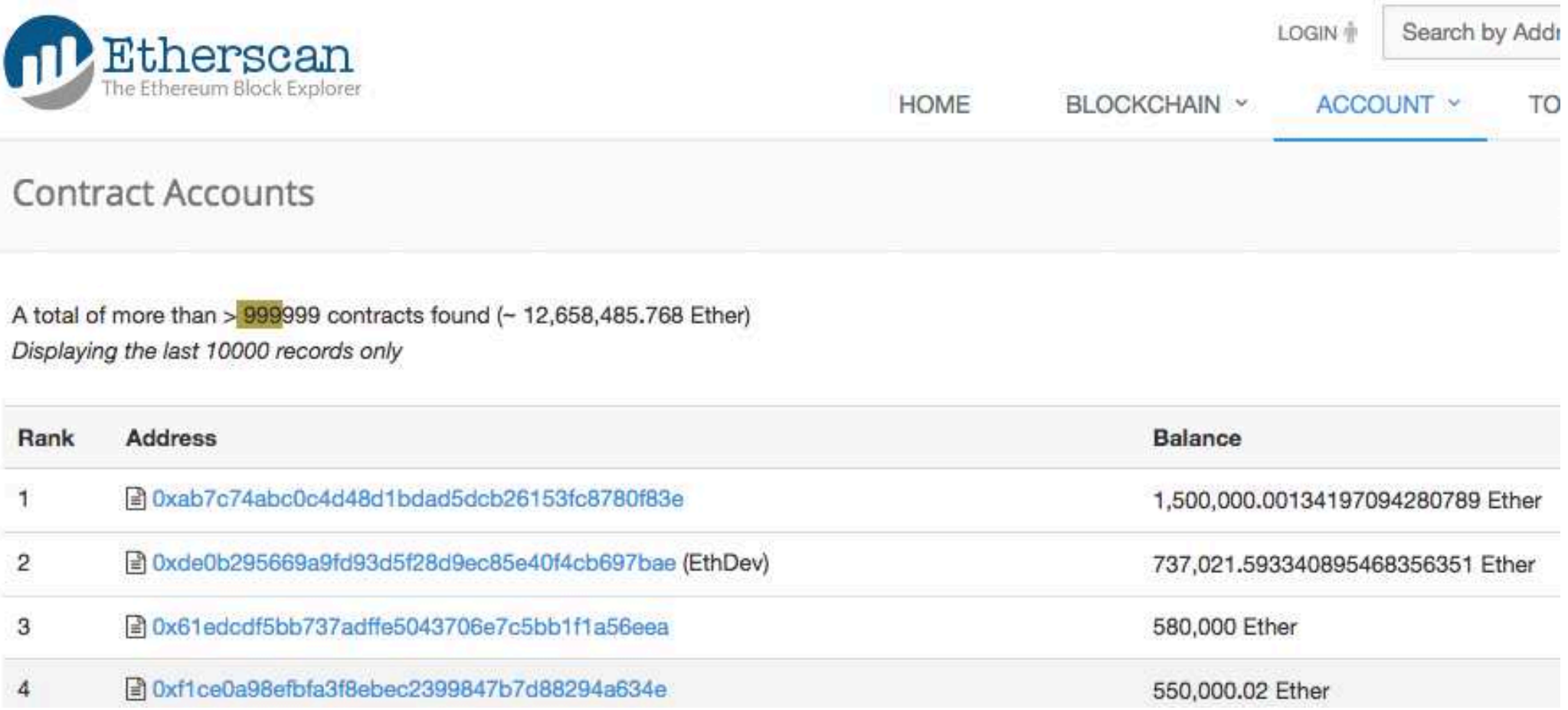


Orphan block

Block on the chain



More generally: “programmable money”



Smart Contract Example (very high level)

If GOOG rises to $1,000 by 30 June 2015, assign 10 shares from Alice to Bob and pay Alice $10,000

Smart contracts

- Smart contracts run in a virtual machine (EVM)
- Turing-complete programming language
- Each operation is executed by every node
- Operations
  - Read or write data
  - Cryptographic primitives
  - Send messages to other contracts
- Each operation costs “gas”

Smart contract problems

- Smart contracts often have exploitable vulnerabilities too
- The DAO (decentralized autonomous organization) was a type of venture capital fund run as a smart contract
- A bug was exploited leading to theft of ~$60M
  - Clawed back by a “hard fork” that cancelled the transaction

Hard fork

- Cryptocurrency splits into two different chains
- Longest chain is supposed to be authoritative but now there are two
- After DAO attack, Ethereum split into Ethereum (ETH) and Ethereum Classic (ETC)
- What are the consequences of splitting the blockchain?

Bitcoin is used for Crime

Ransomware

Bitcoin may be an important tool for freedom/privacy

- A global currency that is not easily bound by borders
- Resilient architecture, seems difficult to shut down
- A competitive force leading banks to “blockchain” movement
- Disintermediation - removing “middlemen”

Global energy usage of Bitcoin mining alone

Average yearly energy consumption of Bitcoin in 2017: 29 TWh

That’s 0.13% of total, global energy consumption

For comparison, Ireland consumes 25 TWh

Morocco consumes 29 TWh

https://powercompare.co.uk/bitcoin/

Global energy usage of Bitcoin mining alone

Average yearly energy consumption of Bitcoin in 2017: 29 TWh

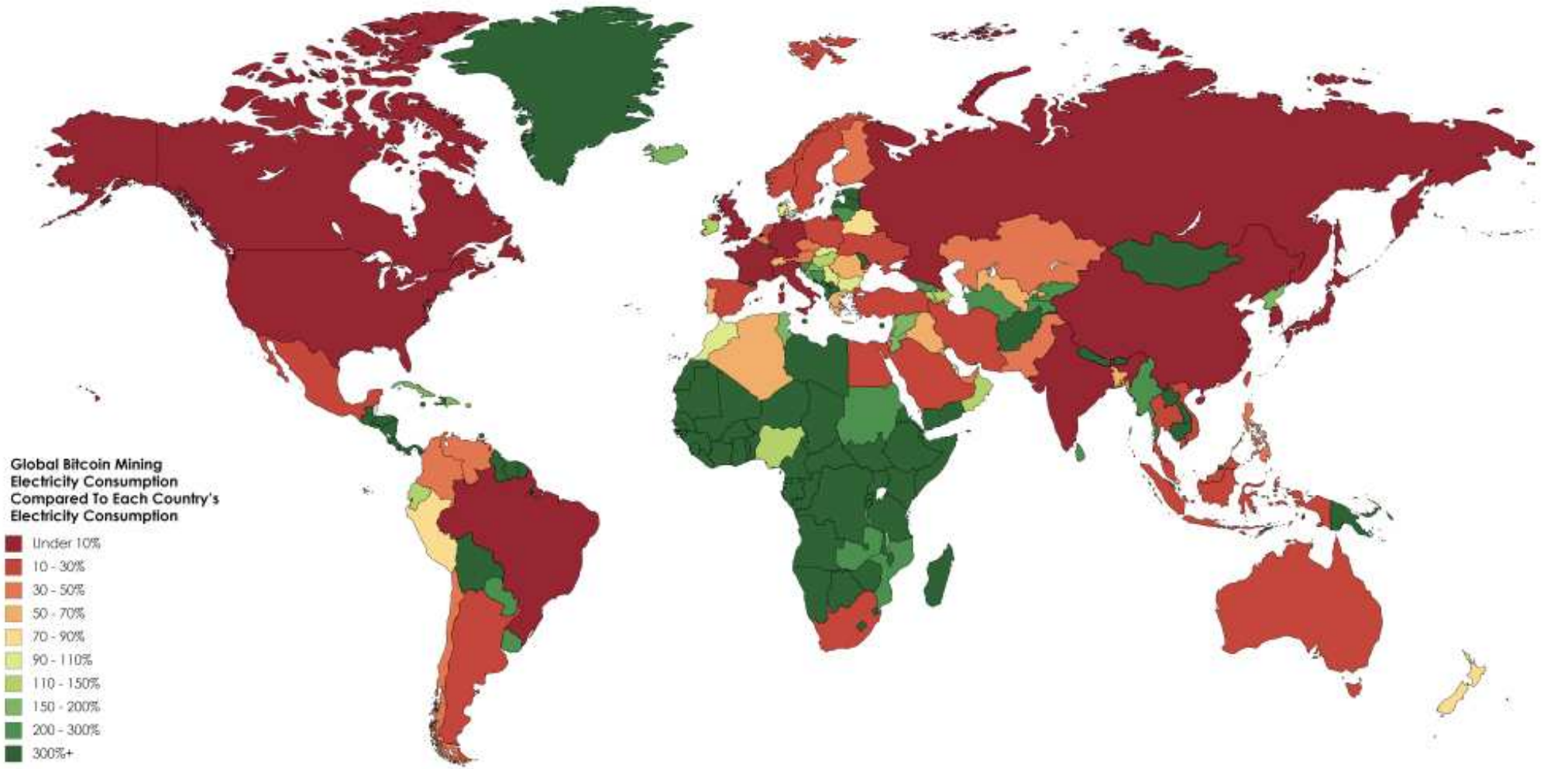
That’s 0.13% of total, global energy consumption

For comparison, Ireland consumes 25 TWh, Morocco consumes 29 TWh

159 countries consume less energy than Bitcoin mining

Other cryptocurrencies consume less energy, globally, but still a significant amount

https://powercompare.co.uk/bitcoin/



Source: https://powercompare.co.uk/bitcoin

Brain Wallets

- Derive a private key from a password

$$\text{secretkey} = \textbf{hash}(\text{salt}, \text{password})$$

- Hash function should be:

  - “Random Oracle” (PRF does not apply, collision resistance not enough)

  - Slow-ish to compute (require *space* not just *cpu*, no amortization)

- Also used for encrypting files on a hard drive

- If you send a bitcoin transaction to a “low entropy” brain wallet address it will be taken within seconds

Bitcoin is not completely private

- Pseudonymous, not “anonymous”

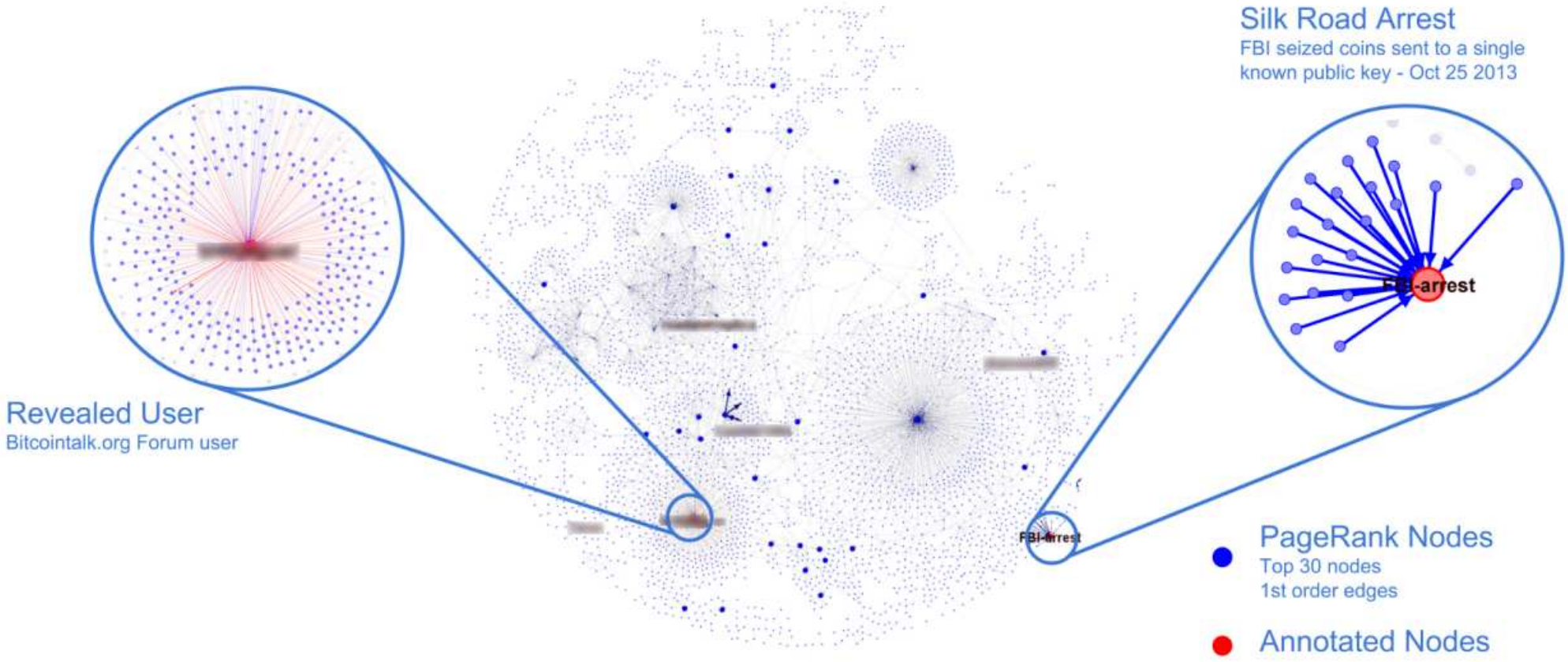
- Transaction graph analysis, clustering

    Can be traced to exchanges

- Mixers….. they mix your coins, but might take them.

- Cryptography can avoid this!

    Coinshuffle, Tumblebit, Zcash, and more…



https://people.csail.mit.edu/spillai/data/papers/bitcoin-transaction-graph-analysis.pdf