DS 593: Privacy in Practice

Blockchains

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News?

TUNING IN TO YOUR EMOTIONS

LG TVs' integrated ads get more personal with tech that analyzes viewer emotions

LG licenses tech for interpreting TV users' feelings and convictions.

SCHARON HARDING – APR 16, 2025 4:14 PM | 135

Credit: Getty

https://arstechnica.com/gadgets/2025/04/lg-tvs-integrated-ads-get-more-personal-with-tech-that-analyzes-viewer-emotions/

Last time

- Decentralized Systems

Today

- Consensus and Blockchains

Activity

- Form into groups
- Have you group decide on a number from 1-20
- Decide on how to tell me your number

Consensus

- One of the key challenges for decentralized applications is *consensus* – coming to a collective decision

- The state of a system or program has major implications for its operation

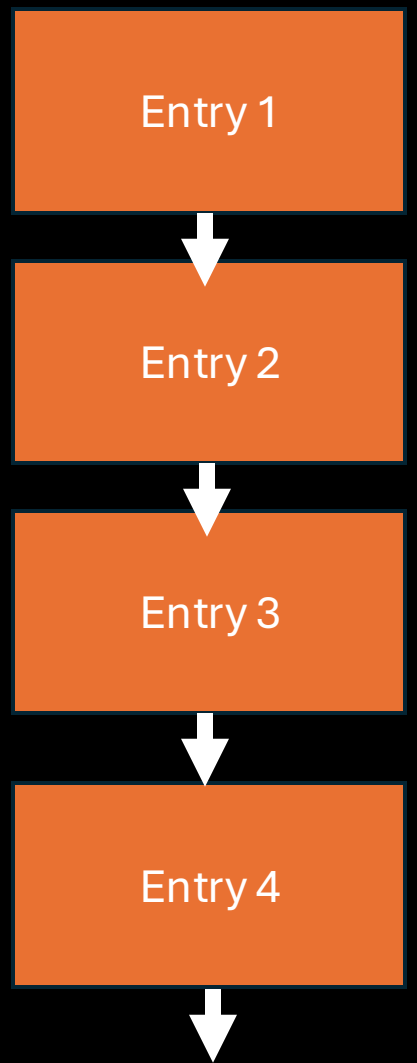
Blockchains

- A system for coming to distributed/decentralized consensus

- Formally introduced in the Bitcoin whitepaper
  - Builds on earlier ideas by Chaum, Haber, Bayer, Stornetta
  - Byzantine Fault Tolerance

Append-Only ledger

- Consider a list of entries that is *append-only*
- We can model the state of a system as a series of transitions from one entry to the next
  - Can't go backwards
- Idea: can we build a distributed ledger?



Naïve Solution to consensus

- Suppose all of the peers in the system are honest
- Each of them has a copy of the ledger
- When something changes, the change is broadcast to all peers
- Each peer updates its ledger
- Decentralized State!

What if the Peers aren’t honest?

What if the Peers aren’t honest?

- Could try a majority vote?

What if the Peers aren’t honest?

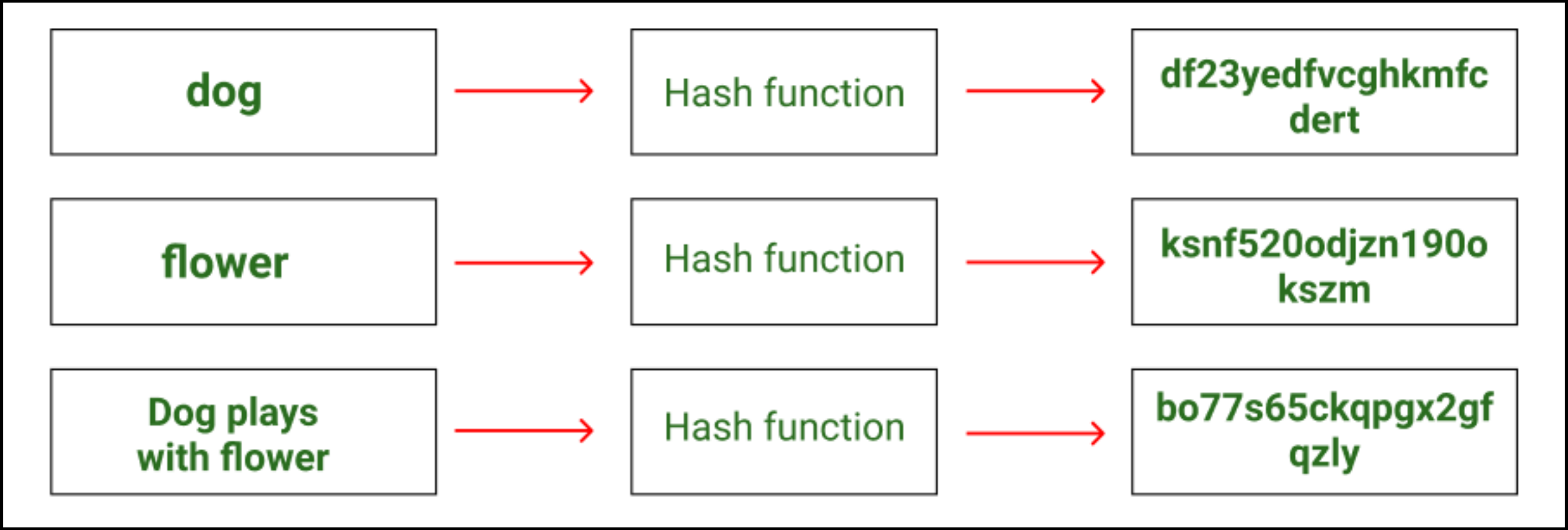
- Could try a majority vote?

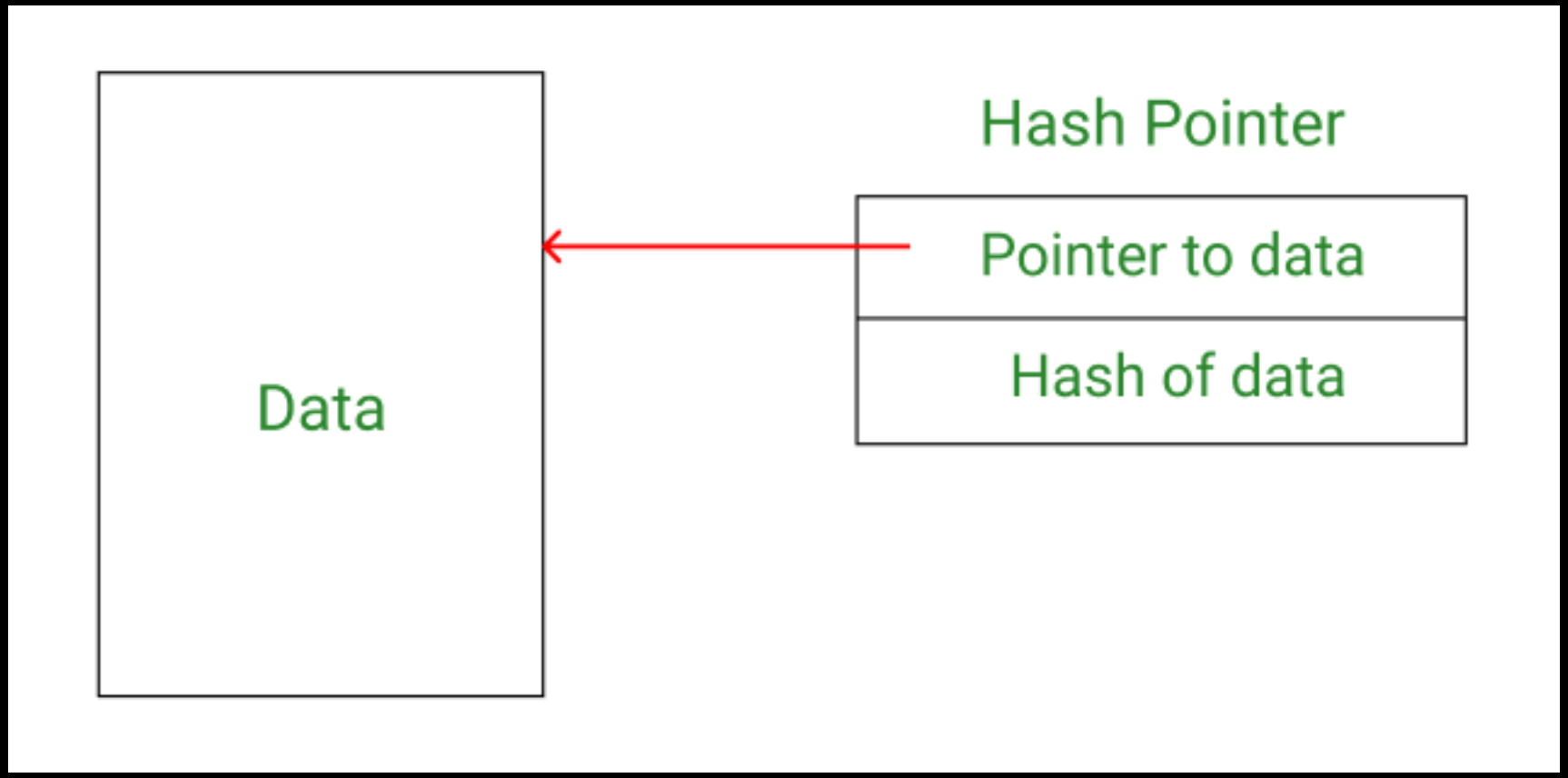
- Problems
  - Inefficient
  - 51% attacks
  - Sybil Attacks

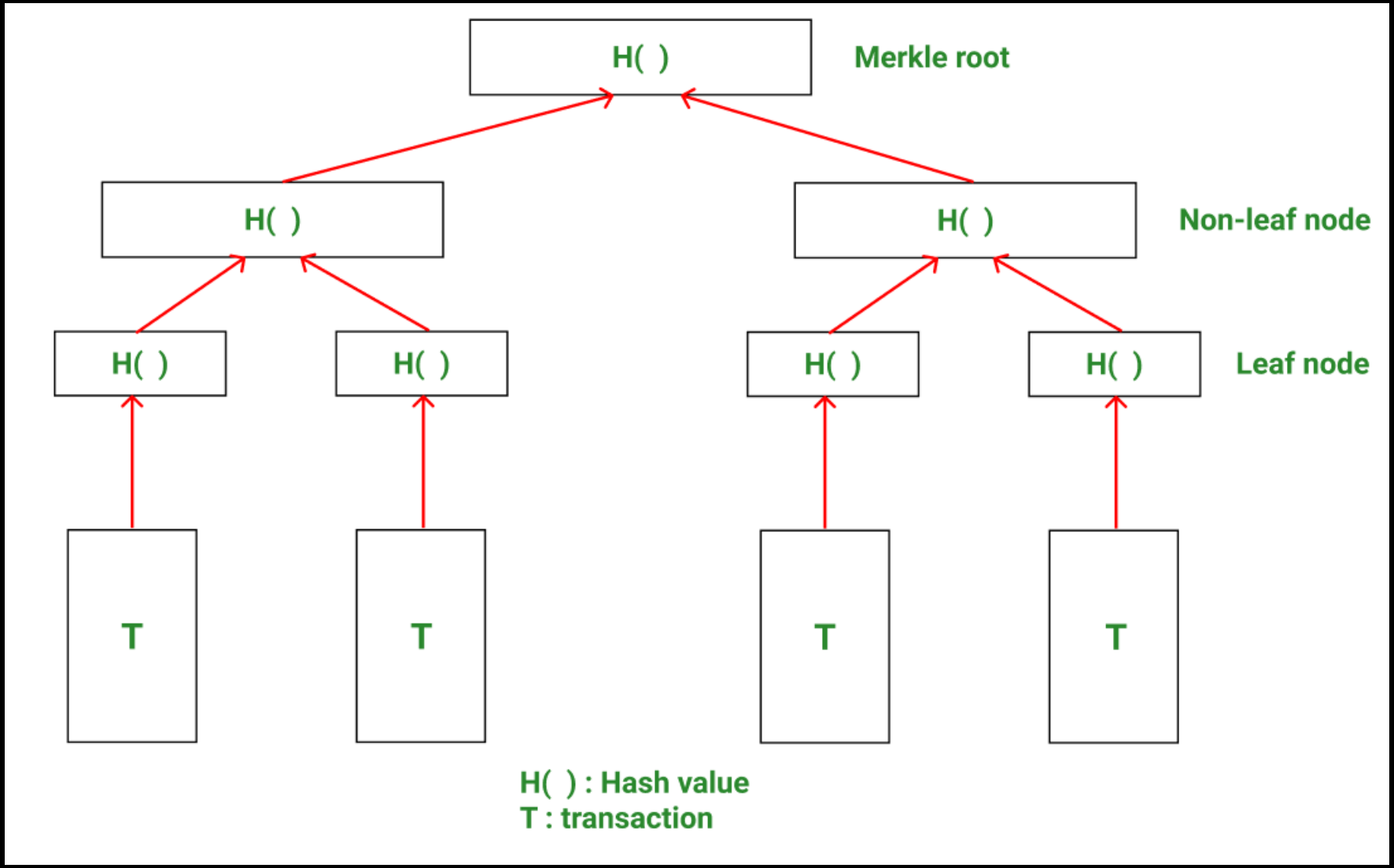
What do we need?

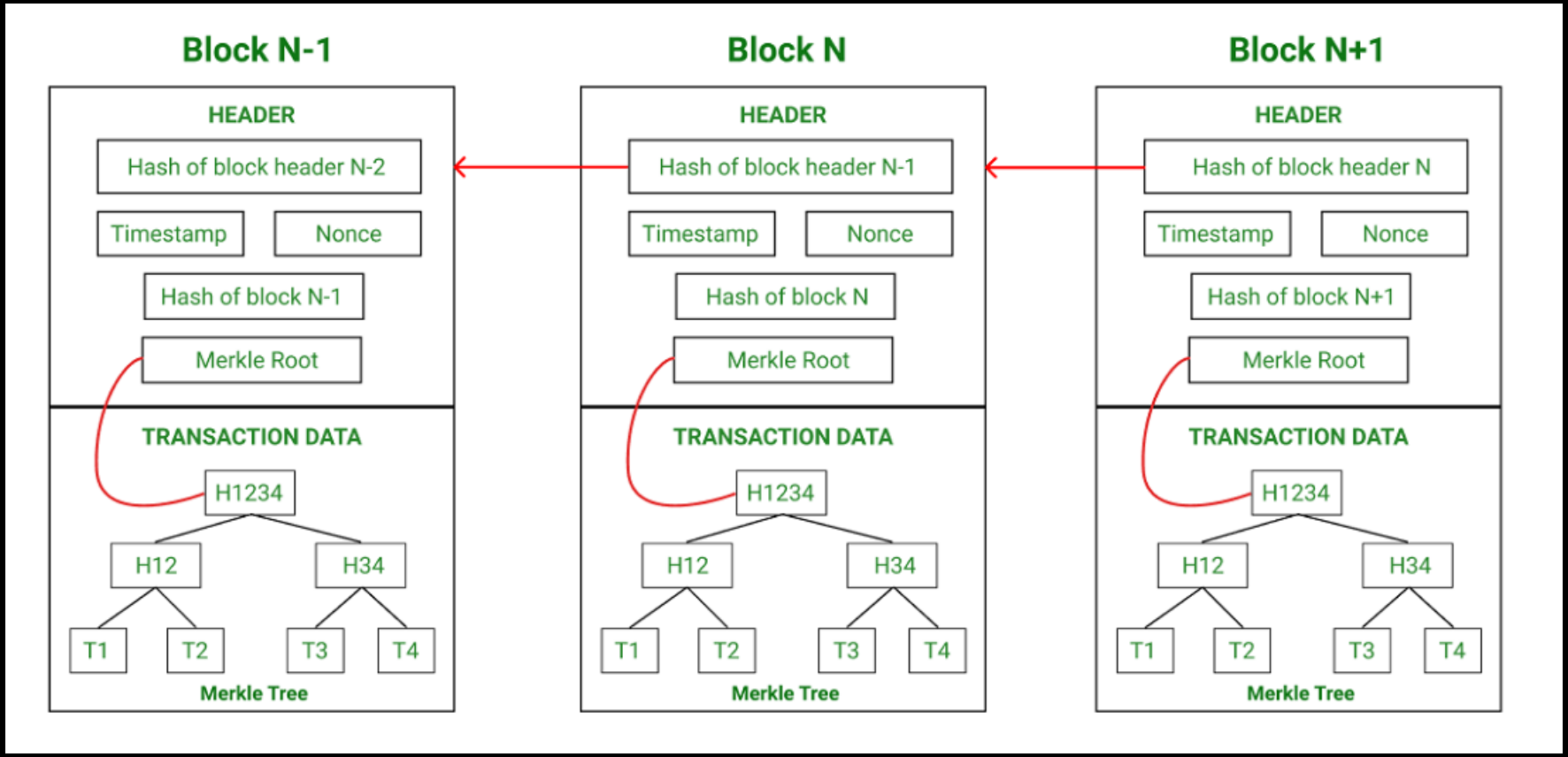
- Efficient way to reach consensus
- Enforces append-only nature
- Resilient to sybil attacks
  - Hard to get an outsized influence on the network

Idea 1: Use Hash Functions




Hash Pointer
Pointer to data
Hash of data
Data


H( )
Merkle root
H( )
H( )
Non-leaf node
H( )
H( )
H( )
H( )
Leaf node
T
T
T
T
H( ) : Hash value
T : transaction


Block N-1
HEADER
Hash of block header N-2
Timestamp
Nonce
Hash of block N-1
Merkle Root
TRANSACTION DATA
H1234
H12
H34
T1
T2
T3
T4
Merkle Tree
Block N
HEADER
Hash of block header N-1
Timestamp
Nonce
Hash of block N
Merkle Root
TRANSACTION DATA
H1234
H12
H34
T1
T2
T3
T4
Merkle Tree
Block N+1
HEADER
Hash of block header N
Timestamp
Nonce
Hash of block N+1
Merkle Root
TRANSACTION DATA
H1234
H12
H34
T1
T2
T3
T4
Merkle Tree

- This lets us check for consistency in an efficient manner
- However, we still have our sybil problem

Idea 2: Hard Consensus Problem

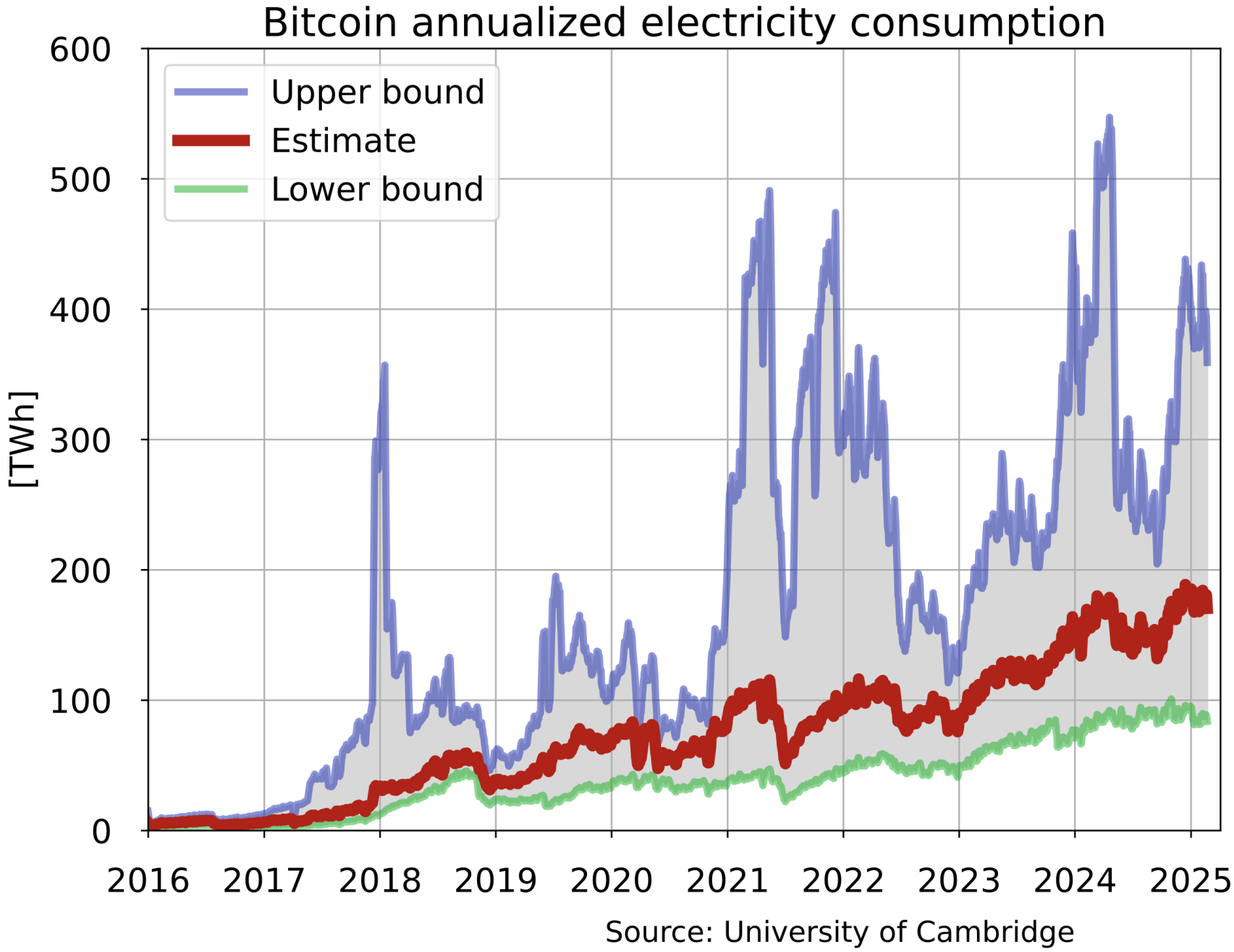
- Need some way to enforce how to add a change to the ledger
- Idea is for whoever is proposing the chain to have to meet some requirement
  - All the other peers should easily be able to verify this
- Only add a block to your view of the ledger if it verifies
- Ideally, this limits who can propose new blocks

Proof of Work

- Introduced in 1993 by Dwork and Naor
- Originally intended to prevent denial of service and spam
- Make everyone have to do something computationally hard
- Core idea is setting a hash rate
  - Need to brute force a hash with a certain number of leading 0s

Proof of Work Consensus

- For a new block to be accepted, the proposer must demonstrate that they completed the proof of work
- For bitcoin hashrate is roughly 10 minutes
- Wait for a few blocks to be confirmed to be certain
- Doesn’t quite solve the 51% attack
- Enviromental Impact ☹


Bitcoin annualized electricity consumption
Upper bound
Estimate
Lower bound
[TWh]
600
500
400
300
200
100
0
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Source: University of Cambridge

Proof of Work is expensive!

- Proof of Work only works if you assume a large amount of the network is trying to propose the next block
  - Otherwise the active members can control what happens
- Requires contributing a lot of computational resources
  - How to incentivize participation?
- Enter Cryptocurrencies

Bitcoin

- A cryptocurrency proposed by Satoshi Nakamoto in 2009
  - Who?
- A cryptocurrency is a decentralized payment system, generally built on top of a blockchain
  - Bitcoin was first prominent example, but ecash dates back to 1983
- Blockchains and cryptocurrencies have a bit of a symbiotic relationship

The Bitcoin Protocol

- Uses a proof-of-work based blockchain
- Peers run the bitcoin client which manages interaction with the rest of the network
  - Official vs Unofficial Clients
- A P2P payment system

Bitcoin Mining

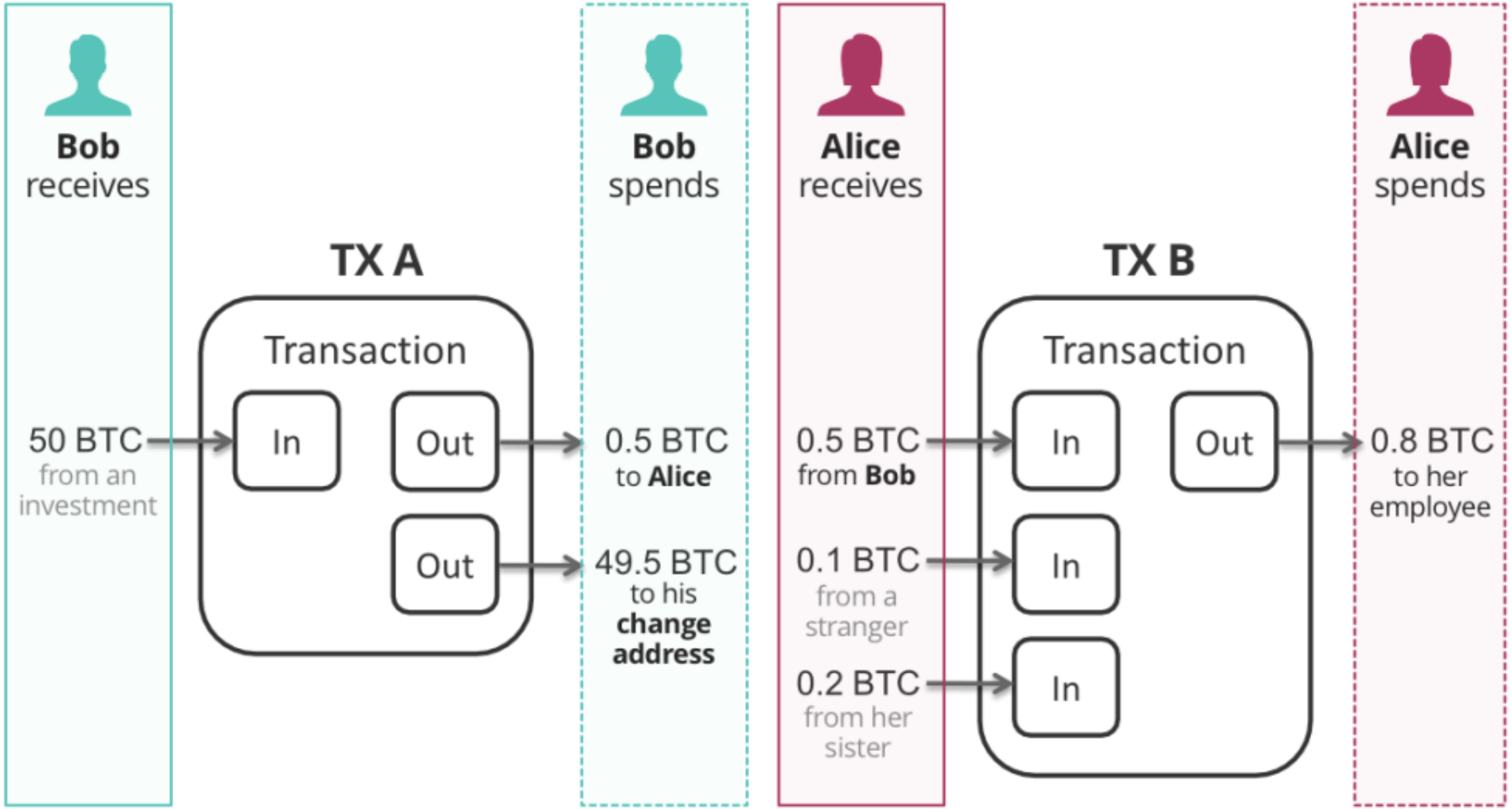
- Miners are the peers competing to generate the next block
- The goal was 1 person 1 vote
- Miners are incentivized as having your block accepted comes with come Bitcoin as a reward

Bitcoin Accounts and Transactions

- Your bitcoin account is represented by a public key pair
  - Each of your bitcoins is “signed”
  - Linked to the public key and possession of private key shows ownership
  - What happens if you lose your key?

- ”Spending” a coin involves using your private key and the recipients public key

- You produce a transaction that is sent to the network


Bob
receives
50 BTC
from an
investment
TX A
Transaction
In
Out
Out
Bob
spends
0.5 BTC
to Alice
49.5 BTC
to his
change
address
Alice
receives
0.5 BTC
from Bob
0.1 BTC
from a
stranger
0.2 BTC
from her
sister
TX B
Transaction
In
In
In
Out
Alice
spends
0.8 BTC
to her
employee

Bitcoin transactions

- Peers, and in particular, miners see new transactions as they are broadcast to the network
- Miners include the transactions they see into the blocks they propose
  - They get a “fee” for including a transaction
- Once a block containing a transaction is confirmed by the network, it is officially considered spent
  - Why is this binding?

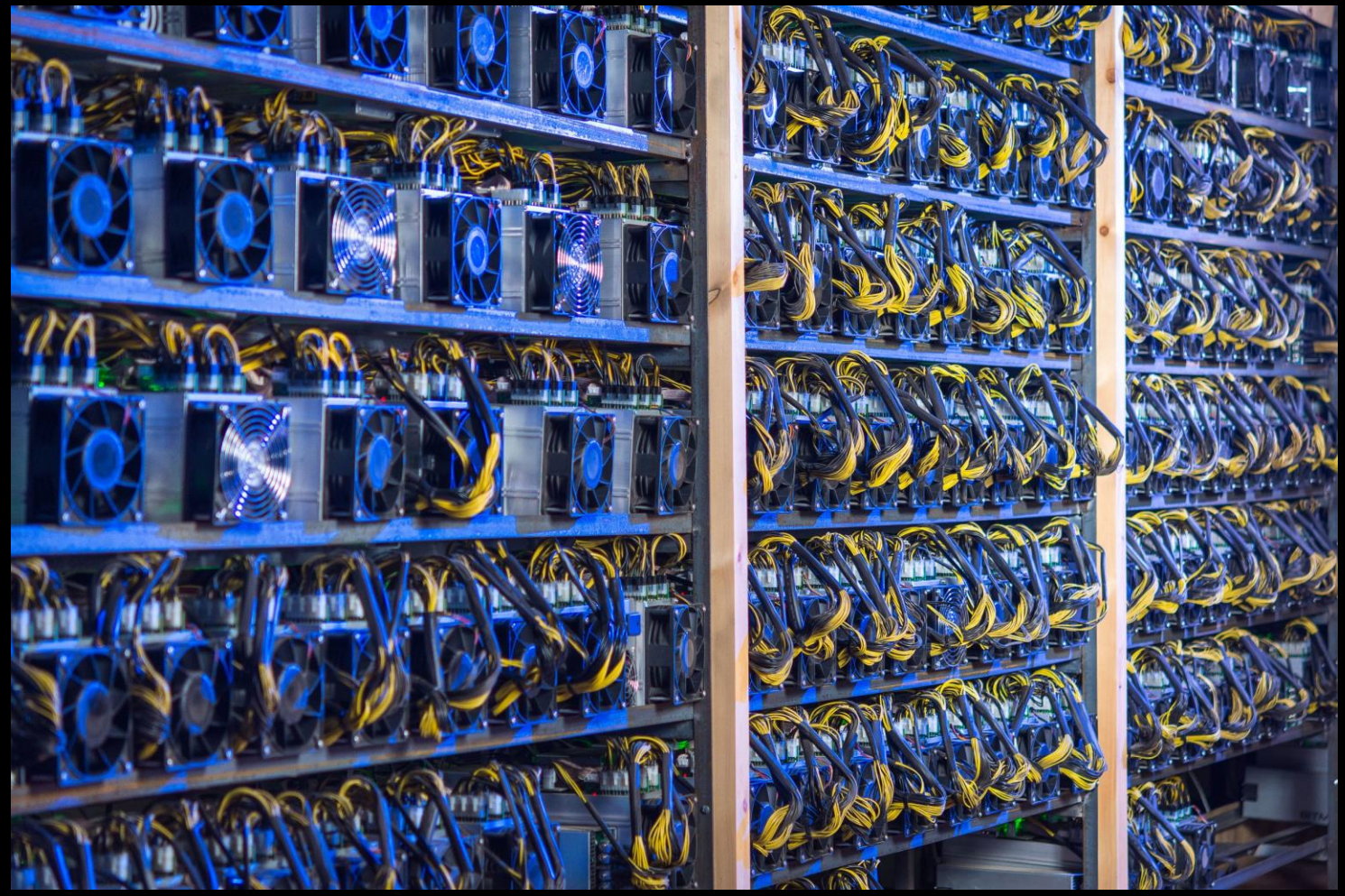
How to get Bitcoin

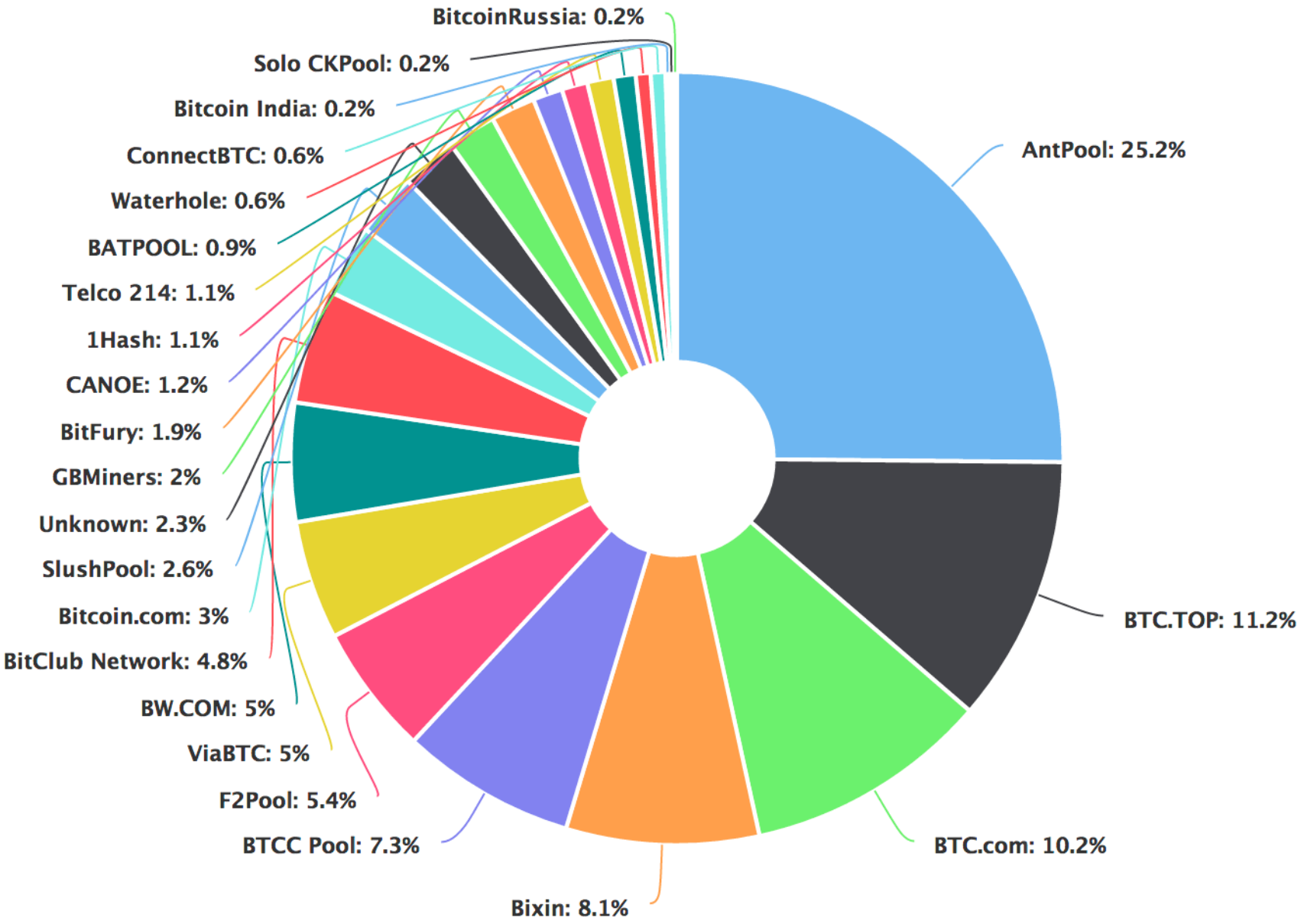
- Exchanges
- Mine a new block and get a reward
- Mine a new block and get fees

Challenges and considerations

- Not exactly ”1 person 1 vote”
- Exchanges can lead to some centralization
- Fees can get quite high
- Hard to change
- Is it actually private?

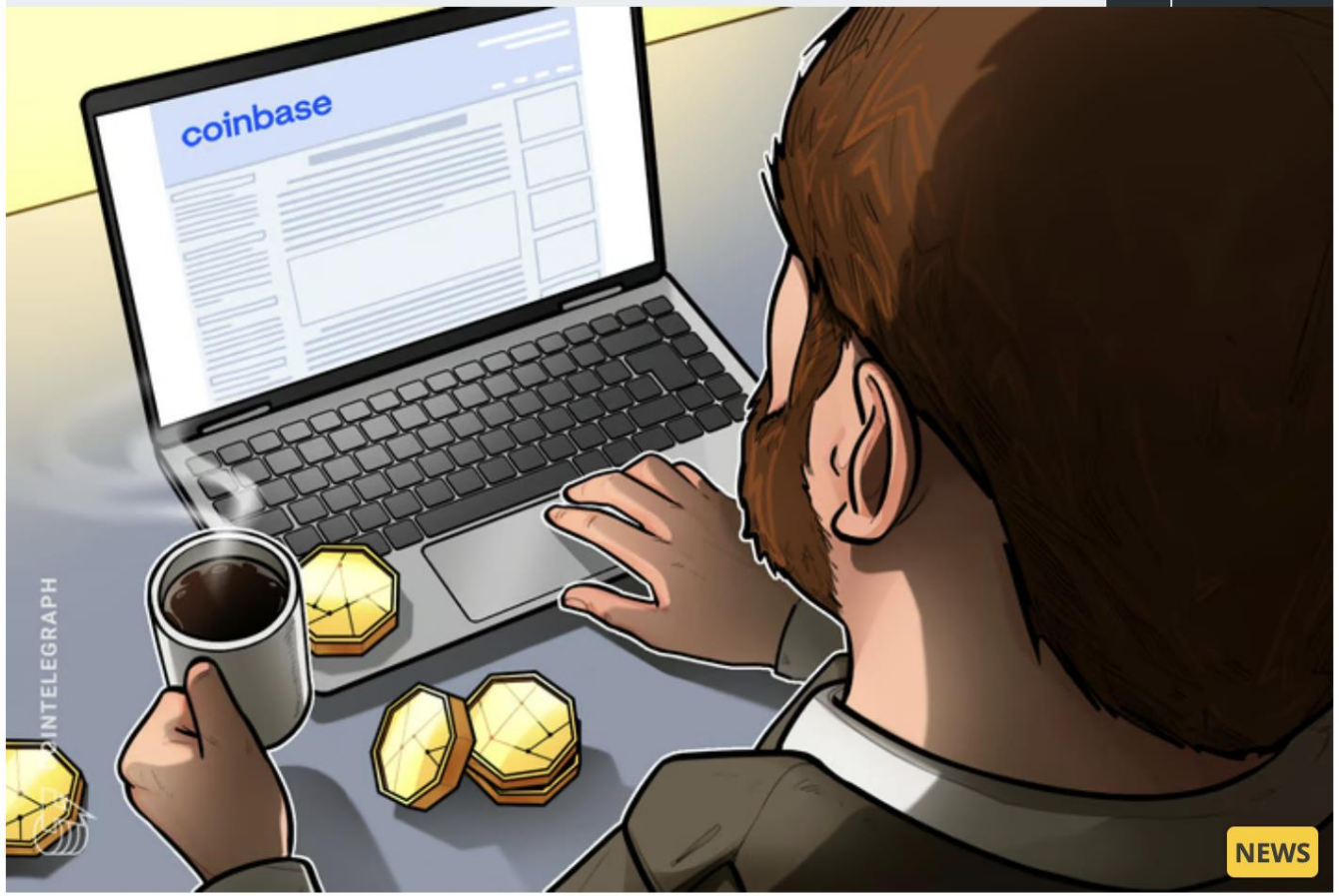
Modern Mining

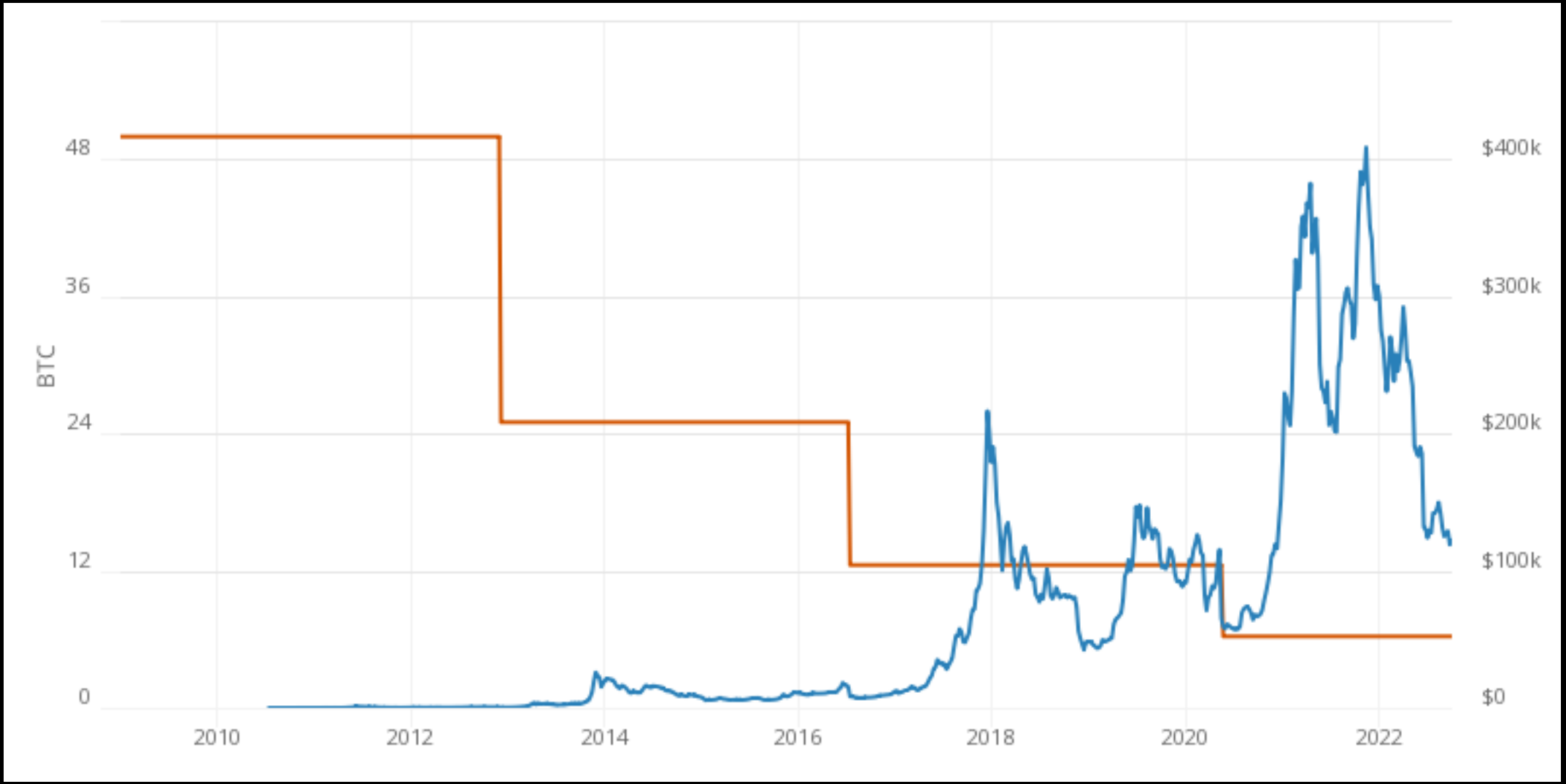



BitcoinRussia: 0.2%
Solo CKPool: 0.2%
Bitcoin India: 0.2%
ConnectBTC: 0.6%
Waterhole: 0.6%
BATPOOL: 0.9%
Telco 214: 1.1%
1Hash: 1.1%
CANOE: 1.2%
BitFury: 1.9%
GBMiners: 2%
Unknown: 2.3%
SlushPool: 2.6%
Bitcoin.com: 3%
BitClub Network: 4.8%
BW.COM: 5%
ViaBTC: 5%
F2Pool: 5.4%
BTCC Pool: 7.3%
Bixin: 8.1%
BTC.com: 10.2%
BTC.TOP: 11.2%
AntPool: 25.2%

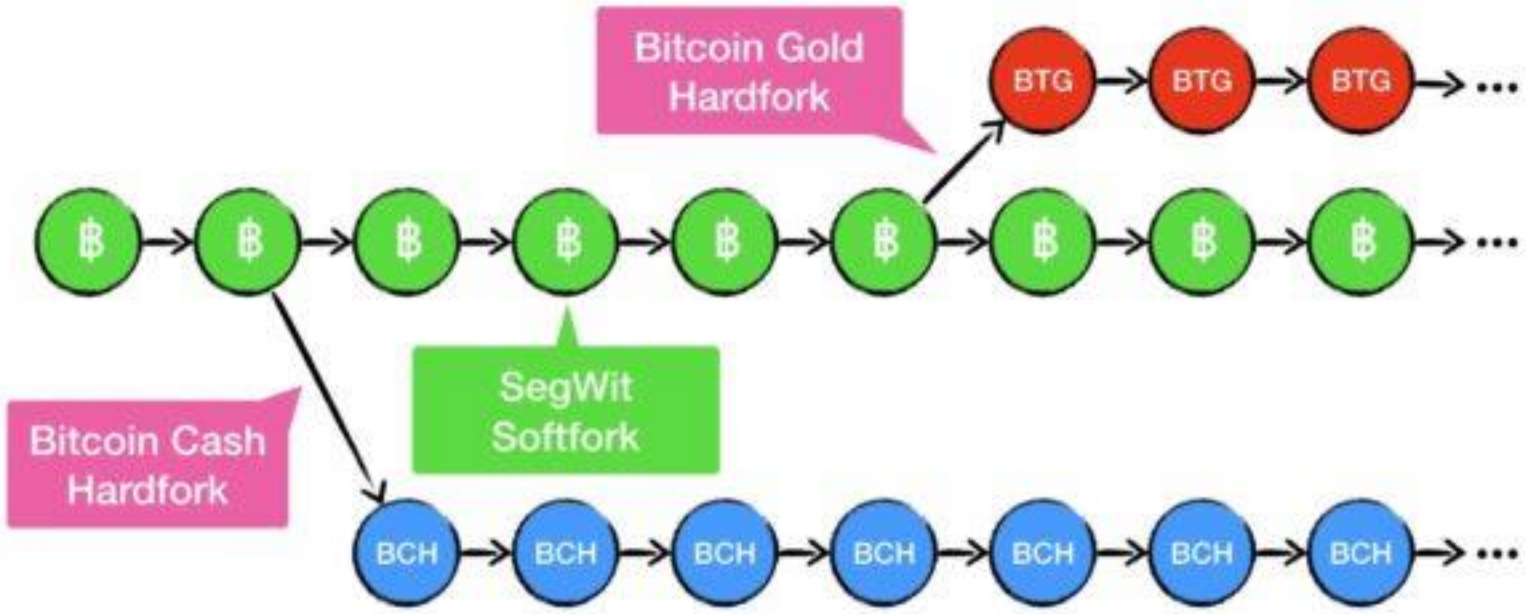
Coinbase website down as crypto exchange cites ‘system-wide outage’

Crypto exchange Coinbase suffered a “system-wide” outage, rendering the platform unusable.




BTC
48
36
24
12
0
$400k
$300k
$200k
$100k
$0
2010
2012
2014
2016
2018
2020
2022

Bitcoin Forks 2017



Is Bitcoin private/anonymous

- Account is only linked to your key pair
  - More like a pseudonym
  - Often gets reused

- Transactions are only linked to this account as well

PRESS RELEASE

Department of Justice Seizes $2.3 Million in Cryptocurrency Paid to the Ransomware Extortionists Darkside

Monday, June 7, 2021

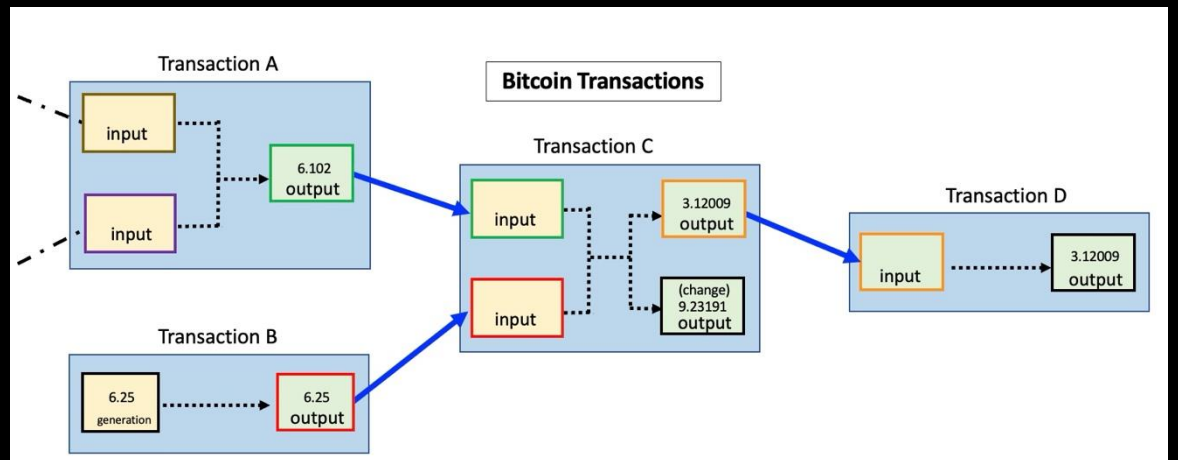
For Immediate Release

Office of Public Affairs

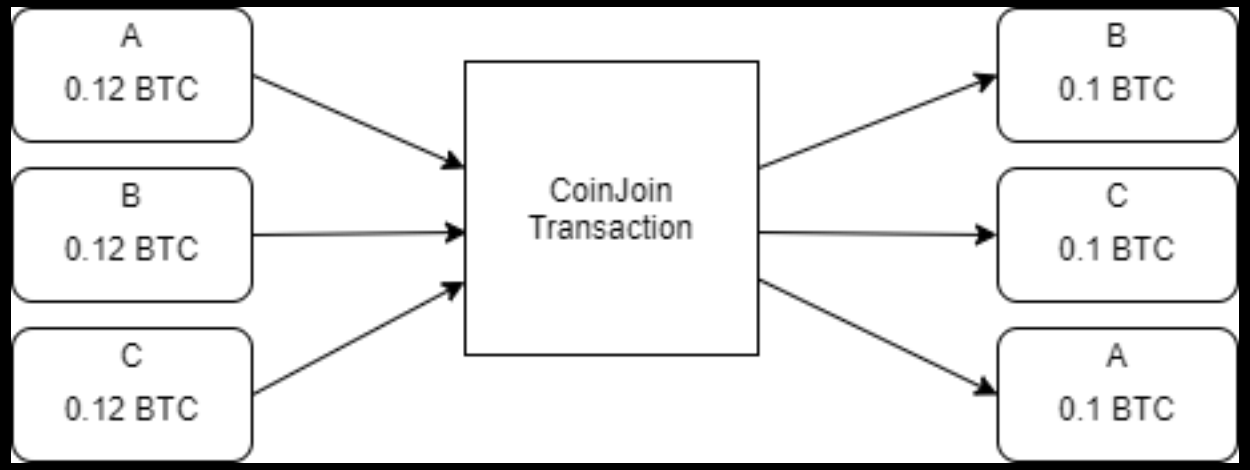
https://www.justice.gov/archives/opa/pr/department-justice-seizes-23-million-cryptocurrency-paid-ransomware-extortionists-darkside

Bitcoin transaction graph

- Recall, blockchains are public by design
- Each bitcoin has a publicly viewable history
  - Albeit pseudonymous
- Arguably less private in some senses



Shuffles and Mixes



Other types of cryptocurrencies

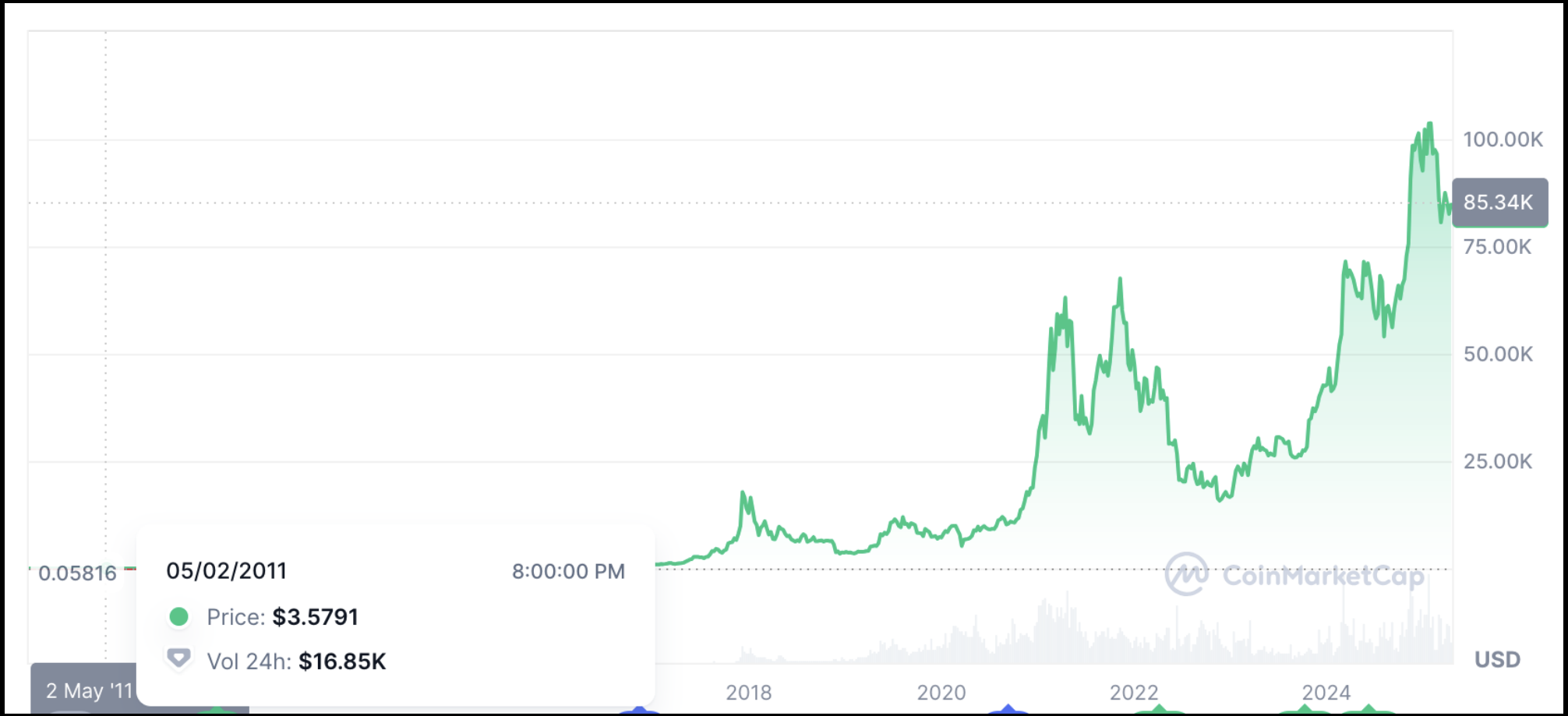
- Can vary in consensus algorithm, level of decentralization, hashrate, blocksize, and more

- Bitcoin-likes
  - Litecoin
  - Dogecoin

- Private
  - Monero
  - Zcash
  - Dash

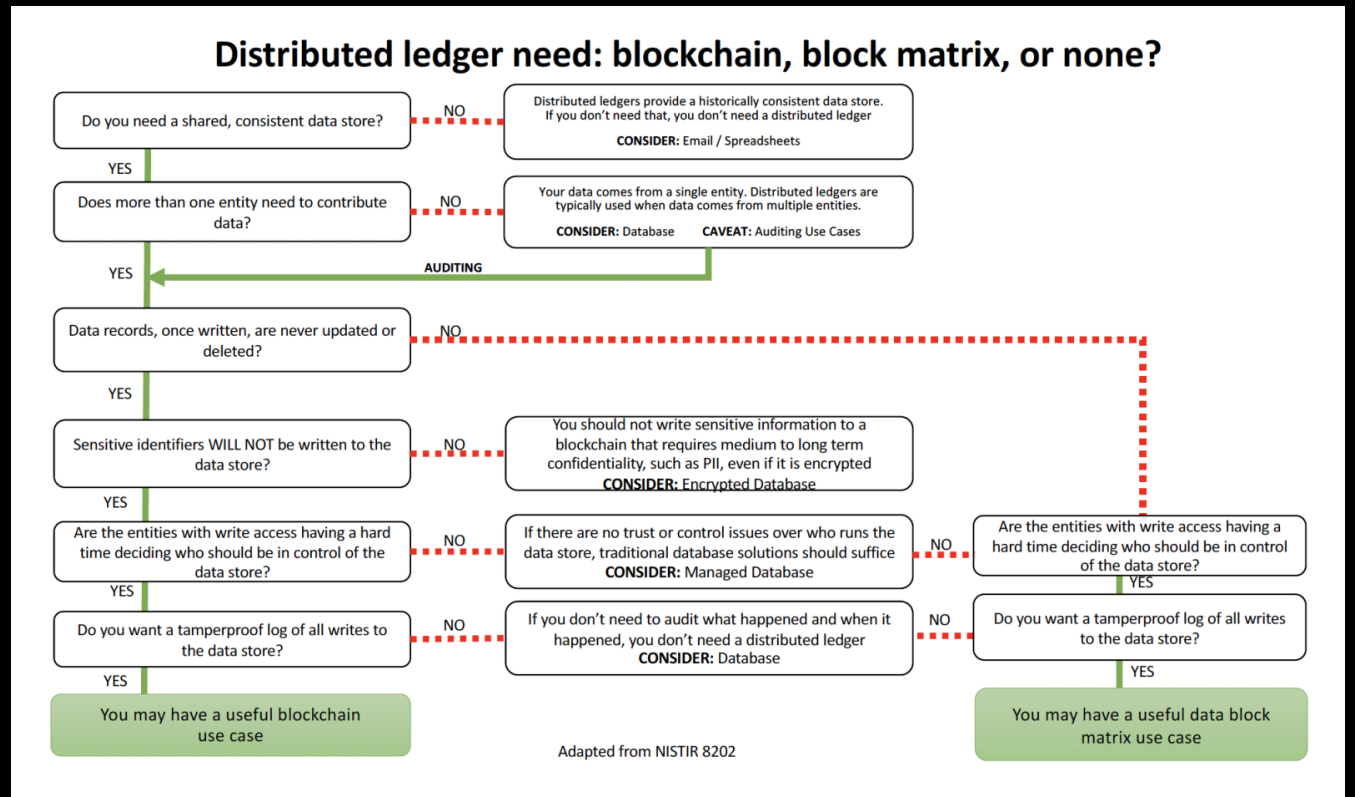
- More featured
  - Ethereum
    - Proof-of-Stake
    - Smart Contracts
    - Bitcoin also has scripts but they are much more limited

#	Name	Price	1h %	24h %	7d %	Market Cap	Volume(24h)	Circulating Supply
1	Bitcoin BTC	$84,749.77	0.31%	0.92%	3.39%	$1,682,503,962,449	$26,089,305,002 309.35K BTC	19.85M BTC
2	Ethereum ETH	$1,598.38	0.32%	1.06%	0.35%	$192,922,139,733	$14,159,313,358 8.89M ETH	120.69M ETH
3	Tether USDT	$0.9994	0.00%	0.07%	0.00%	$144,731,860,004	$54,855,015,423 54.86B USDT	144.8B USDT
4	XRP XRP	$2.10	0.50%	1.13%	4.33%	$123,016,655,899	$2,989,425,304 1.42B XRP	58.33B XRP
5	BNB BNB	$586.88	0.09%	0.79%	1.55%	$82,686,271,375	$1,407,570,581 2.40M BNB	140.89M BNB
6	Solana SOL	$133.85	0.64%	6.26%	16.35%	$69,124,668,854	$4,611,940,014 34.72M SOL	516.4M SOL
7	USDC USDC	$0.9997	0.00%	0.04%	0.03%	$60,388,497,925	$10,098,301,637 10.09B USDC	60.4B USDC
8	TRON TRX	$0.2471	0.41%	2.89%	2.70%	$23,471,239,666	$728,744,274 2.94B TRX	94.95B TRX
9	Dogecoin DOGE	$0.1567	0.05%	2.05%	0.15%	$23,332,299,794	$736,963,088 4.71B DOGE	148.88B DOGE
10	Cardano ADA	$0.6212	0.67%	2.29%	0.69%	$21,921,031,485	$583,286,563 947.23M ADA	35.28B ADA


100.00K
85.34K
75.00K
50.00K
25.00K
0.05816
05/02/2011
8:00:00 PM
Price: $3.5791
Vol 24h: $16.85K
CoinMarketCap
USD
2 May '11
2018
2020
2022
2024

Blockchain proposed applications

- Cryptocurrencies
- Distributed Apps (dApps)
  - Web 3.0



Next Time

Federation, DRM, and Open Source