Blockchain and sensible Web3

COSC312 / COSC412

Learning objectives

- Explain how Web3 seeks to build decentralised systems
  - Likely relies on **peer-to-peer networking** (decentralised)
  - Uses open blockchain systems such as bitcoin, Ethereum

- Gain a high-level view of **blockchain approaches** and beyond cryptocurrencies, *e.g.*, how they support **decentralised autonomous systems**

- Can sketch what **NFTs** are & how they use blockchains

Nodes in bitcoin network

- There are four main roles nodes can take on:
  - **Network**—all nodes help routing within the p2p protocol
  - **Wallet**—manage keys that show ownership of transactions
  - **Miner**—participate in the proof-of-work block verifications
  - **Blockchain**—can carry the full blockchain
- Bitcoin Core **reference client** contains all four functions
  - Miners may leave out wallet
  - Lightweight wallet only has wallet and network components
  - Some nodes may store blockchain, but not do mining

Content of bitcoin transactions

- **No persistent coins**: serial numbers are transaction hashes
- Transaction specifies a **number of inputs and outputs**, with inputs usually previous transactions
  - can **output back to yourself**, thus pocketing ‘change’
  - remainder of input, after subtracting output, is **transaction fee**
- Since all transactions are in the blockchain:
  - can search back in time to find transaction:
  - either **genesis block** (50 bitcoin) or a **coinbase mining reward**

bitcoin: anonymity, privacy and value

- bitcoin has been discussed as being anonymous
  - This makes little sense—the **entire ledger is available publicly**!
  - However it is true that public keys need not be identified
- **Linkability concerns**: metadata may allow subsequent determination of wallet's owners
  - Large state organisations likely want to do this,
    - *e.g.*, law enforcement
- State players globally key to bitcoin's exchange value

bitcoin scalability challenges

- Originally, blocks had no size limit, but that risks DoS
  - Added a limit that **blocks can only be 1 megabyte** at most
- Blocksize limit has **caused scalability problems**:
  - Provides for fewer than ten transactions per second
  - Around ten minutes to add a block to blockchain
  - Thus bitcoin transactions **can take hours to confirm**
- Segregated Witness (SegWit) approx. doubles size
  - Moves witness signature out of transaction blocks

Many more aspects of bitcoin not discussed

- bitcoin blocks also include **management parameters**:
  - e.*g*., **version numbers** to allow the protocol to be modified
  - Versioning is very important given that the protocol behaviour is the fundamental basis on which cryptocurrencies are built

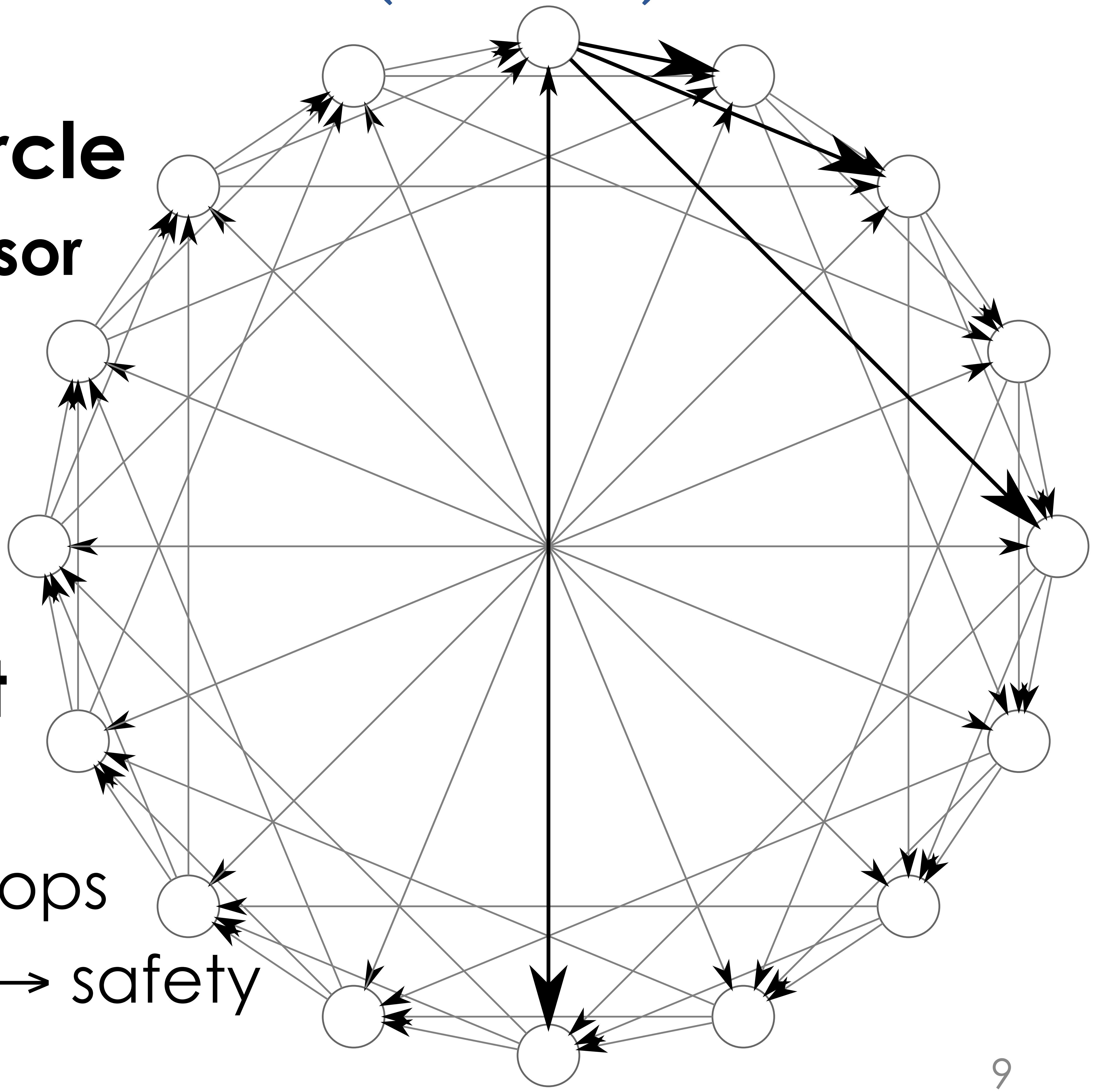
- bitcoin specifies transactions with a **scripting language**
  - P2PKH—‘**pay to public key hash**’ is a common transaction
  - ‘multisig’ transactions allow m-of-n public key sign-off
  - **Smart contracts can be encoded**, beyond money transfer

Peer-to-peer networking for scalability

- No central server: clients do message routing
  - (But uses the Internet, thus **depends on IP**, *etc*.)
- To join network: new client **connects to seed** nodes
  - Can then grow local knowledge of global client set
- Example peer-to-peer structure: **distributed hash table**
  - Hash data items; use hash as position within number space
  - Assign clients responsibility for ranges of that number space
  - Reliable even as clients join and leave (churn) over time

‘Chord’ distributed hash table (DHT)

- Clients + keys **arranged in circle**
  - Every client knows their **successor**
  - Client also has ‘**fingers**’ further ahead in key space
    - Note the four emphasised fingers of top-centre client
- Look up key by finding **client that precedes** that key
  - Can reach any key in $\mathcal{O}(\log n)$ hops
  - Assign **multiple clients per key** → safety



IPFS—the InterPlanetary File System

- Provides **decentralised data storage**
  - Aims for **high availability** (anti-censorship, global replication)
  - Decentralisation avoids reliance on ‘big tech’, or single servers

- Location of data (and replicas) **based on its content**
  - Request data via a cryptographic hash of that data
  - Data is divided up into **immutable blocks**
  - Interplanetary Naming System (IPNS) supports **mutable objects**
  - **Peer-to-peer infrastructure** for finding / reading / writing data

Blockchain aside from bitcoin

- Increasingly **blockchain services** are being offered independently of cryptocurrencies such as bitcoin
  - **Blockchain as a Service** is offered on the commercial cloud
- There is **much hype**, and often gaps in understanding
  - Some existing approaches rebadged as ‘blockchain’
- bitcoin helped show ways in which **decentralised systems can appear to form distributed consensus**

Different sorts of blockchain designs

- **Permissionless** (open) systems—bitcoin, Etherium, *etc*.
  - Any node can join or leave the blockchain at any time
- **Permissioned**—there is control over who participates
  - Can use algorithms like Paxos or RAFT to form consensus
  - … similar sorts of closed systems existed previously
- Other axis is **public** / **private**
  - sovrin is a permissioned+public blockchain managing identity
  - hyperledger is a permissioned, private blockchain

Open, decentralised consensus algorithms

- **Permissionless blockchains**: consensus over open set
  - Nakamoto consensus is term for bitcoin's consensus algorithm
  - As discussed, bitcoin uses proof-of-work to support consensus
    - Nifty … but for the hugely destructive environmental effect
  - Nakamoto consensus also involves the '**longest chain**' rule

- Ethereum now uses proof-of-stake (explained soon)
  - Was bootstrapped from previously using proof-of-work

Proof of space

- As the name suggests: **demonstrate allocating space**
  - … as opposed to demonstrating doing computational work
- One approach: **graph pebbling**
  - prover stores large graph to demonstrate commitment
  - verification needs to be cheap compared to proof generation
- Criticism: messed up supply chain for storage devices!

Proof of stake

- Validators are selected **based on their stake**
  - *i.e.*, selected validators will hold lots of the cryptocurrency
    - Likely required to hold this for some minimum duration
  - it's against their own financial interests to behave maliciously
- Various potential attacks:
  - **Nothing-at-stake**—malicious validator builds on every fork
    - Improved approaches require security deposits from validators
  - **Long-range attacks**—attackers recreate alternate history
    - Mitigations involve, *e.g.*, checkpoints; invalidating old keys
  - **Overcentralisation**—incentive to raise stake → centralisation

Web3 and decentralised applications

- Web3 aim: build **decentralised computing** platforms
  - Tone is sometimes even stronger, *i.e.*, anti-central

- **Executable contracts** rather than transfer of currency
  - bitcoin already shows practicality of scripting language
  - bitcoin facilitates agreement of future events (& cancelation)

- Always ask: **is blockchain really needed?** Alternatives?

Proposed Web3 example applications

- **Supply chain management**: tracked asset transfer
  - Particular with respect to pharmaceuticals
  - Many organisations; common goal; fraud impractical
- Microgrids and neighbourhood **electricity trading**
- Government storage of records (*e.g.*, health records)
  - **e-democracy** and **voting** (how could that go wrong?)
- **Collecting royalties** for performances…
- Legal and financial processes, *e.g.*, **conveyancing**

Web3/crypto: does it avoid central control?

- Web3/crypto doesn't depend on big-tech or big banks
- … but there are many dependencies often ignored:
  - Need **access to computing equipment** *i.e.*, supply chain
  - Need to have **power infrastructure** (solar bitcoin mining: hard)
  - Need Internet service provider (ISP) and **network infrastructure**
  - Crypto needs **an exchange** to gain any real-world cash value
    - Exchanges almost certainly attract **government regulation**

- More pragmatic/efficient to embrace central control?

Ethereum aims to effect dapps (distributed)

- Ethereum aims to build a **global computing platform**
  - Cannot be shut down easily
  - Can scale up and down
  - Resistant to censorship and other interference

- **Ethereum Virtual Machine**
  - Platform on which code executes

- Usually need some sort of bridge to other web APIs

Blockchain scheme governance

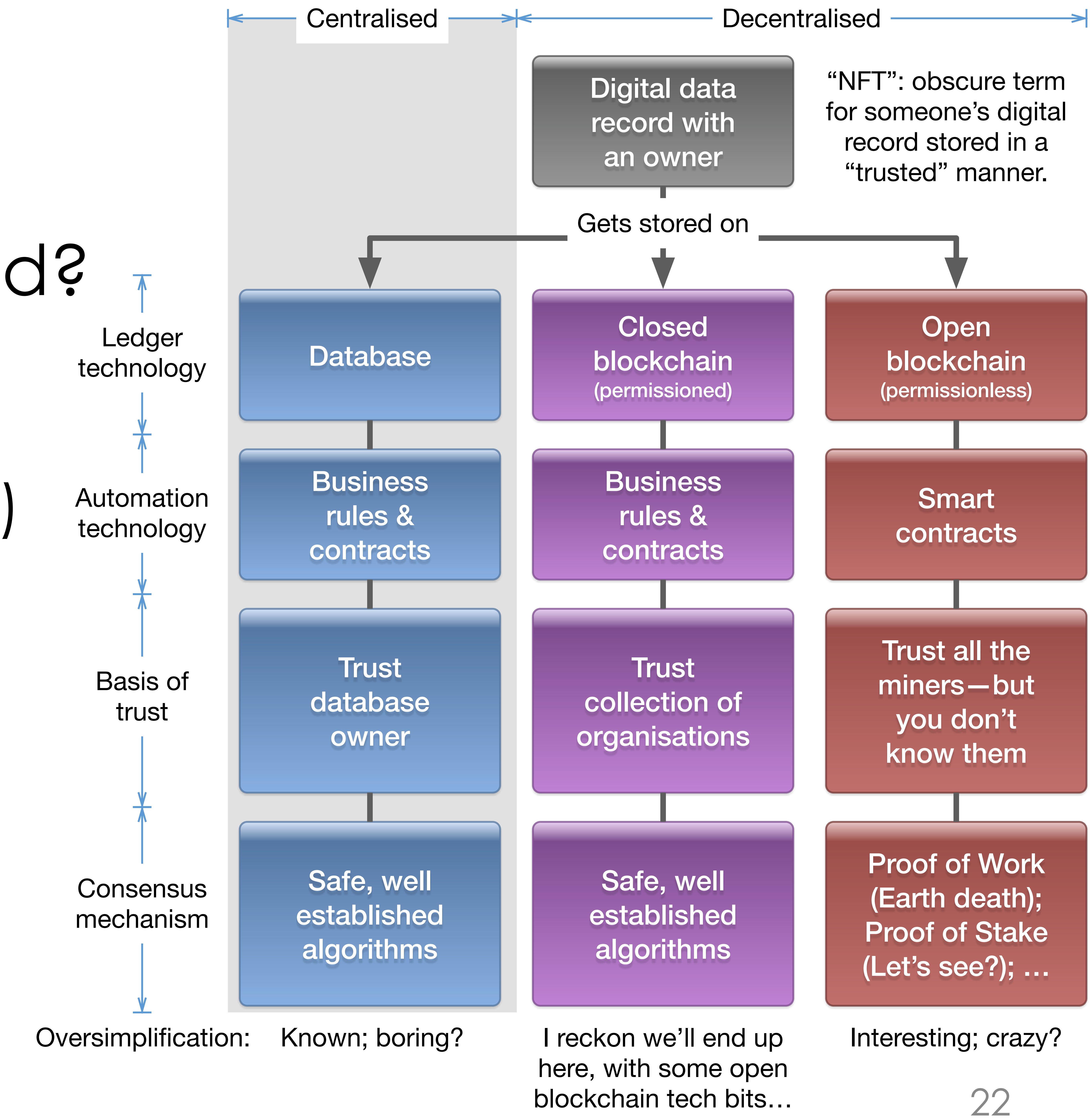
- What if a **protocol vulnerability** is discovered?
  - Say a **hacker steals resources** worth millions of dollars
  - Entire blockchain system can agree to **rewind history**?
  - … but this is a capability blockchain systems seek to give up
  - Alternatively end up **showing lack of real decentralisation**?
- Ethereum *e.g.*: **Decentralized Autonomous Organization**
  - Raised $150m crowd-sourced funding; DAO was ~15% of ether
  - **Code had vulnerabilities**; hacker siphoned off a third of DAO
  - Soft-fork and hard-fork resolutions discussed; hard-fork done

NFTs—non-fungible tokens

- **Cash is fungible**—individual coins are interchangeable
- NFTs are just **unique digital records owned** by someone
- NFTs are usually stored on blockchains
    - Thus **record of ownership** is decentralised and cooperative
- Smart contracts can record NFT **transfer of ownership**
- Blockchains don't suit storing lots of data
    - Thus NFTs often encode a **URI to target object**
    - … but then there is no particular value to NFT's uniqueness

NFT characterisation

- **Blockchain NFTs**: real need?
  - Existing financial systems can be improved to lower friction of transactions (IMO)
- Decentralised Identifiers:
  - **W3C DID standard**
  - Help unify different technology that achieves similar results



Digital data record with an owner

"NFT": obscure term for someone's digital record stored in a "trusted" manner.

Gets stored on

	Centralised	Decentralised	
Ledger technology	Database	Closed blockchain (permissioned)	Open blockchain (permissionless)
Automation technology	Business rules & contracts	Business rules & contracts	Smart contracts
Basis of trust	Trust database owner	Trust collection of organisations	Trust all the miners—but you don't know them
Consensus mechanism	Safe, well established algorithms	Safe, well established algorithms	Proof of Work (Earth death); Proof of Stake (Let's see?); …
Oversimplification:	Known; boring?	I reckon we'll end up here, with some open blockchain tech bits…	Interesting; crazy?

In summary

- Bitcoin demonstrated **decentralised consensus** in an open world: including permissionless blockchains
- Web3 aim: build **decentralised apps** (dapps) & **storage**
  - Depends on peer-to-peer functionality at low levels
  - Embraces many forms of blockchain, *e.g.*, Ethereum
  - Goes beyond cryptocurrency use
- **NFTs** are a particular use of blockchains
  - … mostly using open blockchains, but might not need to