7CCSMDLC: Distributed Ledgers & Cryptocurrencies
Lecture 8: DLT Infrastructure & Platforms

Peter McBurney
Professor of Computer Science
Department of Informatics
King's College London

Email: peter.mcburney@kcl.ac.uk
Bush House Central Block North – Office 7.15

Outline

- Distributed Ledgers
- Ethereum
- Corda
- Hyperledger
- Other technologies
- Comparison of platforms

Distributed Ledgers

- Bitcoin Blockchain was designed for a specific use-case
  - Decentralized electronic currency
  - Key issue: preventing double-spending when no one is in control
- However, it opened our eyes to a whole new class of technology
  - Technologies where transactions are witnessed & validated
  - Participants share state of certain variables
  - Transactions are linked together to strengthen resistance to attack & to fraudulent revision
- Key elements:
  - P2P (decentralized) data sharing
  - Rule-governed processes to enable interactions between entities lacking mutual trust.

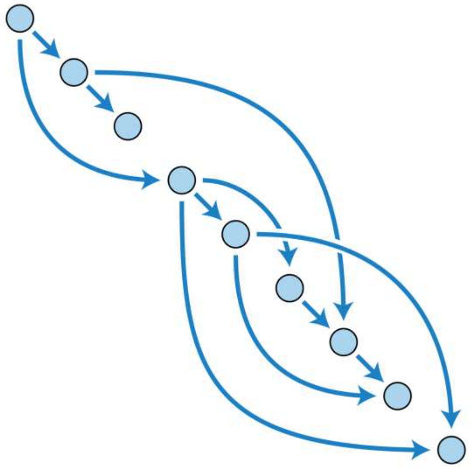
Which features are essential?

- Being open?
  - No: Permissioned ledgers

- Having an electronic currency? No.

- Having particular protocols or consensus mechanisms? No.

- Having blocks or chains? No.
  - Can have a hash-graph (entries linked to past entries by hashing)
  - DAG - Directed Acyclic Graph (see image)
    - Finite directed graph with no cycles



- A world of new structures are still being explored.

Ethereum

Ethereum

- Language for Bitcoin Blockchain (Script) is limited
  - Desired a blockchain with a full programming language

- Ethereum
  - Blockchain platform with a full language Solidity
  - Turing-complete language (so able to do loops)

- 2013: Proposed by Vitalik Buterin
- July-August 2014: ICO raised US$18.4 million
- 30 July 2015: System live
- 15 September 2022: Switched to Proof-of-Stake

- Ethereum Foundation (HQ in Zug, Switzerland)

- Ethereum has about 4.4K nodes (February 2025)
  - Peak was ca. 12.5 K nodes in February 2021

  http://ethernodes.org/history

Ethereum Features

- Ethereum is a public (open) distributed ledger with an external cryptocurrency, called Ether
  - ETH or Ξ (Xi)
  - Called Ethereum MainNet
- Main intended application: A programmable DL (smart contracts)
- Imagines a state-transition machine (Ethereum Virtual Machine)
  - The machine exists on all the full nodes of the network
  - Smart contracts are programs which seek to change the state of the machine.
- Ethereum 2.0 launched December 2020
  - Ethereum MainNet initially used Proof-of-Work protocol
  - Ethereum 2.0 uses Proof-of-Stake (since 15 September 2022)
  - Energy usage fell by estimated 99% after switch to PoS.

Ethereum vs Bitcoin

- Blocktime
  - Bitcoin: 10 minutes
  - Ethereum: 12 seconds

- Mining of new coins:
  - BTC halves every 4 years
  - Ether generates new coins each epoch (each 6.4 minutes)

- Total number of currency:
  - BTC: 21 million hard cap
  - ETH: No cap
    - About 120 million ETH in circulation in January 2025

- Size of networks
  - Bitcoin (started 2009): 21.8K nodes
    http://bitnodes.io
  - Ethereum (started 2015): 4.4K nodes (fell after switch to PoS).

ETH – Ether – Ethereum's currency

- ETH divided into wei (similar to a satoshi in Bitcoin)
  - 1 ETH = 10 ^ 18 wei
  - 1 gwei (giga wei) = 10 ^ 9 wei
  - So, 1 ETH = 10 ^ 9 gwei

- Time divided into Epochs
  - 1 Epoch = 32 slots where validators propose & attest for blocks
  - Validators reshuffled before each epoch
  - Each slot about 12 seconds, so each epoch is about 6.4 minutes
  - At end of each epoch, successful validators rewarded with new ETH

- Before 9/2022 (switch to PoS): about 13K ETH created each day
  - Now: about 1.6K ETH created each day
- One estimate for 2025:
  - About 810K new ETH will be created
  - About 840K ETH will be burned in transaction fees

Ethereum Gas

- Ethereum separates cryptocurrency from measurement of work done

- Gas cost – unit of measurement for transactions
  - eg, 6 gas for each 256-bit hash
  - Like KiloWatts (units of measurement of electricity)
  - Based on complexity of processing, bandwidth needed, memory usage
  - The more complex the commands, the more gas you need to offer

- Gas price (measured and paid in ETH)
  - How much initiator is willing to pay for the transaction to be processed

- Since EIP1559 (August 2021), Initiator of transaction specifies in ETH
  - A base fee (which is burned after the transaction)
  - And a tip to the validator (which the validator can keep) (this acts as an incentive for fast processing)

- Total processing fee in ETH =

  Gas limit (total # of gas to be used) X gas price in ETH.

Examples of gas costs

step	1	Default amount of gas to pay for an execution cycle
stop	0	Nothing paid for the suicide operation
sha3	20	SHA3 Hash
memory	1	For each additional word when expending memory
tx	500	Paid for every transaction

- Miners can accept proposed gas price or not
  - A low tip will mean the transaction is not processed quickly or maybe never

- If accepted, the miner processes until the gas limit is reached.
  - If a transaction fails or is incomplete, initiator still pay the fee (because resources were used), but the state of the EVM remains as it was before the attempt to process the transaction.

Why have Ethereum Gas?

- To ensure programmers pay for the cost of processing smart contracts

- To decouple payment for processing from the market value of the currency

- To eliminate infinite loops and to hinder DoS attacks
  - Eventually an infinite program will run out of finite gas
  - Makes an attacker pay for the resources they use

- The more complex the programming commands requested, the more gas the initiator needs to offer.

EVM = Ethereum Virtual Machine

- Ethereum Virtual Machine
  - Runtime environment for smart contracts
  - 256-bit register stack

- Isolated from the network and from the file systems of clients

- Implemented in
  - C++, Go, Haskell, Java, Javascript, Python, Ruby, Rust

- The platform is designed so that Smart Contracts, when processed by miners, will change the state of the EVM.
  - Hence, Ethereum has been called a global computer.

See:

Gavin Wood: “*Ethereum: A Secure Decentralised Generalised Transaction Ledger*”. (EIP-150 Revision) Ethereum Yellow Paper.

Cryptokitties

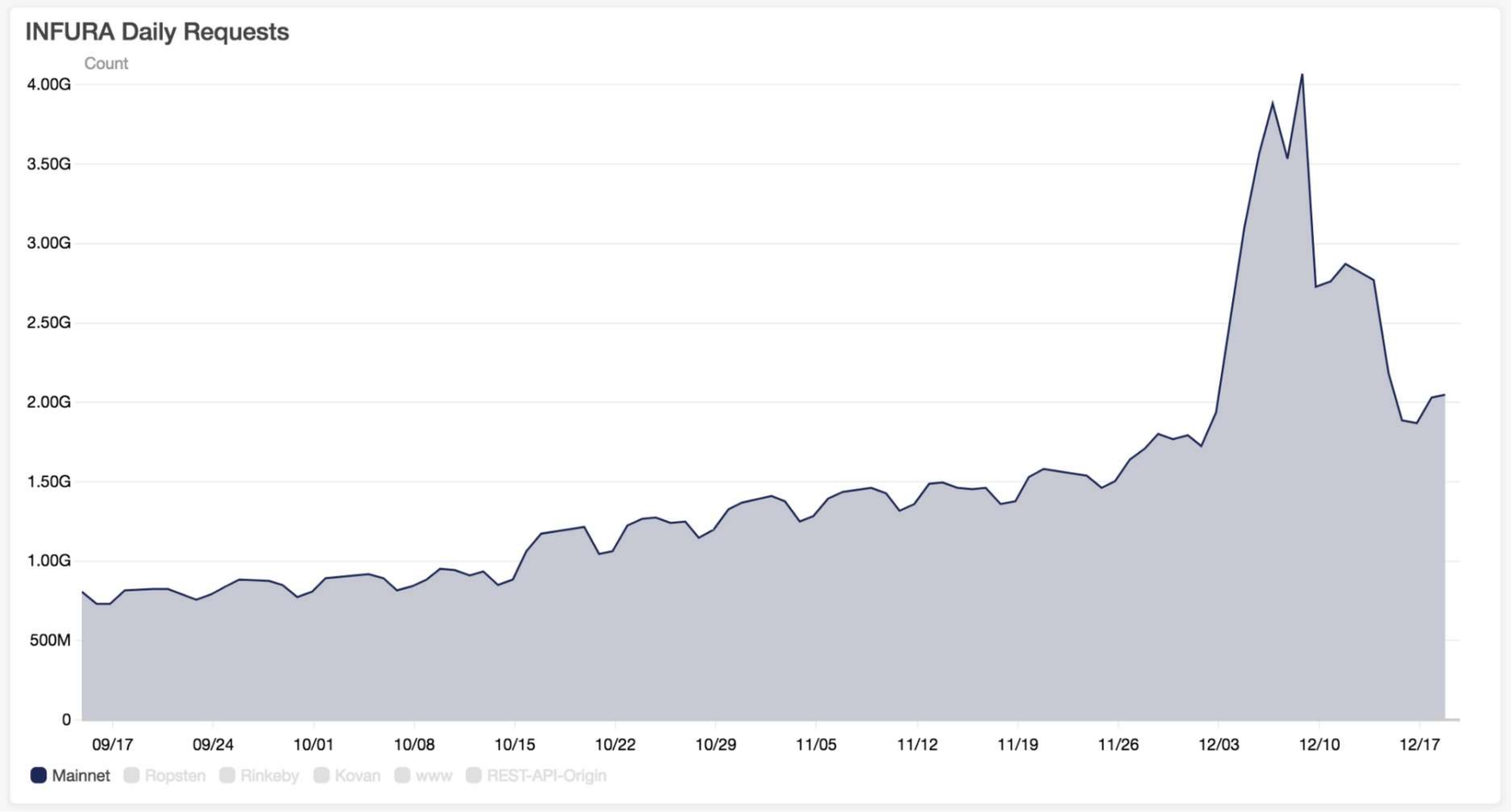
The Problem:

- Cryptokitties launched 12/2017
- Very popular
- Daily requests on Ethereum rose
  From 2 bn/day to 4 bn/day

- Usually such spikes in demand will resolve automatically
  - Miners accept higher gas prices
  - Transactions cost more & market forces control the queue
  - This did not happen

- Response
  - Short-term: Modified front-end to allow users to resubmit their transaction with a higher gas price
  - Longer-term: Move dapps to sidechains.

Daily requests on Ethereum through Infura nodes



Source: Consensys: *The Inside Story of the Cryptokitties Congestion Crisis.* Medium. 20 February 2017.

Ethereum Enterprise

- Ethereum MainNet is the open platform
- Permissioned chains may be run as sidechains
  - With various forms of synchronization to Ethereum MainNet
- Issues of how to manage permissions
  - Ethereum does not have a central node
- Software companies founded by Ethereum alumni:
  - Consensys (Founder Joe Lubin): consensys.io
  - Parity (Founder Gavin Wood): parity.io

Corda

Corda

- Project initiated by a consortium of banks
  - R3cev LLC
  - HQ in New York, main work in London & Dublin
  - Consortium of 70+ banks and financial institutions
  - r3.com

- Established 2015 to develop distributed ledger technologies for banking and financial applications

- Created a platform called CORDA
  - Open-source DL platform released 30 November 2016
  - For scalability and support, will require enterprise version (which is licensed) called R3 Corda.

Problem

- Contracts between 2+ financial entities
  - Legal document
  - Shared facts are just between the entities
  - Visible to appropriate regulators
  - CAP theorem – different users may prioritise consistency over availability

Design

- Consensus
  - Just parties to a transaction, not the entire community
- Validation
  - Just legitimate stakeholders, not the entire community
- Use of Independent notaries
  - For time-stamping & prevention of replayed transactions
- Focus on inter-operability
  - With legal code
  - With legacy IT systems.

Corda features

- Transactions private to the parties involved
  - Witnessed by notaries
  - Only participants to a transaction can view it
  - Not even the existence of a transaction is known to others
- No single chain
- No global state
- No native crypto-currency
- Records an explicit link between legal code and smart contracts
- Supports a variety of consensus mechanisms
- Can include transaction within arbitrary workflows.

Enterprise version: R3 Corda

- R3 Corda is an enterprise version of Corda
- Differs from open-source version in terms of
  - Support & maintenance
  - Node capabilities
  - High availability & disaster recovery
  - Management & monitoring
  - Enterprise network configuration/ firewalls
- Access to template libraries of code and workflows
  - Eg, dispute resolution workflows
  - Flow Hospital – admin can see flows which need fixing
- Integration to other protocols
  - Corda interfaces to RPC (Remote Procedure Call) protocol
  - R3 Corda interfaces to FPML (Financial Products ML) / SWIFT ISO-20022
- Privacy & Key Management, eg
  - Role-Based Access Control in R3 Corda, not in Corda
  - Light-weight Directory Access Protocol (LDAP)
- Pluggable crypto
- Ability to operate Corda nodes inside a corporate firewall
  - Enterprises usually averse to P2P networking
- Operational GUI.

Hyperledger

Hyperledger

- December 2015 – Started by Linux Foundation

- IBM contributed code from OpenBlockchain
  - Became Hyperledger Fabric

- Early members:
  - Tech firms - IBM, Intel
  - Financial Institutions - ABN AMRO, JP Morgan
  - Software companies – SAP
  - Systems integrators – Accenture, Wipro

- HyperLedger became an umbrella project for related projects.

HYPERLEDGER

Platforms

HYPERLEDGER

- HL Burrow
  - an Ethereum Virtual Machine via HL
  - Monax & Intel

- HL Fabric
  - IBM
  - Permissioned BL infrastructure
  - Chaincode (smart contracts)
  - Configurable consensus & membership services

- HL Sawtooth
  - Intel
  - Proof of Elapsed Time (PoET)
  - Hardware-based security

- HL Development tools.

Other technologies

Other technologies

- Common criticism - *"You don't need a Distributed Ledger platform! You could do all this with a centralized database and private messages."*

- Technically correct. But –
  - Who holds this database? How is it paid for?
  - Who can be trusted not to exploit it?
  - Risk of attack?
  - Regulatory issues (eg, anti-trust laws)

- Anti-trust (pro-competition) laws
  - Preclude any member of a partnership holding commercial data from competitors
  - So: A centralized database needs to be held by a third-party host.

- Commercial considerations
  - A third-party host is more expensive
  - A third-party host may be able to monetize the shared data.

Enhanced database technology

A central database with secure private messaging and with

- A private network (closed to entities without permission)
- Digital signatures (public/private keys) for secure identity
- Encryption of messages between participants
- Each participants holding relevant data in their own database
- A consensus mechanism (possibly)
- To ensure immutability, periodic hashing of database contents to a public blockchain (eg Ethereum)
  - Eg, Everledger does this with diamonds records.
    www.everledger.io

Conclusion: It is still early days

- The technology is still immature & functionalities are limited
  - Eg, Scalability is still a challenge

- Dev Tools are still lacking and immature

- Development experience is limited
  - Bitcoin Blockchain and Ethereum are still the only large-scale deployment of open DLT technology
  - There are, as yet, still no large-scale commercial applications
  - Systems in production: Vakt / Komgo / InsurWave

- Consortium of energy trading companies & banks conducted a trial
  - Open Development Challenge (ODC)
  - December 2017 - January 2018
  - Approx. 50 companies approached, 10 invited to build PoC (2 weeks)
  - Big names & start-ups
  - Different platforms trialled
  - No platform is obviously or uniformly best for this problem domain.

Appendix:
Comparison of Platforms

	Ethereum	Corda	Hyperledger	P2P & Hashes
Technical				
True DL?	Yes	Yes	Yes	No
How is state of the system decided?	Validation by all system participants, in accordance with consensus mechanism.	Validation by notaries and parties to each transaction, in accordance with consensus mechanism,.	Validation by all system participants, in accordance with consensus mechanism.	No central system state. Participants agree transactions and then an upload to a blockchain establishes proof-of-existence at time of upload.
Consensus Mechanism	Proof-of-Work. Moving to Proof-of-Stake in 2018. In the transition period, both PoW & PoS will be used.	Validation by participants to a transaction & by independent notaries. Could work with any consensus model, including ones supported by SGX (Intel enclave technology)	Modular structure that could work with any consensus model. May use Proof-of-Authority or Voting-based	N/A. Voting protocols would need to be developed,
Smart contract capabilities	Yes Solidity language (still immature)	Yes In Java and Kotlin	Yes Most mature in Go language. Java is also possible, but still immature.	No Would need to be developed.
Development history	Open source	R3 CEV	IBM and others	The ideas arise from the world of distributed databases.
Development outlook	Good	Good	Good	N/A
Limitations & Flexibility	Public/open	Focused on financial applications	Modular structure makes this flexible Privacy possible but weak and non trivial design.	Need to ensure flexibility and scalability in designing the P2P communications

Scalability	Good With mainnet Ethereum scalability could be seen as extensive.	Medium	Medium	Unclear
Transaction performance	1 Transaction per 15 sec With Plasma and the Lightning network which introduces parallel child blockchains this can improved drastically, to Billions transactions per second.			
Security & Identification	Public/open or Private/closed when set up as a permissioned network.	Private	Private	Private
Non-Technical				
Key backers/ investors	Ethereum Foundation Open-source community Support from many later ICOs.	R3 CEV Some 70+ global banks	IBM Intel Linux Foundation and over 100 others	Database vendors
Vision by	Vitalik Buterin	Mike Hearn	IBM ?	?
Usability	Needs to be developed	Needs to be developed	Needs to be developed	Needs to be developed
Support community	Broad	Financial community	Limited	?
Standardization & adoption levels	Widespread	Support in banking	Unclear	N/A

Thank you!

peter.mcburney@kcl.ac.uk