

Blockchain & Reinforcement Learning applications for the energy sector

A decentralised platform for Demand Side Response trading

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Why Flexibility?

1) Inefficient:

Complex & opaque
Missing markets

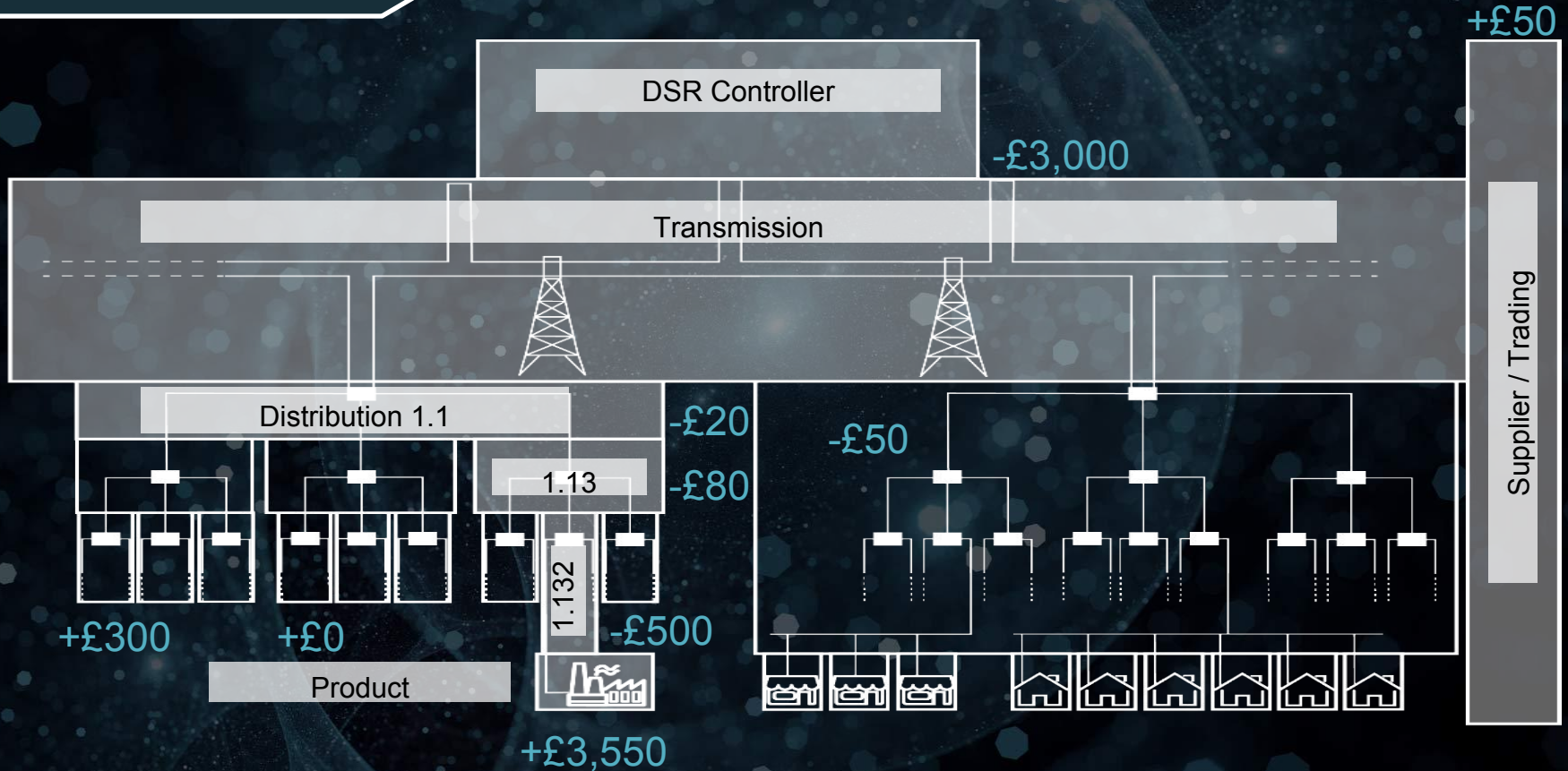
2) Illiquid:

Barriers to entry
No price discovery

3) Fragmented:

No coordination
Non-rival goods

Why Collaborate?



Why Decentralise?

1) Multilateral trades:
Maximum liquidity
Cost savings

2) Asset Inclusion:
100→1m generators
Behind meter DSR

3) Co-operation:
Protocol guarantees
Technology trigger

What is a Blockchain?

A Byzantine-Fault-Tolerant decentralised
singleton fixed-function state-transition system

Gavin Wood



What problem does the blockchain solve?

Blockchain achieves and maintains **integrity** in a **purely distributed peer-to-peer system** that consists of an **unknown number of peers** with **unknown reliability** and **trustworthiness**



The Byzantine Generals' Problem

- A **classic computer science problem** introduced by *Lamport et al.* in 1982
- Several divisions of the Byzantine army are camped outside a city, commanded by generals, who communicate via messengers and must decide upon a common plan of action (**consensus algorithm**)
- The algorithm must guarantee that
 - All **loyal generals** agree on the **same plan of action**
 - **Loyal generals** will **follow the outcome** of the consensus algorithm **regardless of** what potential **traitors** do
 - (A small number of) **traitors cannot cause** loyal general to adopt a **bad plan**



Consensus through Proof-of-Work

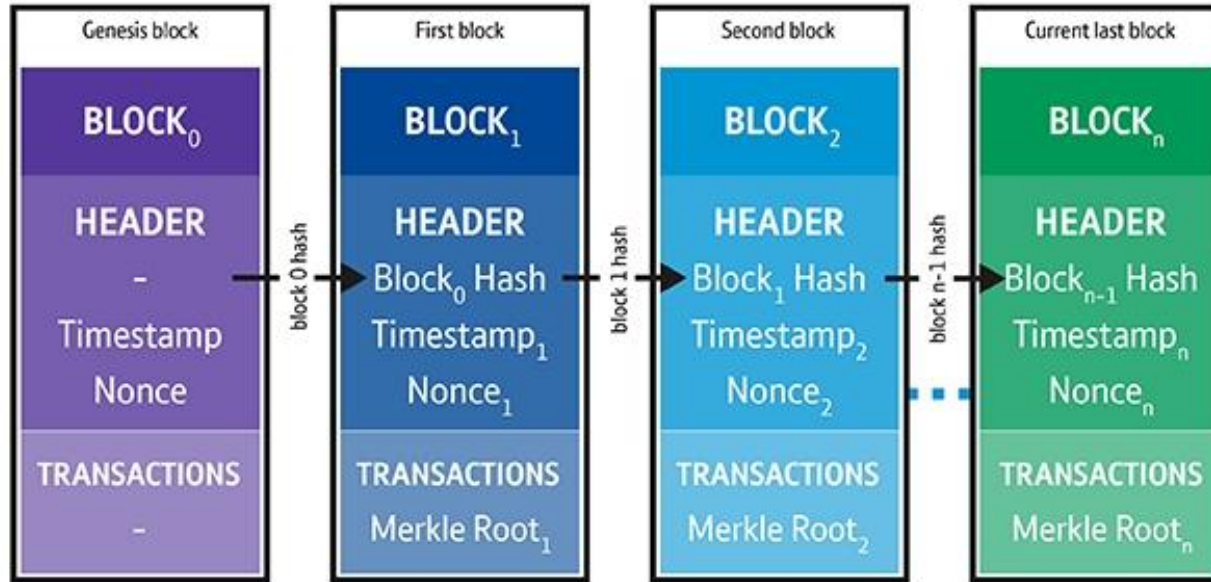
- Need to **tie consensus** on adding a an entry to the chain **to a resource** that is **hard to obtain**
- A **node** can only add an entry to the chain if it **solves a cryptographic puzzle**
- **Other nodes** can **easily validate** new blocks by checking the solution

Bitcoin implementation

- Nodes receive transactions and group them into **blocks** (hence the name blockchain)
- Cryptopuzzle: find a hash function of the combination of the data in the block, the hash of the previous block and a unique input (*nonce*) that satisfies certain constraints



A blockchain overview



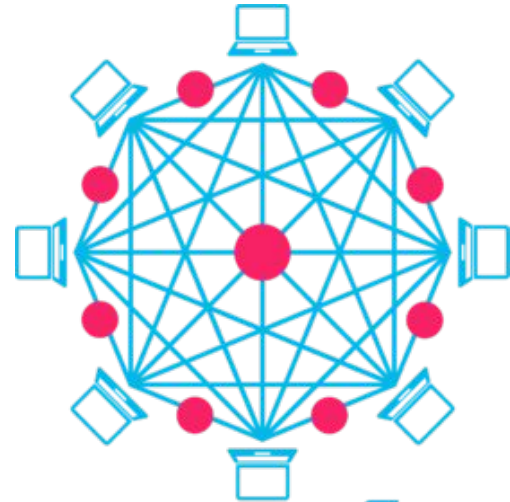
Blocks are linked through hash references, so to modify a block inside the chain one has to change all the following ones (**immutability of the chain**)



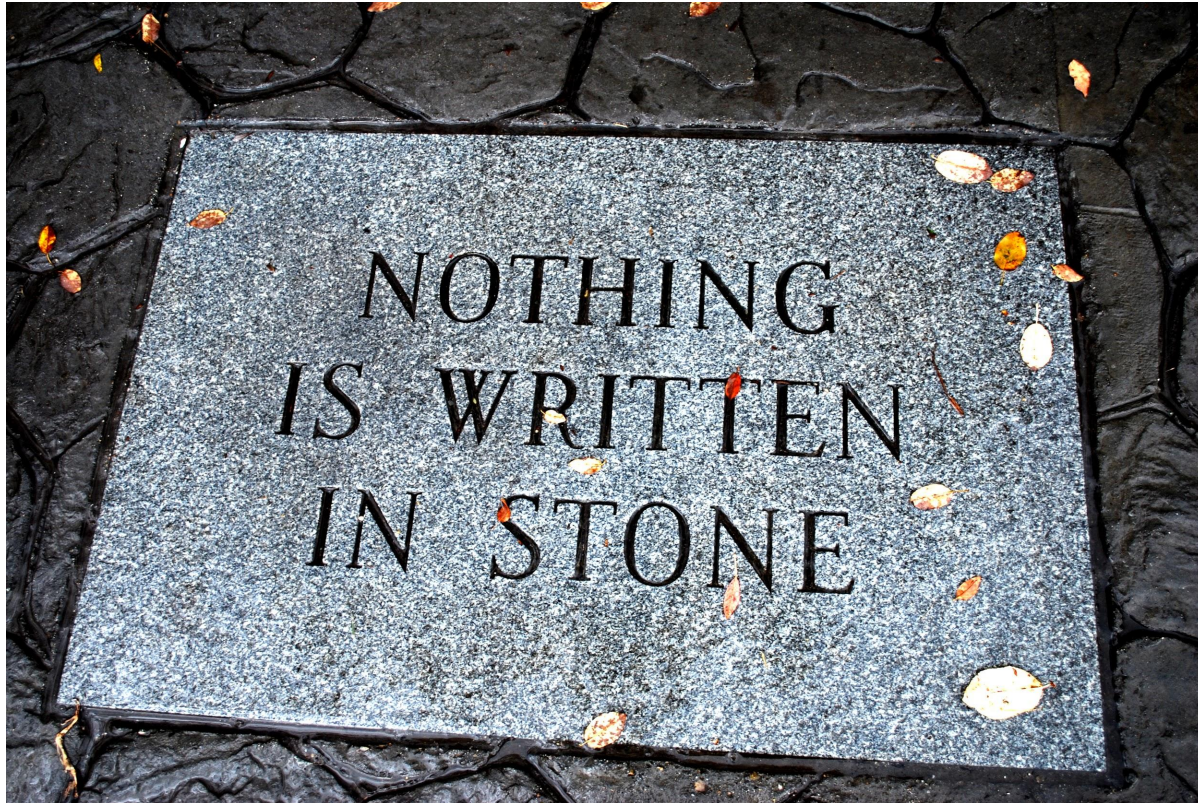
Unique Features of a Blockchain

A **blockchain** is a distributed, Peer-to-Peer, append-only database where it is possible to record transactions and run programs (*Smart Contracts*) that are

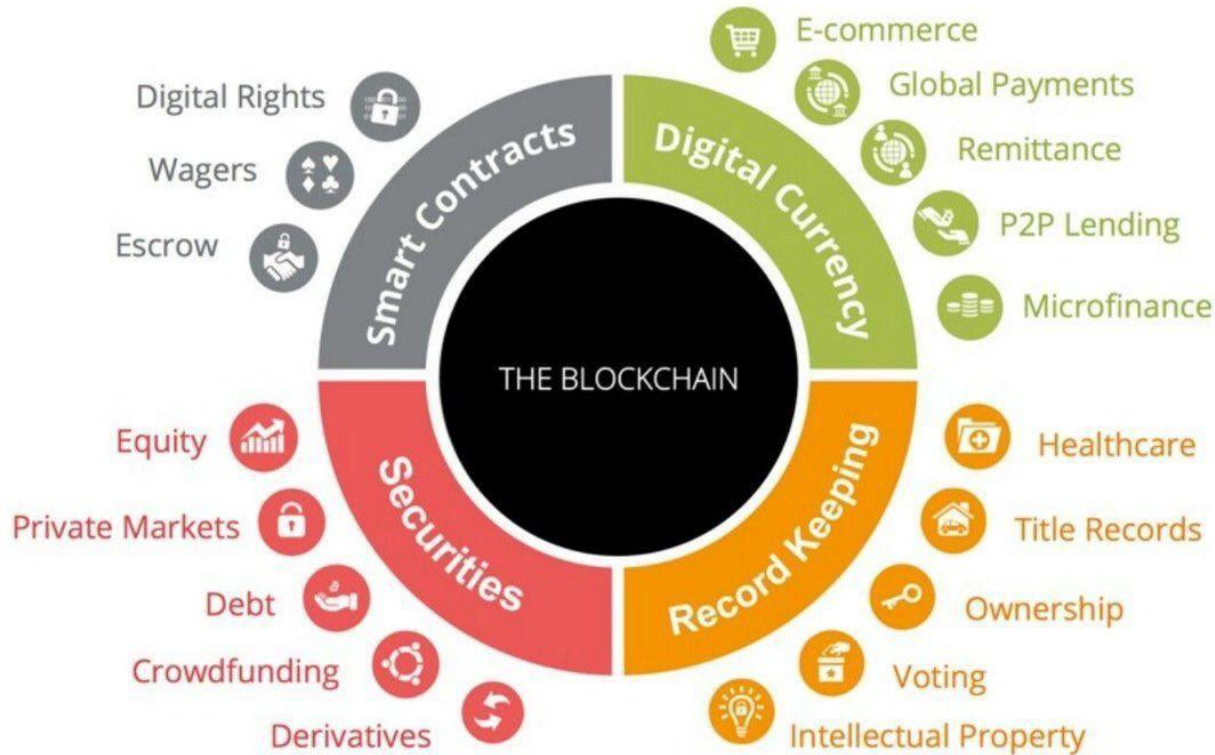
- **Unchangeable**
- **Tamperproof**
- **Resilient**
- **Consensus based**
- **Transparent**
- **Business Logic Coherent**



With a blockchain ...



Blockchain applications - Overview

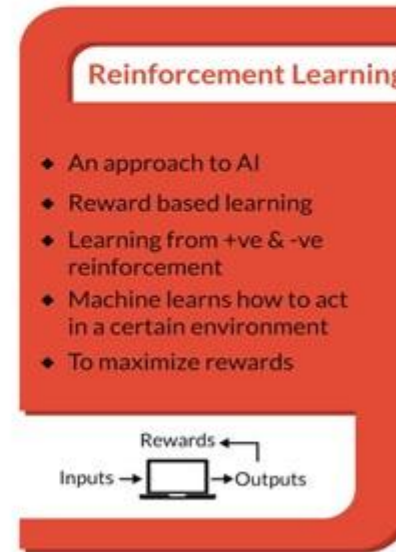
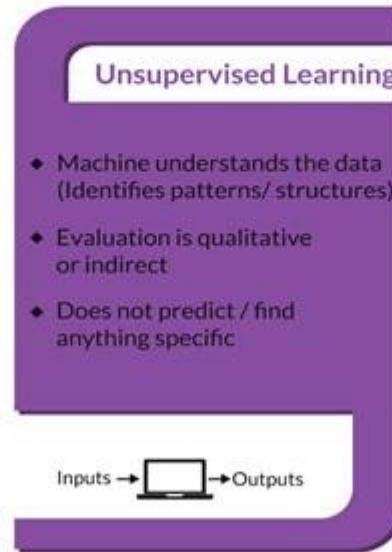


Blockchain applications - Overview

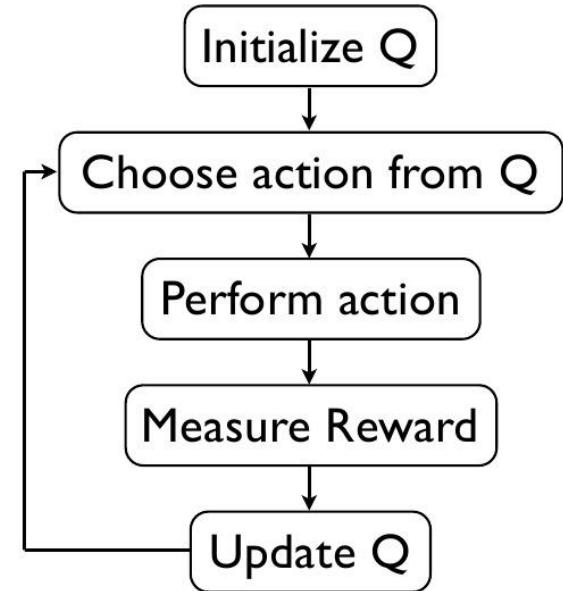
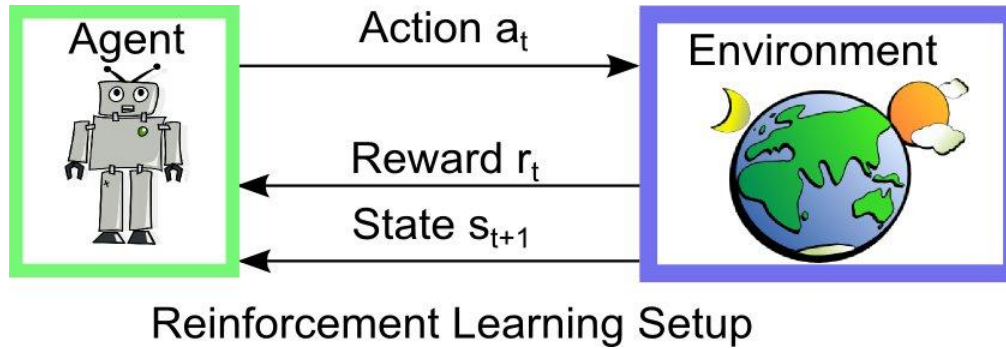


Machine Learning Paradigms

Types of Machine Learning - At a glance



Reinforcement Learning & Q-Learning



Maximise long-term value function through successive discrete actions (time delayed **Markov Decision Process**)



Application to the DSR platform

- Simulate trading behaviour on the platform
- Multi-Agent System
- Individual Agent learn submitting tenders to the platform and looking at the trade outcomes
- Learning through Q-Learning algorithm with modelling of agents cost/value function
- Study the emergence of collaborative behaviour once incentives are put in place through blockchain

