Blockchain-based Payment for Carbon Trading

Oscar Golding (z5160173)
Supervised by: Dr. Sherry Xu, Dr. Qinghua Lu

Thesis B: UNSW

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Outline

Problem

- Energy production can be certified on the blockchain.
- Blockchain solves an Environmental, Social and Corporate Governance (ESG) problem for energy certification.
- Carbon trading is a politically contentious field lacking trust.

Aim

- Can automated certification on the blockchain be used to deliver *trust* in the market for carbon?
- Can blockchain-based hydrogen certification be used as a motivating example for carbon trading?

Thesis B Aims

- Explore how *Hyperledger Fabric* can be used to develop a blockchain carbon market.
- Understand the performance trade-offs of putting a carbon trading platform on the blockchain.
- Identify how ESG hydrogen certificates can be used to automate a carbon market.

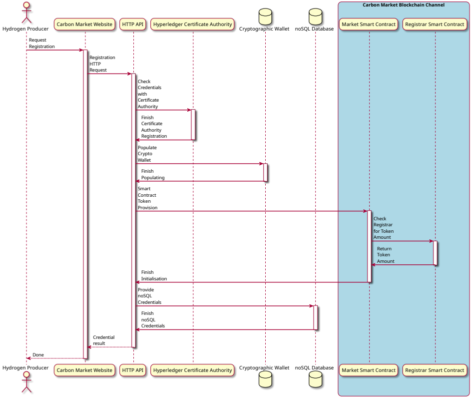
Quick Overview

- *Hyperledger Fabric*
- Full stack blockchain application.
- User roles tied to a blockchain certificate authority - *X.509* certificates.
- On-chain *CouchDB* for indexed blockchain queries.
- Distributed smart contracts.

User Roles

- Energy producers and certifiers are registered with the Hyperledger Fabric Certificate Authority (CA).
- Upon account registration, a producer is registered with the CA.
- Chaincode is called on behalf of a producer/certifier.
- Distributed smart contracts for account creation.

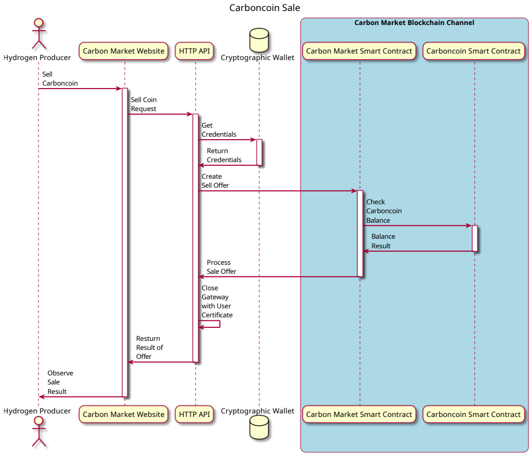
Producer Creation Example



Carbon Sales

- A producer is allowed to sell a fungible token called *Carboncoin*.
- Offer for sale of tokens is stored on the blockchain.
- Aim is to encourage distributed trading of carbon using the blockchain as an intermediary.
- The producer entirely drives the trading process.

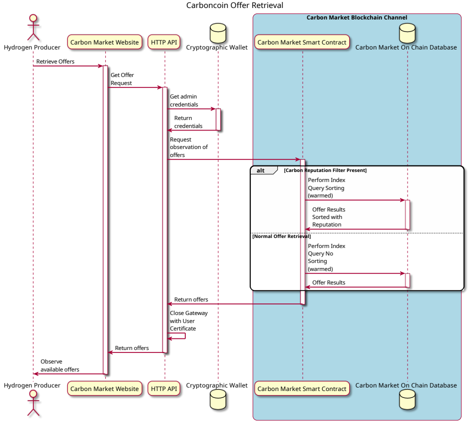
Carboncoin Sale Example



Viewing Offers

- An on-chain *CouchDB* index is warmed for retrieving offers.
  - Warming happens whenever a new block is cut.
- Optional *carbon reputation* is attached to an offer so producers can ethically purchase carbon.
- Carbon reputation assists with increasing market quality.

Retrieving Offers Example

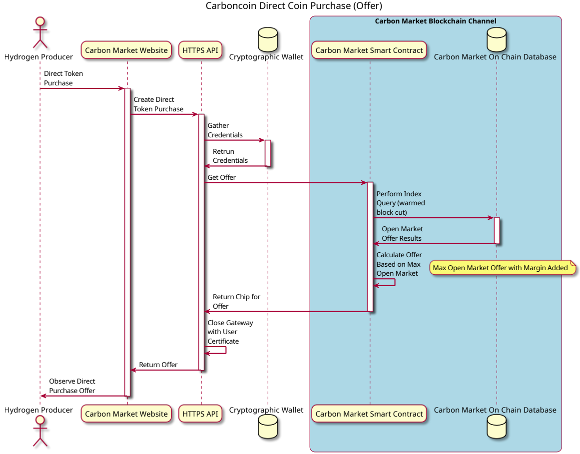


Direct Market Interaction

- A producer can directly purchase *Carboncoin* outside of the open market at an *extra cost*.
- The user is given an on-chain offer token to purchase *Carboncoin*.
- The price per token is calculated using the maximum offer on the open market.
- Each x_i in Equation 1 represents an active offer in the market.

$$\text{Direct Offer} = \max\left(\langle x_1, x_2, \ldots, x_n \rangle\right) + 50 \tag{1}$$

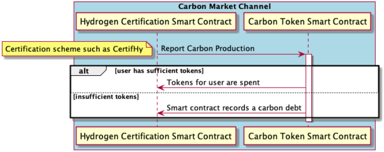
Direct Offer Creation Example



ESG Certificate Interaction

- Market activity triggered by an ESG certifier recording carbon production.
- As a step in certificate creation, the certifier invokes the carbon market smart contract.
- Both the certifier and the carbon market exist on the same *Hyperledger* channel.
- If the user does not have enough *Carboncoin* to pay for production, then a debt is recorded.

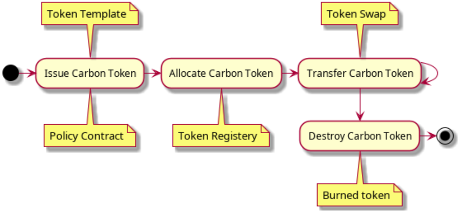
Figure: Channel Interaction



Patterns

- Token template
- Policy contract
- Token registery
- Token swap
- Burned token

Figure: Carboncoin Lifecycle



Policy Contract Pattern

- All blockchain operations are bounded by policies which provide rules on how *Carboncoin* can be used.
- Only producers with the *producer* role can buy or sell *Carboncoin*.
- A user can never sell more *Carboncoin* than the amount contained inside their account.
- A user's *X.509* certificate is required to perform write operations on the blockchain.

Token Swap Pattern

- *Carboncoin* can be swapped between users.
- Policies are attached when doing a swap:
  - Active offer is required.
  - Seller must have enough *Carboncoin*.
  - The buyer must meet their open offer obligations first before purchasing tokens.
- The swap happens for only the *Carboncoin* token.

Burned Token

- A *Carboncoin* is burned when a producer is required to pay for carbon production.
- *Digital Physical Parity* exists between real carbon production and the carbon reputation in the market.
    - Certifiers play a signficant role in maintaining the digital physical parity between carbon production and carbon reputation.
- Debts are recorded when a user does not have enough *Carboncoin* to pay for carbon production. Debts can be paid at later dates.

System Performance

- Although the aim of the thesis is not to produce the most high throughput carbon market - the performance of the system is still worth exploring.
- The performance of *Fabric* has a tendency to suffer in the *Validation Phase* of the transaction lifecycle.
- An observed tendency of Hyperledger is that as the transactions per second (TPS) increases, so do errors [2].

Common Bottlenecks

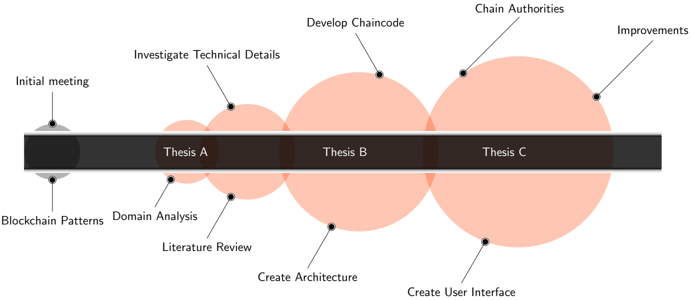
- Multi-Version Concurrency Control (MVCC) - transactions in the same block updating the same key (transaction dependency).
- Phantom Read Conflicts - performing a read on a key range which has been updated.
  - For some reading range i to j, if a key has recently been inserted then read a phantom read happens.

Enhancements to TPS

- Represent assets on the blockchain as a sum of deltas to avoid MVCC errors.
- Example: CarbonCoin is the sum of deltas in Equation 2.
  - Each δ_i contains a unique combination of owner, transaction identifier and sign.
  - Each x_i represents the asset value (for example 500).
- Localise the phantom read conflicts into 'low TPS' domains.

$$\text{Asset Value} = \delta_1 x_1 + \delta_2 x_2 + \cdots + \delta_n x_n \tag{2}$$

Original Research Timeline



Updated Research Timeline

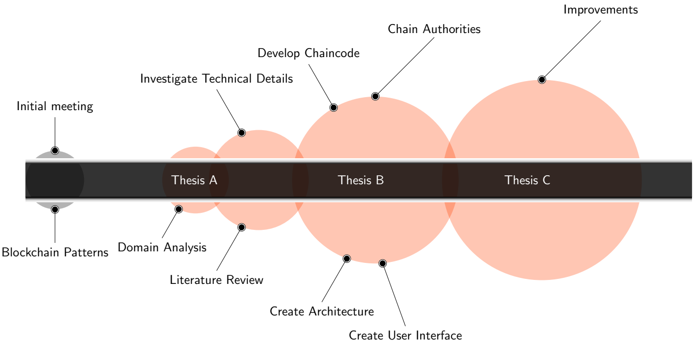


Table Representation

- Original plan for Thesis B. Green records the task being completed.

Table: Plan for Thesis B

Week	Plan
1	Hyperledger Documentation
2	Hyperledger Documentation
3	Hyperledger Documentation
4	Smart Contract Programming - Producer Register
5	Smart Contract Programming - Offer Lifecycle
6	Smart Contract Programming - Carbon Reputation
7	Smart Contract Programming - Direct Purchase
8	API Construction - Account Creation
9	API Construction - Wiring Requests to Offers
10	API Construction - UI Functionality

Plan Update

- Ahead of schedule - working prototype with chaincode, implemented architecture and a user interface.
- Plan for Thesis C:
  - Exploration of blockchain performance (TPS).
  - Generalisation of blockchain patterns to sources of energy outside of hydrogen - for example water.
  - The auctioning of *Carboncoin* to hydrogen producers.
  - Payment channel for recording off-chain transactions.

References I

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