Blockchain-Based Distributed Reputation for a Cap-and-Trade Carbon Emission System

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***Abstract*—Reputation has been widely used in the energy field in recent years. However, their reputation mechanisms are usually centralized even if they are designed for distributed energy systems, which could cause vulnerability to single point failures. This paper explores the design of blockchain-based distributed reputation for a cap-and-trade carbon emission system. The blockchain technology is adopted to achieve distributed management of reputation scores and realize a peer-to-peer carbon trading market. Simulation experiments are carried out to demonstrate the influence of the proposed reputation rules on reputation scores. In addition, a case study shows how reputation affects the results of carbon trading. As far as we know, this paper is one of the few works that incorporate distributed reputation in a carbon emission system.**

***Index Terms*—carbon emission trading, distributed reputation, blockchain, cap-and-trade, energy internet**

I. Introduction

As many countries have recently put forward their own carbon emission targets to slow down the pace of global warming, more and more attention has been paid to the research on carbon emission. Carbon emission trading, or carbon trading for short, aims to establish a carbon emission quota trading market to reduce greenhouse gas emission [1]. Cap-and-trade is a widely accepted mechanism in many carbon emission frameworks. According to the EU Emissions Trading System (EU-ETS), cap-and-trade sets a maximum emission amount at the beginning of each year, called the cap, then allocates emission quotas according to different policies, and allows the trading of these emission quotas as needed [2]. The cap-and-trade mechanism can not only effectively reduce overall carbon emissions, but also bring significant revenues for manufacturers that actively reduce emissions [3].

Facing the increasingly severe energy crisis and environmental problems, the concept of energy Internet (EI) has been put forward to encourage deep integration of information and communication technologies (ICTs) in modern energy systems [4]. As one of the most influential ICTs in recent years, blockchain has been applied to carbon trading scenarios by many researchers and practitioners. In the scenario of residential multi-microgrid network, a peer-to-peer (P2P) coupling energy and carbon trading scheme is proposed in [5], where blockchain brings full decentralization to the trading market. In [6], blockchain is applied in the design of a distributed carbon trading system in vehicular networks to enhance the transparency and trustworthiness of data exchange. In practice, ClimateTrade™ is a platform that helps businesses calculate exact carbon footprint and trade carbon credits, and the transparency and traceability are guaranteed by the blockchain technology [7].

Recently, existing works start to bring reputation system into energy systems to establish mutual trust [8]. In more detail, a reputation system usually maintains a score of credibility for each individual, which is dynamically calculated according to prescribed rules. One major use of reputation system is to implement delegated consensus to improve the efficiency of blockchain-based energy systems, where only participants with higher reputation scores can take part in consensus decision making [9], [10]. Furthermore, [11] designs a comprehensive carbon trading system where the reputation of sellers can affect the matchmaking results. However, the reputation systems for distributed energy systems mentioned above are centralized and are vulnerable to single point failures.

This paper instead studies distributed reputation for a cap-and-trade carbon emission system. In more detail, the system proposed in this paper consists of three modules: the blockchain module that support the decentralization of reputation and carbon emission, the distributed reputation module that evaluates the behavior of participants and incentivizes carbon trading and emission reduction, and the carbon emission module that implements the cap-and-trade scheme with a P2P carbon trading market. Specifically, the P2P carbon trading market uses blockchain to maintain the ledger in a distributed way and implements a novel reputation-based double auction

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matchmaking scheme. Compared with most related works, our reputation module circumvents a centralized entity that usually calculates, stores, and controls reputation scores. By running simulation experiments, the effect of our distributed reputation system is demonstrated, and then a case study is included to show that reputation can be a good incentive for carbon trading.

The rest of this paper is organized as follows: Section II briefly overviews the three modules of our system; Section III explains the cap-and-trade carbon emission module that includes a basic carbon emission framework and a P2P carbon trading market; Section IV describes the implementation methods of the distributed reputation module with the help of the blockchain module, as well as reputation rules decided by the carbon emission module; Section V provides numerical analysis of our system; Section VI concludes this paper.

II. System Overview

This paper considers a regional EI system that consists of n peers acted by microgrids with the need to emit carbon dioxide. Peers are interconnected to enable direct carbon trading. Our system consists of three modules, namely, distributed reputation, blockchain, and carbon emission (shown by Fig. 1). The rest of this section provides a brief introduction of these modules, and detailed explanation are deferred to Section III and IV.

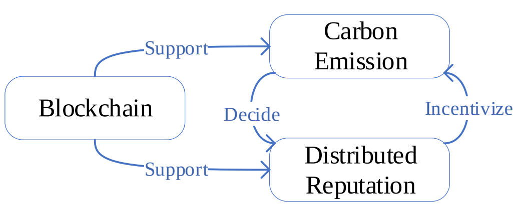


Fig. 1: The relationship between the three modules of our system.

A. Blockchain

The blockchain module is an important foundation of our system that supports the decentralization of the distributed reputation and carbon emission modules. In essence, blockchain is a system that maintains a linked list of blocks with data through various ICTs, including peer-to-peer (P2P) network, cryptography, distributed consensus, and smart contract. The blockchain system can provide many good features, such as decentralization, transparency, traceability, immutability, and automation [12].

Our blockchain module maintains two separate ledgers: one is used to record carbon emission and carbon trading information, called the **emission ledger**, and the other is used to record reputation scores, called the **reputation ledger**. Emission related data, transaction orders, and reputation changes need to be confirmed by peers through distributed consensus before they are stored into the ledgers. We choose practical Byzantine fault tolerance (PBFT) [13] as the consensus mechanism. Smart contracts are implemented to improve automation. In more detail, the mechanism of the carbon trading market, transaction orders, and reputation update rules are written in the form of smart contracts so that corresponding tasks can be automatically executed. This automation can help to avoid the errors and tampers of manual labor. These contracts can be viewed and edited by peers, but any modification does not take effect until it is approved by peers through consensus.

B. Carbon Emission

The cap-and-trade carbon emission module contains two components: carbon emission framework, and P2P carbon trading market. In the cap-and-trade framework, initial emission quotas will be allocated to each peer at the beginning of each period. The emission amount of a peer is sampled at regular time intervals. When the emission balance, or the remaining carbon emission quotas, is insufficient, the peer may need to purchase additional quotas to avoid potential penalty. The P2P carbon trading market supports direct trading between peers, which is more efficient and flexible for a regional EI system. We design a reputation-based double auction matchmaking scheme for the trading market. Compared with traditional double auction [14], the matchmaking results of our scheme is friendlier to the peers with higher reputation.

C. Distributed Reputation

The role of the distributed reputation module is to record a dynamic **reputation score**, denoted by $r(i)$, to evaluate the trustworthiness of each peer i in a distributed way. In other words, the reputation scores are recorded by peers in a collaborative way instead of being controlled by any centralized party. This decentralization is enabled by the blockchain module. Reputation scores can be queried by peers and play an important role in the carbon emission module. The core of the reputation module is a set of rules for reputation score update. These rules are designed based on carbon emission policies and implemented in the form of smart contracts.

III. Cap-and-Trade Carbon Emission

This section provides a detailed introduction to our cap-and-trade carbon emission module that consists of two components: carbon emission framework, and P2P carbon trading market. The carbon emission framework sets out basic rules for emission behavior, while the P2P carbon trading market enables decentralized transactions of emission quotas between peers.

A. Carbon Emission Framework

We choose a carbon emission framework based on the cap-and-trade scheme of EU-ETS [2], with a concept of emission balance proposed by [6]. In more detail, the average carbon emission of peer i at time t, denoted by $\epsilon_i(t)$, is evaluated every T_s time, i.e., $t = 0, T_s, 2T_s, \ldots, T$ where T is a reset period T after which t is reset to 0. We set T_s as one day and $T = 365T_s$ as one year. Once $\epsilon_i(t)$ gets confirmed by distributed consensus, it will be recorded in the emission ledger. The system fixes an emission threshold $\mathcal{E}$ as the maximum average emission level. Failing to keep $\epsilon_i(t)$ under $\mathcal{E}$ will result in a reputation deduction.

The emission balance works as follows. Peer i is assigned with an emission quota balance $B_i(0)$ everytime t is reset. The value of $B_i(0)$ will be decided according to emission policies. We design a reputation-based cap reduction strategy that derives from the linear cap reduction of EU-ETS [2] where the initial quota balance $B_i(0)$ decreases linearly with a factor of $\rho = 2.2\%$ after each reset period T. Imposing cap reduction aims to gradually reduce the emission amount of each peer. When reputation is involved, the cap reduction strategy can be designed to be friendlier to high-reputation peers. One way to achieve reputation-based cap reduction is to make the reduction factor ρ negatively related to reputation scores r, e.g., by the following function whose graph is shown in Fig. 2:

$$\rho(r) = -\frac{2}{100\pi}\arctan(5r - 2.5) + 0.022. \tag{1}$$

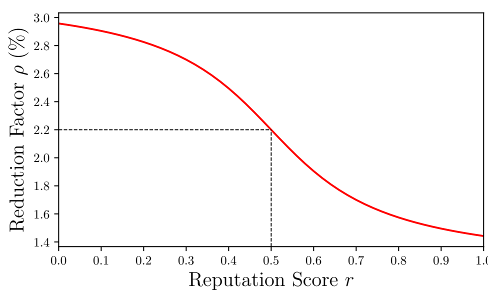


Fig. 2: Reduction factor α as the function of reputation score r in (1).

The balance $B_i(t)$ will decrease as peer i emits carbon dioxide. The unused balance cannot be accumulated in the next T period, but it will improve the reputation score of i and therefore affect the value of $B_i(0)$. Once $B_i(t)$ becomes 0, further emission could be subject to penalties. In order to circumvent penalties, the peer with a low balance may need to purchase additional emission quotas.

The workflow of our carbon emission framework is shown in Fig. 3. We will explain the emission rule and the balance rule in the reputation module later in Section IV-B.

B. Peer-to-Peer Carbon Trading

This paper considers a periodic carbon trading market, where trading occurs every T_s time. Our P2P carbon trading includes three stages: order submission, reputation-based matchmaking, and settlement. The workflow of the P2P carbon trading in a trading period is shown in Fig. 4.

a) Order Submission: In this stage, peers submit selling and buying orders for each trading period. For the sake of brevity, we focus on the trading process for the same trading period. A selling order contains the seller's account address, emission quotas offered, and (minimum) selling price. The the

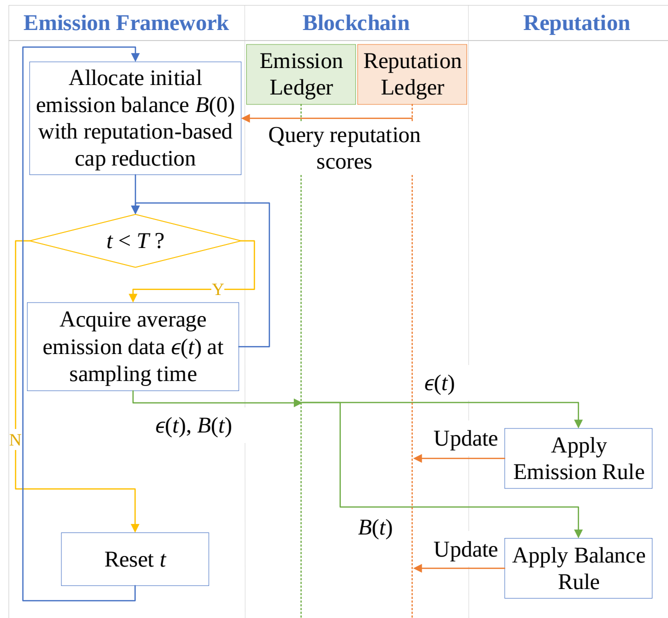


Fig. 3: Workflow of the carbon emission framework.

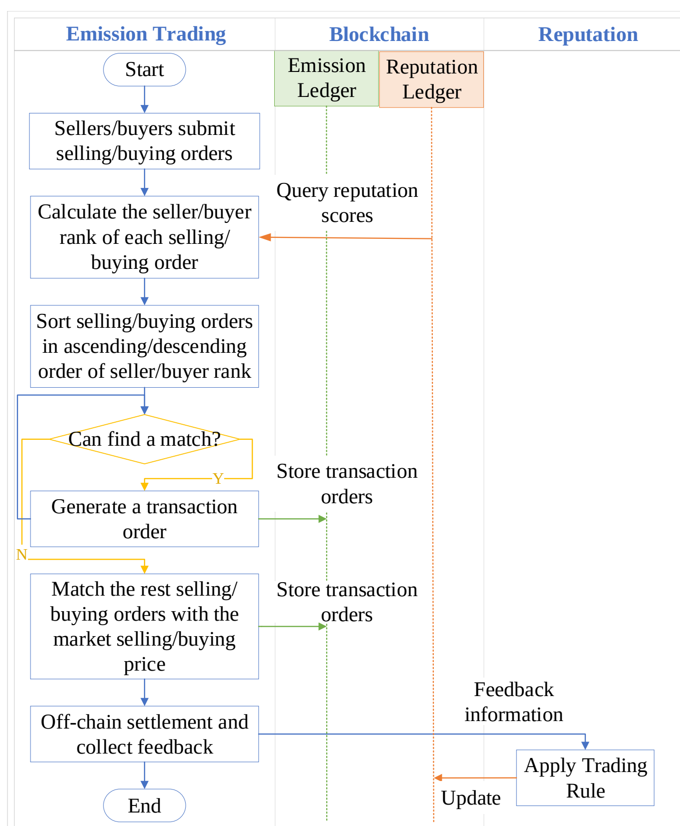


Fig. 4: Workflow of the reputation-based P2P carbon emission trading.

total emission quotas offered should not exceed the balance of the seller. Correspondingly, a buying order contains the buyer's account address, emission quotas demanded, and (maximum) buying price. Fig. 5 provides an example of selling and buying orders.

Selling Order ID: 28746001679133874

Seller Address: 0x5aeda9b208cbb68977a9a42c7cbecd9c
Quotas Offered (ton): 1.30
Selling Price (USD/ton): 26.75

Buying Order ID: 96446341579542353

Buyer Address: 0x9e0461bda6facda53454004fc50b4219
Quotas Demanded (ton): 1.98
Buying Price (USD/ton): 20.00

Fig. 5: An example of selling and buying orders.

b) Reputation-Based Matchmaking: We choose a reputation-based double auction mechanism for the matchmaking stage. Traditional double auction matchmaking first sorts the list of selling orders in ascending order of selling price and sorts the list of buying orders in descending order of buying price. Then a seller-buyer match is reached when it finds a buying price lower than a selling price by going through the selling and buying lists in order [15]. Instead, our reputation-based double auction mechanism sorts orders with respect to the reputation-based rank of the selling or buying orders.

Similar to the seller priority value defined by [11], the reputation-based **seller rank** of a selling order, denoted by $rank_s$, is calculated by:

$$rank_s = \frac{price_s}{r_s + \delta}, \tag{2}$$

where $price_s$ is the selling price, r_s is the reputation score of the seller, and $\delta > 0$ is a small constant to prevent the divide-by-zero error. Correspondingly, the reputation-based **buyer rank** of a buying order, denoted by $rank_b$, is calculated by:

$$rank_b = price_b \cdot (r_b + \delta), \tag{3}$$

where $price_b$ is the buying price, and r_b is the reputation score of the buyer.

Once seller and buyer ranks are calculated for all orders, the list of selling orders will be sorted in ascending order of seller rank, and the list of buying orders will be sorted in descending order of buyer rank. Similar to traditional double auction, a match is reached if it comes across a selling price $price_s$ lower than a buying price $price_b$. Different from double auction where the trade price is $(price_s + price_b)/2$ [14], the final trading price of our reputation-based matchmaking scheme is decided according to the following three cases:

- If $r_s < r_b$, then the trade price is $price_s$;
- If $r_s > r_b$, then the trade price is $price_b$;
- If $r_s = r_b$, then the trade price is $(price_s + price_b)/2$.

The intuition behind this design might not be very straightforward. Consider the case where a match between a seller with a reputation score of 0.7 and a buyer with a reputation score of 0.4, and the selling price and buying price submitted are \$24.75 and \$25.65 respectively. Then the trade price in this example will be \$25.65, higher than the minimum selling price submitted by the seller with higher reputation. As a result, the final trade price provides more advantage for peers with high reputation scores.

A transaction order is generated for each match, containing the information of the seller's account address, the buyer's account address, quotas traded, and trading price (see Fig.6). Then all transaction orders will be stored as smart contracts for automatic execution, and corresponding transaction information will be added into the emission ledger.

Transaction Order ID: 5014256319871653

Seller Address: 0xf20e597bd70f7bc7c5adbf3326178369
Buyer Address: 0xeb488f3bf97e5fb2d44b610fce890371
Quotas Traded (ton): 1.28
Trading Price (USD/ton): 23.65

Fig. 6: An example of a transaction order.

Note that not all selling or buying orders can find a match. In this case, the peer can choose to trade with the carbon market at uniform market prices. In order to encourage the P2P carbon trading, the selling price for a selling order is recommended to be lower than the market selling price, and the buying price for a buying order is recommended to be higher than the market buying price.

c) Settlement: The settlement stage is the process for off-chain transfer of emission quotas and payment. Note that the settlement of a transaction may fail if the seller or buyer fails to fulfill a transaction order. The settlement result of each transaction will provide feedback to the reputation module. As we will explain in Section IV-B, the successful settlement of a transaction will increase the reputation of the seller, while the failed settlement will decrease the reputation of the party who violates the transaction order.

IV. Blockchain-Based Distributed Reputation

This section describes the reputation module that is used to record the reputation scores of peers in a distributed way. We will also explain the reputation rules for the emission systems, which include an emission rule, a balance rule, and a trading rule.

A. Blockchain-Based Design

We define $r(i)$, the reputation score of peer i, as a number in $[0, 1]$ that evaluates the credibility of peer i in the carbon emission system. It can be affected by the behavior of peer i in both carbon emission and carbon trading. Every newly-joined peer will be assigned with a neutral reputation score of 0.5.

In a distributed energy system, distributed reputation can make the system more robust against single point failures. We use blockchain to achieved this decentralization. Specifically, the design of blockchain-based distributed reputation is shown in Fig. 7. The reputation ledger stores the reputation scores of all peers. Peers can query and trace the update of the reputation score of any peer. The update of reputation scores is automatically accomplished by smart contracts that are written based on reputation rules. Peers can add, remove, and modify reputation rules by changing corresponding smart contracts, but any change cannot come into effect until it is approved by peers through the consensus mechanism.

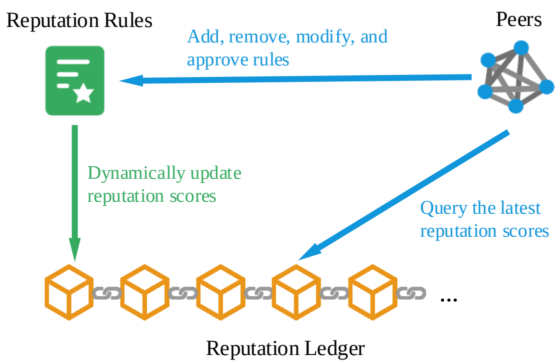


Fig. 7: Design of distributed reputation based on blockchain.

B. Reputation Rules

The core of the reputation module is reputation rules for the update of reputation scores. In the next, we will explain these rules in detail.

a) Emission Rule: Reputation score $r(i)$ updates every-time $\epsilon_i(t)$ is confirmed by peers:

- If $\epsilon_i(t) \leq \mathcal{E}$, then $r(i)$ increases as follows:

$$r(i) \leftarrow \min\{\max\{r(i) + r_\epsilon^+(i), 0\}, 1\}, \tag{4}$$

where $r_\epsilon^+(i)$ is positively related with $\frac{\mathcal{E}-\epsilon_i(t)}{\mathcal{E}}$ and is negatively related with $r(i)$;

- Otherwise, $r(i)$ decreases as follows:

$$r(i) \leftarrow \min\{\max\{r(i) - r_\epsilon^-(i), 0\}, 1\}, \tag{5}$$

where $r_\epsilon^-(i)$ is positively related with $\frac{|\mathcal{E}-\epsilon_i(t)|}{\mathcal{E}}$ and $r(i)$.

b) Trading Rule: Suppose $e^+(t)$ is the total quotas successfully traded with i, and $e^-(t)$ is the total quotas failed to be traded due to i's fault. Then the reputation score $r(i)$ is updated as follows:

$$r(i) \leftarrow \min\{\max\{r(i) + w^+ r_{trade}^+(i) - w^- r_{trade}^-(i), 0\}, 1\}, \tag{6}$$

where

- $w^+ = \frac{e^+(t)}{e^+(t)+e^-(t)}$ and $w^- = 1 - w^+$;
- $r_{trade}^+(i)$ is positively related with w^+ and is negatively related with $r(i)$,
- $r_{trade}^-(i)$ is positively related with w^- and $r(i)$.

c) Balance Rule: At the end of each sampling interval t, $r(i)$ will updates according to balance $B_i(t)$:

- If $B_i(t) \geq 0$, then $r(i)$ increases as follows:

$$r(i) \leftarrow \min\{\max\{r(i) + r_{balance}^+(i), 0\}, 1\}, \tag{7}$$

where $r_{balance}^+(i)$ is positively related with $\frac{B_i(t)}{B_i(0)}$ and is negatively related with $r(i)$;

- Otherwise, $r(i)$ decreases as follows:

$$r(i) \leftarrow \min\{\max\{r(i) - r_{balance}^-(i), 0\}, 1\}, \tag{8}$$

where $r_{balance}^-(i)$ is positively related with $\frac{|B_i(t)|}{B_i(0)}$ and $r(i)$.

Note that there are some similarities between these three rules. Therefore, we design the following functions as an example:

$$\begin{cases} f^+(a,b) = \gamma \cdot \left[\alpha \cdot a + (1-\alpha) \cdot \left(0.5 - \dfrac{\beta}{b+\beta}\right)\right], \\ f^-(a,b) = \gamma \cdot \left[\alpha \cdot a + (1-\alpha) \cdot \dfrac{\beta}{b+\beta}\right], \end{cases} \tag{9}$$

where α, β, γ are positive numbers. We can see that f^+ is positively related to a and negatively related to b, and f^- is positively related to both a and b. Then the corresponding reputation increase and decrease can be calculated by:

$$\begin{cases} r_\epsilon^+(i) = f^+\left(\dfrac{\mathcal{E}-\epsilon_i(t)}{\mathcal{E}}, r(i)\right), \\ r_\epsilon^-(i) = f^-\left(\dfrac{|\mathcal{E}-\epsilon_i(t)|}{\mathcal{E}}, r(i)\right), \end{cases} \tag{10}$$

$$\begin{cases} r_{trade}^+(i) = f^+\left(w^+, r(i)\right), \\ r_{trade}^-(i) = f^-\left(w^-, r(i)\right), \end{cases} \tag{11}$$

$$\begin{cases} r_{trade}^+(i) = f^+\left(\dfrac{B_i(t)}{B_i(0)}, r(i)\right), \\ r_{trade}^-(i) = f^-\left(\dfrac{|B_i(t)|}{B_i(0)}, r(i)\right). \end{cases} \tag{12}$$

V. Evaluation

In this section, the performance of the proposed system is evaluated through simulation experiments. The three modules are implemented in Go language (2020.3.1 x64), and the simulation programs are run on a computer with Intel(R) Core(TM) i7-6500U CPU at 2.50 GHz and 12 GB RAM. All data used in this section are cultivated based on the data from [2], [11], [16], [17]. We choose parameters $\alpha = 0.3$, $\beta = 0.5$, $\gamma = 5\times10^{-3}$, $\delta = 0.01$. Moreover, the daily emission threshold $\mathcal{E}$ is 2.74 ton, and the initial balance is 180 ton.

A. Reputation Scores and Reputation Rules

We first show the influences of reputation rules on reputation scores. Note that our carbon emission module has universality in the sense that it can be adapted to any carbon emission model. For simplicity, we generate the emission data $\epsilon(t)$ in $3T = 1095$ days from Gaussian distributions. When the peer strictly abides by the reputation rules in Section IV-B, its reputation score will gradually rise over time (as shown by Fig. 8). We then demonstrate the reputation change when each of the reputation rules is violated.

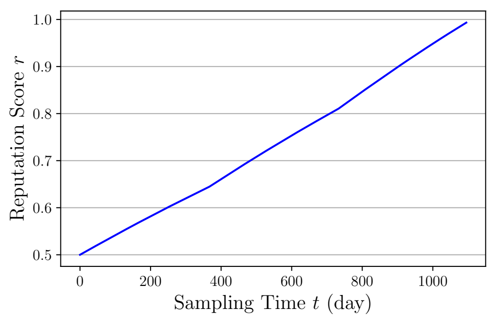


Fig. 8: Reputation score of following all reputation rules.

In Fig. 9, the daily emission amount $\epsilon(t)$ (orange curve) exceeds the emission threshold $\mathcal{E}$ (red dashed line). It causes a rapid decrease in the reputation score. Since the emission rule is violated with $\epsilon(t) > \mathcal{E}$ at most of the time in this example, the overall reputation score in three years is decreasing.

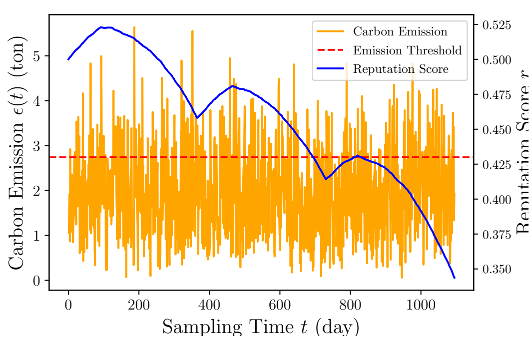


Fig. 9: Reputation score of violating emission rule.

When the balance is low, the peer is recommended to purchase extra emission quotas from the carbon market. Failing to keep a nonnegative balance will cause reputation penalty. In Fig. 10, the peer tries to increase the balance by purchasing emission quotas, but it is not sufficient to bring the balance above zero. As a result, the blue curve that represents the reputation score keeps going downwards in three years.

Finally, we show an example where the total quotas of failed transactions (due to the fault of this peer) is about ten times of that of successful transactions (shown in Fig. 11). We can see that the resulting reputation score falls very fast even

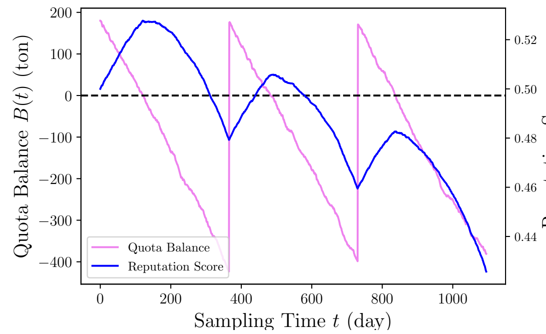


Fig. 10: Reputation score of violating balance rule.

if the peer follows the other two rules. This resembles real-world credit systems that discourage the behavior of violating contracts.

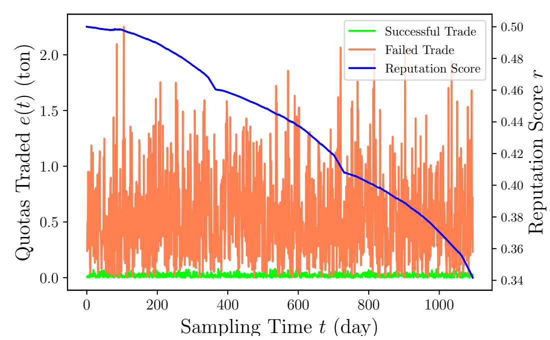


Fig. 11: Reputation score of violating trading rule.

B. Case Study for Carbon Trading

We then show a case study that compares the trading results between our reputation-based double auction and traditional double auction [14] matchmaking schemes. In this case study, all unmatched orders are assimilated by the market. We set the market selling price by \$19/ton and the market buying price by \$25/ton.

Table I provides the lists of buying orders from buyers and selling orders from sellers during the order submission stage. Note that peers can be both a seller and a buyer at the same time. Then buyer and seller ranks are calculated. The reputation-based double auction matchmaking scheme sorts the buyer list in descending order of buyer rank r_b and the seller list in ascending order of seller rank r_s. The corresponding matching results are shown in Table II. In traditional double auction without reputation consideration, however, orders are sorted according to submitted prices. The corresponding matchmaking results of the same buyer and seller orders are given by Table III.

In order to explain the impact of reputation on the matching results, we calculate the average cost of each buyer and the average revenue of each seller based on the data in

TABLE I: Buying and Selling Orders for Case Study

Buyer	Quotas Demanded (ton)	$price_b$	r_b	$rank_b$
B	2.57	22.60	0.5712	13.1351
D	3.79	21.08	0.7545	16.1157
E	3.52	22.59	0.3791	8.7898
F	1.81	24.67	0.5365	13.4822
G	2.06	20.36	0.4468	9.3004
H	5.27	21.53	0.6259	13.6909
K	3.64	19.08	0.1894	3.8046
L	5.72	23.27	0.3594	8.5959
M	1.04	19.68	0.1832	3.8022
P	3.59	23.57	0.6487	15.5256

Seller	Quota Offered (ton)	$price_s$	r_s	$rank_s$
A	3.92	20.71	0.5329	38.1470
C	1.49	23.49	0.3298	69.1289
D	2.39	21.16	0.7545	27.6782
G	4.46	23.65	0.4468	51.7732
H	3.18	21.62	0.6259	33.9991
I	4.02	21.75	0.5712	37.4226
J	3.94	19.32	0.6177	30.7790
K	4.72	22.08	0.1894	110.7322
M	5.59	21.12	0.1832	109.3168
N	3.19	21.55	0.4457	47.2899
O	2.91	23.47	0.6538	35.3570

TABLE II: Transaction Orders by Reputation-Based Double Auction Matchmaking Scheme

Buyer	Seller	Quotas Traded (ton)	Trade Price
D	J	3.79	19.32
P	D	2.39	23.57
P	J	0.15	19.32
P	H	1.05	21.62
H	A	3.92	20.71
H	M	1.35	21.12
F	H	1.81	24.67
B	H	0.32	22.60
B	I	2.25	22.18
E	I	1.77	22.59
E	N	1.75	22.59
L	N	1.44	23.27
L	M	4.24	21.12
L	K	0.04	22.08
G	Market	2.06	25.00
K	Market	3.64	25.00
M	Market	1.04	25.00
Market	O	2.91	19.00
Market	G	4.46	19.00
Market	C	1.49	19.00
Market	K	4.68	19.00

Table II and III. Fig. 12 provides the scatter graphs that reveal the correlation between average cost/revenue of each buyer/seller and reputation score. Let $corr_b$ be the correlative coefficient between average buyer costs and reputation scores, and $corr_s$ be the correlative coefficient between average seller revenues and reputation scores. These correlation coefficients are visualized as the slopes of the regression lines of the corresponding scatter graphs.

From both Fig. 12a and 12b, we can see that the correlative coefficients of reputation-based double auction have larger absolute values than that of traditional double auction. This

TABLE III: Transaction Orders by Traditional Double Auction Matchmaking Scheme

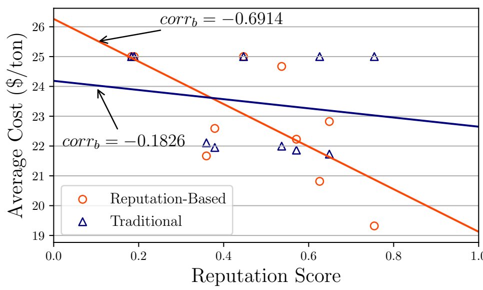
Buyer	Seller	Quotas Traded (ton)	Trade Price
F	J	1.81	22.00
P	J	2.13	21.45
P	A	1.46	22.14
L	A	2.46	21.99
L	M	3.26	22.20
B	M	2.33	21.86
B	D	0.24	21.88
E	D	2.15	21.88
E	N	1.37	22.07
H	Market	5.27	25.00
D	Market	3.79	25.00
G	Market	2.06	25.00
M	Market	1.04	25.00
K	Market	3.64	25.00
Market	N	1.82	19.00
Market	H	3.18	19.00
Market	I	4.02	19.00
Market	K	4.72	19.00
Market	O	2.91	19.00
Market	C	1.49	19.00
Market	G	4.46	19.00

means that average buyer costs and the average seller revenues of reputation-based double auction is more closely related to reputation scores. In other words, under the same conditions, the buyer with higher reputation will have a lower average cost, and the seller with higer reputation will have a higher average revenue. This indicates that the reputation score can serve as a good incentive for the participation of P2P carbon trading.

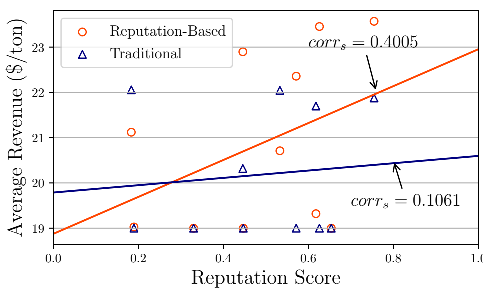
VI. Conclusion

This paper proposes a system that incorporates cap-and-trade carbon emission with distributed reputation. The decentralization of both distributed reputation and P2P carbon trading is accomplished with the help of blockchain. This paper provides a simple example of designing reputation rules based on the policies of the carbon emission framework. It is shown that the reputation score of a peer can be affected when reputation rules are violated by simulation experiments. Our case study of carbon trading demonstrates the influence of reputation on the trading results.

This paper still has several points that can be further explored in our future work. First, our reputation module treats three reputation rules equally in updating reputation scores for simplicity, but practical projects may put different emphasis on these three aspects. How to reflect this difference in a reasonable way needs to be studied. Second, in addition to the cap-and-trade scheme, emission offsetting is also an effective way to reduce green house emission. It is another direction to study that includes emission offsetting and supplements corresponding reputation rules. Last, reputation has been applied to establishing real-world trust in a wide range of scenarios. In the future, our future work will also explore the design of distributed reputation in green certificate trading, microgrid control and management, and many other energy systems.



(a) Average costs of buyers



(b) Average revenues of sellers

Fig. 12: Comparison of buyer average cost and seller average revenue between reputation-based and traditional double auction.

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