Design of A Double-blockchain Structured Carbon Emission Trading Scheme with Reputation

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***Abstract*—This paper proposes a double-blockchain structured trading scheme (DBR-ETS) in carbon emission permits secondary market and introduces the enterprises' reputation, which is used to urge enterprises to actively invest in carbon emission reduction, and ultimately achieve carbon emission reduction in the overall society. The application of blockchain technology guarantees the security and privacy of distributed system. The confirmation chain and financial chain in the double-blockchain structure divide the transaction into two relatively independent processes, which can not only alleviate the transaction redundancy in the system but also improve the security of the system through the mutual verification of the two chains. The reputation-based transaction fee mechanism allows enterprises to promote their reputation by increasing investment in emission reduction. In the case study, we verified the superiority of the double-blockchain structure and the effect of the transaction fee mechanism on emission reduction.**

Keywords—carbon emission permits; double-blockchain; reputation；mechanism design

I. Introduction

The effects of the greenhouse effect and global warming in recent years have made people around the world aware of the negative consequences of excessive carbon emissions, and the emission trading scheme (ETS) has emerged [1, 2]. In ETS, the government grants a certain amount of carbon emission permits (CEPs) to enterprises according to the needs of them or through auctions [3]. This is the so-called primary market. In the secondary market, enterprises with excess or insufficient CEPs can trade to meet their respective needs [4, 5].

The traditional carbon emission trading market is a centralized market. This centralized feature will bring about the heavy central tasks and low transaction efficiency. Blockchain technology provides a decentralized or distributed solution that considers both the distributed organizational structure and the problem of consistency and consensus mechanisms in distributed systems [6]. Therefore, the central burden can be alleviated, and the system security and privacy are enhanced [7]. Khamila Nurul Khaqqia and other scholars proposed a novel ETS and proposed a reputation-based mechanism to limit the trading options that the enterprises can see according to the level of reputation value. Moreover, their paper mentioned that this scheme was based on blockchain technology. [8]. However, there is no strong correlation between the content of the article and the blockchain theory, and there is no explanation for the source of the reputation, and the priority value introduced in this paper is not reasonable in the transaction.

In order to improve the efficiency of ETS, ensure the security and privacy of the system, urge the enterprises to improve their own reputation, and ultimately promote the emission reduction in society, this paper proposes a double-blockchain structured carbon emission trading scheme with reputation (DBR-ETS) in secondary trading market. The model uses distributed processing to simplify management, and its security is guaranteed by blockchain technology. The double-blockchain structure proposed to improve the overall transaction speed and further secure the system will be explained in part two. The source of the reputation and the reputation-based transaction fee mechanism will be described in part three. The case study in part four will tell the general flow of the transactions in the DBR-ETS and more intuitively shows the advantages of the DBR-ETS model.

II. Double-blockchain Structure

In this paper, the introduction of blockchain technology is to ensure the security and privacy of distributed and decentralized systems. The transaction information stored in the blockchain is completely public and recorded by all nodes, but the account identity information is highly encrypted and can only be accessed if authorized by the account holder, thereby ensuring data security and enterprise privacy [9].

In the traditional blockchain technology, the structure of single chain has some drawbacks. First, existing blockchain systems often take more than a few hours to reach a deal.

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When transactions occur frequently, the time may be even longer, and the phenomenon of system congestion or even breakdown is more likely to occur [10]. Secondly, although it is very difficult, the form of single-chain structure does not completely guarantee the security of the system and the irreversible modification of information [11]. In response to these problems, the DBR-ETS model in this paper introduces a structure of double-blockchain.

In a transaction, the enterprise nodes in the trading network will form sellers, buyers and other nodes for their different purposes, as shown in Fig. 1. Sellers and buyers are free to find and decide on the transaction object which can meet their needs. Through the support of other nodes (including the process of generating and verifying blocks) the trading nodes can complete transaction in DBR-ETS.

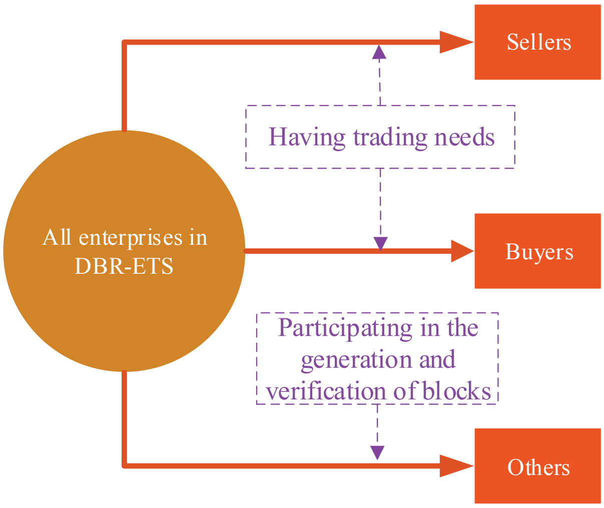

Fig. 1: Possible roles of the enterprises in DBR-ETS.

In decentralized processing, the completion of the transaction relies on the existence of double-blockchain structure. Sellers, buyers, and other nodes will complete their own tasks in the DBR-ETS to achieve the transaction, as shown in Fig. 2.

In DBR-ETS, the confirmation chain and the financial chain coexist. The two chains have the same status, except that the confirmation chain acts before the financial chain. The confirmation chain is used to support the agreement between buyers and sellers to determine the intent of transaction, so that nodes with trading needs can determine their choices as quickly as possible throughout the network. The financial chain is mainly used to complete the circulation of funds and CEPs. The combination of the confirmation chain and the financial chain can complete the entire transaction.

The procedure of the transaction is as follows:

First, enterprises with trading needs look for their trading targets in the confirmation chain and confirm the transaction. This process is similar to the signing of a trading contract in a real transaction. After the generation and verification of the block, the new confirmation block can be accessed into the confirmation chain.

Secondly, at the same time that the confirmation chain is completed, the information of the transaction (including the transaction nodes' public key, reputation value, transaction quantity and amount, etc.) will be transmitted to the financial chain through the communication channel between the two chains.

Finally, after receiving the information from the confirmation chain, the financial chain will continue to complete the flow of funds and CEPs. In this process, similarly, the legal financial block can be inserted into the financial chain after generating and verifying. It is worth mentioning that the completion of the financial chain work also involves the transaction fees, which will be introduced later.

From the above design, it is obvious that a complete transaction is divided into two parts by the confirmation chain and the financial chain. The determination of the trading intention is independent of the transfer of funds and CEPs. But the two chains can be connected through the communication channel between them.

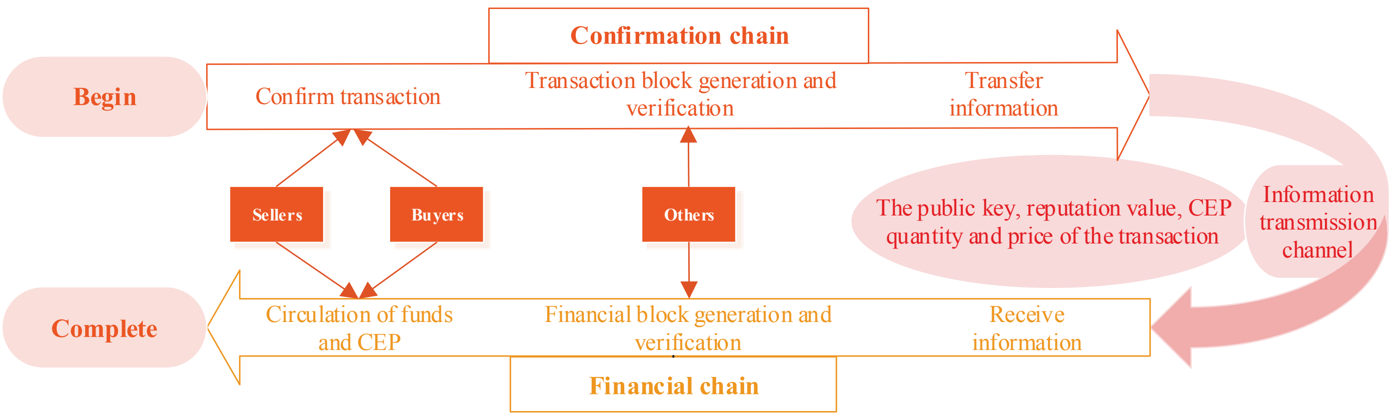

Fig. 2: General procedure of transaction in DBR-ETS.

The introduction of blockchain technology often brings about the problem of transaction congestion. However, after the relative independence of confirmation of the transaction intention and the circulation of funds and CEPs, a transaction is not required to be completed continuously, and the execution of the financial chain can be continued when the system is idle. To a certain extent, it alleviates the congestion phenomenon in the face of a large number of transactions. Through a relatively independent double-chain structure, it is possible to give the enterprises a more flexible transaction process.

The double-blockchain structure of the DBR-ETS also has an important function. In order to further ensure the security of the system and the irreparable modification of the data, the contents of the confirmation chain and the financial chain will be regularly checked and synchronized. So we can achieve a relatively safer system by mutual verification.

III. Reputation-based transaction fee mechanism

Different from the traditional trading mechanism, in order to further encourage enterprises to reduce carbon emissions, this paper creatively proposes a reputation-based transaction fee mechanism. In the processing of the financial chain, the transaction fees that the enterprises need to pay extra will vary depending on their reputation value.

Reputation reflects the comprehensive evaluation of the past emission reduction performance of enterprises, which compares current carbon emissions with initial carbon emissions. Through this comparison, the percentage of emission reduction is calculated and converted into reputation. Among them, smart meters will be needed to monitor the carbon emissions of enterprises to obtain relevant data.

Tab. 1: Proportion of transaction fees at different levels.

Sum of reputation	Total transaction fee ratio	A transaction fee ratio
[160,200]	2%	1%
[120,160)	10%	5%
[0,120)	20%	10%

In order to further encourage enterprises to increase investment in carbon emission reduction, we propose a hierarchical incentive mechanism of transaction fees. The transaction fees here will be automatically deducted by the system and used for system maintenance and reward the verification nodes, which will also reduce the operational burden of the system. In the course of the transaction, the sum of the buyers' and sellers' reputation is used as a reference value to rank the transaction fees. The higher the reputation, the lower the proportion of transaction fees that the two parties need to pay extra, as shown in Tab. 1. In the long term, it is a good choice for enterprises to spend a certain amount of money on emission reduction work and pay less transaction costs in the CEPs trading process.

IV. Case Study

Tab. 2: Public information of buyers.

Buyers	Reputation
A	83
B	61

Tab. 3: Public information of sellers.

Sellers	Price	Reputation
E	1.98	81
F	1.96	72
G	1.95	43
H	1.93	38

The case study presented in this paper are based on the DBR-ETS model. The buyers and sellers' information is shown in Tab. 2 and Tab. 3.

Before the transaction, buyers A, B and sellers E, F, G, and H initialize their transaction information. Then the identity information will be encrypted and packaged information will be broadcast throughout the network.

Tab. 4: Trading results for different trading options.

Buyers	Sellers	The average cost for buyers	The average revenue for sellers
A	E	1.9998	1.9602
	F	2.058	1.862
	G	2.145	1.755
	H	2.134	1.746
B	E	2.076	1.881
	F	2.058	1.862
	G	2.145	1.755
	H	2.134	1.746

According to their respective needs and the principle of free trade, enterprises A and B can purchase the CEPs of the enterprises E, F, G and H. By comparison, it is found that different reputation will result in different proportions of transaction fees, and the final cost or revenue of trading with different enterprises will be different as well. The prices per unit of CEPs calculated for different trading options are shown in Tab. 4. The data shows that for enterprises A and B, the choice of E or F with higher reputation will be less expensive; for enterprises E, F, G and H, if choosing A with a higher reputation their revenue will be relatively higher.

For example, suppose all nodes in Tab. 2 and Tab. 3 are online, sometime, enterprises A and E have reached a trading intention, and A makes a confirmation order broadcast to the network. Then, from the enterprises B, F, G, and H, a node will be selected as a verification node through POW to verify the transaction and create a new block. After verifying the transaction at other nodes, the new block will be added to the confirmation chain. At the same time, the transaction information will be passed to the financial chain.

When the transaction information is transmitted to the financial chain, enterprise E will make a financial order, including the digital signature used for encryption, the CEPs sold, and the transaction fees that enterprise E needs to pay. The financial order is then broadcast to the network. Similarly, a node is selected as a verification node by POW, resulting in a new block. After the new block is checked by other nodes, it will be added to the financial chain. Enterprise A can obtain the CEPs after paying the transaction funds and fees for purchasing the CEPs, and the enterprise E also obtains the transaction funds paid by A.

Assuming that enterprises A and B have reached deals with two of sellers at the same time, then the system will need to process two transactions simultaneously. At this time, in order to speed up the progress, the system will complete the confirmation chain process of the two transactions first, and then complete the processing of the financial chain later. This approach allows resources and time to be used reasonably when transactions occur frequently.

In this case study, Firstly double-blockchain structure adopted in DBR-ETS is to isolate the determination of the transaction from the circulation of funds and CEPs. Through the consensus mechanism, the two processes have achieved consistent results under decentralized processing. Secondly, the existence of the reputation has a certain influence on the choice of the buyers' and the sellers' transaction object, and it is to promote the cooperation of enterprises with higher reputation. When enterprises consider economically, they will choose to increase their investment in reducing emissions to improve their reputation.

V. CONCLUSION

In the DBR-ETS model of this paper, the double-blockchain structure is taken as the core and runs through the whole transaction process. Meanwhile, in the process of realizing the transaction, the transaction fee mechanism based on reputation also play an indispensable role.

The transaction speed in the blockchain technology is always not fast. Through the use of the double-blockchain structure, the overall transaction speed can be improved. At the same time, the regular check and synchronization of the two chains also improves the security of the entire system, and the difficulty of maliciously tampering with data is higher than single-chain structure. The reputation-based transaction fee mechanism can also allow enterprises to more directly see the concessions brought by the high reputation, which can encourage enterprises to increase their investment in the emission reduction to obtain higher reputation. However, there are still some defects in DBR-ETS that need to be improved. In terms of data acquisition, it is necessary to use smart meters with higher precision to obtain more accurate basic data. When determining the proportion of transaction fees, it also needs to consider the specific situation. In addition, how to specifically allocate and use the transaction fees after collection is also needs to be discussed in the actual application.

The introduction of the DBR-ETS model will provide a different approach to the current carbon emission trading market. Decentralization and distributed processing will have broader application prospects in current and future transaction processing.

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