Blockchain-Based Supply Chain Traceability Application Research

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Abstract. To deal with the problems of inefficient data sharing and security occurring in the traditional supply chain, the author proposes a supply chain collaboration model accordingly that aims to apply blockchain and smart contract technology. Based on the features of distributed storage, decentralization, open transparency, and de-trust of blockchain technology, this paper considers the physical enterprises in the supply chain as the participating nodes of the blockchain to meet the demand for collaborative operation in the supply chain business process. Take the apparel supply chain enterprises as an example, the author verifies the practicality of the supply chain collaboration model based on the Ethernet blockchain platform. The model not only avoids the drawbacks of centralized storage in the traditional supply chain collaboration model, but also improves the reliability, trustworthiness, and security of information stored in the smart contract. Most importantly, it contributes to realizing the trustworthy storage of information in each participating supply chain node.

Keywords: Blockchain · Smart Contracts · Supply Chain Traceability

1 Introduction

Under the influence of globalization on economic development, supply chain competition has become an indicator to measure the competitiveness of enterprises. To have more advantages in the market competition, many enterprises have built organizational alliances that "complement each other's strengths and work together" to improve the overall efficiency by applying the supply chain management model. The purpose of collaborative supply chain management is to improve the overall competitiveness of the upstream and downstream enterprises through mutual collaboration and joint efforts. It emphasizes information sharing between upstream and downstream of the supply chain, which can improve the credibility of the information while ensuring the timeliness of information delivery [5]. Therefore, how to break the information silo between enterprises and improve the information-sharing ability has become an urgent problem in supply chain collaborative management.

As the number of companies joining grows, the breadth of collaboration expands. The connections between supply chain companies have become numerous and complex. Data is difficult to flow, and collaboration of information is difficult. The collaborative

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management of the supply chain is conducive to improving the efficiency of information sharing upstream and downstream of the supply chain, guaranteeing timeliness and effectiveness, enhancing the traceability of quality and safety, and improving supervision efficiency. However, in reality, the supply chain information sharing system has problems such as high cost of collaboration, low trust between enterprises, and information asymmetry, which cause the low degree of information collaboration among supply chain enterprises [2].

Blockchain is a distributed ledger, and its data immutability, decentralization, and traceability fit well with the openness, information sharing, and data safety and security of the supply chain. In recent years, more and more scholars have started to study the application of blockchain in the supply chain. In supply chain finance, blockchain can provide convenience for small and medium-sized enterprises in financing and solve the problem of financing difficulties. In the field of supply chain traceability, the constructed framework of a blockchain-based supply chain traceability system can create a transparent and reliable traceability environment. In supply chain management, blockchain technology is used to build an integrated system of regulation and management that enables supply chain subjects to upload, query, and trace information, which guarantees the security and privacy of data and realizes information sharing and regulation. Based on the concept of supply chain collaboration, this paper constructs a decentralized, transparent, and open model with the help of blockchain technology to optimize the supply chain collaboration process and achieve the goal of collaborative supply chain management and mutual benefit.

2 Analysis of Traditional Supply Chain Collaboration Problems

Under the influence of globalization, enterprises cannot rely solely on internal coordination to achieve the development goals of reducing production costs and improving efficiency. Instead, they need to strengthen the collaboration among enterprises in the supply chain to meet future challenges and improve their competitive advantages in the industry. However, there are many limitations in the practical application of traditional supply chain collaboration, which makes it difficult to guarantee the reliability, creditability, and security of information storage.

First, trust, sharing, and collaboration are the core issues of supply chain management. The business flow of an enterprise involves economic activities such as purchasing, manufacturing, sales, and transportation. Supply chain collaboration usually refers to the business synergy between upstream and downstream of the enterprise. The information sharing between enterprises based on mutual trust can improve the operation efficiency of the whole supply chain, which shows the importance of information sharing in collaboration [4]. Therefore, trust between enterprises is the premise and foundation for information sharing, and information sharing is the way to realize efficient collaboration in the supply chain.

Secondly, the upstream and downstream enterprises in the supply chain, all pursue the goal of maximizing the profits of individual enterprises, forming individuals with different goals and economic interests, and forming “data silos” among enterprises. For a long time, companies have been self-centred and lacked a sense of cooperation. In addition, there is a lack of trust between companies and inefficient collaboration.

Finally, with the continuous influx of participating enterprises, the amount of data circulating between enterprises has increased substantially. However, there is no guarantee that the data is safe and secure. The reason is that the information between enterprises is semi-transparent or even opaque, and some unscrupulous enterprises may tamper with the data for their interests to achieve illegal profits in each link of the supply chain. Once the quality and safety of goods, it is difficult to find out in which link the problem arises, which causes difficulties in the pursuit of responsibility, and increases the difficulty of information flow regulation. A large amount of data verification is required to improve regulatory efficiency. However, it not only consumes time, manpower, and economic resources but also makes it difficult to achieve ex-ante control, on-site supervision, and post-evidence collection. In addition, the regulatory efficiency is low. At the same time, commodities need to spend a lot of time and energy on fragmentary tracking to obtain information during transportation, and the authenticity of the data is difficult to discern, which causes great difficulties in information traceability.

3 Design of Supply Chain Model

3.1 Model Architecture Design

Based on the analysis of supply chain collaboration, this paper proposes a supply chain model by combining Ether, Metamask wallet plug-in, and IPFS file storage system, as shown in Fig. 1. The entities in the supply chain obtain the Ethereum user address through the MetaMask wallet plug-in and use the Ethereum address to register and obtain the entity attributes, which are divided into suppliers, manufacturers, and logistics enterprises in the supply chain. Sometimes it is necessary to upload corresponding pictures or files in the supply chain business, but only single text and numbers can be stored in the blockchain. Therefore, IPFS needs to be used to store data such as images and then upload the file hash returned by the IPFS encryption algorithm to the blockchain. According to the needs of the business layer, the function implementation is deployed to the blockchain in the form of code with smart contracts, and the application layer can complete the storage, traceability, and business interaction operations of information through the interface functions in smart contracts.

As shown in Fig. 1, the node-set of the system is divided into four parts, including supplier enterprises, manufacturing enterprises, logistics warehousing, and distribution enterprises and users. Among them, suppliers provide the corresponding raw materials; manufacturing companies obtain raw materials from their suppliers and use their processes to turn these raw materials into goods for sale; logistics warehousing and distribution enterprises provide goods delivery services for users after they generate orders. In the blockchain-based supply chain platform, enterprises in the supply chain complete their operations according to different business needs. Unlike traditional supply chain platforms that store data in a centralized database, the data in the blockchain platform is stored in a decentralized distributed ledger. Supply chain enterprises can upload data information, check commodity information, place orders, logistics and delivery, and make transaction payments on the blockchain platform.

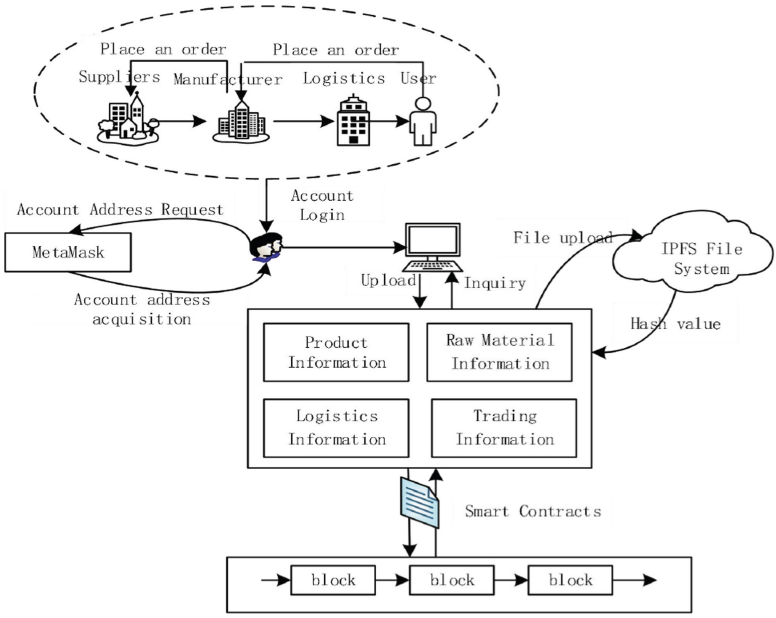

Fig. 1. Supply Chain Model Architecture

3.2 Function Description

By analyzing the architecture of the supply chain collaboration model based on blockchain smart contract, this paper designs modules for raw material information up-linking, raw material procurement, product information up-linking, logistics delivery, commodity order transaction, transaction payment and reverse traceability for the system. To meet the business needs of supply chain companies, data and transaction information of each distribution chain, such as production, distribution, and retail, need to be written into the blockchain, and proof of information origin is provided. Information about a product's raw materials, production, and distribution processes should be traceable throughout the entire product flow in the supply chain, from production to distribution.

Chain up of raw material information, commodity information and logistics distribution information: raw material suppliers in the supply chain participants need to collect raw material information of product production and upload it to the blockchain, such as raw material origin, type, raw material logo, pictures, etc.; the manufacturer needs to collect the production process information of the product, store the product number, type, date and other information together with the hash of the product testing certificate into the blockchain, so as to facilitate other entities in the supply chain to obtain the raw materials and production information of the product; the logistics distributor needs to deliver the goods of the order transaction from the manufacturer to the customer, and deposit the logistics information, cargo status and other information appearing in the process of goods delivery into the blockchain, so that the buyer and the seller can check the commodity transportation information between them in real-time.

Order transaction: The entities in the supply chain can record and update transaction information in the blockchain on time after completing the transaction. The entry of transaction information is executed by the seller, which mainly contains the information of raw material purchase transaction by the manufacturer and the commodity purchase transaction between the customer and the manufacturer. If a manufacturer buys raw materials from a raw material supplier, the purchase contract information is recorded on the blockchain using smart contracts, where information such as corporate information and transaction details are written into the transaction record. The manufacturer processes the raw material to produce the product and then stores the product information in the blockchain. The customer buys the product from the commodity manufacturer, and the commodity manufacturer updates the transaction information after the transaction is completed. Transaction information is entered in this way to achieve the continuity of product information in the supply chain and prevent information breakage.

Information traceability query: Users in the supply chain can view product information after the transaction is completed, trace back to raw material supplier's information through layers of transaction data, and provide the query results as source credentials to consumers. Through the information inquiry, you can get the information of suppliers, manufacturers, logistics companies, and users involved in the process of product circulation, so that you can find the responsible parties in time when there are problems with the products. At the same time, it can notify the buyer and recall the product, which will reduce the loss for all parties.

3.3 Smart Contract Design

This paper designs the application of smart contract technology in each link of the supply chain based on the characteristics of the supply chain business process. The information of the participating nodes in each link of the supply chain, the process of business interaction of enterprises, the traceability of information and payment transfer, and default rules are all reflected in the formulation of smart contracts, and the information is stored on the blockchain through smart contracts, which will be executed automatically when the external conditions meet the pre-set conditions in the contract, reducing human intervention and achieving reliable storage and efficient execution of data [1]. The business interactions of each enterprise in the supply chain will generate the corresponding blocks through smart contracts, such as raw material suppliers information, product information, customer order purchase information, logistics information, and payment information. In this paper, we design the smart contract with the participation of raw material suppliers, processing enterprises, consumers, and third-party logistics. The relationship between the different participating entities of suppliers, producers, logistics, and consumers and the functions of the trading contract is shown in Fig. 2. The solid line indicates the call of the function in the contract by the firm and the dashed line indicates the transfer path of the commodity between firms. In the process of a physical transaction, the user initiates the transaction by calling the function to input the transaction information and completing the transfer of the product and then updating the transaction information with the help of the event response mechanism.

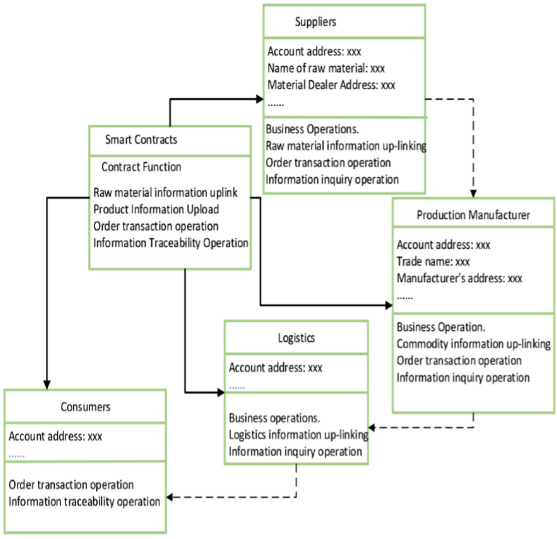

Fig. 2. Entity Relationships.

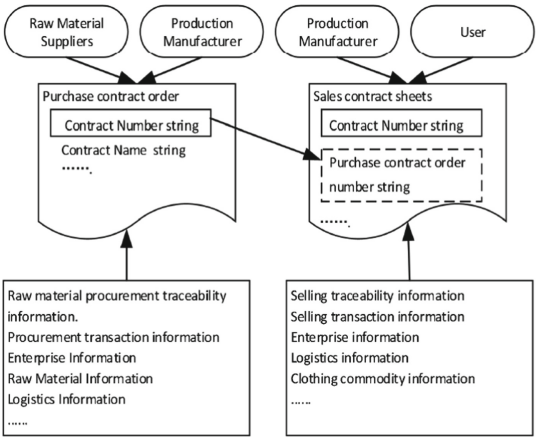

Fig. 3. Traceability information logic.

The purchase and sales information transactions in the supply chain link are recorded in the ledger as transactions after the consensus of the member nodes of the organization, and the transaction information is open and transparent. The transaction numbers between raw material suppliers and product the individual transaction contract numbers, in turn, correlate with the traceability information of each organization, which in turn correlates the traceability information of transactions into a complete chain in the ledger [3]. The logical structure of traceability information is shown in Fig. 3.

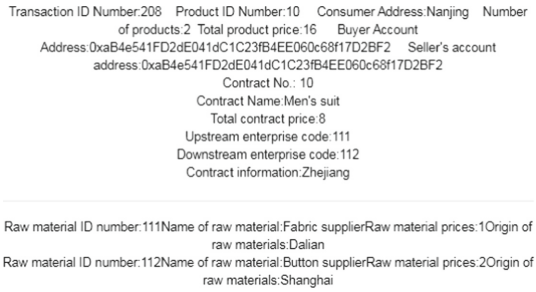

Fig. 4. Traceability Diagram.

4 System Implementation

In the process of business interaction in the supply chain, the system stores the complete chain information in the supply chain management into the blockchain codes the smart contract design according to the business interaction process, and users can append or trace the transaction information by calling the smart contract interface function to realize the supply chain traceability based on the blockchain. The paper takes the apparel supply chain as the research context and validates the constructed supply chain collaboration model. This subsection shows the effect of the traceability information query interface. When a user acts, the logged-in user rights are verified. If the permission verification is passed, the user will be able to check the details of the order. The information traceability inquiry is performed on the website as shown in Fig. 4. The consumer fills in the transaction traceability code in the transaction ID to initiate a transaction inquiry request for the order, and then the traceability information of the transaction is available.

5 Benefits of a Blockchain-Based Supply Chain Collaboration Model

5.1 Information Data Integration and Transparency

At present, the data sharing provided by the supply chain system is mainly for internal enterprises, and the data between enterprises in the supply chain cannot be collected effectively. The system platform based on blockchain can record the data of purchasing raw materials, production and processing, sales and transactions without passing through a third party, avoiding data loss or tampering in the process of information transmission, breaking the information barrier between enterprises, enabling timely understanding of the real-time situation and making more efficient decisions, truly realizing the integration and transparency of information and data, and providing huge data support for financial institutions and government It can provide huge data support for financial institutions and government regulatory departments.

5.2 Promote the Development of Supply Chain Finance Industry

The decentralization, data sharing and traceability of blockchain guarantee the integrity and authenticity of data. The financial industry can judge the risk of lending and financing based on the information on the chain without relying on other enterprises, which promotes the business of insurance, auditing and financing in the financial industry, facilitates the improvement of the financing ability of the financial industry, and solves the problem of difficult financing for small and medium-sized enterprises.

5.3 Improve Regulatory Efficiency

Unlike traditional supply chain systems, using blockchain technology to track the procurement, production and transportation trajectory of products allows for fast and complete access to information and real-time monitoring of information on the supply chain system without taking hours or even days. Each enterprise node on the blockchain will publish data to the blockchain, which can be successfully synchronized to the blockchain after the approval of other nodes, and supervise the business processes on the supply chain through smart contracts, turning passivity into initiative, truly achieving early warning, process control and accountability afterwards.

5.4 Enhance Mutual Trust Between Enterprises and Reduce the Cost of Trust

In the supply chain, information flow runs throughout the whole chain. Due to the decentralized mechanism of blockchain technology and P2P network transmission mechanism, nodes on the blockchain have equal rights and obligations and are de-trusted between enterprises. Blockchain can make transaction rules (develop smart contracts) and the technology to ensure the execution of the rules, and the participants do not need to trust each other because the rules are relying on the technology to ensure the execution. Therefore de-trusting, it is not that trust is not needed, but the object of our trust has changed from our transaction participants to the program. So it can also be understood that blockchain builds trust and establishes trust based on data and procedures.

6 Conclusion

Blockchain technology and supply chain collaboration play an important in handling problems of data security, business process execution efficiency, information sharing, and information traceability in the supply chain system, and hits the difficult points of supply chain collaboration management. In the future, the eternal topic for the supply chain is how to optimize the supply chain synergy and maximize the overall benefits. In recent two years, the government takes measures to support the development of blockchain and encourages to advance the development of the supply chain in three major industries, namely supply chain management, product traceability, and data sharing. More and more researchers are aware of the development of blockchain in the field of supply chain collaboration mode to achieve innovative thinking and mutual benefit among enterprises of all parties. Ultimately it aims to achieve the long-term goal of a win-win situation.

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