Blockchain Based Logistics Tracking and Traceability Method for E-Commerce Products

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Abstract. To improve the traceability effect of e-commerce product logistics and shorten its response time, this study proposes a blockchain based e-commerce product logistics traceability method. This method first conducts theoretical research on the traceability of e-commerce product logistics information, and then obtains data through the collection of e-commerce product logistics information. The ProVOC model is used to complete the design of e-commerce product logistics information storage model. Finally, based on this, the process design of e-commerce product logistics traceability is completed, achieving the function of e-commerce product logistics traceability. The experimental results show that the proposed method has better application effect and shorter response time, which has greater application value.

Keywords: Blockchain Technology · Electronic Commerce · Product Information · Physical Distribution Management · Traceability

1 Introduction

With the development of internet technology, e-commerce has flourished in China, and the efficient and convenient shopping experience it brings has been increasingly loved by consumers. In recent years, with the popularization of mobile devices and the rapid development of mobile internet technology, the proportion of mobile e-commerce in the e-commerce market has continued to increase. By 2021, mobile e-commerce has accounted for 72.9% of all e-commerce transactions [1, 2]. With the booming development of e-commerce, people's consumption patterns have also changed greatly. Online shopping, takeout and other ways have become an important part of People's Daily life, but the quality problems in online shopping are also increasing. Due to the lack of a unified and effective management mechanism, there are many phenomena in the field of e-commerce, such as counterfeiting, shoddy goods, and false advertising, which seriously affect consumers' trust in the quality of e-commerce products. Due to the fact that most of the products sold on e-commerce platforms are standardized, it is difficult to determine the responsible party when there are product quality issues, and it is also difficult to find a solution in the first place when there are quality issues [3, 4]. In recent years,

L. Yun et al. (Eds.): ADHIP 2023, LNICST 549, pp. 123–135, 2024.
https://doi.org/10.1007/978-3-031-50549-2_9

relevant national departments have been committed to exploring the quality and safety assurance system of e-commerce products, and logistics information traceability is one of the most direct and effective means to ensure the quality and safety of e-commerce products. Therefore, it is very important to track the logistics traceability of e-commerce products.

The so-called logistics traceability is a method to track the whole logistics process through technical means, which can obtain logistics information accurately and in real time, and provide consumers with more safe, efficient and reliable logistics services [5]. In the logistics tracking and tracing system, each logistics package is endowed with a unique identification code, which can be used to track the entire transportation process of the package and understand the location, status and other relevant information of the package. The application of logistics tracing technology can optimize logistics services, improve logistics efficiency and reduce liability disputes. Its application in e-commerce products can play an important role in guaranteeing product safety and other aspects. At present, logistics traceability technology has been widely applied in the food industry. By identifying and recording the entire process data of products from production to transportation, it can achieve full supervision of products and greatly prevent the occurrence of various food safety issues [6]. In addition, logistics traceability technology has been widely applied in industries such as pharmaceuticals, chemicals, and textiles, achieving the goals of full traceability, rapid response, and loss reduction. In short, logistics traceability is a logistics management method with broad application prospects. It can provide timely, accurate, and fully recorded logistics information, help improve logistics efficiency and safety, thereby improving consumer satisfaction, enhancing the competitiveness and market reputation of enterprises.

At present, there are mainly two methods for e-commerce product traceability, one is based on product coding system, the other is based on product identification system. Among them, the former is mainly used in food, medicine and other fields; The latter is mainly used in cosmetics, clothing and other fields. However, due to its higher cost and higher technical requirements, it is difficult to popularize comprehensively in our country. Many scholars have carried out research on this issue and have achieved certain research results. Some scholars proposed the design of cluster agricultural product supply chain traceability model based on blockchain relay technology in view of the characteristics of product logistics supply chain, such as long and multiple chains, dispersed production, heterogeneous information sources and complex network chain structure [7]. This method first analyzes the business composition of the clustered agricultural product supply chain, utilizes blockchain relay technology to connect the upstream and downstream blockchains of the supply chain, and constructs the relay multi chain topology structure and traceability model of the clustered agricultural product supply chain; Then, the application chain utilizes relay chains and cross chain routing to achieve cross chain interaction, and verifies the effectiveness of cross chain transactions through the Hyperledger Fabric endorsement strategy. Finally, taking the clustered kiwifruit supply chain as an example, a prototype system of the model was designed and implemented, and functional, performance, and scalability testing and analysis were conducted. Some scholars have proposed a study on the storage method of fruit and vegetable blockchain traceability data based on smart contracts to address issues such as untimely sharing of product data upstream and downstream traceability enterprises in product logistics traceability systems, difficulty in ensuring traceability data security, and inability of regulatory authorities to monitor all traceability data in real-time [8]. Firstly, a fruit and vegetable product traceability framework and traceability data storage model based on blockchain multi-chain architecture are designed. Intelligent contracts are used to realize the encryption storage on the classification chain of traceability data, authorization access between chains, decryption and query based on authorization vouchers, so as to ensure the ciphertext link of traceability privacy data in the whole supply chain of fruit and vegetable. Reduce the block chain storage pressure, realize the upstream and downstream enterprise privacy data traceability without island authorization sharing, based on Hyperledger Fabric channel technology to achieve product multi-chain traceability. Some scholars proposed a blockchain based reliable traceability system for agricultural product quality safety, aiming at the problems of centralized data storage, easy data tampering and data trust existing in the existing product quality traceability system. On the basis of analyzing the business processes and key blockchain technologies of the agricultural product industry chain, this method designs a trustworthy traceability block structure for agricultural products; Then, the "On Chain + Off Chain" collaborative management and storage strategy for agricultural product quality and safety traceability information was proposed to solve the problems of high data storage pressure, low query efficiency, and data explosion at each node in the agricultural product traceability blockchain network. The Kafka consensus mechanism was adopted to achieve consensus operation involving multiple agents, providing real-time data processing capabilities with high throughput and low latency; Finally, a set of intelligent contract rules and contract triggering conditions for agricultural product traceability were developed to ensure the reliability of agricultural product data and the credibility of the traceability platform; A trustworthy traceability system for agricultural product quality and safety has been developed based on the Hyperledger Fabric blockchain platform [9]. In the application process of the above three methods, due to the large amount of overall calculation, the response time is long, and the traceability results are not accurate. In view of the above deficiencies, this study introduces blockchain technology and RFID to complete the design of e-commerce product logistics traceability method based on blockchain.

2 Theoretical Research on Traceability of E-commerce Product Logistics Information

E-commerce product logistics information traceability refers to the phased tracking and recording of logistics information starting from the logistics transportation of e-commerce products, in order to achieve the purpose of consulting and tracing logistics process information. With the rapid development of e-commerce, more and more consumers are starting to shop online, making logistics one of the core links of e-commerce and promoting the research of logistics information traceability theory. The theory of logistics information traceability for e-commerce products mainly includes the following aspects:

1) Logistics information technology. Logistics information can be traced through the Internet of Things, RFID, GPS, bar code and other technical means to collect and record the whole process of logistics information [10].
2) Logistics process management. Standardize the logistics process to ensure that every link is effectively monitored and managed, and respond to abnormal situations in a timely manner.
3) Information system integration. The logistics information system will be integrated and unified management, so as to effectively avoid information island and information lag.
4) Data security protection. Efficient encryption, backup and recovery of logistics information to ensure the security and integrity of logistics information.
5) Data analysis and mining. By analyzing and mining logistics information, data support is provided for optimizing logistics management and improving customer satisfaction.

In short, the research on the traceability theory of e-commerce product logistics information aims to improve logistics efficiency, optimize logistics service quality, and achieve lean management of logistics processes. At the same time, it also provides consumers with a safe and reliable trading experience, promoting the sustained and rapid development of e-commerce.

3 Design of E-commerce Product Logistics Information Collection Module

The logistics information collection of e-commerce products needs to be realized with the help of RFID technology. In this study, the high-frequency long-distance reader produced by Texas Instruments is selected for data collection. Its main performance is shown in Table 1 below.

Table 1. RFID Parameter Table

Operating Frequency	13.56 MHz
Support label types	Tag-it HF/Tag-it HF-1/ISO15693-2
Supply Voltage	24V DC + 5%/−1%
Power consumption	Maximum 60 W
Transmitter power	0.5 W–10 W
Radiation modulation method	AM (10%–30%)
Communication protocol	ISO Host Protocol
Communication parameters	Maximum 115 KBits
Storage	EEPROM 1 kByte

The label selected for the production of a standard label package can be compatible with global open standards to provide user readable storage space. This type of label is more suitable for application and product security, library, supply chain management, property tracking ticket and other fields. Table 2 lists the main features of labels.

Table 2. Label Characteristics Table

Project	Parameter
Supported Standards	ISO/IEC15693-2
Recommended operating frequency	13.56 MHz
UID Digits	64 bit
User available storage capacity	2 Kbit
Accumulated access times	100000 times
Data storage specimen	>10 years
Size	48 × 101 mm
Operation temperature	−25 °C– +75 °C

Each reader is connected to a desktop computer and the reader works as a data acquisition tool. Considering the characteristics of generality and equipment communication between them through the RS232 serial port. Read/write device configuration commands, speaking, reading and writing control command is used to adjust to read and write device parameters to adapt to specific application host command, buffer read mode is used for data exchange between the host and the label.

4 Design of E-commerce Product Logistics Information Storage Model

The decentralized and immutable characteristics of blockchain provide a reliable storage environment for data traceability information. This makes it almost impossible for malicious nodes to tamper with traceable data stored in the blockchain. This paper proposes a blockchain data tracing storage model based on ProVOC model. The data tracing information in the ProVOC model is described as a triplet of "performing entities," "activities," and "data," but the relationships between the components are not well represented in the triplet, and "relationships" need to be introduced to document the relationships between the components. Therefore, this paper defines a data traceability information as a quad consisting of "execution entity", "activity", "data" and "relationship" between components. The container storing the quintuple is called traceability *Document*, and its metadata description method is shown in Formula (1):

$$Document = (Agent, Activity, Data, \mathrm{Re}lations) \tag{1}$$

In the formula, *Agent* represents the "executing entity" component; *Activity* represents the "activity" component; *Data* represents the "data" component; Re*lations* represents the relationship between various components.

The metadata description method for a 'executing entity' component is shown in Formula (2):

$$Agent = (ID, Name, Type, Parameter) \tag{2}$$

where *ID* is used to globally identify an "execution entity" component. *Name* Identifier used to identify a human-readable "executing entity". *Type* is used to identify whether the "executing entity" is human or non-human. *Parameter* Indicates the creation time and place of the execution entity.

The metadata description method of an "active" component is shown in Formula (3):

$$Acivity = (ID, Type, Parameter) \tag{3}$$

Among them, *ID* is used to globally identify an "activity" component. *Type* is used to identify the type of "activity", such as copying, adding, modifying, etc. *Parameter* is used to identify information such as the time, location, and conditions of the occurrence of the 'activity'.

The metadata description method for a "data" component is shown in Formula (4):

$$Data = (ID, Name, Type, HashType, Hash, Parameter) \tag{4}$$

where, *ID* is used to determine the unique data globally. *Name* is used to identify a piece of data in a human-readable manner so that users can understand the actual meaning of a piece of data by its name. The *Type* of data identifies the type of data, for example, docx, mp3, or png. *HashType* identifies the hash value of the data, which can quickly verify the integrity of a piece of data, and *HashType* identifies the hash algorithm.

The hash value obtained. *Parameter* is used to represent information such as the time, location, and condition of data generation. The 'parameter' component is possessed by other first-level components and is used to describe the time, location, and conditions of the existence of other components.

The metadata description method for a "parameter" component is shown in Formula (5):

$$Parameter = (ID, Temporal, Spatial, Condition) \tag{5}$$

where, *ID* is used to globally identify the "parameter" component, *Temporal* is used to represent "time parameter", *Spatial* is used to represent "spatial parameter", and *Condition* is used to represent "condition parameter".

The term 'relationship' is used to describe the 'relationship' records between components in the serialized ProVOC model. The metadata description method for a 'relationship' record is shown in formula (6):

$$\mathrm{Re}lation = (ID, Name, UpperComponent, LowerComponent) \tag{6}$$

ID is used to globally identify a relational record. *Name* a name used to identify Relationship. In addition, each "relationship" record contains *UpperComponent* (the upper component) and *LowerComponent* (the lower component). *UpperComponent* identifies the main component of "relationship" and F identifies the object component of "relationship". ProVOC model relationship names are shown in Table 3.

Table 3. ProVOC Model Relationship Table

Upper component	Relationship	Lower component
Agent	*Associate*	*Activity*
Activity	*Input*	*Data*
Activity	*Output*	*Data*
Activity	*Trigger*	*Activity*
Data	*Derive*	*Data*
HumanAgent	*Control*	*NonHumanAgent*
Agent *Activity* *Data*	*With*	*Parameter*

The structured modeling of the ProVOC model is incorporated into the storage model, as shown in Fig. 1. The user's upload of the ProVOC model's serialization module converts the user's upload of the Provoc model into the JSON format of the traceability, which is then uploaded to the blockchain. At the same time, the system needs to monitor the block information on the blockchain in real time. When it is confirmed that new traceability information is packaged into blocks and written into the blockchain, the system converts the traceability information into structured data through the structured modeling module of the ProVOC model and stores it in the relational database.

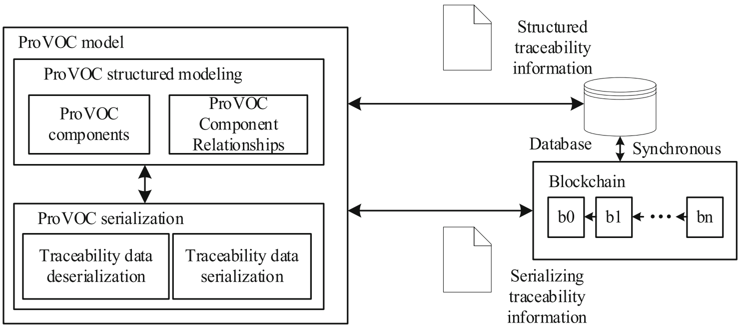

Fig. 1. Improved ProVOC storage model diagram

In the blockchain data traceability storage model, the same data traceability information needs to be written into both the blockchain and the relational database. The main function of data traceability information stored in relational database is to facilitate complex operations of traceability business. Its essence is a copy of traceability information stored in the blockchain, and the process of storing data traceability information in the database is shown in Fig. 2. The data traceability system detects that new data traceability information has been written to the blockchain network, and obtains the newly written data traceability information in the blockchain. The serialized data traceability information in the blockchain is structured through the ProVOC model and stored in the relational database.

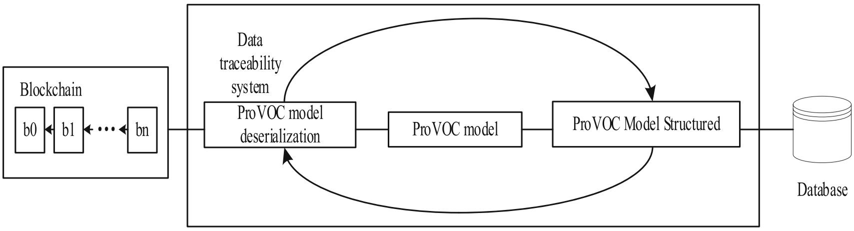

Fig. 2. Flow Chart of Data Traceability Information Entry

5 Design of Logistics Traceability of E-commerce Products

E-commerce product logistics traceability is to return the data traceability information that meets the query conditions, and the query process is shown in Fig. 3.

Blockchain is not suitable for complex query operations, so we put the query operations in a traditional relational database. The local relational database stores the structured data of the traceability information of the upper link, and the system will synchronize the traceability information of the upper link to the local database when it monitors the link of new traceability information. The traceability information in the local database is not up-to-date due to problems such as network delay. Therefore, in order to ensure the timeliness of the queried traceability information, it is necessary to check whether the latest traceability information in the local database is consistent with that in the blockchain during each query operation. If the traceability information in the local database is detected to be not up-to-date, the latest data traceability information in the blockchain should be obtained and stored in the local database to ensure the timeliness of the traceability information in the local database. After ensuring the timeliness of the data in the database, query the eligible data traceability information based on the user's query criteria, serialize the queried data traceability information into JSON format, and return it to the user. The data traceability system supports querying traceability documents through the ID of the traceability document, querying traceability documents through the "executing entity" component ID, and querying traceability documents through the "data component ID." By entering the "executing entity" component ID, information about all data traceability documents that the "executing entity" component is involved in can be queried. Similarly, by entering the "data" component ID, You can query the information of all data traceability documents involved in this' data 'component. After the data traceability system queries the data traceability information that meets the requirements, it will be displayed on the front-end page. Click the "View" button after the corresponding traceability information to view the retrieved JSON format traceability document. After clicking the save button, the viewed data traceability information can be downloaded as a JSON file and saved locally.

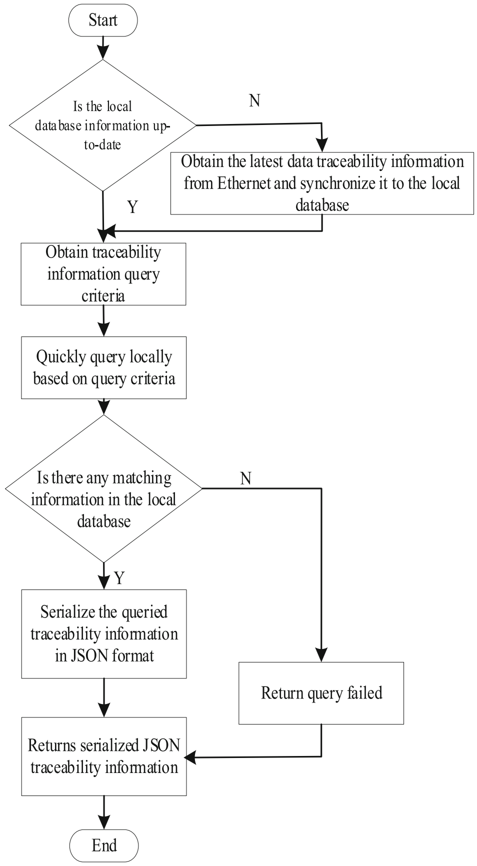

Fig. 3. Flow Chart of Data Traceability Information Query

6 Experimental Analysis

6.1 Experimental Environment Settings

This test chooses to build and start a private Geth Ethereum client locally, simulate the real operating environment of blockchain, and generate blockchain of different heights to complete the test. The specific test environment is shown in Table 4.

6.2 Performance Testing

Hyperledger Fabric was tested using the Caliper testing framework. The Caliper testing Framework is a tool developed specifically for Hyperledger federated chain testing. After setting the configuration parameters, we can test the performance of the traceability system network built in this paper. The tests mainly include write test and query test. Write test is the write performance test of blockchain ledger, and query test is the read performance test of query ledger. According to the actual application, the number of

Table 4. Test Environment Settings

Configuration information	Version parameters
CPU	Inter i7-8750H 2,20 GHz
Memory	16 GB DDR4
Hard disk	512 GB HDD
Operating system	Ubuntu 18.04 LTS
Co language	1.15.7
Hash algorithm	SHA256

traceability query of blockchain ledger is higher than that of product write operation. There are six rounds of test, each round initiates a total of 2,000 transactions on the network, and the number of requests per second of each round is set to 50, 100, 200, 400, 800 and 1600. The write performance test results are shown in Table 5.

Table 5. Write performance test results

Number of tests	Success/times	Transmission rate/TPS	Mean delay/s	Throughput/TPS
1	2000	45	1.67	43
2	2000	100	10.14	75
3	1997	198	16.73	105
4	1998	405	19.01	142
5	1999	430	19.25	145
6	1998	415	21.12	137

Based on the comprehensive data in Table 5, it can be seen that the overall network successful transaction rate is greater than 99%, ensuring the normal operation of the system. When the actual transmission rate approaches around 430TPS, network congestion occurs, and the actual transmission limit under the local configuration is 430TPS. When the sending rate reaches around 400TPS, the transaction throughput reaches a peak of 145TPS. Continue to increase the transmission rate, but the actual transmission rate will not increase, and the throughput will basically remain stable. When the sending rate is below 50 times/s, the average transaction delay is 2 s, which can quickly respond to user operations and meet a large number of write operation requirements. However, when the request sending rate exceeds 200 times/s, the average transaction delay increases to over 16 s, and the highest average delay in the test reaches 21 s.

The query type test was tested in 6 rounds. A total of 2000 transaction requests were launched to the network in each round, and the number of requests per second in each round was set to 50, 100, 200, 400, 800 and 1600, respectively. The test results of query performance were shown in Table 6.

Table 6. Query Performance Test Results

Number of tests	Success/times	Transmission rate/TPS	Mean delay/s	Throughput/TPS
1	2000	48	1.67	49
2	2000	100	0.08	97
3	2000	199	4.12	193
4	2000	397	14.21	321
5	2000	425	18.35	297
6	2000	451	17.62	305

Based on the data in Table 6, it can be seen that the success rate of query requests is 10%, ensuring the normal operation of the system. When the system transmission rate reaches about 440TPS, it is the actual transmission upper limit. The results show that when the number of requests reaches 400TPS, the actual send rate is 397TPS, and the throughput reaches a peak of about 321TPS. When the number of requests is not more than 200 times/s, the maximum transaction delay is about 4 s, while the lower transmission rate will have a transaction delay of less than 1 s, and the response speed is fast, which can meet the requirements of users to query product data when tracing the source. When the transmission rate exceeds 400 times per second, the transaction delay approaches 19 s.

6.3 Comparative Testing

In order to verify the progressiveness of the proposed method, literature [6] method and literature [7] method are selected as the comparison methods to carry out comparative tests. Three methods are used to jointly conduct logistics traceability, and response time is selected as an indicator to compare the performance of the three methods. Using three methods to jointly trace 10 e-commerce products, the comparison of traceability accuracy is shown in Fig. 4.

As shown in Fig. 4, during this test, there are 300 concurrent users in the simulation system, and all functions of the operation and maintenance management system are executed simultaneously. The proposed system starts to enter the transaction processing scene from 30 s, and the lowest transaction processing response time of the system is 0.36 s at the 6th minute. At around 4 min and 10 s, the maximum transaction response time is 1.12 s. When tracing the logistics of e-commerce products in the actual operation scenario, the average response time of transactions is about 0.69 s, while the comparison method enters the transaction processing scenario at 1.25 s and 2.00 s respectively, and the response time of transaction processing is much higher than that of the proposed method. Therefore, it can be proved that the proposed method has shorter response time and better performance. It can meet the requirement of real-time logistics inquiry.

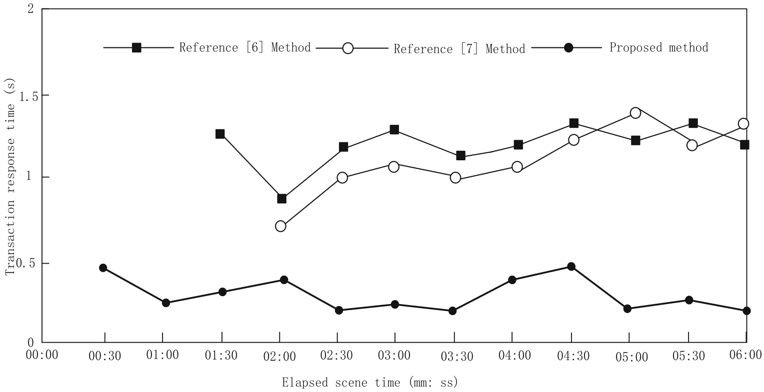

Fig. 4. Comparison of Response Times of Three Methods

7 Conclusion

This study proposes and designs a blockchain based e-commerce product logistics tracking and traceability method to address the issues of long response time and poor traceability effectiveness of traditional logistics tracking and traceability methods. This study is based on RFID technology to obtain commodity logistics information, and then uses the ProVOC model to design an e-commerce product logistics information storage model. Finally, the traceability process is designed to achieve its functionality. Experimental results show that the proposed method has good performance, and its minimum Transaction processing response time is 0.36 s, which is better than the comparison method, and has certain application value. Although this study has achieved certain results, its data confidentiality was not designed in the study, which is also the next research direction.

Acknowledgement. 2022 Annual Project of the "14th Five-Year Plan" Education and Science Planning of Shaanxi Province: Research on the improvement of digital literacy and skills of college students majoring in economics and management in the digital economy era (SGH22Y1715).

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