Blockchain-Based Cross-Border Supply Chain Model

Jianyu Zou, Jianmao Xiao(✉), Xuanying Long, Xin Yang, Yu Xiao, Yuanlong Cao, and Yong Luo

School of Software, Jiangxi Normal University, Nanchang 330027, China
{jm_xiao,ylcao,luoyong1020}@jxnu.edu.cn

Abstract. With the rapid development of cross-border e-commerce in China, cross-border transactions are becoming more and more frequent, and the problems of centralized and easy tampering, information siloing, difficulty in traceability, and cumbersome recourse mechanism of traditional cross-border import and export systems are becoming more and more serious. Blockchain technology has the characteristics of decentralization, distributed storage, openness and transparency, security, information encryption, and anonymity, which provides an important way to solve the problems of cross-border transactions. In this paper, by analyzing the business logic of cross-border products, the parties related to cross-border products are set as organizations to participate in the Consortium Blockchain Hyperledger Fabric, followed by combining the business logic of each participant, configuring the network environment, proposing the dual-chain architecture, designing the corresponding smart contracts, and finally conducting performance tests in terms of throughput and response time through Caliper. The results show that compared with the traditional inventory management system, the system throughput can be stabilized above 300 TPS while ensuring data security and safety, which meets the current inventory business requirements.

Keywords: Blockchain · Cross-border transactions · Supply chain · Information security · Smart contracts

1 Introduction

Nowadays, China's economic environment is developing steadily, residents can continue to expand consumption, cross-border transactions are frequent, enterprises are beginning to look at cooperation with multiple institutions to reach alliances to enhance market competitiveness, and the scale of the supply chain industry is expanding, and the scale of the cross-border e-commerce industry has almost maintained a growth rate of more than 20% since 2016, and the scale of China's cross-border e-commerce transactions will reach 12.5 trillion yuan in

Y. Cao and X. Shao (Eds.): MONAMI 2022, LNICST 474, pp. 48–62, 2023.
https://doi.org/10.1007/978-3-031-32443-7_4

2022 [1]. Blockchain is an important part of the new generation of information technology and a new database software integrated with various technologies, which is expected to solve the trust and security problems in cyberspace and reconstruct the information industry system. Combining blockchain with cross-border import and export inventory is of great significance to the development of cross-border trade.

The growing scale of cross-border transactions has generated a series of issues, To ensure the accuracy of the information, the traditional technical solution will generate many intermediate links, which is tedious and inefficient and consumes a lot of resources, and at the same time, the authenticity and reliability of the information of each enterprise are not guaranteed, so the merchants change the labels and counterfeit the national products, the manufacturers tamper with the shipping places, and the goods information is not updated in time, which leads to the accumulation of inventory, and other problems occur frequently. The IoT system for collecting information is set up in different participants' systems, and the actual data of the supply chain which seems to be connected through the Internet is relatively independent, with centralized data storage and serious information siloing.

In this paper, by analyzing the current situation of cross-border inventory, analyzing the supply chain business process, and combining it with blockchain technology, we design and implement a model of a cross-border inventory system based on blockchain, and also compare the changes in the system throughput under different number of nodes and transaction volume. Blockchain is a distributed database system, a distributed technology system in which multiple parties work together to maintain a public ledger. Its features include decentralization, immutability, traceability, Enhanced Security, information encryption, anonymity, and so on. Once the transaction information is uploaded to the chain through the nodes, no one can change it. This feature of being difficult to forge comes from the blockchain mechanism itself rather than through the operation of developers, and the features of being open, transparent, and traceable can quickly locate and pursue responsibility in the case of product problems. The above excellent features make blockchain technology an effective solution to the trust problem and provide important technical support to solve the cross-border transaction problem. The main contributions of this paper are as follows:

- The new model of combining blockchain and cross-entry supply chain is proposed to provide a feasible solution to the traditional cross-border cross-entry supply chain pain points.
- It proposes a dual-chain model for product transaction separation, which solves the problem of traditional blockchain supply chain information ecological silo.
- The changes in throughput with different numbers of nodes and transaction volume are tested, and effective module matching is proposed to support the business.

2 Related Work

2.1 Blockchain

After Satoshi Nakamoto proposed the concept of Bitcoin in 2008 and made it publicly available, blockchain technology also gradually entered people's view. The blockchain 1.0 period is represented by the decentralized concept of Bitcoin, which plays more of a distributed bookkeeping role; the 2.0 period is represented by the smart contracts of Ether, and in the upcoming blockchain 3.0 era, it is an era of comprehensive application of blockchain technology. Blockchain is essentially a decentralized distributed database, relying on peer-to-peer transmission, cryptography, algorithms, and other technological fusion to jointly secure the distributed ledger.

Weili Chen et al. [2] stand for the data type and environment to divide the blockchain into three horizontal and one vertical structures. As shown in Fig. 1, the three horizontals represent both the three key stages of blockchain development from1.0 to 3.0, and also divide the underlying technology. The one vertical represents the distributed environment throughout the blockchain architecture, which summarizes the blockchain as a distributed database with decentralization, immutability, traceability, and multi-party maintenance, which can establish trust without the need for a third-party centralized system.

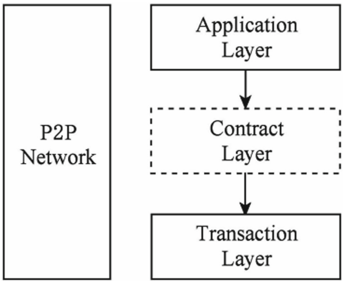


Fig. 1. Three horizontal and one vertical structures.

A block in blockchain is a storage unit. Blocks containing transaction information are connected in chronological order by pointers to form a blockchain, and blocks are composed of a block header and a block body. The block header includes parent hash, version number, mining difficulty, Merkle root hash, timestamp, and mining difficulty.

Meanwhile, blockchain is divided into three categories according to the access mechanism: public chain, Consortium chain and private chain. The public chain is open and transparent, and anyone has read and write access; the Consortium chain is open to specific organizations and groups, and read and write access is developed only to alliance members; the private chain read and write access is limited to a certain node.

2.2 Supply Chain Model

The traditional supply chain is a network of companies and departments that acquire and process materials into intermediate or finished products, and then deliver the finished products to users [3]. Ma Shihua et al. [4] proposed a supply chain cooperation method based on Shapley value for solving the revenue distribution problem among supply chain partners [5]. The supply chain management is a network consisting of suppliers, manufacturing and assembly plants, distribution centers, retailers, and end customers in the supply chain. Since the concept was introduced in the early 80s, the supply chain has developed greatly and can be divided into four levels according to the scope of coverage [6]: The Internal supply chain, Supply management, Chain structured supply chain and Mesh supply chain.

In recent years, with the popular application of blockchain technology, barcode technology and electronic fund transfer technology, blockchain technology provides technical support for new ideas in supply chain management. Naif Alzahrani et al. [7] proposed Block-Supply chain, which uses blockchain and near-field communication (NFC) technology to detect counterfeit attacks, replacing centralized supply chain design and balancing efficiency and security. Meanwhile, Thomas Bocek et al. [8] Abeyratne et al. [9] build a conceptual model of manufacturing supply chain management using blockchain technology, which guarantees the transparency and traceability of information and reduces supply chain management costs and operational risks. Srinivas Jangirall [10] et al. designed a blockchain and RFID-based authentication protocol for supply chains in 5G mobile edge computing environments to better trade-off the overhead of supply chain communication between security and computational cost, and improve the security of supply chain information transmission.

Supply chains exist in all service and manufacturing industries, but they differ greatly in structure and complexity [11]. However, compared with other fields, the research on the application of blockchain technology in the field of supply chain is not abundant. Most of the existing literature discusses the application of blockchain technology from a single perspective of supply chain finance or supply chain products, and the supply chain conceptual model or supply chain collaboration process model constructed in this way is rather thin, without exploring the specific application of blockchain consensus mechanism and smart contract in the field of the supply chain in depth [12]. The supply chain concept model or supply chain collaborative process model is thin, and does not explore the specific application of blockchain consensus mechanism and smart contract in the supply chain field.

This paper aims to use blockchain technology to build a dual -chain model of cross-border supply chain, to involve cross-border product-related parties as organizations in the alliance chain Hyperledger Fabric, to form an industrial environment of multi-party collaboration and win-win cooperation, and to adjust the inherent mode of blockchain consensus mechanism and smart contracts, so as to provide new ideas for the application of blockchain technology in supply chain information systems.

3 Blockchain-Based Supply Chain Framework

3.1 Model Overview

The cross-border supply chain system designed in this paper is an alliance chain Hyperledger Fabric platform with multiple participants and multiple maintenance, featuring decentralization, low deployment cost, and high scalability. Each organization node participating in the cross-border inventory system must first accept CA authorization from a third-party authority to read and write blockchain information, which raises the access threshold and reduces maintenance costs. In this system, each alliance chain node backs up an identical ledger, i.e., the public ledger, which makes the quality information and flow direction of each product in the supply chain transparent and cannot be modified. At the same time, the built-in multi-channel structure of Hyperledger Fabric can realize the data independence of different businesses, and each channel corresponds to a public ledger, which is maintained by the members in the channel, and the setting of the channel is also the basis for building a dual-chain model. Channel information is shown in Table 1.

Table 1. Blockchain information on the chain schematic.

Symbol definitions	Description
P = {P,P,P,P}	Channel node members
C = {C,C,C,C}	Channel
B = {B,B,B,B}	Block
T = {T,T,T,T}	Transaction
N	Blockchain network
O	Orderer nodes

The basic architecture of the blockchain-based cross-border supply chain dual-chain model is shown in Fig. 2. The dual-chain system is divided into five layers: application layer, contract layer, consensus layer, network layer, and data layer. The cross-border supply chain industry focuses on the win-win cooperation of organizations and the ability of the system to handle business. Value transfer and profitability are the common goals of organizations, so the cross-border supply chain dual-chain model eliminates the incentive layer and adds the contract layer for business processing compared with the traditional blockchain system. In the data layer, the cross-border supply chain is different from the traditional blockchain system in that it uses IoT collection devices to automate the information processing on the chain, which eliminates data loss and modification in the process of information collection and transmission, and at the same time, the dual-chain structure built to cooperate with the import, export and inventory business separates product information from transaction information to solve the problem of blockchain supply chain information ecological silo. The network layer encapsulates the networking method, information dissemination protocol, data validation mechanism, and other elements of the dual-chain system of inventory and sales, which is the basis for data tamper-evident. The contract layer serves as a data interaction medium with the application layer, logically processes requests sent by the application layer data, and returns the corresponding results. The application layer calls the chaincode to query and verify the data on the chain by calling the SDK to realize functions such as product traceability, logistics tracking and privacy protection, and is the interface between the system and the outside world. There are many kinds of cross-border supply chain business information, and in order to facilitate classification and verification, this paper divides them into the following two categories and defines them.

Definition 1 Cross-border supply chain information data mainly includes Cross-border Product Information (CPI) and Financial Transaction Information (FTI), CPI includes information on the attributes of the products themselves, including production time, quality grade, yield, quality period, etc., FTI includes information on contracts, invoices, financing, credit, and other related transactions. CPI includes product attributes, including production time, quality level, yield, shelf life, etc. FTI includes contracts, invoices, financing, credit and other related transaction information.

Definition 2 CPI is stored in the Cross-border Product Information Chain (CPIC); FTIC is stored in the Financial Transaction Information Chain (FTIC).

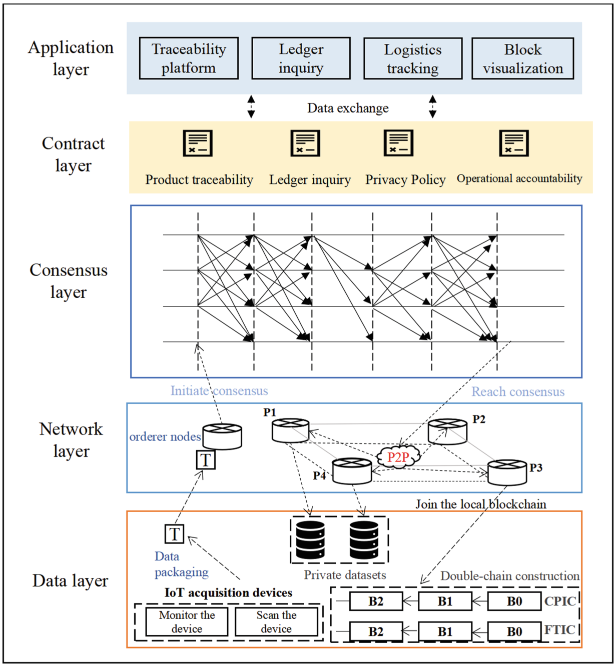


Fig. 2. Basic architecture of blockchain-based model for supply chain traceability.

3.2 Data Layer Module

Blockchain is a new software architecture to ensure the authenticity of data can only work in the blockchain network, and any step of product information from collection to transmission to the blockchain system may be modified. The data generated without relying on the support of hardware cannot ensure its original data authenticity. The model expands the scope of authenticity through the form of blockchain + IoT, so that the data is real and verifiable from generation to the whole chain, and after the external IoT node authorizes the read and write right, the product automatically records the data in the local network through the detection and scanning devices, and transmits it to the network layer through the local server, which receives the information After the package will be packaged into blocks and passed to other nodes in the channel to save.

In order to solve the problems such as confusion of books and difficulties in checking accounts, the model uses the dual-chain model of product information and transaction information, and the dual-chain model of blockchain-based inventory system can effectively isolate product information and transaction information and solve the problem of information silos in different chains. To solve the problem of information island on the chain, the system uses the cross-chain interoperability model and adds a relay organization to act as the medium of information interaction to achieve information separation without losing the internal connection of data, as shown in Fig. 3, the implementation of the relay organization is also based on smart contracts, and the cross-chain components formed by multiple smart contracts can realize data interaction between different chains. The implementation of relay organization is also based on smart contracts.

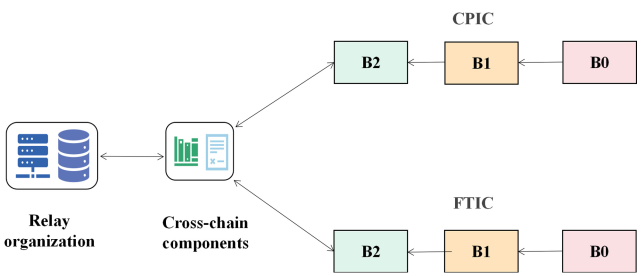


Fig. 3. Dual chain interaction model.

In the cross-border inventory system, there are some data that need to be recorded and not made public, such as the cost of raw materials produced by the original manufacturer should not be disclosed to consumers, the cooperation between processing plants and different distribution plants should not be disclosed to their peers, and the total amount of transactions between different organizations should not be disclosed, which need to be stored in the privacy data set in the network. For privacy data, the relevant participants will set up hardware sending routes in advance, and the information will not be sent to all nodes after collection by Orderer nodes but directly stored in the privacy database by privacy data authorizers and through Gossip protocol [13] It is sent to all authorized nodes, and only the privacy data hash value is provided to the public, as shown in Fig. 4, Organization 1 and Organization 3, where the authorized nodes are located, share a private dataset, while the unauthorized organization nodes only have the channel public ledger.

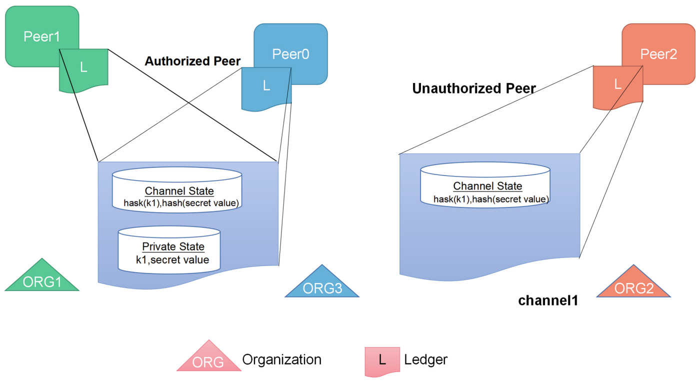


Fig. 4. Dual chain interaction model.

3.3 Network Layer

The network layer module contains the organization of node communication to synchronize the information uploaded from the IoT collection devices. All the nodes deployed by the supply chain participants need to communicate in a P2P network. As shown in Fig. 5, the relevant participants as nodes in the blockchain network upload the product information through the chaincode, and the Orderer node equipped with each channel sorts and packs the uploaded information submitted by the supply chain participants and then generates blocks and broadcasts them, and all nodes in the network receive the transaction blocks and verify the rationality, and after successful verification, they will connect with the local blockchain, and the block height increases and the uploading operation is completed.

3.4 Consensus Layer Module

Each node in the blockchain network can individually provide services for the application, preventing a single point of failure from affecting the normal operation of the entire supply chain system, and the consensus mechanism also ensures

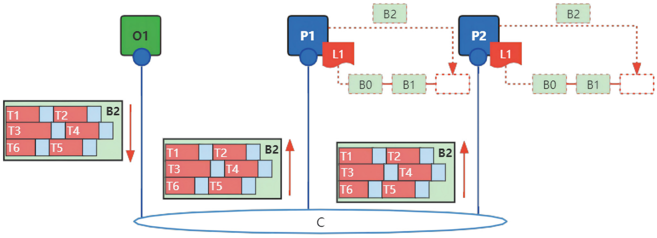


Fig. 5. Network layer module.

the uniqueness of the dual chain [14]. The model proposed in this paper uses the Paxos-based algorithm [15] An improved consistency algorithm Raft consensus algorithm in order to manage logs is the mainstream consensus algorithm for coalition chains and private chains.

3.5 Contract Layer

Smart contract is a computerized transaction protocol that requires no intermediary, self-verification and automatic execution of contract terms [16] As an important part of Blockchain 2.0, it can be flexibly embedded with various business functions in combination with cross-border supply chain scenarios to help realize secure and efficient information interaction, value transfer and information protection. As a middleware for business processing, the contract layer processes the requests issued by the application layer and data layer, which include product traceability, ledger query, privacy data inspection, logistics tracking, etc. The execution processing of the contract is embedded in the nodes of the blockchain bookkeeping function, and the requests arriving at the contract layer will be processed by the corresponding smart contracts and return the corresponding data, and the overall flow of contract invocation is shown in Fig. 6.

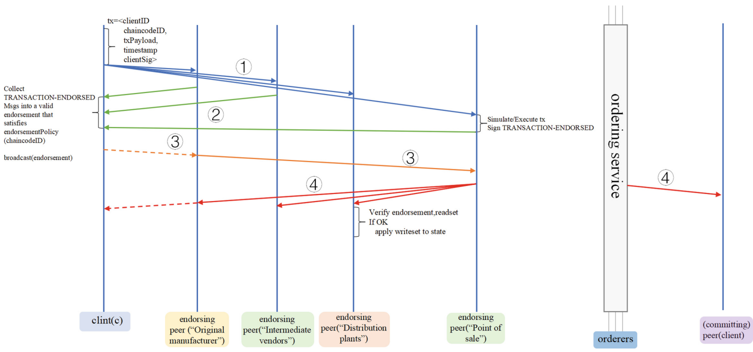


Fig. 6. Contract execution process.

1. The client initiates the transaction proposal, the backing node executes it and produces the signature. The transaction initiated by the client contains ¡ clientID, chaincodeID, txPayLoad, timestamp, clientSig¿ and other information sent to the endorser node in the organization node that has deployed the corresponding smart contract, and the endorser node simulates the proposal execution and produces its own signature.
2. The endorsement node returns the execution result with signature to the client. The endorsement node executes the proposal and packages it and returns the result to the client, which receives a certain number of returned results and executes the next step.
3. The client submits the transaction. The client receives enough endorsement results to combine the proposal, the results, and its own signature into one transaction to send to the Orederer node, which sorts and packages the submissions.
4. Commit. the sort node broadcasts the sorted packed blocks to all nodes in the organization.

There are more entities involved in the cross-border inventory system, and the business needs of different entities are different. In this paper, the participants are divided into five categories by analyzing the cross-border inventory process, and the process and the functions of each participant are shown in Fig. 7.

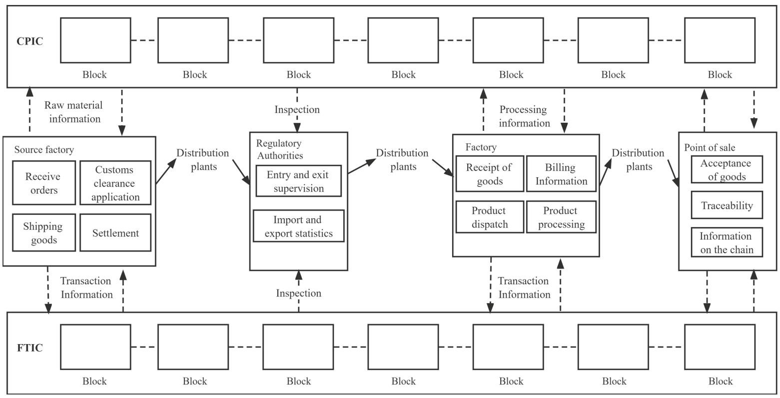


Fig. 7. System flow and each organization function diagram.

3.6 Application Layer

The application layer mainly realizes the interaction function between the terminal and the user, converts the interfaces provided by the outside world, such as traceability interface and book checking, into requests to the server side, and the server side returns the corresponding results. For example, if a consumer receives a product and wants to verify whether its origin is shown in the logo, the user only needs to input the product traceability code in the import and export platform, and the underlying business will return all information of the product after processing.

By Postman simulating the application layer to accept the request and return the query supply chain system product block information, the following information can be returned by selecting the product traceability code as DF-001 json values: “date”: [“Key”: “DF-100”, “Record”: “Date”: “2022-06-04 20:19:42”, “Id”: “DF-100”, “Name”: “Jiangxi Nanchang”, “ObjectType”: “proObj”, “ProdutName”: “Pure Milk”, “Quality”: “Excellent”, “State”: “1”, “Transaction Hash”: “a9e8f73a477004cbc57654bf5ef28a03d88ec26cb62774a45c6954ed5d1fbdea”], the transaction ID indicates the summary of the transaction that enables the traceability of this product.

4 Analysis of Experimental Results

4.1 Test Indicators

In order to test the effectiveness of the blockchain-based dual-chain model proposed in this paper, the information storage and query of this system under the supply chain scenario is tested using Caliper, a performance testing plug-in, and the methodology of the simulation experiment will be described in detail in Sect. 4.3. The experimental test metrics are throughput (Transaction Per Second, TPS) and average latency (average latency. AL) as the metrics to evaluate the efficiency of information storage and query, and the relevant values are calculated as follows.

$$T_{\Delta t} = \frac{M_{\Delta t}}{\Delta t} \tag{1}$$

$$AL = \frac{T_{\max} + T_{\min}}{2} \tag{2}$$

where M indicates the total number of transactions processed by the t time model and transaction latency.

This chapter tests the model's resource consumption, throughput variation, and average latency variation by modifying the number of nodes and the amount of data in the test dataset.

4.2 Test Environment

This paper builds a supply chain based on blockchain model based on the Hyperledger Fabric federated chain framework, writes smart contracts using Golang programming language and integrat, es them into chaincode, and the chaincode containing multiple smart contracts is deployed in the blockchain network in the following experimental environment: virtual machine Ubuntu 20.04 64-bit, Fabric 2.2, Docker 20.10. 16, Golang 1.17.5, Caliper 0.42, a 1.10 GHz Intel Core i7-10710U CPU computer. The Fabric network is simulated to run through Docker containers, and the Docker containers launched during the experiment are shown in Table 2. The cross-border import and export system consists of multiple organizations, and for the convenience of simulation, each organization consists of a Peer node, an Orderer node, CouchDB as the database to store transaction information, and Caliper as the tool to test the performance.

Table 2. Docker containers started during the experiment.

Docker Container name	Quantity	Function
Fabric-Peer	4	Client to initiate a trade request
Fabric-Orderer	4	Transaction orderer nodes
Fabric-CouchDB	4	Transaction storage database
Caliper	1	Blockchain performance testing

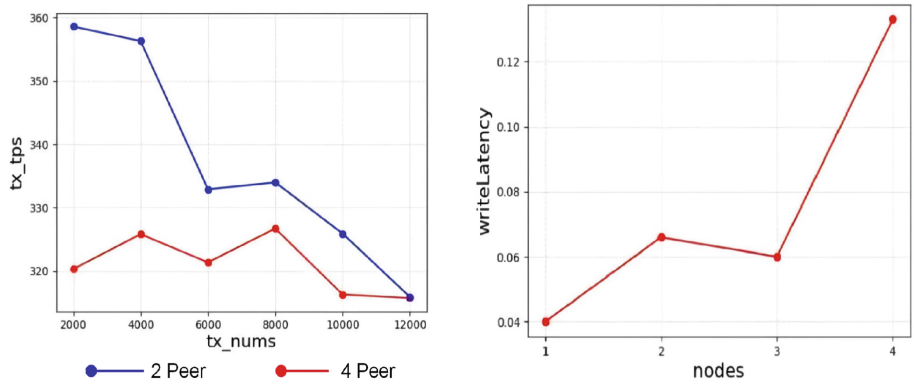
4.3 Efficiency Testing

In order to test the write throughput and average latency of the model under the condition of different alliance chain nodes, two sets of test datasets were created, and 2000, 4000, 6000, 8000, 10000, and 12000 transactions were initiated by Caliper to an organization node with a guaranteed write success rate of 100%, and in order to avoid experimental accidents, each experiment was repeated 5 times to obtain the average. Avoid experimental chance, the results are shown in Fig. 8a), it can be seen that when the number of nodes is 2, the transaction TPS is stable above 300 transactions/s. The throughput decreases more significantly, when the throughput in each data volume case is less than 2 nodes, but still can maintain above 300 transactions/s. As shown in Fig. 8b), the response time of system writes increases with the number of nodes, and the system latency can reach below the second level.

The resource consumption when recording the maximum throughput is shown in Table 3. The hardware consumption of the components in the model is not high, which can meet the deployment requirements in the actual cross-border supply chain scenario.

Table 3. Resource consumption at maximum throughput.

Node type	Cup% (avg)	Memory (avg)
Peer	31.05	82.2
Orderer	5.25	20.5



a) Throughput with different. b) Write latency with different nodes.

Fig. 8. Performance chart

Table 4. Model Comparison.

System model	Article [17]	Article [18]	Article [19]	Article [20]	Model of this article
Decentralization	No	Yes	Yes	Yes	Yes
Control access	No	Yes	Yes	Yes	Yes
Privacy Protection	No	No	Yes	Yes	Yes
Gas consumption	No	No	Yes	No	Yes
IoT devices	No	Yes	No	No	Yes

Different information storage methods have a greater impact on the query efficiency, the system query is achieved by key-value pairs efficiency graph shown in 10, from the graph it can be seen that the number of nodes has a greater impact on the query throughput, when the number of nodes is 4, the query throughput is 40TPS (Table 4).

Article [19] is a traditional inventory management model where control access does not exist at the system level and requires manual processing arrangements based on actual business, Article [20] equipped with IoT collection devices but not equipped with private datasets for supply chain information, private data cannot be handled, Article [21] The blockchain framework used is Ether, and transaction fees need to be submitted for each Article [22]. The literature is equipped with privacy protection module, but the source of information cannot be guaranteed to be true and accurate.

5 Conclusion

Blockchain technology is in the development stage, and how to realize industrial combination is the focus of the industry. In this paper, we propose a blockchain-based inventory dual-chain model for cross-border inventory problem, which solves the problems of easy data tampering, opaque information and confusing books of the traditional inventory system, promotes the cooperation among global enterprises and improves business efficiency. Experiments show that the blockchain-based inventory dual-chain model has the ability to carry current inventory commercial capabilities. At present, IOT collection devices cannot automatically chain information, and the collection devices are unstable and vulnerable to attacks. In order to realize the direct chain of information, it is necessary to design a blockchain-specific module/chip, so that the blockchain can be deeply integrated with the IoT to realize automated and credible data collection, and in the future, it will be deeply combined with IoT devices to realize fast, low-latency and low-cost data credible chain of terminal devices.

Acknowledgements. This work is supported by the No. 62262030, 62067003, National Natural Science Foundation of China (NSFC) under Grant No. 61962026, the National Natural Science Key Foundation of China grant No. 61832014 and No. 62032016, the National Natural Science Foundation of China under Grant No. 62002143, the Natural Science Foundation of Jiangxi Province under Grant No. 20192ACBL21031 and the Foundation of Jiangxi Educational Committee under Grant No. GJJ210338.

References

1. Mi, Y.: Research on the optimization mechanism of cross-border e-commerce development model in china—based on the perspective of supply chain. Bus. Econ. Res. 136–140 (2022)
2. Chen, W., Zheng, Z.: Blockchain data analysis: status quo, trends and challenges. Comput. Res. Dev. **55**, 1853–1870 (2018)
3. Lee, H.L.: Material management in decentralized supply chains. Oper. Res. **41**, 835–847 (1993)
4. Ma, S.: Income distribution mechanism among supply chain partners based on Shapley's value method. Industr. Eng. Manage. **2006**, 1007–5429 (2006)
5. Chu, C.: Supply chain management: problems, determinants and implementation strategies. In: Proceedings of the First China- Japan Joint Conference on Industrial Engineering and Management, pp. 135–142 (1998)
6. Harland, C.: Supply chain operational performance roles. Integr. Manuf. Syst. **8**, 70–78 (1997)
7. Naif, A.: Block-supply chain: a new anti-counterfeiting supply chain using NFC and blockchain, pp. 30–35. Association for Computing Machinery (2018)

8. Bocek, T., Rodrigues, B.B., Strasser, T., Stiller, B.: Blockchains everywhere - a use-case of blockchains in the pharma supply-chain. In: 2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM), pp. 772–777 (2017)
9. Abeyratne, S.A.: Blockchain ready manufacturing supply chain using distributed ledger. Int. J. Res. Eng. Technol. **5**, 1–10 (2016)
10. Jangirala, S., Das, A.K., Vasilakos, A.V.: Designing secure lightweight blockchain-enabled RFID-based authentication protocol for supply chains in 5g mobile edge computing environment. IEEE Trans. Industr. Inform. **16**(11), 7081–7093 (2020)
11. Gupta, S.: Supply chain management in complex manufacturing. IIE Solut. **5**, 18–23 (1997)
12. Yang, H.: Construction of mutual trust and win-win supply chain information platform based on blockchain technology. Sci. Technol. Progr. Countermeas. **35**, 21–31 (2018)
13. Jelasity, M., Voulgaris, S., Guerraoui, R., Kermarrec, A.-M., van Steen, M.: Gossip-based peer sampling. ACM Trans. Comput. Syst. **25**(3), 8-es (2007)
14. Castro, M., Liskov, B.: Practical byzantine fault tolerance. In: Proceedings of the Third Symposium on Operating Systems Design and Implementation, OSDI 1999, USA, pp. 173–186. USENIX Association (1999)
15. Zhao, W.: On the quorum requirement and value selection rule for fast paxos. In: 2014 IEEE 5th International Conference on Software Engineering and Service Science, pp. 406–409 (2014)
16. He, P.: A review of blockchain technology and application prospects. Comput. Sci. **44**, 1–7+15 (2017)
17. Zhou, Y.: Design and implementation of invoicing inventory management system based on spring cloud microservice architecture. Industr. Control Comput. **31**, 129–130+133 (2018)
18. Shao, H.: Research on supply chain traceability model based on blockchain. J. Jiamusi Univ. (Nat. Sci. Edn.) **40**, 62–65 (2022)
19. Zhang, C.: Design of supply chain traceability system based on side chain technology. Comput. Eng. **45**, 1–8 (2019)
20. Yu, H.: Research on traceability information protection model of mybibliographyrice supply chain based on blockchain. Trans. Chin. Soc. Agric. Mach. **51**, 328–335 (2020)