

Research Article

Contract Design for Cloud Logistics (CL) Based on Blockchain Technology (BT)

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Purpose. This paper aims to design the contract and present the profit distribution mechanism for CL platform, so as to realize the intelligent and automatic operation of the artificial intelligent- (AI-) based CL platform. *Design/Methodology.* A smart contract based on BT is designed for the AI-based CL platform. Profit distribution mechanism based on the Nash bargaining model for the CL platform is also put forward to coordinate different participators' benefit relationship in CL. *Findings.* The AI-based CL platform and the proposed smart contract based on BT map the scenario which may be influenced by human factors and involve trust issues onto execution of codes. *Practical Implications.* The study will help CL practitioners in establishing effective profit mechanism and designing contracts on the platform, thus facilitating its sustainable operation. *Originality/Value.* The AI-based CL platform with BT smart contract can be totally free of human intervention, and hence, the problems of trust during CL platform's operation are solved.

1. Introduction

Logistics industry has been the third source of profit after saving resource and cutting human cost. However, due to low level of information sharing, logistics industry in China shows the characteristics of low service capability and high cost [1]. The cost of logistics accounts about 17.8% of GDP in China, which is much higher than that of developed countries [2]. Considering the advantages of cloud computing and characteristics of logistics industry, there are natural interlinks between them. Applying cloud computing into logistics industry is able to solve the aforementioned problems in logistics industry. Therefore, a new service-oriented mode of logistics based on cloud computing, named cloud logistics (CL), has been put forward, and especially, we have proposed an AI-based CL platform [3]. Compared to earlier CL platforms, the AI-based cloud logistics platform is totally automatic and without human intervention. Built-in algorithms are invoked to implement all the procedures required on the platform.

As the operation of CL platform requires participation of a number of enterprises or individuals who are service requesters or resource providers of logistics service, or both, there exists complicated conversion of elements and problems in service quality assurance and credibility. Meanwhile, as resources of logistics services on the CL platform are scattered and vary in size and structure, trust mechanism is hard to be established among participators on the platform. Therefore, an intelligent mechanism must be established to minimize or even remove the credit crisis between anonymous participators of the AI-based CL platform. Traditional solution is membership, such as Alipay. However, membership is still with the 3rd party human intervention, security, and reliability of which are thus limited and cannot satisfy requirements of the AI-based CL platform. The AI-based CL platform is an automated platform without human intervention. The contract in the AI-based CL should also be intelligent, automatic, and reliable without the 3rd party guaranty or credit crisis. Obviously, BT provides a possible solution for designing a reliable and smart contract mechanism. BT has emerged in the recent

years that is artificial intelligent-based and decentralized with the 3rd party guaranty contract mechanism. BT is a distributed database of records or shared public/private ledgers of all digital events that have been executed and shared among blockchain participating agents [4]. It is different from most existing information systems in the following four characteristics: decentralization, security, auditability, and smart execution [5]. There are three types of blockchains: public, consortium, and private. The consortium blockchain is used in this research. As the script on blockchain, smart contract is executed in different subsections, similar to laws and regulations applied in transactions and contracts. Based on terms and conditions agreed in advance, smart contract can be conducted in security, credibly, and on demand, as well as under supervision. However, the proposed smart contract used in the AI-based CL platform is not exactly the same as the conventional BT. Decentralization is an important property of the BT, and it involves two parties of a transaction and is without the 3rd party guaranty, whereas the proposed smart contract in the AI-based CL platform involves three parties: the platform, resource providers, and AI algorithm of CL platform. The proposed smart contract is based on BT but is monitored and managed by the AI algorithm of CL platform or the so-called robot.

The main contribution of the paper is to present an AI-based CL platform which adopts the centralized model and Nash bargaining model to realize the intelligent and automatic operation of the AI-based CL platform. By this the AI-based CL platform, it solves the problems of information sharing and safety in the current CL platform. Contributions of this paper include the following: (1) a smart contract for the AI-based CL platform is designed. (2) Execution procedures of the smart contract for the AI-based CL platform are also provided in detail. (3) Profit distribution mechanism based on Nash bargaining model for the AI-based CL platform is put forward to coordinate different participators' benefit relationship in CL, which is essential for the proposed smart contract's execution.

Protecting the commercial sensitive information of the participators in CL platform is critical for the success of the CL platform. The AI-based CL platform is free of human intervention, which can protect the information sharing and safety. Therefore, we design such an CL platform based on heuristics rules, which we call it as AI-based CL platform. Framework of the AI-based CL is shown in Figure 1. There are mainly three types of participators involved in the AI-based CL, which are operators of the platform, service demanders, and resource providers. All the allocation and scheduling of logistics tasks and resources are done on the AI-based CL platform through its built-in algorithms, which are intelligent and automated without human intervention. Both resource providers and service demanders are anonymous to each other and will be satisfied with the scheduling and allocation of the AI-based CL platform. Resource providers issue and offer the detailed information of these extra resources, and the CL platform will then store the information in its resource pool. Meanwhile, service demanders send their service tasks to CL platform through

computers or smart mobile phones. The platform will store the demand information in the task pool.

It is free of human intervention; i.e., virtually a robot makes decisions. Meanwhile, to realize the "AI-based" robot decision-making process, the contract in the AI-based CL should be intelligent, automatic, reliable, and without the 3rd party guaranty or credit crisis. BT provides a promising solution for designing a reliable and smart contract. Consequently, the proposed profit distribution mechanism can be realized and implanted into smart contract's execution algorithm so that the platform can operate intelligently and automatically.

The rest of this paper is organized as follows: Section 2 is a literature review which provides the basis of our research. Section 3 presents the smart contract designed for the AI-based CL platform. Section 4 provides the profit distribution mechanism necessary for the proposed smart contract's execution. Section 5 is a conclusion.

2. Literature Review

As to our best knowledge, there has not been found any paper which addresses the work as presented in this paper. However, there are some related papers which have been used as references in our research and are briefly discussed as follows.

2.1. BT and Smart Contract. BT is a distributed database of records or shared public/private ledgers of all digital events that have been executed and shared among blockchain participating agents [4, 5]. In recent years, as decentralized cryptocurrency, such as Bitcoin [6], Ethereum [7], Zcash [8], has become hot, BT as the underlying cryptocurrency has attracted a lot of attention [9]. Focusing on private blockchains, Dinh et al. [10] present BLOCKBENCH, a benchmarking framework for understanding performance of private blockchains against data processing workloads, and conduct a comprehensive evaluation of 3 major blockchain systems based on BLOCKBENCH. Babich and Hilary [11] identify 5 key strengths and corresponding 5 main weaknesses, as well as 3 research themes of applying BT to operation management (OM). BT has been widely used in different areas. Li et al. [12] conceptualized a blockchain-based decentralized framework for crowdsourcing named CrowdBC, in which a requester's task can be solved by a crowd of workers without relying on any third trusted institution. Xu et al. [3] apply blockchain application design approaches in a project called OriginChina. OriginChina is a traceability system based on BT, which restructures the current system by replacing the central database with blockchain. Zu-Jun et al. [13] employ BT into digital rights management. Their proposed BT-based scheme provides trusted and high-level credible content protection and conditional traceability of violation content service. Dorri et al. [14] propose a memory optimized and flexible blockchain (MOF-BC) for large-scale networks. The MOF-BC enables the users and service providers of Internet of Things (IoT) to remove or summarize their transactions and

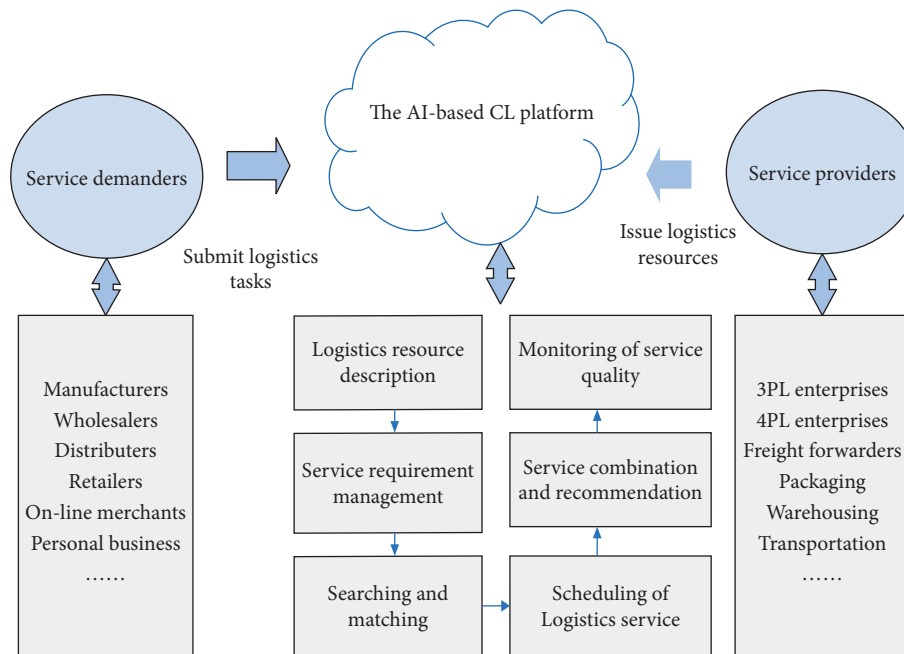


FIGURE 1: Framework of the AI-based CL.

age their data, so as to ensure privacy. Wang et al. [15] propose a framework for data sharing which combines the decentralized storage system interplanetary file system, the Ethereum blockchain, and attribute-based encryption technology.

Regarding BT adopted in logistics or supply chain management, Kamble et al. [16] develop a statistically validating model for understanding user perceptions on BT adoption in supply chain. Their study implies that the supply chain practitioners perceive BT adoption free of efforts and would help them derive maximum benefits for improving the supply chain effectiveness. Wang et al. [9] explore how BT may transform supply chains. They identify areas where blockchain may penetrate in supply chains, namely, supply chain tracing and tracking, supply chain disintermediation, simplification, and digitalization of supply chain process and smart contract. Saberi et al. [5] examine the potential application of BT and smart contracts into supply chain management. They put forward four BT adoption barriers, which are interorganizational, intraorganizational, technical, and external barriers. Montecchi et al. [17] propose to implement BT in supply chain to increase customers' knowledge of products' provenance. Casado-Vara et al. [18] propose a new model of supply chain based on BT, which enables the concept of circular economy and eliminates many of the disadvantages of current supply chain. Choi [19] highlights the values of BT supported platforms for diamond authentication and certification. They build models and examine both the traditional retail network operations and the BTS selling platform.

Choi et al. [20] discuss how the mean-variance approach can be applied to explore global supply chain operations risk with air logistics in the blockchain technology era. They propose how BT can be applied to facilitate the

implementation of mean-variance risk analysis for global supply chain operations. Galvez et al. [21] report the application of BT to solve traceability issues and ensure transparency in food supply chain management and they examine future challenges in it. Polim et al. [22] consider BT as an appropriate tool to search and negotiate a logistics contract. They propose a decentralized retailer-logistics provider lodger based on BT.

With the advent of BT, smart contracts have become one of the most sought-after technologies due to its high customizability they add to transactions. Smart contracts have been widely used in more and more areas, such as financial services [23], electricity transaction [24], tea trading [23], crowdsourcing [12], supply chain management [15], and healthcare [25]. Nugent et al. [25] describe a method based on BT to prove the existence of documents providing prespecified endpoints in clinical trials. They use smart contracts to extent the idea, which are code and data residing at a specific address in a blockchain. Wang et al. [9] propose potential applications of BT-based smart contracts in automatic validation of shipments, automated track-and-trace, and multiagent validation for information checking in supply chain management. Based on the Hyperledger fabric blockchain platform, Chen et al. [26] explore the smart contract and provide the taxation-scenario design of the smart contract, as well as its implementation model and description of the Go language contract. Liu [23] proposes a tea trading model based on smart contract of the blockchain, which enables no need for human intervention during implementation. Gan [27] designs a smart contract-based model for local energy micronetwork transaction, providing an idea for the application of BT to the pilot project of distributed energy market. Sheng et al. [28] propose a blockchain smart contract-based data capitalization method

for Internet of Things to meet the challenges when ascertaining data ownership, dealing with the inefficiency of quantification and value transfer of digital asset.

In short, BT and smart contract have been gaining increased attention of researchers and practitioners. Some related research work has been done by scholars from various areas. However, there have been no related studies of BT and smart contract's application in CL by far. One of the key issues for the success of cloud logistics is how to protect the commercial information of these logistic companies when they use the cloud logistics to deal between each other. The smart contract of BT provides a good protection of the information since the BT-based contract does not need the identification of the contractors. Furthermore, in terms of BT, the cloud logistics can be designed as a robot dealer which does not need human interference. Therefore, BT-based smart contract becomes a key technology for the success of cloud logistics.

2.2. Contract Design in Logistics and Supply Chain Management. Contract design in logistics and supply chain has been fully studied. Many studies have dealt with the problem from different perspectives and for different scenarios. Raj et al. [29] study coordination issues of a sustainable supply chain that arise due to simultaneous consideration of greening and corporate social responsibility initiatives undertaken by supply chain agents. Different contract types are used to analyze the decentralized supply chain setting based on two-stage Stackelberg game-theoretic approach. Zhu and Fung [30] apply the principal-agent theory to the logistics industry by studying the horizontal cooperation between 4PL and 3PL providers through the use of incentive contracts. Chen et al. [31] consider the cooperation effort between an integrated enterprise and the other logistics service providers and propose a new profit distribution model based on principal-agent theory. Jouida et al. [32] study the coalition-formation problem for sourcing contract design in supply chain networks. Seifbarghy et al. [33] address the problem of contract design in a supply chain considering price and quality-dependent demand with customer segmentation. They design the retailer's revenue sharing contract and found the optimal values of wholesales price and quality degree. Wu et al. [34] study coordinating contracts for fresh product outsourcing logistics channels with power structures. Their study indicates that the power structures have an important contract design, each firm's decision behaviors and channel performances. They also develop two novel incentive mechanisms to coordinate the decentralized channel considering risk preference of the TPLSP. Cai et al. [35] develop an option contract to improve the performance of a VMI supply chain under yield uncertainty. Hu et al. [36] propose five typical contracts to coordinate decentralized reverse supply chains with strategic recycling behavior of consumers. Zu-Jun et al. [13] investigate interactions among different parties in closed-loop supply chain, and they found that cooperative strategies can lead to win-win outcomes and increase an alliance's profit. Selvaridis and Norrman [37] empirically explore key

challenges of adopting, designing, and managing performance-based contracts for advanced logistics services, as seen from a service provider viewpoint. Some of the challenges include customer and provider intention to align their goals and incentives as well as their views on risk and reward sharing. Zheng et al. [38] address the problem of how to make decisions on pricing, collecting, and contract design in a reverse supply chain with incomplete information. Kouvelis and Zhao [39] study supply chain contract design with one supplier and one retailer, both of which are under financial constraints and in need of short-term financing for their operations. He [40] analyzes different supply risk sharing contracts and derives equilibrium between the recycling price decision and the remanufacturing quantity decision based on game-theoretical models.

As seen from the above, there are plenty of research on contract design for logistics and supply chains under various considerations. However, as far as supply chain coordination under CL situation is concerned, no related research has been found. Moreover, there is no paper found to meaningfully address smart contract in CL in general and AI-based CL in particular. This paper aims at the research gap by understanding the adoption of smart contract into AI-based CL platform, as well as designing the profit distribution mechanism for the AI-based CL platform. The study will help CL practitioners in establishing effective profit mechanism and designing contracts on the platform, thus facilitating its sustainable operation.

3. The Smart Contract for the AI-Based CL Platform

In this section, a smart contract based on BT is designed aiming at the logistics service process on the AI-based CL platform. The execution procedure for smart contracts of the CL platform is also provided and explained.

3.1. Overview of Smart Contract. The term smart contract is generally understood as a computer protocol that automatically facilitates, executes, and enforces a contract being mutually agreed and set between two or more counterparties, removing the need for contractual clauses and resource to the law [41]. Smart contracts replace the trusted third parties (the intermediaries between contract members) with the help of automatic code execution that is distributed and verified by the network nodes in a decentralized blockchain network. From the perspective of users, smart contract is an automatic account which will be executed automatically once the preset condition is satisfied. A smart contract usually includes a mechanism of transaction processing and saving and a complete state machine to receive and process various smart contracts, while the saving and processing of transactions are conducted on blockchains. Invoking a smart contract requires satisfying the trigger conditions. Once the conditions are met, preset data resource will be sent from code of the smart contract. The important characteristics of smart contracts are that the input of smart contracts is a set of affairs, and the output

after processing is also a set of affairs. The general model of smart contracts is shown in Figure 2.

As shown in Figure 2, a smart contract can be seen as a set of promises defined by digital codes, while these promises are rights and responsibilities of different parties involved in the contract. A sales contract is taken as an example. The vendor promises to forward the goods, and the vendee promises to pay for the goods. In this transaction, statements of “If-Then” are included; that is, if the vendor forwards the goods, then the vendee will pay. Once the condition is satisfied, the contract will be executed automatically with no human intervention. Smart contracts are able to enable transactions between untrusted parties without any intermediary commission fees, the third-party dependence, and the need of mutual interaction directly of the counterparties [42, 43]. Considering all these characteristics of a smart contract, it is quite suitable and applicable for the AI-based CL platform, which is fully automatic and no human intervened in execution.

3.2. The Smart Contract for the AI-Based CL Platform. A smart contract is designed aiming at the logistics service process on the AI-based CL platform. Figure 3 demonstrates the execution procedure for smart contracts. When the CL platform receives the triggering affair of relative code, the code will be read and called from the database (similar to blockchain) in the platform, and the smart contract for logistics service will be triggered to be executed.

In the service chain of CL platform, information such as demands, resources, and transactions of logistics services will be recorded in the database of the platform. Capital transfer and check of its usage in each process are implemented through the jointly agreed (users’ registration on the CL platform means to agree on the terms of the contracts) and automatically executed smart contracts. The record and supervision of the reliable database based on BT are without human intervention, so that users do not need worry about issues of trust during the process of service delivery such as reliability of services and safety of capitals. Users (both service requesters and service providers) join the logistics service chain through the CL platform, and their behaviors will be tracked and recorded by the platform to ensure the proper operation of the platform, as well as the ordering and standardization of logistics services.

The use of smart contract allows entities to write specifications for conditions where funds can be stored and transformed based on other affairs [44, 45]. As shown in Figure 3, three parties are involved in the execution of a smart contract for the AI-based CL platform, which are service requesters, resource providers of logistics services, and the CL platform. Therefore, a distributed shared network with information interaction is firstly designed and nodes of which are main bodies from service requesters and resource providers of logistics services. They are also differentiated according to their roles and thus given the role-based access. After that, the information interaction will be recorded onto the reliable database based on timestamp, which is tamper resistant, similar to

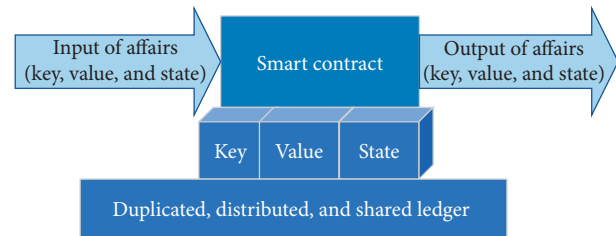


FIGURE 2: General model of a smart contract.

blockchains. Secondly, in view of capital transfer among different nodes during the service providing process, corresponding profit distribution mechanisms and incentive and penalty mechanisms should be designed, thus formulating the smart contract for the AI-based CL platform. Various affairs in reality will trigger the smart contract and invoke its automatic execution, which results in the transfer and ownership of capital among different parties. These smart contracts introduce many opportunities to implement and enforce rules on financial transactions without depending on trusted-third parties. Instead of human monitoring, mechanical execution of codes in smart contract provides a logistics service provision mechanism which is transparent and detrusting, and no human intervened. Detailed steps of the execution procedures of smart contracts for the AI-based CL platform is as follows (shown in Figure 3):

Step 1: users, both service requesters and resource providers of logistics services, register on the platform. Their registration is also considered as agreeing on the terms and signing the contract.

Step 2: both service requesters and resource providers submit their information to the CL platform, which, respectively, formulates the task pool and resource pool in the database of the platform. Meanwhile, all users should pay a certain amount of deposit, in case of their breach of contract. Transaction fees paid by users is locked. The CL platform accepts all the information submitted by users and conduct the service-resource matching through the built-in scheduling algorithm.

Step 3: the platform then determines if the task has been completed up to the standard regulated by the contract. If “Yes,” meaning conditions of agreement being satisfied, then the profit distribution mechanism is triggered. If “No,” the platform will judge why it happens. Corresponding processing mechanism follows. Incentive and penalty mechanisms in the smart contract are in effect to deal with the breach. At the same time, rematching of service and resource is conducted.

Step 4: upon the completion of a service task and triggering of the profit distribution mechanism, the locked transaction fees are then unlocked, and corresponding fees are paid into accounts of the CL platform and resource providers of logistics services.

Step 5: deposit from users, both service requesters and resource providers of logistics services, is released.

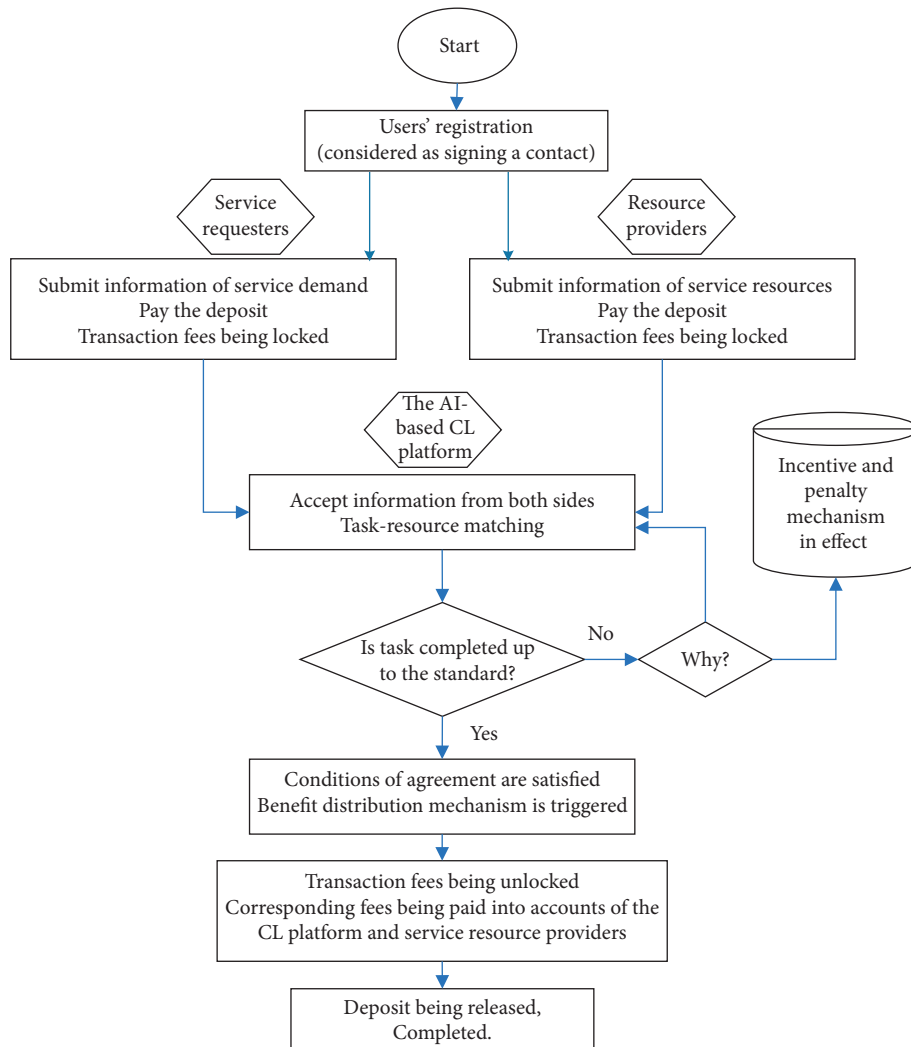


FIGURE 3: Execution procedures of the smart contract for the AI-based CL platform.

As described above, a smart contract for the AI-based CL platform includes the following functions:

- (1) Main function of the contract: once the contract is issued, only the function with the same name in the contract will be executed automatically. Therefore, main function should have the same name with the smart contract so that issuing the contract meaning initialing a transaction. The main function is used to realize the basic structure of the smart contract.
- (2) Function of guarantee for transactions: a certain amount of deposit will be deducted from registered users, both service requesters and resource providers, in case of false information of service demand or resources, or other breach of the contract.
- (3) Logistics service provision function: the function of logistics service provision is related to the CL platform. According to the feedback of service provision from the CL platform, it will determine whether the provided resource of logistics service is true, and whether it fulfills the task issued by service requesters as stipulated by the contract. If the return value is true, the following step of profit distribution will be called.
- (4) Penalty function: on basis of the designed penalty mechanism, penalty function is called when certain conditions are met during behavior monitoring. For example, in view of the issued information from users, if they are withdrawn out of given time fencing, or if the service task is not fulfilled as stipulated by the contract, penalty function will be invoked. A certain amount of penalty will be taken away from relative account, so as to minimize the loss to the platform brought by the breach of the contract.
- (5) Query function: when the contract expires, query function returns the result of whether the resource provider has completed the task by contract through inquiries of transaction information.
- (6) Profit distribution function: when logistics service provision function returns the value of true, profit distribution function will be called and corresponding amount of money will be taken off from

service requesters onto account of CL platform and service providers. Value of true will be returned to initial the next step after profit distribution has been finished.

- (7) Function of releasing deposit: the function of releasing deposit will be called when profit distribution function returns the value of true. Deposit from service requesters and service resource providers will be returned to their accounts, respectively, meaning the successful completion of the service transaction.

3.3. Discussion. Smart contracts are essentially containers of codes that encode and mirror the real-world contractual agreements in the cyber realm. A smart contract for the AI-based CL platform is designed, and as described in its execution procedures, two kinds of mechanism are essential for the design and execution of the smart contract, which are incentive: penalty mechanism and profit distribution mechanism. Here are some discussions about the two mechanisms.

As far as incentive and penalty mechanism is concerned, when designing the smart contract for the AI-based CL platform, all behaviors, such as the breach of the contract, as well as some behaviors taking advantages out of the platform while adversely affecting the application and sustainable development of the CL platform, must be taken into account. For example, once submitting their information of service demand or resources of logistics services, registered users can withdraw during a given time fencing. However, they cannot go back on it and withdraw out of the time fencing; otherwise, the penalty mechanism in the smart contract will be triggered, and a certain amount of money will be taken away as a penalty to compensate the platform for a loss in seeking alternative information. On the contrary, users' behaviors taking advantages of the CL platform which adversely affect sustainable development of the platform should also be considered while designing the smart contract. For instance, some users may find that CL is a useful platform to undertake logistics tasks, and they may exploit an advantage that they only accept task from customers and submit them to the CL platform while contributing no resources to the resource pool. In this way, they obtain low-cost logistics services, which provides them with competitive advantage over other logistics companies. Therefore, corresponding preventive measures are necessary to be involved into the penalty mechanism. Monitoring of users' behavior is required. Once such kind of behavior being identified, the penalty mechanism in the smart contract will be triggered. Meanwhile, incentive mechanism should also be designed to make sure service providers would make efforts to provide logistics services of high quality.

Profit distribution mechanism is the most important mechanism in designing the smart contract for the AI-based CL platform since it deals with the core problem of profit distribution of the platform concerning the normal operation and long-term development. Establishment and design of profit distribution mechanism based on Nash bargaining is detailed in the next section.

4. Profit Distribution Mechanism for the AI-Based CL Platform

4.1. Problem Description and Model Hypothesis. The benefit model for cooperation between the AI-based CL platform and resource providers of logistics service is analyzed from the two scenarios: decision-making of decentralization and centralization. Variables are defined as follows in Table 1.

In the scenario of decentralized decision-making, the CL platform only outsources logistics services from service requesters to resource providers, and there is no substantive cooperation among them; that is, resource providers provide logistics services for the CL platform, and the CL platform provides logistics services for service requesters. The prices of logistics services set by the CL platform and resource providers of logistics services will make an impact on demand for services, which is negatively correlated. The higher the price, the lower the demand from service requesters, and vice versa.

In the scenario of centralized decision-making, the CL platform still outsources logistics services to resource providers. However, under this condition, prices of logistics services will change thus influencing quantity of demand. There is substantive cooperation between them.

Although there are many models or theories for profit distribution, such as the Stackelberg model, principal-agent theory, and theory of Shapley value, the Nash bargaining model is most reasonable and appropriate for the CL platform. Assumption for the Stackelberg model is that there exists one leader and one follower in the game, while in the scenario of our CL platform, such assumption does not hold. Profit distribution based on principal-agent theory is to solve incentive problem under information asymmetry, which is not the problem in the CL platform either. And the Shapley value provides solution for profit distribution among 3 or more participators, while only 2 parties, the CL platform and resource providers of logistics services, are involved in this problem. As seen from above comparisons, these mentioned models or theories are not applicable for the profit distribution problem on the CL platform. The Nash Bargaining model is a classic and well-established model to solve bargaining problems between two participators in cooperation. For two rational and intelligent participators and a set of feasible configurations, theory of Nash bargaining provides a perfect axiomatic solution. In our profit distribution problem in the AI-based CL platform, two parties, the CL platform and resource providers of logistics services, are involved, and they are also in cooperation with each other to achieve maximal system profit. In all, the Nash bargaining model is most appropriate and reasonable here. The whole process can be further modeled as a cooperative game of Nash bargaining: the CL platform and resource providers of logistics services cooperate based on their own profits. They determine the price of logistics service jointly, aiming at maximizing profit of the system. Then, the total profit will be distributed between them on a pro rata basis.

TABLE 1: Variables for the model.

No.	Variables	Clarification
1	P	Unit price of the logistics service provided by the CL platform under decision-making of centralization
2	P_1	Unit price of the logistics service provided by the CL platform under decision-making of decentralization
3	P_2	Unit price of the logistics service provided by the resource provider of logistics services under decision-making of decentralization
4	Q	Quantity of total demand for logistics service
5	C_1	Unit cost of the CL platform to provide the logistics service
6	C_2	Unit cost of the resource provider to provide the logistics service
7	N_1	Profit of the CL platform under centralized decision-making
8	N_2	Profit of resource providers on the platform under centralized decision-making
9	N	Total profit of the CL platform and resource providers under centralized decision-making
10	M_1	Profit of the CL platform under decentralized decision-making
11	M_2	Profit of resource providers on the platform under decentralized decision-making
12	M	Total profit of the CL platform and resource providers under decentralized decision-making
13	λ	The proportion to distribute profit between CL platform and resource providers
11	a	Market size of the CL platform
12	b	Sensitivity coefficient of service demanders to the price provided by the CL platform
13	c	Sensitivity coefficient of service demanders to the price provided by the resource provider of logistics services

4.2. *Profit Analysis under Decentralized Decision-Making.* Under decentralized decision-making, demand is influenced by both prices set by the CL platform and resource providers. Demand function can be expressed as

$$Q = a - bP_1 - cP_2. \quad (1)$$

In equation (1), a , b , and c are all constants.

Then, profit of the CL platform π'_1 and profit of resource providers π'_2 are expressed as (2) and (3), respectively:

$$M_1 = (P_1 - P_2 - C_1) * Q, \quad (2)$$

$$M_2 = (P_2 - C_2) * Q. \quad (3)$$

Under decentralized decision-making, goals of the CL platform and resource providers of logistics services are to maximize their own profits. Therefore, assume that the CL platform is the leader and first mover in setting prices, while resource providers of logistics services are followers. The CL platform makes a first move in setting the price of logistics service as P_1 , then it allocates the service task to corresponding resource providers. Upon observing service demand Q , resource provider of logistics services chooses its price P_2 for its service.

Plugging equation (1) into (3), we can get

$$M_2 = (P_2 - C_2)(a - bP_1 - cP_2). \quad (4)$$

According to the first-order necessary condition of function's extreme value, let $(\partial M_2 / \partial P_2) = 0$, and we can obtain optimal price for the resource provider of logistics services:

$$P_2 = \frac{a - bP_1 + cC_2}{2c}. \quad (5)$$

Plug equation (5) into (2), and according to the first-order necessary condition of function's extreme value, let $(\partial M_1 / \partial P_1) = 0$, so

$$P_1 = \frac{ab + ac - c^2C_2 + 2bcC_1 + bcC_2}{b(3c + b)}. \quad (6)$$

Plugging equation (6) into (5), we get

$$P_2 = \frac{a + 2cC_2 - bC_1}{3c + b}. \quad (7)$$

Plugging equations (5)–(7) into equation (1), we can obtain the quantity of demand under decentralized decision-making Q' :

$$Q' = \frac{ac - c^2C_2 - bcC_2 - bcC_1}{3c + b}. \quad (8)$$

Plugging equations (5)–(7) into equations (2) and (3), respectively, profits of the CL platform and resource provider of logistics services M_1 and M_2 are obtained:

$$M_1 = \frac{(ac - c^2C_2 - bcC_2 - bcC_1)^2}{b(3c + b)^2}, \quad (9)$$

$$M_2 = \frac{(ac - c^2C_2 - bcC_2 - bcC_1)(a - cC_2 - bC_2 - bC_1)}{(3c + b)^2}. \quad (10)$$

Therefore, under decentralized decision-making, total profit of the two is

$$M = M_1 + M_2 = \frac{(ac - c^2C_2 - bcC_2 - bcC_1)(ab + ac - c^2C_2 - 2bcC_2 - bcC_1 - b^2C_2 - b^2C_1)}{b(3c + b)^2}. \quad (11)$$

Seen from equations (9) and (10), profits of the CL platform and the service provider are both correlated to their costs C_1 and C_2 . Therefore, cooperation between the CL platform and resource providers of logistics services should be strengthened to cut costs. As the total cost is cut, the final equilibrium price will be lower, and then the quantity of demand for logistics service on the CL platform will increase so that the total profit will increase too.

4.3. Profit Analysis under Centralized Decision-Making. Profit analysis under centralized decision-making means that the CL platform and resource providers of logistics services make an agreement on profit distribution, and they distribute the profit brought by their cooperation on the CL platform on a pro rata basis. Under such circumstances, the CL platform and resource providers of logistics services provide required logistics services to service requesters together and jointly set the price P for the service through negotiation, as well as the proportion λ ($0 < \lambda < 1$), to which they distribute their profit. If the two cooperate on a benefit-sharing basis, they set the price P of logistics service jointly as follows.

In such circumstances, the total profit of the CL platform and resource providers = (unit price paid by service requesters to the CL platform - unit cost of resource providers - unit cost of the CL platform) * quantity of demand, which is

$$N = (P - C_1 - C_2)Q. \quad (12)$$

Under centralization, the CL platform faces service requesters (customers) directly, so the price-demand function is

$$Q = a - bP. \quad (13)$$

Plugging equation (13) into (12), we can get

$$N = (P - C_1 - C_2)(a - bP). \quad (14)$$

From equation (14), and according to the first-order necessary condition of function's extreme value, let $(\partial N / \partial P) = 0$, so the optimal price is

$$P = \frac{a + bC_1 + bC_2}{2b}. \quad (15)$$

Plugging equation (15) into (13), we can obtain

$$Q = \frac{a - bC_1 - bC_2}{2}. \quad (16)$$

Then, plugging equations (15) and (16) into (12), we get

$$N = \frac{(a - bC_1 - bC_2)^2}{4b}. \quad (17)$$

Then, profits of the CL platform and resource providers N_1 and N_2 are

$$N_1 = \lambda N = \lambda \frac{(a - bC_1 - bC_2)^2}{4b}, \quad (18)$$

$$N_2 = (1 - \lambda)N = (1 - \lambda) \frac{(a - bC_1 - bC_2)^2}{4b}. \quad (19)$$

From equations (17)–(19), we can see that both of the two's profits are correlated to the unit cost of them C_1 and C_2 . The lower the total cost $C_1 + C_2$, the higher the profits of them. Therefore, the CL platform and resource providers on the platform should enhance cooperation to cut cost and improve overall efficiency of logistics service provision. Meanwhile, specific profits of the two also depend on the proportion λ to distribute their profit. Therefore, it is of essential importance to coordinate the profit distribution between the two sides.

4.4. Nash Bargaining Model Relating to Profit Distribution under Centralized Decision-Making

4.4.1. Establishment of the Nash Bargaining Model. To address the issue of profit distribution, Nash bargaining solution is used as fairness reference in this paper. Nash postulates four axioms that he argues solutions to bargaining problems do satisfy, which are scale invariance, Pareto optimality, symmetry, and independence of irrelevant alternatives [46, 47] and only one bargaining rule, commonly known as the Nash bargaining rule, satisfies these axioms [48]. Nash bargaining is the game of two bargainers, and it is essentially a distribution of certain benefit between two parties, for example, bargaining for price in bilateral transaction [49] and profit distribution between cooperators [47, 50, 51]. Solution of the bargaining game is called Nash bargaining solution. In this section, the proportion λ to distribute the profit between CL platform and resource providers is determined based on solution of Nash bargaining model. As $N_1 + N_2 = N$, under certain value of N , N_1 and N_2 cannot be raised simultaneously. If one of the two increases, the other one will be cut. Therefore, (N_1, N_2) is Pareto optimal. The set of all (N_1, N_2) meeting the equation of $N_1 + N_2 = N$ is the Pareto optimal set. Cooperation represented by each point in the set is effective.

According to the concept of solution for Nash bargaining, the CL platform and resource providers are regarded as the two participators of Nash bargaining. Their minimum requirement on profit, that is (M_1, M_2) under decentralization, is regarded as the present situation $d = (d_1, d_2)$. Then, the Nash bargaining model for profit distribution between CL platform and resource providers on it is as follows:

$$(N_1, N_2) = f(X, d) = \arg \max[(N_1 - M_1)(N_2 - M_2)]. \quad (20)$$

In equation (20), X stands for the feasible configuration set. The bargaining problem is to find the unique vector of configuration from X , and the unique configuration based on Nash bargaining is $f(X, d)$ in equation (20).

4.4.2. *Solution of the Model.* The profit distribution mechanism that is satisfied by both of the CL platform and resource providers must ensure that both of them would get

more, that is, $N_1 > M_1$ and $N_2 > M_2$. So, according to equations (9), (10), (18), and (19), we get

$$\lambda \frac{(a - bC_1 - bC_2)^2}{4b} > \frac{(ac - c^2C_2 - bcC_2 - bcC_1)^2}{b(3c + b)^2}, \quad (21)$$

$$(1 - \lambda) \frac{(a - bC_1 - bC_2)^2}{4b} > \frac{(ac - c^2C_2 - bcC_2 - bcC_1)(a - cC_2 - bC_2 - bC_1)}{(3c + b)^2}. \quad (22)$$

From (21) and (22), we can get

$$\frac{4(ac - c^2C_2 - bcC_2 - bcC_1)}{(3c + b)^2(a - bC_1 - bC_2)^2} < \lambda < 1 - \frac{4b(ac - c^2C_2 - bcC_2 - bcC_1)(a - cC_2 - bC_2 - bC_1)}{(3c + b)^2(a - bC_1 - bC_2)^2}. \quad (23)$$

As equation (20),

$$(N_1, N_2) = f(X, d) = \arg \max[(N_1 - M_1)(N_2 - M_2)] = \arg \max\{(\lambda N - M_1)[(1 - \lambda)N - M_2]\}. \quad (24)$$

Let $g(X, d) = (\lambda N - M_1)[(1 - \lambda)N - M_2]$, there is a λ maximizing $g(X, d)$, and thus corresponding values of N_1 and N_2 are the solution of $f(X, d)$. According to the first-order necessary condition of function's extreme value, let $(\partial g(X, d)/\partial \lambda) = 0$, and we get

$$\lambda = \frac{N^2 - NM_2 + NM_1}{2N^2} = \frac{1}{2} + \frac{M_1 - M_2}{2N}. \quad (25)$$

Plugging equations (9), (10), (17), into (25), we get the coefficient for distributing profits between the CL platform and resource providers of logistics services:

$$\lambda = \frac{2(ac - c^2C_2 - bcC_1 - bcC_2)(ac - ab - c^2C_2 - bcC_1 + b^2C_1 + b^2C_2)}{(3c + b)^2(a - bC_2 - bC_1)^2} + \frac{1}{2}. \quad (26)$$

Proposition 1. *The proportion λ to distribute the profit between CL platform and resource providers based on solution of Nash bargaining model is Pareto efficient.*

Proof. To prove that (N_1, N_2) , which is $[(\lambda N), (1 - \lambda)N]$, meets the condition for Pareto optimality, we have to prove that there is no $(\widehat{N}_1, \widehat{N}_2) \in f(X, d)$, $\widehat{N}_1 = \lambda N$, $\widehat{N}_2 = (1 - \lambda)N$, making $\widehat{N}_1 \geq N_1$, $\widehat{N}_2 \geq N_2$.

Furthermore, at least one of the two “ \geq ” is strict “ $>$,” meaning that $\widehat{N}_i \geq N_i$ ($i = 1, 2$) holds for at least one participator.

Proof by contradiction: assume that there exists such $(\widehat{N}_1, \widehat{N}_2)$.

As there exists $(y_1, y_2) \in f$, which meets $y_1 > M_1$, $y_2 > M_2$.

In this optimization, maximum value of Nash product $W(x_1, x_2) = (x_1 - d_1)(x_2 - d_2)$ is strictly larger than zero. As the goal function $W(x_1, x_2)$ increases on both x_1 and x_2 , we then get $W(\widehat{N}_1, \widehat{N}_2) > W(N_1, N_2)$. This is impossible since $W(N_1, N_2)$ is the maximum value of $W(x_1, x_2)$. So,

our assumption does not hold, and there is no such $(\widehat{N}_1, \widehat{N}_2)$.

According to Proposition 1 and its proof, the proportion λ obtained from equation (26) is Pareto efficient. It is an inevitable choice for rational participators, including the CL platform and resource providers of logistics services. By adopting the well-established Nash bargaining model, we are trying to obtain an optimal profit-sharing proportion λ to distribute the profit between CL platform and resource providers so that the two can benefit more, as well as the system achieves the maximum profit. The cooperation will thus go on, and the CL platform can have a sustainable development. \square

4.5. *Application.* In order to verify the practicability and efficiency of our proposed approach for profit distribution in CL, simulations are conducted and realized. Let $a = 1000$, $b = 15$, $c = 20$, and C_1 and C_2 vary from 1 to 10. The proposed profit model in the AI-based CL is then

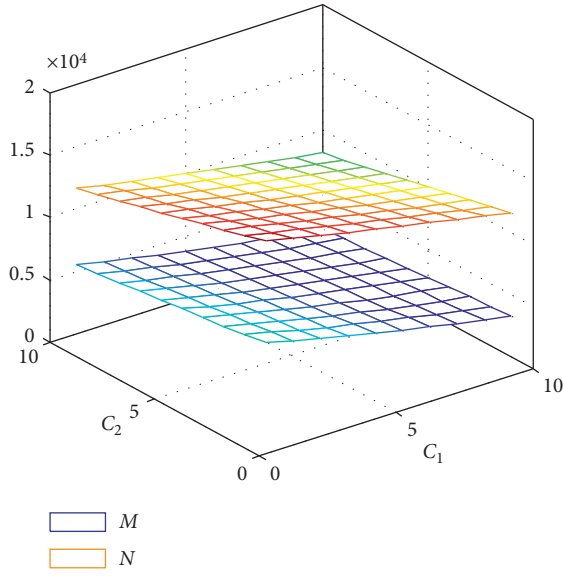


FIGURE 4: Total profits under decentralized and centralized decision-making.

applied. Comparisons are made with decentralized decision-making scenario. Results of simulation are shown in Figures 4~6. Figure 4 shows comparisons of total benefits of the CL platform and the service provider under decentralized (M) and centralized (N) decision-making. We can see that, with the decrease in their costs C_1 and C_2 , both M and N increase. Moreover, total benefits under centralized decision-making are always larger than that under decentralized scenario. Figures 5 and 6 show comparisons of their respective profits under different scenarios. We can see that both the CL platform and service provider's profits are larger with our proposed distribution mechanism.

5. Conclusion

The purpose of our research is to provide more options for logistics service providers' decision-making. The logistics providers can cooperate with the AI-based CL platform and provide some of their services through CL; i.e., a complementary approach to make the best use of their resources. However, this does not mean that the CL will replace their original businesses. According to the calculation process of the proposed model, i.e., equations (21) and (22), if the CL platform and logistics providers make decisions together in a centralized system, all of them will benefit more, as well as the profit of the whole system increases. However, how to protect commercial sensitive information of these logistics providers when they use the CL platform to cooperate between each other has hindered the development and implementation of CL platform, e.g., the failure of Stars Express in China. The adoption of smart contract based on BT makes all record and supervision of the reliable database without human intervention and is able to remove the credit crisis between anonymous participators of the AI-based CL platform. Users do not need to worry about issues of trust during the process of service delivery such as reliability of

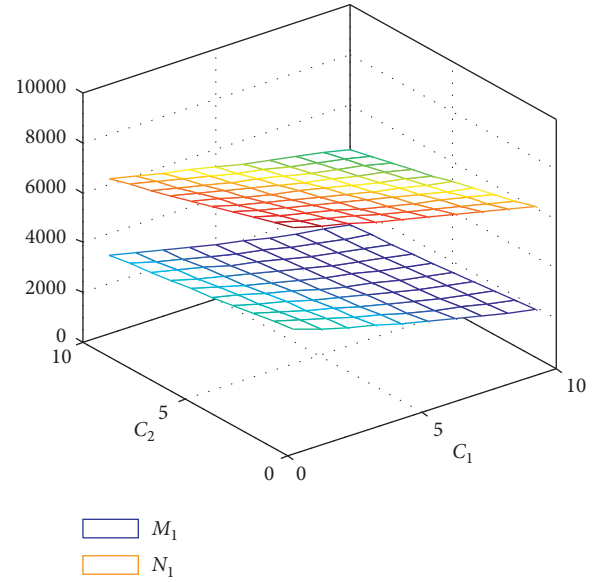


FIGURE 5: CL platform's profits under decentralized and centralized decision-making.

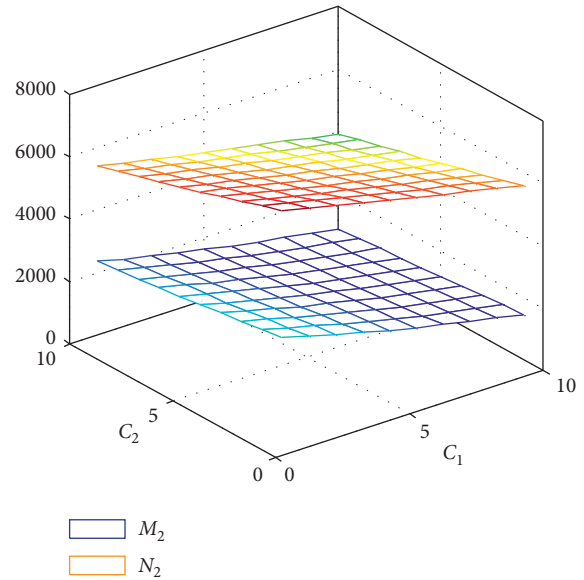


FIGURE 6: Service provider's profits under decentralized and centralized decision-making.

services and safety of capitals. The BT-based smart contract for the CL platform designed in this paper provides a service transaction mechanism for the AI-based CL platform, which needs no trust and is established by codes. Participators of logistics service transactions on the CL platform only submit their actual information of service demand or resource of services. Reliability of submitted information, provided service, and money transfer are guaranteed by codes of the smart contract. No one can tamper with the codes nor can anyone deny. Equally, the one who submits information cannot withdraw, regret, or deny. Therefore, the smart contract ensures all participators' interest, and it is able to solve the problem of trust needed in logistics service

provision on the CL platform. BT guarantees that all participants' behaviors of almost every step on the CL platform are recorded effectively and supervised properly so that all behaviors of each node are reasonable and legitimate. The role of smart contract is to supervise the implementation of all demand and resource information, as well as the process of transactions through codes. The AI-based CL platform and the proposed smart contract based on BT map the scenario which may be influenced by human factors and involve trust issues onto execution of codes which are free of human intervention, and problems of trust during CL platform's operation are thus solved. Therefore, it also makes the operation of CL platform feasible and sustainable.

Data Availability

Data used in this paper to support the findings of this study are created from simulation.

Conflicts of Interest

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