Future Generation Computer Systems 86 (2018) 641–649

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Research on agricultural supply chain system with double chain architecture based on blockchain technology

Leng Kaijun [a,b], Bi Ya [b], Jing Linbo [a], Fu Han-Chi [b,*], Inneke Van Nieuwenhuyse [c]

[a] National Academy of Economics Strategy, China Academy of Social Sciences, Beijing, China
[b] Research Centre of Hubei Logistics Development, Hubei University of Economics, Wuhan, China
[c] Faculty of Economics and Business, KU Leuven, Leuven, Belgium

HIGHLIGHTS

- We've proposed a dual-chain agricultural business resource public block chain.
- We've designed the block chain based on "user information chain" and "transaction chain".
- The block chain can provide security guarantee mechanism for the public platform.
- The block chain can greatly improve the utilization of business resources.

ARTICLE INFO

Article history:
Received 28 February 2018
Received in revised form 3 April 2018
Accepted 19 April 2018
Available online 27 April 2018

Keywords:
Public blockchain
Consensus mechanism
Agricultural supply chain system
Double chain architecture

ABSTRACT

As an underlying support technology, blockchain is a shared ledger system and a computational paradigm, which is decentralized, and it is highly compatible with the distributed economic system. The distributed scheduling model of agricultural business resources based on the public service platform is a comprehensive solution to the current situation of agricultural industry which is "scattered, small, disorderly and weak", and plays an important role in integrating decentralized resource and making on-demand scheduling. Aiming at some key problems in the current Chinese public service platform, this paper proposes a public blockchain of agricultural supply chain system based on double chain architecture, mainly studying the dual chain structure and its storage mode, resource rent-seeking and matching mechanism and consensus algorithm. The results show that the chain of agricultural supply chain based on double chain structure can take into account the openness and security of transaction information and the privacy of enterprise information, can self-adaptively complete rent-seeking and matching of resources, and greatly enhance the credibility of the public service platform and the overall efficiency of the system.

1. Introduction

Agricultural supply chain is a complex system which responsible for the circulation of agricultural products in the market. As the carrier of the circulation of agricultural products, agricultural commercial resources are important guarantee to meet the demand of agricultural products and to maintain their quality and safety. At present, there are more than 230,000 agricultural business enterprises in China, most of which are small and medium-sized enterprises. Agricultural commercial resources could be characterized as dispersion significantly. Driven by interests, agricultural business resources have high coverage rates in developed regions, and the resource investment is obviously surplus. However, the coverage rate in remote and underdeveloped regions is extremely low, and agricultural business enterprises can hardly spontaneously meet the demands for agricultural products in remote and underdeveloped regions, showing extrusive social contradictions.

With the rapid development of computer technology and distributed computing, public service platform with the targets of "centralized management of decentralized resources and decentralized service of centralized resources" has become the key to solve the contradiction between the demand and supply of agricultural business resources. Public service platform is a non-profit network system based on the third party, which can directly provide high quality and cheap standardization service to the

* Corresponding author.
E-mail addresses: lengkaijun@hbue.edu.cn (K. Leng), Biya@hbue.edu.cn (Y. Bi), jinglinbo@sina.com (L. Jing), frankfu0318@126.com (H.-C Fu), inneke.vannieuwenhuyse@kuleuven.be (I. Van Nieuwenhuyse).

https://doi.org/10.1016/j.future.2018.04.061

resource demand side in the point-to-point form through virtual aggregation and scheduling of decentralized agricultural business resources. The general process is: Firstly, the supply and demand parties of agricultural business resources provide their information to the public service platform, including ID, resource demand and supply quantity, resource types and rent-seeking conditions. Secondly, the public service platform implements virtual integration of various decentralized agricultural business resources through various cloud-based technologies [1,2], encapsulates these resources [3], and forms standardized service [4] to realize the "centralized management of decentralized resources" [3]. Thirdly, the public service platform implements dynamic rent-seeking and matching to the demand and supply of agricultural business resources, [5] and realizes the "decentralized service of centralized resources" [6]. The public service platform is open to both supply and demand parties in the whole process of resource allocation, and can also provide "user-centered" push public service [7], which substantially reduces complexity of specific resource management for the resource supply and demand parties, and provides a wide, personalized and regular resource use environment for both parties [8]. Obviously, the public service platform breaks the tight coupling relationship between soft management and hard resources in practice, removes the subordinate relationship between resources and their owners, standardizes the contents and price of resource services, changes the single service mapping relationship between the supply and demand sides in the traditional resource management mode, and coordinates the operation of resources at all levels and links. To sum up, it is a comprehensive solution that can optimize the allocation of decentralized resources at the macro level [9–11].

Although the above literature has thoroughly studied on the public service platform and its scheduling model, there are still some key issues to be resolved.

(1) Adaptive Rent-seeking and matching between resources supply and demand sides

The public service platform is a distributed system. The supply and demand of the public service platform are decentralized and scheduled according to the characteristics of agricultural business resources such as dispersity, magnanimity, randomness, commonweal and heterogeneity. At present, the public service platform has not established the adaptive rent-seeking and matching mechanism of resources, and the utilization ratio of the agricultural business resources and the overall benefit of the system are not ideal. This can not only increase the transaction cost, but also make resource demand and supply parties withdraw from the strategy choice behavior of the public service platform.

(2) Security and transparency of transaction information and privacy of user information

On the one hand, the public service platform should ensure the security and openness of transaction information. On the other hand, the privacy of user information should be guaranteed. The existing public service platform does not have a mature and reliable information security mechanism, which cannot guarantee the security and transparency of rent-seeking and transaction, or the privacy of user information. This is likely to cause unauthorized access to and tampering with information on public service platforms, illegal misuse or misappropriation of the right to allocate and use resources, and the risk of deferred payment.

(3) Platform credibility

Public service platform is a decentralized intermediary organization without the leading or direct participation of government departments, and it is difficult to establish its credibility. This may lead to the risks of illegal operation of public service platform, false publication of information about demand and supply of agricultural commercial resources and malicious breach of contract, which will undoubtedly harm the interests of the public service platform participants. Therefore, establishing the credibility of public service platform through technology rather than power is the key to set up the distributed scheduling and management model of agricultural commercial resources based on public service platform.

In order to solve the above problems, this paper proposes a dual-chain agricultural business resource public block chain, and introduces it to the public service platform to provide the running environment and technical support for the public service platform. The block chain can provide distributed rent-seeking and matching mechanism for decentralized public service platform. According to the requirements of different types of information on the public platform, it can provide security guarantee mechanism for the public platform, so as to greatly improve the utilization rate of agricultural business resources, the credibility of the public service platform and the overall efficiency of the system.

2. Methodology

2.1. Concept and data structure of block chain

Block chain is a distributed accounting system implemented by computer technology [12], such as multi-node collective maintenance, point-to-point transmission, encryption algorithm and consensus mechanism, namely, a distributed database. It has the characteristics of high reliability, data integrity, decentralization and distrust. Without endorsement of the third party, it can realize the transmission and transaction of information between any nodes.

Block chain has a chained data structure, each of which consists of two parts: ① Block head, including the Hash value of the forward block (the hash value is composed of the block head, the block body and the random number), which is used to link the forward block and provide the users with the functions of information query, tracking and validating; ② Block body, containing the main information of the block, such as the time, position, quantity, amount and rule of the transaction. The data structure of the block chain is shown in Fig. 1.

This chained data structure of the block chain allows each block to store the information of the forward block and place its own information on the head of the subsequent block. Asymmetric key systems and intelligent contracts ensure that malicious attacks cannot tamper with information [13], which guarantees the authenticity and completeness of the data in the block chain. Therefore, block chain is not only a distributed shared ledger system, but also a programmable infrastructure and computing paradigm [14]. Such characteristics make block chain highly applicable to economic systems characterized by decentralization, decentralized resources, adaptive supply and demand matching and automatic transaction execution.

2.2. Application of block chain in agricultural supply chain

(1) Adaptive rent-seeking and matching between supply and demand of resources

All nodes in the block chain write their information and transaction rules in the block and broadcast to the whole network. Each resource supply node automatically searches the appropriate demand node according to the latest information in the block. Once a transaction is completed, there is a point-to-point data interoperability between nodes. Therefore, the efficiency of transaction conclusion, execution and completion is high. This solves the problem of low efficiency of small volume agricultural commercial enterprises participating in real-time wholesale market and improves the limited controllable resources and resource schedulable

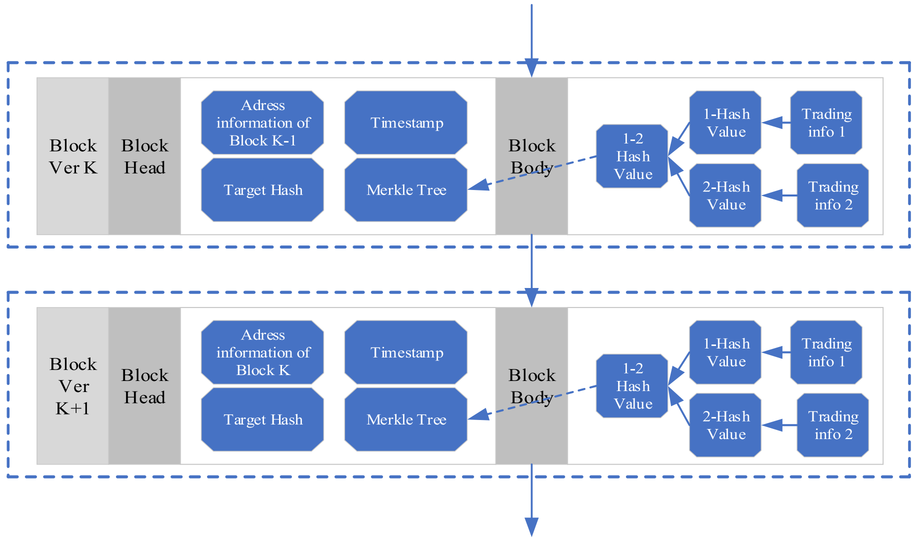

Fig. 1. Data structure of block chain.

of single user and reduces the risk of uncertainty caused by single user's policy selective behavior. In the meantime, block chain allows the demand node to write the selective incentive system into the transaction rules and guides the transaction in a given direction, thus forming a selective preference for the more remote and underdeveloped regions. This has great practical significance for the realization of the commonweal attribute of agricultural business resources.

(2) Decentralized collective maintenance and consensus mechanisms

Traditional accounting system is centralized management. Once the centralized nodes are "disloyal" or unexpected events occur, the whole system will be incredible. There is no centralized node in the block chain, and all nodes participate in the operation and maintenance of the system.

This means that each node contains the same account book information, which requires a consensus mechanism to ensure data consistency. Block chain encrypt data in the chain through elliptic curve cryptography. A tiny change on any node can be easily detected and quickly corrected. As a result, all nodes reach a consensus on security, authenticity, validity, integrity, tamper-proof and traceability of in decentralized systems with highly decentralized decision-making power. Block chain technology can not only provide strong robust data security for the public service platform with a large amount of decentralized agricultural commercial resources, but also offer a highly compatible application environment for the public service platform with the characteristics of decentralization.

(3) Intelligent contract

Intelligent contract endows the transaction parties with the corresponding rights and obligations, and manages and controls the execution of the transactions in the block chain [15]. Intelligent contract codes the rules and logic of transactions into contract codes, which can be applied to all kinds of programmed rule situations. Intelligent contract is protected by the encryption algorithm, and the data have high authenticity and integrity. In other words, once the demand and supply of resources match successfully on public service platforms, intelligent contract will implement the automatic execution of transaction without artificial intervention and the third party regulation. The whole process of the transaction will be recorded, and the record will not be tampered. It can be seen that intelligent contract can not only guarantee the authenticity, reliability and compulsion of transaction records, but also provide evidence for the execution of transactions, which greatly enhance the credibility of public service platform.

3. Design of public block chain in agricultural system with double chain structure

Criteria one is the influence of business in the industry. Supply chain is a synergistic coalition, so it needs a leading core enterprise. In addition, the core enterprises have certain influence and motivation in the industry, so that the supply chain is continuously developed and extended. For affiliates, they will join in this chain when the supply chain is profitable. Otherwise, they will invest their resources in other more profitable supply chains.

Criteria two is market share of products. The level of products in the market share can reflect the scale of development of an enterprise in the industry. High market share will generate great appeal to suppliers and sellers. As a supplier, they hope to find a company with high market share and strength as their partner. A powerful enterprise can influence the market behavior of consumers and take the initiative in the market competition. At the same time, large market share can get more orders, thereby expanding the scale of supplier benefits [15].

Criteria three is business reputation. In the process of seeking partners, economic factors and business reputation are the main factors. In general, the size of the supplier is small. If the money cannot be obtained in time, the normal production activities of suppliers will be affected. This effect may become a chain reaction, thus affecting the survival of the supply chain.

Criteria four is business ideas and management concepts. Core enterprises should focus on long-term interests. In addition, they should give top priority to establishing long-term relationships with suppliers, thereby sharing risks and sharing benefits. Whether the supply chain can coordinate operation is closely related to the mutual trust and cooperation among enterprises [16,17]. If we do not cooperate well with people and even take a hostile attitude, we will lose trust and we will not be able to promote the development of our supply chain partnership. The core enterprises have greater discourse power and control power. They are not only the core force that the supply chain can maintain, but also the makers and executors of the "game" rules in the supply chain.

3.1. Design of double chain structure and its storage mechanism

Block chain can be classified into public chain and private chain according to the recording rights of nodes. Every node on public chain has equal read–write access permission and can realize complete decentralization. However, due to the huge amount of data, the consensus and transaction speed is low, and the users' information privacy cannot be protected. There are quite a few centralized nodes with read–write access permission in private chain. Because there are fewer record nodes, the speed of consensus and transaction is faster. However, the unequal status of all nodes goes against the idea of decentralization of the block chain.

In order to realize the adaptive rent-seeking and matching of resources, public service platform requires that the nodes must be equal and can interoperate with each other. Therefore, as the application basis of the public service platform, agricultural business resource block chain must adopt the public chain structure. Considering that public block chain cannot protect the privacy of enterprise information, this paper designs a public block chain of agricultural business resources based on "user information chain" and "transaction chain". "User information chain" is used to record and store the user information of the agricultural business enterprises in the public service platform, and "transaction chain" is used to record and store all transaction data. The overall structure is shown in Fig. 2.

There are three benefits of adopting a double chain structure in agricultural business resource public block chain. Firstly, any nodes in the chain can view the resources on the public service platform without knowing the private information of the enterprise, which not only guarantees the authenticity, integrity and non-tampering of transaction data, but also ensures the privacy of user information. Secondly, diverting enterprise information and transaction data can reduce the redundant amount of information recorded by nodes and improve the throughput rate and consensus speed of the system to a certain extent. Thirdly, business expansion can be easily implemented between platforms and platforms, platforms and financial institutions.

Public block chain of agricultural business resources is designed with double chain structure, and the contents or function of each chain is not the same, leading to different storage types and data structures.

User information chain mainly guarantees the authenticity, integrity and privacy of the personal information of the participants, which can be stored through Merkle Tree structure. Merkle Tree is a generalization of Hash List with simple structure and error detection function. Its unique Hash value can meet the requirements of user information chain for data security.

Transaction chain guarantees the authenticity, integrity and openness of the transaction process, as well as the authenticity, integrity, openness, traceability, accessibility and extensibility of the transaction results. Therefore, transaction process data are recorded and stored through Merkle Tree structure in this paper. The Merkle Patricia Tree structure is essentially an encrypted authentication data structure that can be used to store all (key, value) pairs. In addition to ensuring the authenticity and integrity of the transaction results, it is easy to query and trace the trading results through the key value, and also reserves environmentally friendly interfaces for future business chain extensions.

3.2. Design of resource adaptive rent-seeking and matching mechanism

Suppose there are a resource demand DU set and a resource supply Su set on a public service platform. The transaction process of DU and Su based on dual-chain agricultural commercial resource public block chain is shown in Fig. 3:

The adaptive rent-seeking and matching process of the agricultural commercial resource block chain is designed as follows

Step 1. Initialization of public block chain of agricultural business resources, as shown in Formula (1), where BN is a block chain after initialization, DU is a set of resource requirement units, SU is a set of resource supply units, DU and SU constitute a set of nodes on BN. $BN_{\inf o}$, BN_{tran} are user information sub chain and transaction sub chain. CA is consensus method, and IC is intelligent contract. $T = \{t_i \in DU \times SU\}$ is Descartes set of resource transaction.

$$BN = (DU, SU, BN_{\inf o}, BN_{transaction}, CA, IC, T) \tag{1}$$

Step 2. Public service platform generates its own public and private keys, see Formula (2).

$$BN_{public} = Hash\left(BN_{private}\right) \tag{2}$$

Step 3. du_i and su_j are arbitrary resource demand points and supply points in DU and SU. In order to participate in the transaction, du_i and su_j need to generate their own key pairs and addresses for encryption and transmission of subsequent information, as shown in formulas (3)–(6).

$$du_{i.public} = Hash\left(du_{i.public}\right) \tag{3}$$
$$Address_{du_i} = Hash\left(du_{i.public}\right) \tag{4}$$
$$su_{j.public} = Hash\left(su_{j.public}\right) \tag{5}$$
$$Address_{su_j} = Hash\left(su_{j.public}\right) \tag{6}$$

Step 4. du_i and su_j broadcast their messages on public service platforms, see Formulas (7) and (8), where $Message.du_i$ is a resource requirement initiated by du_i, and E_{du_i} is a message broadcast by du_i on a public service platform. The parameters in E_{du_i} are: identity of du_i, resource demand amount, geographical location, response time and incentive selection weight, etc. $Message.su_j$ is the message that su_j broadcasts on the public service platform. The parameters in E_{su_j} are the identity of su_j resource supply, resource price, resource type, geographical location, response time and weight set of each parameter. All nodes monitor the information of other nodes on the network and generate the distance matrix $\overrightarrow{D}$ according to the location provided by other nodes.

$$Message.du_i = \left(E_{du_i}(ID_{du_i}, r_i, d_i, t_i, c_i) \left\| du_{i.public} \right\| Address_{du_i}\right) \tag{7}$$
$$Message.su_j = \left(E_{su_j}(ID_{su_j}, s_j, p_j, g_j, d_j, t_j, W) \left\| su_{j.public} \right\| Address_{su_j}\right) \tag{8}$$

Step 5. According to the information provided by each su_j, the system implements adaptive rent-seeking and matching for all idu, and synthetically weighs various factors to generate the intelligent contract with the minimum total equity value, as shown in Formula (9), where $\sum_{i=1}^{n} P_j Q_C \overrightarrow{D} T_C W$ is the resource price which is the sum of the final supply, distance, final response time and the product of the corresponding weights. The intelligent contract is encrypted with the private key of the public service platform.

$$IC = \min\left(\sum_{i=1}^{n} p_j, Q_c, \overline{D_{ij}}, T_c, W\right)_{BN_{private}} \tag{9}$$

Step 6. According to intelligent contract, the su_j that serves the du_i first looks for the public key of du_i on the $Address_{du_i}$, and compares it with $du_{i.public}$ provided by du_i to verify the identity of du_i. If the identity is confirmed, su_j returns the message $P_{respond}su_j$ to the du_i, as shown in formula (10). This message is encrypted with the public key of du_i C_{ij} is the specific content of the resource provided by du_i, and $Sign.su_j$ is a digital signature encrypted with the private key of su_j

$$P_{respond}su_j = \Big(C_{ij}(ID_{du_i}, ID_{su_j}, Q_c, p_j, g_j, d_{ij}, t_j, W) \times \left\| sign.su_{j_{su_{j.private}}} \right\| Address_{su_j}\Big)_{du_{i.public}} \tag{10}$$

Step 7. After receiving the message, du_i first decrypts the message with its own private key and learns that the message is

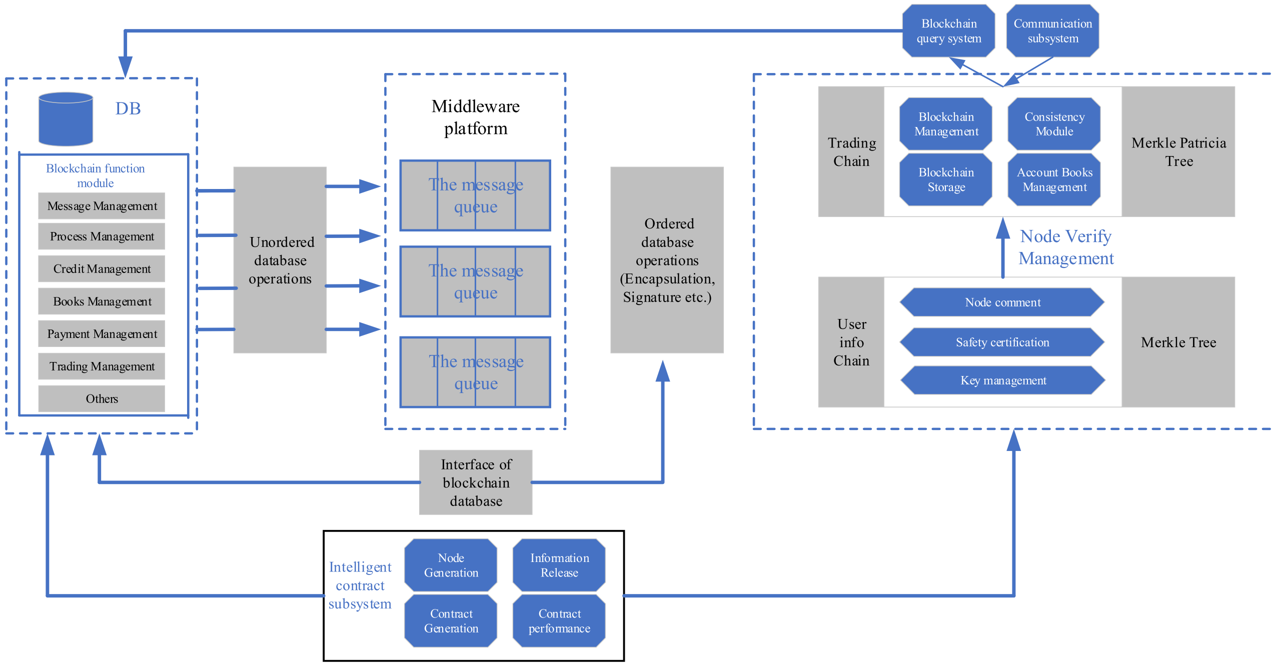

Fig. 2. Double chain structure of agricultural business resource block chain.

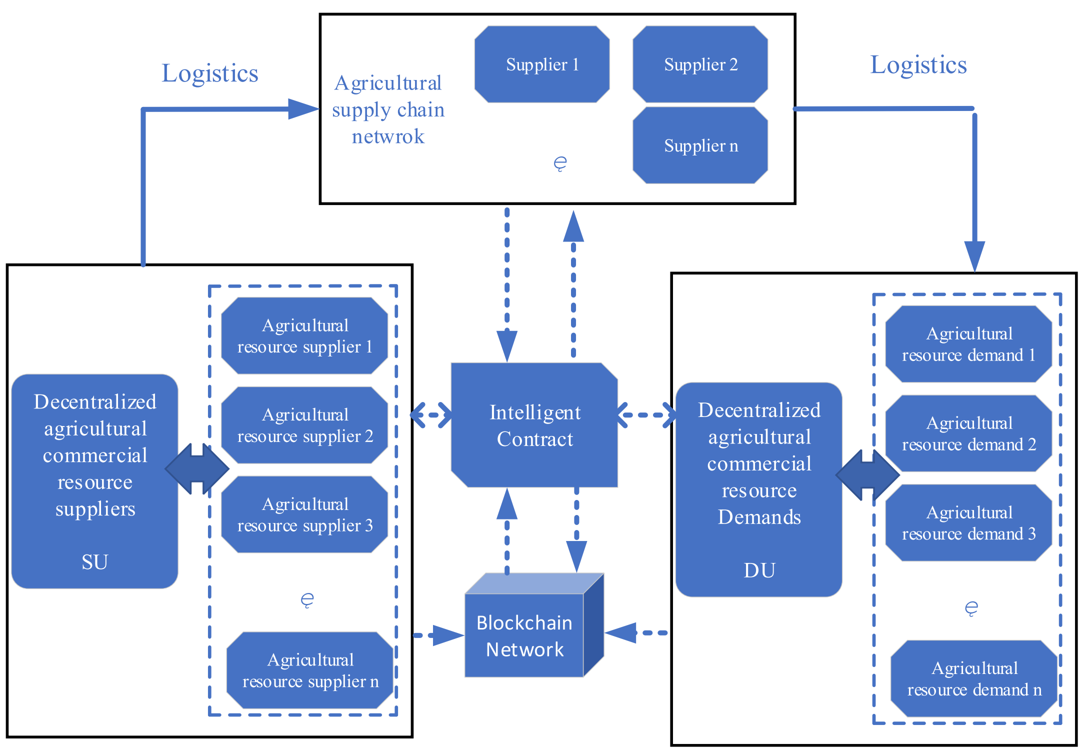

Fig. 3. Transaction process of agricultural business resource block chain.

feedback from su_j. The public key of su_j is found by the $Address_{su_j}$ provided by su_j. The digital signature of su_j is decrypted and the identity of su_j is confirmed. Secondly, $N_{version}$ is the serial number of the transaction and N_{time} is the time when the transaction is concluded. Once the transaction is successful, the public service platform will broadcast the contract information to all nodes and update the information in the block chain to complete a new round of consensus. Therefore, contract scripts require a common digital signature of three parties, namely, du_i, su_j and the public service platform.

$$Script = \left[N_{version} \| N_{time} \| \, Sign.du_i Sign.su_j.Sign.BN(C_{ij})\right] \tag{11}$$

Step 8. After the supply and demand transaction of agricultural business resources is completed, each resource supply node su_j carries out the actual logistics distribution of agricultural products to the demand node du_i according to the contract. In the meantime, Block chain and actual agricultural business resource logistics network continuously interact with each other to record, confirm, review and monitor transactions and ensure smooth and complete transaction [16]. In this process, the information of transaction process and transaction result will be recorded in the block chain, and instantly agreed and updated in all nodes.

Step 9. If du_i and su_j default in the transaction process, public service platform can penalize them by agreement. If du_i defaults, Formula (12) shows the punishment for du_i in money and credibility, where M is the resource reward that du_i needs to pay in this transaction. C is the current credit of du_i. W_n is the weight coefficient of du_i default clause, and it can be set as different values according to different default cases. The information is encrypted and broadcast by the private key of the public service platform.

$$Punish.du_i = [(M \| C)\, W_n]_{BN_{private}} \tag{12}$$

3.3. Design of consensus algorithm

There is no centralized accounting mechanism in block chain. Therefore, establishment of block chain and data updating and storage require the "consistency process" of all nodes by using consensus algorithm. Consensus algorithm is the core technology of block chain and an important guarantee for establishing credibility of block chain. Because of the large number of participating nodes, the low availability, and huge information amount, public block chain generally adopts consensus algorithms such as proof of workload (PoW), proof of stake (PoS) and DPoS.

The idea of PoS consensus algorithm is to replace the Hash rate based on SHA256 with proof of stake. That is, the recording right of the block is obtained by the node with the highest right in the block chain. Compared with PoW that requires a great deal of computational power, PoS requires only a small amount of computing time and ability to ensure the normal operation of the block chain [17]. The consensus speed of the public block chain is slow. In the process of scheduling the agricultural business resources, the selective incentive weight should be used to guide the agricultural business resources to flow to the remote and underdeveloped areas so as to realize the commonweal attribute of agricultural business resources. Therefore, this paper proposes a consensus algorithm which is more concise and more suitable for agricultural business resource block chain considering weight based on the PoS consensus algorithm.

Its algorithm pseudocode is as follows:

(1) Begin
(2) transaction X (ID, request, t)
/*Node X generates a new transaction and requires update. t is the timestamp to ensure that the request is made only once. */
(3) listen by every node
/*All nodes remain listening*/
(4) broadcast by every node (ID, R)
/*Each node broadcasts its message to the entire network*/
(5) Weight=comp(*Ri,Wi*) for every node
/*Each node calculates the equity value of all nodes according to the pre-agreed weight. */
(6) primary =Max (Weight);
/*Select the accounting node according to the highest equity value. */
(7) block=comp(X) by primary;
/*The accounting node calculates the block value of node X*/
(8) MS=broadcast block by primary;
(9) if MS is received
/*If the node receives the messages*/
(10) No.=count(MS);
/*Record the number of messages received by the node*/
(11) if the No. >=N for any node
/*If any node receives more than N messages, N is related to the fault tolerance of the system. */
(12) then updating for every node (X, block);
/*All nodes update the new block value of node X*/
(13) else give up;
/*Otherwise, give up the update. */
(14) End

Table 1
Demand nodes and demand amount.

Unit	Demand amount	Response speed	Selective incentive weight
du_1	740	<=0.8	0.2
du_2	270	<=0.7	1.0

4. Numerical simulation

4.1. Parameter description

In order to verify the applicability and superiority of block-chain technology in agricultural business resource scheduling based on public service platform, two experimental schemes are designed in this paper, and the corresponding scheduling simulation model is constructed by using Matlab. Finally, the experimental results are analyzed and discussed.

The following assumptions and explanations are made to the simulation model:

(1) There is a set of agricultural business resource demand nodes, and the parameters are as shown in Table 1. A set of agricultural business resources supply nodes exist, and the specific parameters are shown in Table 2. The parameter weights are shown in Table 3, and the weights of agricultural business resource types are shown in Table 4.

(2) All resource types are reachable for demand points.

(3) The weights of all parameters are normalized.

(4) In order to highlight the typicality of the research object, one of the two demand nodes in Table 1 is set in the central city and the other in the remote area.

(5) All nodes are on BN, and the rent-seeking, matching and transaction between the supply and demand of agricultural commercial resources are completed according to the rules and algorithms of BN.

4.2. Simulation experiments

Experiment 1 calculates the results of adaptive rent-seeking and matching between the supply and demand nodes of agricultural business resources through the block chain technology in Tables 1 and 2, which aims to verify the feasibility and applicability of block chain technology for decentralized resource scheduling and management. The simulation results of Experiment 1 are shown in Table 4.

Table 2
Supply nodes and supply amount.

Unit	Supply amount	Supply price	Response speed	Resource type	Distance du_1	Distance du_2
su_1	10000	2.3	0.9	Cold chain special train	1300	180
su_2	200	5.5	0.6	Box-type cold chain truck with multiple temperature zones	1800	240
su_3	300	4.6	0.7	Box-type cold chain truck with a single temperature zone	1200	80
su_4	1150	6.5	0.8	Dumping trailers + cold chain container	1900	120
su_5	70	5.3	0.8	Box-type cold chain truck with multiple temperature zones	1100	340
su_6	100	15.8	0.5	Cold chain aeronautical dedicated line	1700	550
su_7	400	2.5	0.7	Common van + cold chain container	900	680
su_8	300	4.2	0.7	Box-type cold chain truck with a single temperature zone	2100	350
su_9	60	5.2	0.6	Box-type cold chain truck with a single temperature zone	1900	200
su_{10}	80	6.1	0.8	Dumping trailers + cold chain container	1500	400

In experiment, under the premise of specific resource supply, the average optimal costs of the demand node based on the traditional resource scheduling mode and the block chain technology scheduling are calculated so as to verify the superiority of distributed resource scheduling in system cost through block chain technology.

The traditional resource scheduling model does not set the weights of the parameters. In order to make the cost comparable in different scheduling modes, experiment 2 only considers node demand, supply quantity, supply price, location of supply and demand node and final trading volume, while the weights of parameters are not considered. The resource supply node and the supply quantity are extracted from Table 2. The scale of the demand nodes is gradually expanded from 1 to 10, and the demand amount is obtained through a random function in [1,500]. According to the idea of set covering model in [18], the formula for calculating the equity cost of demand node based on the traditional model is shown in formulas (13)–(16). Formula (13) indicates that the optimal average cost of the demand nodes is the average value of the minimum cumulative sum of price, distance between the supply and demand nodes, and the product of the demand amount and weight. Formula (14) means that each demand node is covered by at least 1 and at most 3 supply nodes (see Fig. 4).

$$\min \sum_{i=1}^{n} \left(P_j, \overline{d_{ij}}, Q_C\right)/n \tag{13}$$

$$s.t. 1 \le \sum_{j} c_{ij} du_i \le 3 \quad \forall j \in J \tag{14}$$

$$du_i = 1 \quad \forall i \in I \tag{15}$$

$$c_{ij} = \begin{cases} 1, & if\ su_j \quad \text{cover} \quad du_i \\ 0 & if\ su_j \quad \text{notcover} \quad du_i \end{cases} \tag{16}$$

4.3. Analysis and discussion of experimental results

(1) According to the results of experiment 1, under the premise of only 10 resource supply nodes, there are 6 resource supply nodes that meet the requirements of du_1, and only one resource supply node that meets the requirements of du_2. Only three of the seven selected resource supply nodes are small supply points with the supply amount of less than 100 (There are only four small resource supply nodes in the model). This fully shows that block chain technology can allow decentralized agricultural commercial sources to achieve adaptive rent-seeking and matching. Resource scheduling is only related to the ability of the resource and transaction rules, and independent from the information held by the resource owner, so that more small scale agricultural commercial resources can enter into the market and fairly participate in transaction. This is essentially different from the traditional mode of resource scheduling and management.

Table 3
Weights of parameters.

Parameter attribute	Weight reference value
Amount	0.5
Price	0.2
Distance	$0.5(d_{ij} \le 100)$ $0.6(100 < d_{ij} \le 300)$ $0.7(300 < d_{ij} \le 500)$ $0.8(d_{ij} > 500)$
Response speed	0.6
Resource type	0.7

(2) Setting up selective incentive weights on the resource demand side aims to encourage the spontaneous flow of agricultural commercial resources to remote and underdeveloped areas and to realize the commonweal nature of agricultural business resources. According to calculation, the overage order of 10 resource supply nodes to the demand nodes du_1 and du_2 in experiment 1 is: su_3 (du_2)- su_7 (du_1) -su_9 (du_2)- su_2 (du_2) -su_3 (du_1) -su_8 (du_2) -su_5 (du_1) -su_{10} (du_1)- su_9 (du_1) -su_8 (du_1) -su_2 (du_1) -su_{10} (du_2) -su_7(du_2) -su_4 (du_1) -su_6 (du_1) -su_6 (du_2). According to this order, the two demand nodes with different geographical positions have no obvious order when they are covered by the supply nodes, which is in line with the established goal of the system. Several experiments have proved that selective excitation weight is strongly related to the three parameters of node size, distance matrix and response speed.

(3) According to the result of Experiment 2, under the premise of fixed resource supply, the average cost of demand nodes based on traditional resource scheduling mode is significantly increased and the cost growth rate is also significantly enlarged with the increase of demand nodes. This is because: Firstly, there are information barriers in the traditional resource scheduling mode and the transaction cost is high. Although the transaction between resource supply and demand has occasionally and randomness, it is relatively fixed, and the resource debris rate is high. Secondly, driven by the benefits, the superior resources will satisfy the nodes with lower demands first. Demand nodes with higher costs in remote and underdeveloped regions are often covered by more inferior sources, thus increasing the average cost of demand nodes. However, resource information is transparent under block chain technology, and a demand node can be covered simultaneously by several supply nodes. The supply node has very few "fragmented resources", and the transaction costs can be negligible. As a result, the average cost and growth rate of the demand node are obviously lower than the traditional model. The cost advantage is more obvious in the environment of massive resources.

5. Conclusion

Under the background of "Internet+" and distributed computing, the characteristics and scheduling mode of agricultural business resources have experienced substantial changes. In view of

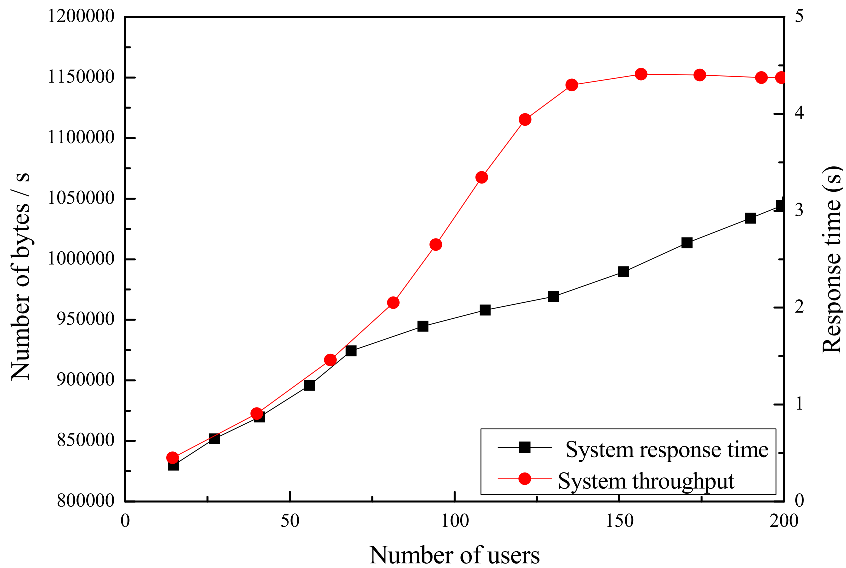

Fig. 4. Average optimal cost of demand nodes in different modes.

Table 4
Weight of resource type.

Resource type	Weight reference value
Cold chain special train	0.4
Box-type cold chain truck with multiple temperature zones	0.7
Box-type cold chain truck with a single temperature zone	0.6
Dumping trailers + cold chain container	0.5
Cold chain aeronautical dedicated line	0.8
Common van + cold chain container	0.9

the key technical problems in the distributed modulation model of agricultural business resources based on public service platform, this paper proposed a agricultural business resource block chain with double-chain structure. The research results show that the agricultural business resource block chain based on double-chain structure can provide adaptive rent-seeking and matching mechanism for public service platform. It can not only guarantee the transparency and security of transaction information and privacy of enterprise information, but also significantly improve the credibility of the public service platform and the overall efficiency of the system. Therefore, it is the core technology support and friendly application environment of public service platform.

There are several points that need to be further studied: Firstly, there are a huge amount nodes and resources on public service platform, which raise requirements for the speed and efficiency of consensus algorithm. Although the consensus algorithm based on PoS designed in this paper considers the weight of parameters, it should be further improved in terms of speed and efficiency. Secondly, the simulation experiment environment designed in this paper is relatively ideal, and fails to consider many practical situations, such as carbon emissions and depreciation of refrigeration vehicles. Thirdly, selective incentive mechanism is the key to realize the public welfare attribute of agricultural business resources. How to set up the implementation object, rule, method and intensity of selective incentive strategy without triggering the strategic choice behavior of enterprises needs to be further studied.

Acknowledgments

The authors acknowledge the National Natural Science Foundation of China (Grant: 70160376), Hubei society of social sciences, China (Grant: 2016101).

References

[1] P. Shi, B. Yan, Factors affecting RFID adoption in the agricultural product distribution industry. Empirical evidence from China, Springerplus 5 (1) (2016) 20–29.
[2] N.Y. Harun, M.T. Afzal, Combustion behavior and thermal analysis of agricultural and woody biomass blends, Adv. Environ. Biol. 9 (15) (2015) 34–40.
[3] M.A. Hossain, M. Quaddus, N. Islam, Developing and validating a model explaining the assimilation process of RFID: An empirical study, Inf. Syst. Front. 18 (4) (2016) 645–663.
[4] M. Yuan, P. Chahal, E.C. Alocilja, et al., Wireless biosensing using silver-enhancement based self-assembled antennas in passive Radio Frequency Identification, RFID tags, IEEE Sens. J. 15 (8) (2015) 4442–4450.
[5] S.S. Ibrahim, A. Ibrahim, A.N. Allah, et al., Building of a community cattle ranch and Radio Frequency Identification, RFID technology as alternative methods of curtailing cattle rustling in Katsina state, Pastoralism 6 (1) (2016) 1–9.
[6] B. Yan, S. Shi, B. Ye, et al., Sustainable development of the fresh agricultural products supply chain through the application of RFID technology, Inf. Technol. Manag. 16 (1) (2015) 67–78.
[7] X. Dong, W. Jianbo, J. Tong, et al., Locating logistics locations of suspicious agricultural production food safety emergencies, Adv. J. Food Sci. Technol. 8 (6) (2015) 452–455.
[8] R. Zayou, M.A. Besbe, H. Hamam, et al., Agricultural and environmental applications of RFID technology, Int. J. Agric. Environ. Inf. Syst. 5 (29) (2017) 50–65.
[9] C. Chen, X. Xu, Design and application of traceability and supervision platform for broiler based on internet of things, Nongye Gongcheng Xuebao/Trans. Chin. Soc. Agric. Eng. 33 (5) (2017) 224–231.
[10] T. Ojha, S. Misra, N.S. Raghuwanshi, Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges, Comput. Electron. Agric. 118 (3) (2015) 66–84.
[11] T. Chi, M. Chen, A frequency hopping method for spatial RFID/WIFI/Bluetooth scheduling in agricultural IoT, Wirel. Netw. (10) (2017) 1–13.
[12] L. Olinde, J.P.L. Johnson, Using RFID and accelerometer-embedded tracers to measure probabilities of bed load transport, step lengths, and rest times in a mountain stream, Water Resour. Res. 51 (9) (2015) 7572–7589.
[13] M. Chen, W. Luo, Z. Mo, et al., An efficient tag search protocol in large-scale RFID systems with noisy channel, IEEE/ACM Trans. Netw. 24 (2) (2016) 703–716.

[14] D.N. Bonter, E.S. Bridge, Applications of Radio Frequency Identification, RFID in ornithological research: A review, J. Field Ornithol. 82 (1) (2015) 1–10.
[15] R.Y. Zhong, G.Q. Huang, S. Lan, et al., A two-level advanced production planning and scheduling model for RFID-enabled ubiquitous manufacturing, Adv. Eng. Inform. 29 (4) (2015) 799–812.
[16] D.P. Rose, M.E. Ratterman, D.K. Griffin, et al., Adhesive RFID sensor patch for monitoring of sweat electrolytes, IEEE Trans. Bio-agric. Eng. 62 (6) (2015) 1457–1468.
[17] A. Arbit, Y. Livne, Y. Oren, et al., Implementing public-key cryptography on passive RFID tags is practical, Int. J. Inf. Secur. 14 (1) (2015) 85–99.
[18] D. Zhang, L.T. Yang, M. Chen, et al., Real-time locating systems using active RFID for internet of things, IEEE Syst. J. 10 (3) (2017) 1226–1235.

Kaijun Leng is a post doctor who works in China Academy of Social Sciences at the moment, and he also worked as an associate professor in school of logistics and engineering management, Hubei University of Economics, China. He obtained his Ph.D. in Huazhong University of Science and Technology. And his research area mainly focuses on logistics and supply chain management, theory of constraints. In recent years he has presided and attended a number of National Natural Science Foundation of China, the ministry of education funding in key projects, the Hubei province and abroad research project by the university research project. And he has published many academic research papers in many international journals and conferences.

Bi Ya is a post doctor who works in Hubei University of Science and Technology at the moment, and he also worked as an associate professor in school of logistics and engineering management, Hubei University of Economics, China. He obtained his Ph.D. in Huazhong University of Science and Technology. And his research area mainly focuses on Blockchain, Intelligent computing etc. In recent years he has presided and attended a number of National Natural Science Foundation of China, the ministry of education funding in key projects, the Hubei province and abroad research project by the university research project. And he has published many academic research papers in many international journals and conferences.

Jing Linbo was born in 1966, Doctor of economics, Doctoral supervisor who works in Chinese Academy of Social Sciences, director of the center for evaluation, enjoy the state council special allowance experts, "pacesetter engineering" in the new century national choice, and gain great contributions to the young and middle-aged experts "" honorary title. Vice President of the Chinese Society of Logistics, vice President of the China association of culinary arts, vice President of the China association of business economics, Vice President of the national council for trade and economic teaching. He is also works as the deputy director of the China Society for Social Science and Information Research, etc., has been engaged in various ministries and commissions, and has participated in the drafting of major research projects of various countries and ministries, especially important authorities document of China.

Fu Han-Chi is an associate professor who works in school of logistics and engineering management, Hubei University of Economics, China. He obtained his Ph.D. in National Cheng Kung University (Taiwan). And his research area mainly focuses on logistics and supply chain management, theory of constraints, cold chain management. In recent years he has presided and attended a number of National Natural Science Foundation of China, the ministry of education funding in key projects, the Hubei province and abroad research project by the university research project. And he has published many academic research papers in many international journals and conferences.

Inneke Van Nieuwenhuyse is a professor who works in the Research Center for Operations Management, Department of Decision Sciences and Information Management, K.U. Leuven in Belgium, her research interests mainly focused in queueing and simulation modeling, simulation optimization, performance analysis of production systems and supply chains, inventory management, lot sizing and healthcare operations management, who had published lots papers in those areas already.