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Jingjing Yang

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Development strategy of rural e-commerce in the context of new media: construction of traceability system based on improved DPoS algorithm

Jingjing Yang

Department of International Business,
Hebei Institute of International Business and Economics,
066311, China
Email: yangjj886@hotmail.com

Abstract: In response to the shortcomings of cold chain traceability of rural e-commerce products in new media, this paper constructs a rural e-commerce product traceability system based on improving the consensus mechanism of entrusted rights and the Merkle Patricia tree. Firstly, aiming at the shortcomings of the consensus mechanism for entrusted equity, the witness committee model and Shapley value are introduced to select block nodes and allocate node values. It is used to efficiently identify and eliminate malicious nodes, thereby improving the consensus mechanism for entrusted rights. After applying the system proposed in this study, the complaints and negative reviews of rural e-commerce enterprises significantly decreased. The above results demonstrate that the rural e-commerce product traceability system can efficiently and accurately trace the origin of rural e-commerce products, thereby ensuring product quality and promoting the development of rural e-commerce.

Keywords: new media background; rural e-commerce; development strategy; consensus mechanism for entrusted rights and interests; traceability system.

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Biographical notes: Jingjing Yang obtained her Master's degree in Business Administration in 2016 from Yanshan University. Currently, she is working as a Lecturer in the Department of International Business, Hebei Institute of International Business and Economics. As a teacher in e-commerce, she is mainly responsible for teaching professional courses and has been conducting research on e-commerce. She has published more than ten journal articles in the fields of e-commerce related. Her areas of interest include new media operations, rural e-commerce, and cross-border e-commerce.

1 Introduction

As internet technology evolves, new media has become an essential driving force in developing rural electronic commerce. Rural e-commerce (REC) is vital in promoting rural revitalisation and economic development (Karine, 2021). As REC mainly involves

food, ensuring food safety and clarifying the responsibilities of parties involved in food safety accidents are key issues related to the development prospects of REC. The traceability system can trace products, explore their roots and sources, and cover the entire food industry chain upstream and downstream, including food production bases, food processing enterprises, and food terminal sales. Through dedicated hardware devices similar to bank withdrawal systems, information sharing can be achieved to provide services to end consumers. When there are food quality issues on the consumer side, traceable codes on food labels can be used for online queries to identify all circulating information such as the production enterprise, place of origin, and specific farmers of the food. This can help clarify the corresponding legal responsibilities of the parties involved in the accident. This system is of great significance for food safety and self-restraint in the food industry (Liu et al., 2020; Chao et al., 2021). A traceability system is a process that tracks and records the production, processing, circulation, sales, and other aspects of a product. This is done to ensure the quality and safety of the product (Yang et al., 2021). The construction of a traceability system is of great significance for safeguarding consumer rights, helping to get agricultural products distributed, and enhancing the brand awareness of enterprises (Zhang et al., 2020). Given the prevalence of agricultural products in rural areas, which are susceptible to corruption, the necessity for cold-chain transportation is frequently evident. However, the traditional cold chain traceability system has many problems. The control method of the traceability system is centralised, and the collection of traceability data is mostly managed by regulatory departments or enterprises. The traceability information of cold chain products is stored in traditional databases, which are severely centralised, have low storage security, are susceptible to attack and tampering, and the authenticity and integrity of the information cannot be guaranteed. Blockchain is a distributed public data ledger based on cryptography, consensus mechanisms, peer-to-peer networks, and other technologies. It has natural characteristics such as decentralisation, traceability, transparency, security, reliability, peer-to-peer, and trustworthiness. Blockchain is maintained by achieving consensus among multiple organisations or nodes. Therefore, it is of great significance for the traceability of REC products. The so-called blockchain is a distributed ledger with a chain data structure that combines data blocks in chronological order and is guaranteed by cryptography. To address these issues, this paper proposes a traceability system construction strategy based on an improved delegated proof of stake (DPOS) mechanism. This strategy can improve the efficiency and dependability of the traceability system, thereby promoting the REC and having positive significance for rural economic development. There are two main innovations in the research. The first point is to introduce the Witness Committee model and Shapley value in DPOS to improve its performance and enhance blockchain performance. The second point is to combine the improved DPOS with the tracking method based on the Merck Patricia tree. It utilises external databases to store the latest fast product information within the storage area. Merkle Patricia trees are utilised to search for the final circulation information, and digital signature technology is adopted to ensure the security of the central database. The research content is mainly divided into five parts. The first part is an analysis of relevant research literature on REC and traceability systems. The second part is to construct the REC product traceability system by combining improved DPOS and a traceability method based on the Merkle Patricia tree. The third part is to analyse the performance of the improved DPOS and build a traceability system. The fourth part is a discussion that

compares the differences between the existing traceability system and the proposed research. The final part is a summary of the research content.

2 Related works

The REC offers farmers the opportunity to purchase goods and services, as well as engage in rural tourism, via an online platform, thereby enhancing their income and living standards. Therefore, the development of REC has received attention from many researchers. Tang and Zhu (2020) researched informal rural industries and explored the impact mechanism and effectiveness of REC on China's rural economy, which has positive implications for the development of rural areas in China. Feng and Zhang (2022) used ten rural revitalisation demonstration counties in Guizhou as examples to explore the coupling and coordinated development path and model of REC and rural revitalisation. This provided ideas for developing China's REC and certainly contributed to the revitalisation of rural areas. Liu et al. (2021) explored the development path and application effects of REC in China based on an endogenous switching regression model and analysed the importance of REC in developing the rural economy. Based on this, they proposed countermeasures for the development of REC in China. Li and Qin (2022) analysed the income effect of the REC industry in China based on data from Taobao Village and obtained its income data structure, providing theoretical guidance for the development of REC in China. Li et al. (2021) took the e-commerce-related data published by Zhejiang Province of China as an example to discuss the impact of the REC industry on the narrowing of the urban-rural income gap. The research was of positive significance for promoting common prosperity in China. Liu (2020) has designed a distribution path optimisation model based on the ant colony optimisation (ACO) algorithm to address the problem of "last mile delivery" in current REC, which is difficult to achieve home delivery. This effectively shortened the delivery distance and improved delivery efficiency. This model provided an effective solution for reducing the delivery path of the last kilometer. Jin et al. (2020) explored the impact of constructing REC service centers on farmers' subjective happiness from the perspectives of economy, entertainment, and convenience of life. Mei et al. (2020) analysed the impact mechanism and effectiveness of the phenomenon of REC clusters in China on family entrepreneurship behaviour. Their research has created pathways and reference significance for the income generation of rural households and the increase of farmers' income in China.

A traceability system is a system that achieves product tracking and traceability through computer technology. It uses computer technology to record the information of each product, including production date, batch, model, specifications, etc. and then transmits this information to relevant departments and personnel through the internet or other mobile communication networks for traceability and management. The application of traceability systems is very extensive, and can be applied in fields such as e-commerce, food safety, drug safety, and agricultural product quality control. Gopalakrishnan et al. (2021) constructed a solid waste management traceability system based on blockchain technology for current solid waste recycling management, analysed its cost, and optimised it based on the analysis results. The cost of the optimised system has been effectively controlled. Zheng et al. (2021) established a traceability system for residents' health and food security built on internet of things (IoT) and big data

technology to address food safety issues, providing guarantees for people's food safety. Masudin et al. (2021) analysed the mechanism of management measures in relation to the impact of a traceability system on the performance of the food cold chain during the period of COVID-19. They also discussed the influence of these measures on the refrigeration performance of food products in Indonesia. Ming-Fong and Huei-Yu (2021) proposed an agricultural product traceability system to address the lack of protection for agricultural products on the current REC platform, which affects consumer trust. This improved the traceability of products on the REC platform. Zhang et al. (2021) explored the food safety traceability mechanism from the angle of sustainable development of e-commerce platforms. They analysed the application effect of the current e-commerce product traceability system in it, providing more guarantees for food safety and having positive significance for stimulating the e-commerce. Zhou et al. (2021) used the case of the global quality traceability system announced by Chinese customs as an example to analyse the visibility and compliance of the supply chain achieved through resource information sharing with customs. This research achievement provided new ideas for the quality assurance of cross-border e-commerce in China, as well as the application and improvement of traceability systems. Lu et al. (2022) constructed a food anti-counterfeiting and traceability system based on blockchain and IoT technology. This system had a positive impact on China's food safety and was also beneficial for the development of China's food production and processing industry. Ab Rashid and Bojei (2020) used the Malaysian halal food supply-chain as an example to explore the relationship between environmental factors of its integrity and the adoption of halal traceability systems. Empirical analysis showed a significant positive correlation between the two.

As the rural economy continues to expand, the role of the REC in fostering rural economic development is becoming increasingly significant. The REC has garnered considerable attention in this regard. In addition, traceability systems are widely used and have important applications in the field of e-commerce, which is of great significance for e-commerce. Nevertheless, the REC is still in its nascent stages, and there are still numerous deficiencies in its traceability system, which the current research findings have not addressed. In response to this issue, an improved DPOS algorithm is proposed and a REC traceability system (REC-TS) is constructed based on the improved DPOS to improve traceability accuracy and efficiency, and promote the development of REC.

3 Construction of REC-TS based on improved DPOS algorithm

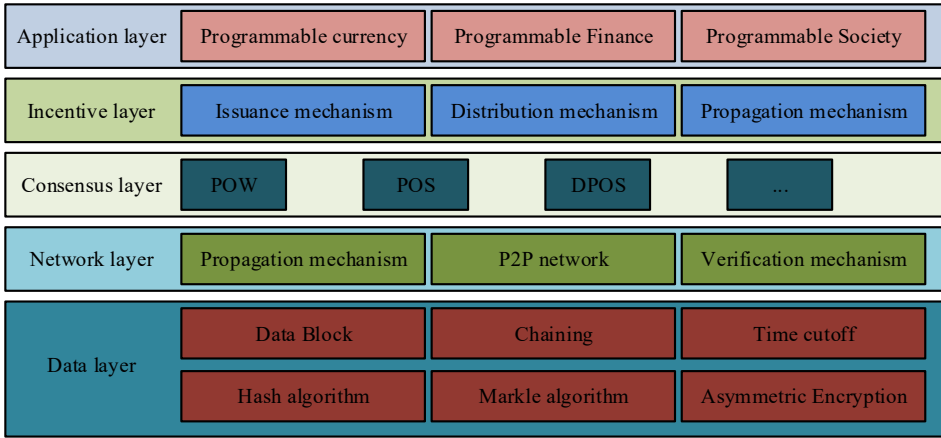
The REC-TS system enables consumers to monitor the production, processing, transportation, and sales of food products, thereby facilitating the assurance of their quality and safety. Concurrently, the implementation of a food traceability system enables the establishment of a standardised system that aligns with international standards across the various stages of food production and distribution. This facilitates the accurate identification of supply chain links, enhances the reliability of agricultural product sources, and optimises the speed of information transmission and processing. These developments pave the way for the integration of EDI, e-commerce, and global trade. To guarantee food safety, effectively control the occurrence of foodborne diseases, and facilitate global trade integration, an enhanced DPOS algorithm has been put forth,

upon which REC-TS has been developed to enhance traceability efficiency and advance the advancement of REC.

3.1 *Block node selection based on witness committee model*

In the current REC, agricultural products are the main product and are mainly sold through the cold chain, so the cold chain traceability system is very important. However, due to some defects in traditional cold chain traceability systems, such as difficulty in ensuring authenticity, there are many problems with cold chain products, which affects the image of REC and is detrimental to its development. In response to this issue, many researchers have built REC-TSs based on blockchain technology. The basic structure of blockchain is shown in Figure 1.

Figure 1 The infrastructure of blockchain (see online version for colours)



DPOS is one of the core focuses of blockchain technology, which is improved on the basis of POS. It has the characteristics of high throughput and strong flexibility, and can reduce the node consensus cycle to the second level. DPOS is mainly divided into two stages, namely election witness node and witness node consensus block. However, DPOS also has many shortcomings, including the concentration of accounting rights on weight nodes and the lack of active voting among nodes. It seriously affect the stability and fairness of the algorithm and have a certain negative impact on the traceability system. Secondly, there is no penalty mechanism for malicious outbound nodes in DPOS, which can lead to the gradual accumulation of malicious nodes and ultimately pose a threat to the security of the entire system. Therefore, firstly, it needs to improve by selecting candidate witness nodes with the right to be elected through the witness committee model. The so-called witness committee represents a mechanism through which the DPOS algorithm selects witnesses to address the issue of consensus through a process of democratic voting. In addition, the elected witnesses are granted the authority to adjust the network parameters, the exit time, and the transaction size. These nodes are special nodes that are added to the witness committee after paying the deposit. In the witness committee model, N block witnesses, N candidate witnesses, and $10 N$ blocks are elected for each round of voting. Candidates can exit the model, but a portion of the deposit needs to be deducted. This measure can prevent malicious nodes from entering the

committee and reduce voting efficiency. When candidates vote, the total equity for each round is calculated using formula (1).

$$E = E_{vote} + \lambda \cdot E_{witness} \quad (1)$$

In formula (1), E_{vote} is the voting rights value of the candidate witness, that is, the rights value of the ordinary voter node that delegates its own ownership to the trusted candidate witness. $E_{witness}$ is the equity value of the candidate witness, i.e., the collateral deposit. λ is the cumulative coefficient, which is an integer with a value range of $[1, 10]$. The top N candidate witnesses with the highest total equity value is selected as the block witnesses and blocked out in order. In DPoS, not all nodes are willing to perform accounting due to the inability of ordinary nodes to receive sufficient returns during the accounting process. Therefore, it is necessary to redistribute the block income so that all nodes can achieve income from labour. The study proposes a method of generating rewards based on the output period, which ensures that N new blocks can receive profits in any given period, as shown in formula (2).

$$R_i = \frac{2R(2N+2-i)}{3N(N+1)} \quad (2)$$

In formula (2), R_i represents the reward income obtained by the i^{th} new block. R is the total revenue for the period. The common benefit G_{vote} of ordinary nodes and the total benefit $G_{witness}$ of alternative witnesses are given by formula (3).

$$\begin{cases} G_{witness} = \sum_{k=1}^q gas + \frac{\alpha E}{\alpha E + E_{vote}} R_i \\ G_{vote} = \frac{E_{vote}}{\alpha E + E_{vote}} R_i \end{cases} \quad (3)$$

In formula (3), gas is the cost of a single transaction. q is the number of block transactions. α is the distribution coefficient. In blockchain, consensus mechanism is essentially a cooperative game, as shown in formula (4).

$$(N; V), N = \{1, 2, 3, \dots, n\}, 2 \leq n \quad (4)$$

In formula (4), N is the set of players, i.e., the node numbers participating in the consensus mechanism, and its subset is a sub-alliance. V is the value function, and $V(S) = K$. The value of the sub alliance is K .

3.2 Improved DPOS algorithm based on shapley value

Although a blockchain-based food traceability system can be constructed through the above methods, the stability and fairness of the traceability system are seriously affected due to the fact that the accounting rights of DPoS are easily controlled by weight nodes. DPoS has an important feature that any system parameter can be changed through stakeholder voting. These parameters include block spacing and size, transaction costs, witness rewards, and even the number of witnesses (specific support parameters vary from project to project), which provides greater flexibility and decentralised governance for the network. At the same time, the consensus cycle is reduced to the second level,

realising the rapid generation of blocks. However, there are also problems that nodes do not vote actively and malicious nodes can deal with difficulties. The study introduces the Shapley value to fairly distribute the value of profits among all players in the game alliance, and the distribution method is more scientific and fair. In this process, the profits distributed by the players are the Shapley value, expressed in formula (5).

$$f(N, V) = \frac{1}{|N|!} \sum_{S \subseteq N/\{i\}} |S|!(|N| - |S| - 1)! \times [V(\cup\{I\}) - V(S)] \quad (5)$$

In the DPOS algorithm, all nodes participating in block generation are considered as alliance game (M, V) , and any node k is a player. Therefore, the Shapley value $\varphi_k(M, V)$ of node k is given by formula (6).

$$\varphi_k(M, V) = \sum_{S \subseteq M} \omega(|S|) \cdot [V(S) - V(S/\{k\})] \quad (6)$$

In formula (6), M is a set composed of m voting nodes in this cycle. $S/\{k\}$ is the set that does not include player k . $\omega(|S|)$ is the weighting factor. $V(S) - V(S/\{k\})$ represents the contribution made by k , a member of the team, to himself in S . In formula (6), if the voting node of alliance S successfully becomes the block witness, then $V(S) = 1$, otherwise $V(S) = 0$. To increase the voting enthusiasm of each node and improve voting efficiency, based on the ranking order of voting, the first voting node is given more rewards. The ranking proportion $O_{k/j}$ is given by formula (7).

$$O_{k/j} = \frac{n - j + 1}{n(n+1)/2} \quad (7)$$

In formula (7), n is the amount of voting nodes behind the witness. j is the sorting of voting nodes. Therefore, for a voting node k , its return should be determined by the combination of Shapley value and ranking proportion, as shown in formula (8).

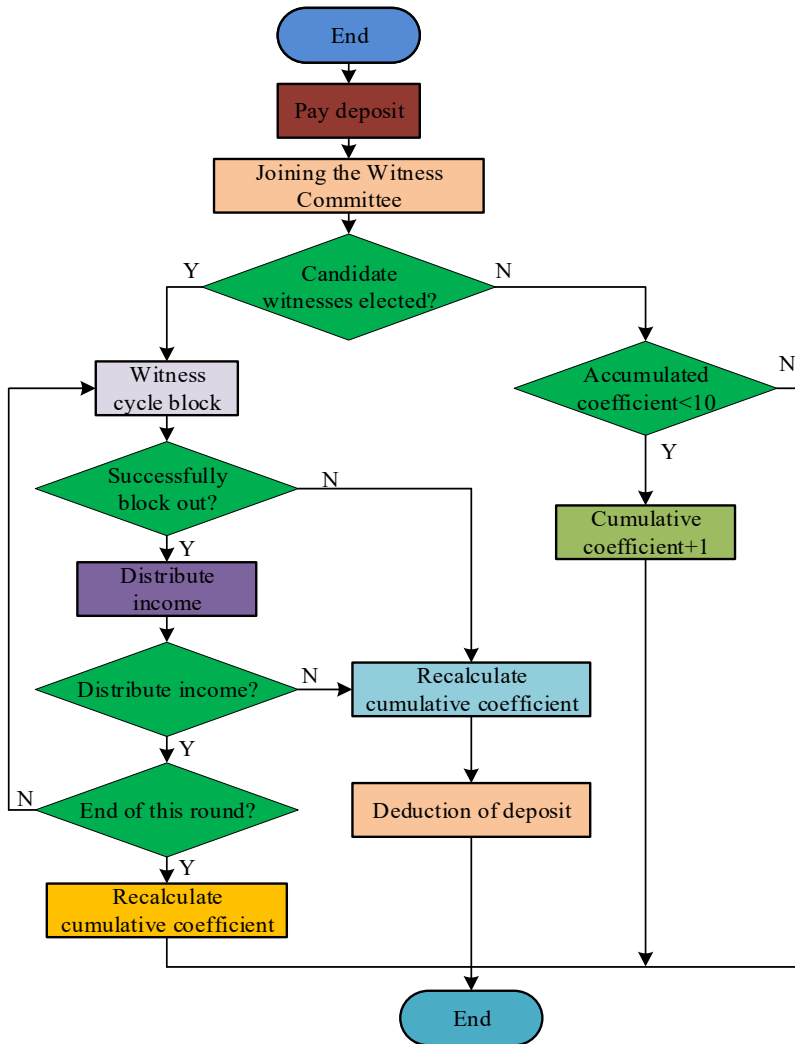
$$r_k = [\beta \cdot \varphi_k(M, V) + (1 - \beta) \cdot O_{k/j}] \quad (8)$$

Nevertheless, the malicious witnesses of DPOS may attempt to destroy the normal block or bribe the weight nodes to vote for themselves, thereby compromising the security of the entire blockchain system and negatively impacting the interests of the nodes. Concurrently, the absence of penalties for malicious block nodes allows these nodes to accumulate continuously, thereby further compromising system security. In addition, to avoid malicious chunking and eliminate malicious nodes, a penalty mechanism is introduced in the DPOS algorithm. After the witness node is blocked, it is checked by that node and other alternative nodes. If it passes the inspection of $2N/3$ inspectors, it indicates that the block has passed validation and is added to the blockchain. On the contrary, it is considered that the block has not passed verification. At this point, the witness node will be punished, and the next witness node after the node will be removed from the block. The accounting rights of the node in this round of voting will also be cancelled. When a witness node receives a block out reward but is not allocated to a voting node that supports the node, it is considered a block out failure and a penalty of deducting the deposit is imposed. Therefore, the penalty mechanism is expressed in formula (9).

$$E_{witness/(t+1)} = E_{witness} - \sum_{i=1}^p \frac{i^2}{2d} \times E_{witness/t} \quad (9)$$

In formula (9), $E_{witness/t}$ is the collateral deposit of the witness node in round t . $E_{witness/(t+1)}$ is the remaining margin of the node in round $t+1$. p is the sum times the node maliciously blocks out and the number of times the block out reward is not allocated to the voting nodes that support the node. d is the number of times the node was elected. In formula (9), as the number of failed block attempts by witnesses increases, the amount of deposit deducted will also sharply increase, thereby quickly eliminating malicious nodes. The witness block production process is shown in Figure 2. Based on the above content, the DPoS algorithm is improved and the performance of the blockchain consensus mechanism is enhanced.

Figure 2 Witness block production process (see online version for colours)



3.3 Traceability method based on merkle patricia tree

In the previous section, improvements are made to DPoS to enhance the performance of blockchain consensus mechanisms. This method can effectively enhance the performance of blockchain based food traceability systems. However, the traceability efficiency of existing blockchain-based traceability systems is relatively low, and their application effect in RECs with large data scales is poor (Barma and Modibbo, 2022). Therefore, a Merckle Patricia tree-based cold chain traceability method for REC products is proposed to improve traceability efficiency and promote the development of REC. The Merckle Patricia tree, also known as a state tree, is a data structure utilized by the Ethereum blockchain. It serves as a storage mechanism for the state of each account. It provides an encryption-based, self-verified tamper-proof data structure to store key value pairs. Within the specification range, the type of key value can only be a string. In this method, an auxiliary database is first introduced to query the latest messages, improving the efficiency of message query, as shown in Figure 3.

Figure 3 Auxiliary database (see online version for colours)

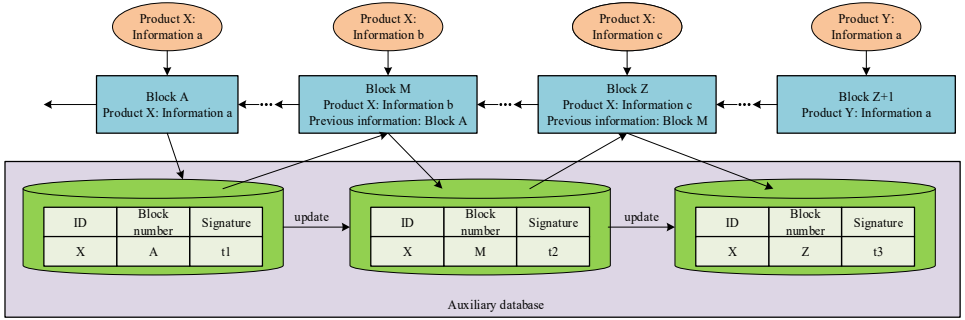
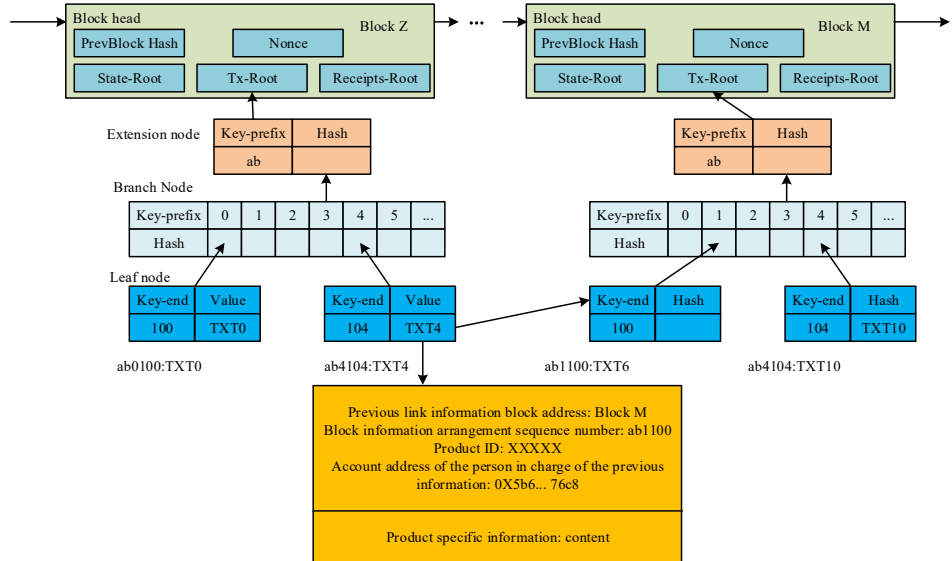


Figure 4 Merkle Patricia tree structure (see online version for colours)



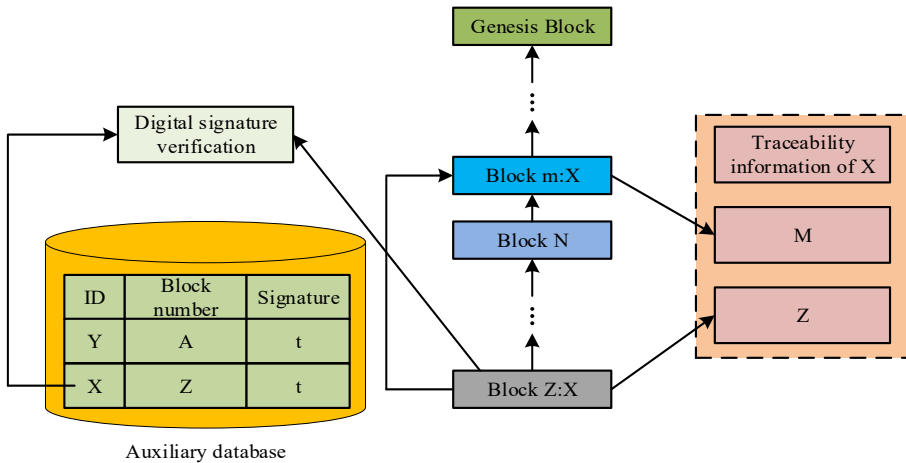
By using the auxiliary database shown in Figure 3, the number of downstream information queries can be effectively reduced. It is still necessary to search and match from the current block towards the Genesis block, and there is still room to improve the productivity of querying information within the block. Therefore, the study is based on the Merkle Patricia tree to improve the information search process and improve information search efficiency. The basic process is shown in Figure 4.

In Figure 4, the structure of the state Merkle root, receipt Merkle root, and transaction Merkle root is basically the same, with only the difference reflected in the value of the leaf node. In the proposed traceability method, in addition to product information, the leaf nodes of the transaction tree also need to record information such as the address of the information block, the arrangement number of the information transaction tree, and the product ID in the previous step. Then, based on the information from the previous block and transaction tree, the transaction address and specific information are queried. If the ID of a REC product is X, its chain up and traceability process can be represented as follows. The first step is to input product information at the source node on the chain. At this point, the product ID (*productID*) is demonstrated in formula (10).

$$\begin{aligned} productID = & SHA(framAddress + productName \\ & + productDate + productBatch) \end{aligned} \quad (10)$$

In formula (10), *SHA()* is the hash 256 function used to generate the QR code of the product. *productBatch* is the product batch. *productDate* is the production date of the product. *framAddress* represents the storage location. At this point, the uplink module will connect various information of the product, coexisting it in a distributed ledger to return the uplink results, and store the traceability information of the product in the auxiliary database. The second is to use smart contracts and digital signature technology to complete the chain of circulation information, thereby updating product traceability information and storing it in an auxiliary database. The third step is to link all subsequent information of the product according to the content of the first step. The fourth is to quickly query product information through auxiliary databases and achieve product traceability. The fifth is to obtain the latest information storage address block Z of the product through the traceability module (Figure 5).

Figure 5 Block search diagram (see online version for colours)



The sixth is to obtain product related information through the order of block Z and block M. The final step is to recursively query product information until obtaining the upstream information of the product, which is the source information. Based on the above content, product traceability is completed. At last, a blockchain REC product traceability system based on improved DPOS consensus mechanism and Merkle Patricia tree-based traceability method is constructed.

4 Performance analysis of REC product traceability system

A blockchain-based REC food traceability system has been proposed. To test the performance of the food traceability system, it is tested and compared with existing food traceability methods to verify the effectiveness of the proposed strategy.

4.1 Performance analysis of improved DPOS algorithm

The consensus mechanism is an algorithm for achieving distributed consensus in blockchain transactions, which determines which participating node to refer to for accounting. In current blockchain-based traceability systems, commonly used consensus mechanisms include the practical Byzantine fault tolerance (PBFT) and the vague sets-DPOS algorithm. The paper compares the performance of PBFT and vague sets-DPOS with improved DPOS algorithm to verify the superiority of improved DPOS. Multiple virtual machines and port mappings are used to simulate a multi-node blockchain environment for experimentation. The testing environment is as follow. CPU: Intel Core i7-10700; Memory: 8 cores/16 GB; Operating system: Ubuntu 18.04; Ethereum client: Geth1.9.18. The communication costs for improving DPOS, PBFT, and vague sets-DPOS are shown in Figure 6. In 6(a), when the number of nodes is 40, the communication cost of improved DPOS is only 83 KB, which is 201 KB and 308 KB lower than PBFT and vague sets-DPOS. In 6(b), when the number of requests increases to 40, the communication cost of improving DPOS is only 98 KB, which is 148 KB and 209 KB lower than PBFT and vague sets-DPOS.

Figure 6 Communication cost of algorithm, (a) number of different nodes (b) number of different requests (see online version for colours)

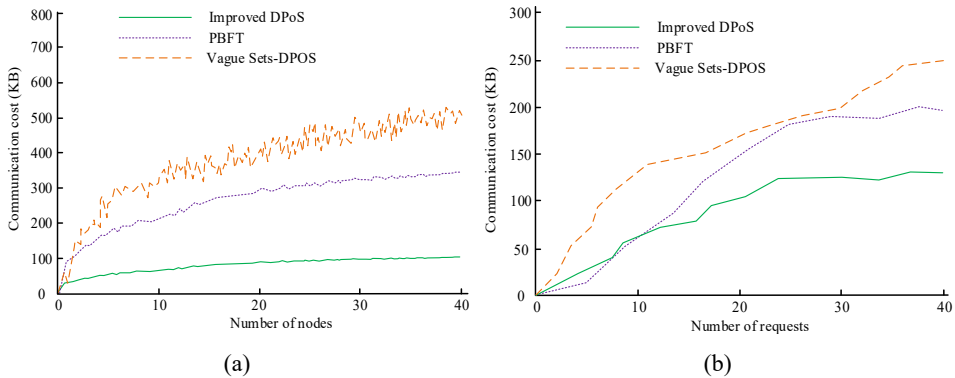


Figure 7 is the communication latency of improved-DPOS, PBFT, and vague sets-DPOS. In 7(a), when the number of nodes increases to 40, the communication delay of the improved DPOS is only 4.04 seconds, which is 1.50 seconds and 2.61 seconds lower than PBFT and vague sets-DPOS. In 7(b), when the block size increases to 2 MB, the communication delay of the improved-DPOS is only 2.00 s, which is 0.50 s and 1.52 s lower than PBFT and vague sets-DPOS.

Figure 7 Communication delay of algorithm, (a) number of different nodes (b) different block sizes (see online version for colours)

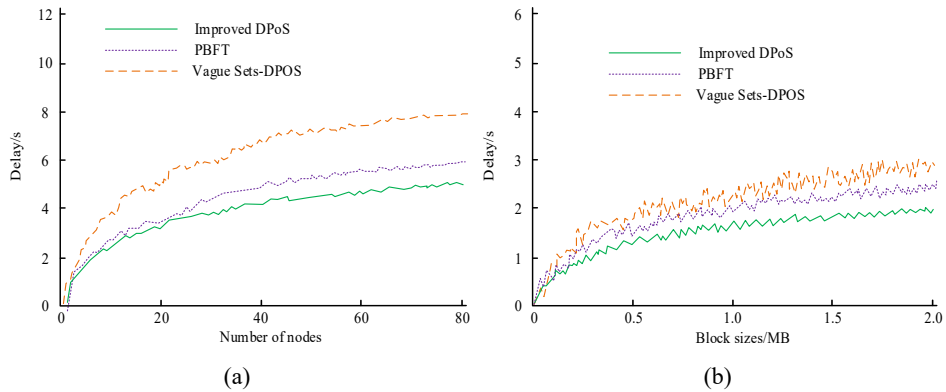


Figure 8 is a schematic diagram of node election security for three algorithms. After increasing the blocking to 1 MB, the security of the improved DPOS reaches 95.04%, which is 4.96% and 5.01% higher than the other two algorithms.

Figure 8 Node election security of algorithms (see online version for colours)

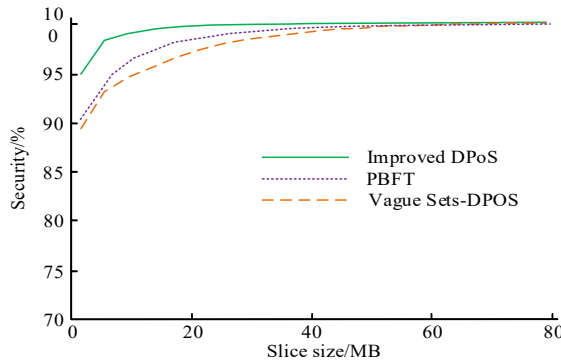


Figure 9 shows the throughput graphs of the three. The throughput of the optimised DPOS is always lower than the other two. In summary, the improved DPOS proposed in the study has good performance and can effectively improve the consensus mechanism of blockchain.

Figure 9 Algorithm throughput (see online version for colours)

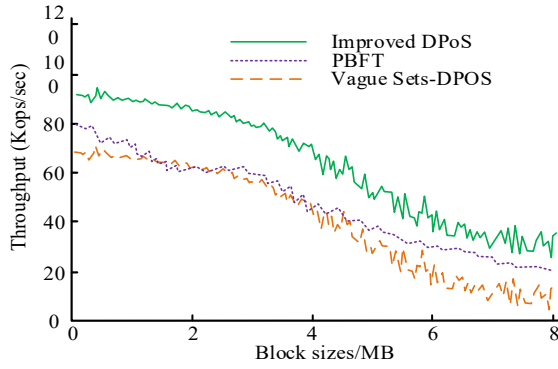
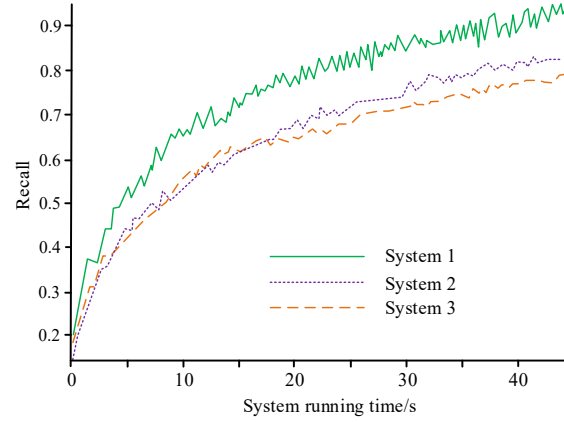
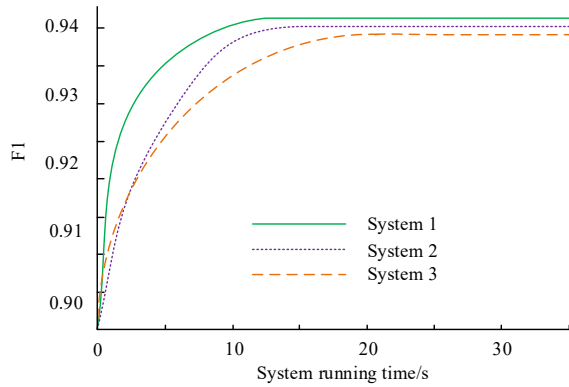


Figure 10 F1 and recall values of the system, (a) recall (b) F1 (see online version for colours)



(a)



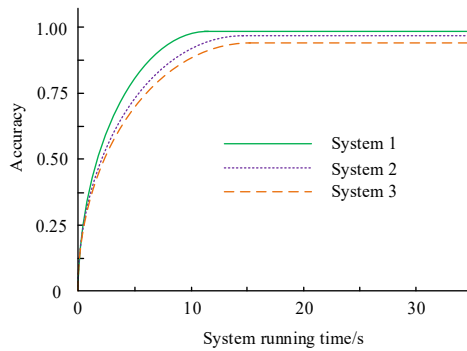
(b)

4.2 Performance analysis of REC traceability system

To verify the performance of the blockchain REC product traceability system (system 1), which combines the improved DPOS consensus mechanism and the Merkle Patricia tree-based traceability method, traceability systems are constructed that combined the PBFT (system 2) and the DPOS (system 3) with the Merkle Patricia tree-based traceability method, respectively. Historical data are obtained from three REC enterprises to test system performance. The Recall and F1 values of several systems in operation are compared, as shown in Figure 10. The recall value of system 1 is 0.920, which is 0.121 and 0.152 higher than system 2 and system 3, respectively. The F1 value is 0.941, which is 0.002 and 0.004 higher than system 2 and system 3.

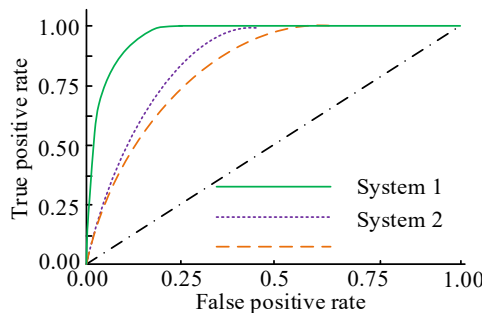
The traceability accuracy of the three systems is shown in Figure 11. The traceability accuracy of system 1 has reached 0.978, which is 0.018 and 0.019 higher than system 2 and system 3, thus enabling effective traceability of REC products.

Figure 11 Traceability accuracy of the system (see online version for colours)



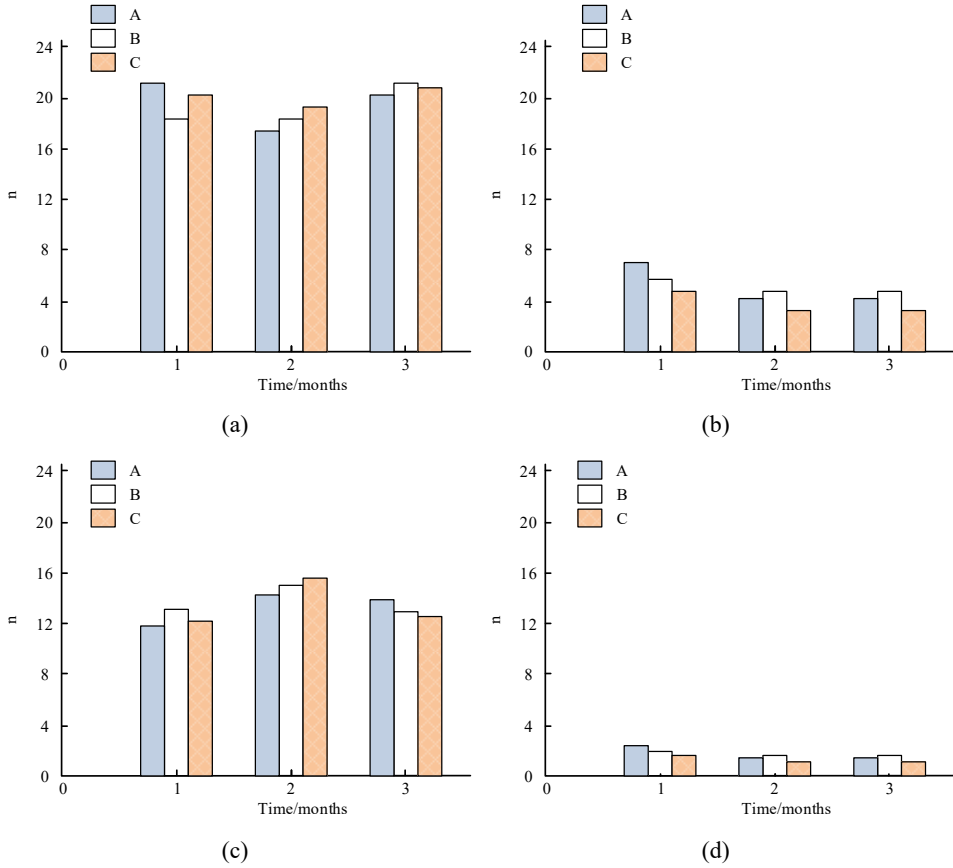
The ROC curve trend and AUC value are adopted to evaluate the comprehensive performance of three systems. The AUC values of the three systems are shown in Figure 12. In Figure 12, the AUC value of system 1 reaches 0.921, which is 0.011 and 0.018 higher than system 2 and system 3, indicating that the overall performance of system 1 is greater than that of system 2 and system 3.

Figure 12 AUC of the system (see online version for colours)



System 1 is applied to three REC enterprises A, B, and C, and the complaint and negative feedback levels of the three e-commerce enterprises before and after the application of system 1 are compared, as shown in Figure 13. After the application of system 1, the number of complaints and negative reviews of REC enterprises significantly decrease. It indicates that system 1 can effectively achieve product traceability, thereby more efficiently handling inferior products, improving consumer satisfaction, and ultimately promoting the development of REC.

Figure 13 Application effect of system 1, (a) number of negative comments before application (b) number of negative comments after application (c) number of complaints before application (d) number of complaints after application (see online version for colours)

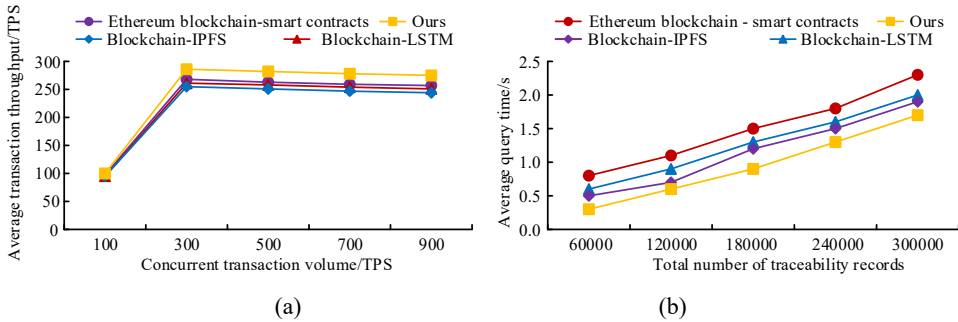


To further explore the performance of the proposed traceability system, the study takes agricultural product traceability as an example and compares it with the traceability system of Ethereum blockchain-smart contract, blockchain-LSTM, and blockchain-interstellar file system (blockchain-IPFS). The results are shown in Figure 14.

According to Figure 14(a), the average transaction throughput of Ethereum blockchain-smart contract, blockchain-LSTM, and blockchain-IPFS is 263 TPS, 258 TPS, and 251 TPS respectively when the concurrent transaction volume is 500 TPS. However, the average transaction throughput of the proposed traceability system is 282 TPS, which is higher than other methods. In Figure 14(b), when the total number of

traceability records is 180,000, the average query times for Ethereum blockchain-smart contract, blockchain-LSTM, and blockchain-IPFS are 1.5 s, 0.9 s, and 0.7 s, respectively. The average query time for the proposed method is only 0.6 s. The above results indicate that the traceability speed of the proposed method is fast.

Figure 14 Traceability system test results, (a) average transaction throughput (b) average query time for traceability (see online version for colours)



5 Discussion

In recent years, problems with cold chain products have occurred frequently, not only damaging the image and reputation of product producers, but also endangering the physical health of consumers. By tracing the origin of food, the fundamental and source of the product can be explored, and the corresponding legal responsibilities of the parties involved in food safety accidents can be clarified. This is of great significance for food safety and self-restraint in the food industry. The food anti-counterfeiting traceability system proposed by Lu et al. utilised the decentralised storage and tamper proof characteristics of blockchain technology to store traceable data of food production, sales, and transportation, effectively ensuring the uniqueness of food. Through the IoT technology, it effectively ensured the authenticity and reliability of blockchain source data, promoted the development of food traceability systems, and effectively reduced the communication costs and transaction delays of food traceability. However, it ignored the security, traceability speed, and accuracy issues of the traceability system itself. Compared to the food anti-counterfeiting traceability system based on blockchain and IoT technology constructed by Lu et al., the proposed traceability system based on improved DPOS algorithm had higher traceability speed and accuracy, and could better protect the security of the system. This was because the traceability system based on the improved DPOS algorithm did not need to search for all blocks after introducing a centralised database. Through the Merkle Patricia tree, specific blocks and information records within blocks could be found more quickly, reducing the search time for blocks and information within blocks. At the same time, the Shapley value algorithm would distribute benefits between witnesses and voting nodes, and participating voting nodes would receive benefits fairly, thereby improving the enthusiasm of nodes to participate in consensus. In addition, by increasing penalties for malicious block nodes, the security deposit pledged by witnesses in the committee could be deducted, reducing the number of malicious block nodes and improving the security of the system.

6 Conclusions

REC refers to the integration of internet technology with traditional agriculture, and the realisation of agricultural product sales, purchases, and rural tourism services through online platforms. It is one of the important ways for the current modernisation of agriculture. To this end, a blockchain REC product traceability system based on the improved DPOS consensus mechanism was constructed by combining the improved DPOS algorithm and the Merkle Patricia tree-based traceability method, to promote the development of REC. This demonstrated that by the time the node number was 40, the communication cost of improved DPOS was only 83 KB, which was 201 KB and 308 KB lower than PBFT and vague sets-DPOS. After the block size increased to 2 MB, the communication delay of the improved DPoS was only 2.00 s, which was 0.50 s and 1.52 s lower than PBFT and vague sets-DPOS. After increasing the blocking to 1 MB, the security of the improved DPoS reached 95.04%, which was 4.96% and 5.01% higher than PBFT and vague sets-DPOS. The Recall value of system 1 was 0.920, which was 0.121 and 0.152 higher than system 2 and system 3, respectively. The F1 value was 0.941, which was 0.002 and 0.004 higher than system 2 and system 3. The traceability accuracy reached 0.978, which was 0.018 and 0.019 higher than system 2 and system 3. The research results provide important reference and inspiration for the development of REC. Therefore, the strategies proposed will provide new ideas, methods, and models for the development of REC, which will help promote the development and growth of REC industrial clusters. Although the research has enhanced the DPOS consensus mechanism, augmented the enthusiasm of node voting, and guaranteed the stability and fairness of the consensus mechanism, the mechanism still adheres to a partially decentralised concept. Consequently, the subsequent stage is to investigate more exemplary decentralised consensus mechanisms. In the future, research will be conducted on how to combine traceability systems with IoT technology, and use various sensors to upload real-time flow information of each link of the product to the system, further ensuring the authenticity of the information source.

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