Design and Evaluation of a High-performance Support System for Credibility Tracing of Agricultural Products

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***Аннотация*. Отслеживание достоверности данных по операциям с сельскохозяйственной продукцией зависит от всех организаций во всей цепочке поставок. При традиционном централизованном управлении данные о транзакциях с продукцией хранятся только в одной организации из цепочек поставок, что делает управление ими непрозрачным и ненадежным. Однако блокчейн соединяет блоки информации о транзакциях в защищенную от несанкционированного доступа и распределенную базу данных с помощью хэш-функции, которая позволяет решить эту проблему. Но производительность доступа к данным в блокчейне все еще нуждается в улучшении. Используя Hyperledger Fabric в качестве базовой технологии децентрализованной системы отслеживания сельскохозяйственной продукции и повышая производительность системы с помощью метода структурирования данных на основе Redis, в данном исследовании была разработана и внедрена полная система отслеживания цепочек от производства, обработки, упаковки и логистики до продажи сельскохозяйственной продукции. Данное исследование не только представило программу проектирования и технологическую архитектуру этой системы, но и оценило производительность системы в одноузловых и многоузловых серверных средах. Результаты эксперимента показывают, что программа, интегрирующая Hyperledger Fabric и Redis, имеет скорость доступа к данным, по крайней мере, в четыре раза быстрее, чем без Redis, особенно для многоузлового сервера, в котором производительность повысилась более чем в 20 раз. Таким образом, данная программа проектирования может предложить приемлемый подход для повышения производительности системы поддержки отслеживания достоверности сельскохозяйственной продукции.**

Ключевые слова: сельскохозяйственная продукция; система прослеживаемости; блокчейн; Hyperledger; Redis

I. INTRODUCTION

Blockchain technology is a solution that represents the change of information Internet to value Internet. The traceability, decentralization and tamper-proofing features of blockchains are applied in scenarios that require credibility. The agricultural product supply chain covers the whole process from farms, processing, logistics and consumers. The product tracing system developed based on traditional centralized databases lacks reliable supervision and results in data sharing gap [1]. Recently, many scholars attempt to leverage the features of blockchain to solve these problems. Casino et al. introduced a case of dairy products credibility trading supported by blockchain, which enhances the consumers' recognition of product quality [2]. Yang et al. reviewed the storage structures in the tracing process of fruits and vegetables, promoting the application of blockchain in this area [3]. Shahid et al. came up with a complete solution to agricultural product supply chain, achieving realtime tracing from farm to dining-table [4]. Some scholars employ the IoT technologies to collect and store off-chain data on the blockchain, enhancing the credibility of the tracing results of agricultural products [5][6].

Although blockchain technology is valuable in agricultural product supply chain, blockchain as a distributed ledger for logging product transactions is not as efficient as centralized

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database in terms of data storage and query. To overcome this shortcoming, this paper designs a high-performance blockchain agricultural product tracing system with the Redis data structuring method. The major work includes:

1. Designing agricultural product credibility tracing system;
2. Using Redis to enhance the storage performance of the system;
3. Using Kafka clusters to improve the fault tolerance of sequencing nodes;
4. Using Ngnix to realize the load balance among peer nodes.

II. MATERIALS AND METHODS

A. System framework

The agricultural product tracing system is divided into three layers by functions, namely data storage layer, data processing layer and application layer. As shown in Fig. 1, the application layer provides consumers with query services when they access the system via varied terminals. At the data processing layer, the tracing system processes data in the storage layer and returns the processing results to the application layer after the data is further processed by gateways, routers and firewalls. The data storage layer stores the supply chain data. It is composed of two major components, namely Redis and consortium chain network. When the system deals with a query request, it first queries Redis. If the data can be retrieved, then the results would be returned directly; if not, continue to query the blockchain database, and write the query results into Redis as key-value pairs [7].

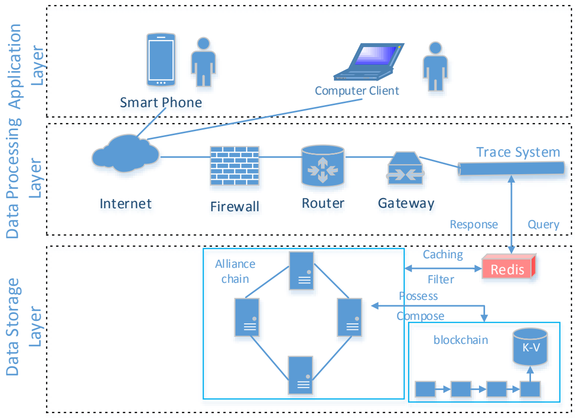

Fig. 1. System framework

Logically, the system can be divided into seven layers, namely network layer, consensus layer, chain code layer, cache layer, model layer, control layer and view layer. As shown in Fig. 2, the system is designed with Hyperledger Fabric as the underlying technology. The network layer is built with Docker and includes basic components such as Peer, Orderer and Certificate Authority (CA) [8]. The consensus layer is used to maintain consistency among distributed systems. Kafka and Zookpeeper are employed to build clusters, thus improving the fault tolerance of the system [9]. The chain code layer runs smart contracts (i.e., chain codes). The chain codes are developed in Golang and run in a safe and isolated container. The cache layer uses the Redis database and serves as the middle layer of the system. The model layer includes the functional modules of the system, including Fabric-sdk-go for Fabric network connection, API for chain codes operation, data encryption algorithm and QR code generation algorithm. Programmed with GoWeb, the control layer connects the view layer and the model layer, and provides services for the view layer. The view layer is a visual interface for user operation. It includes a blockchain browser, the tracing system for consumers, and the management system for supply chain organizations.

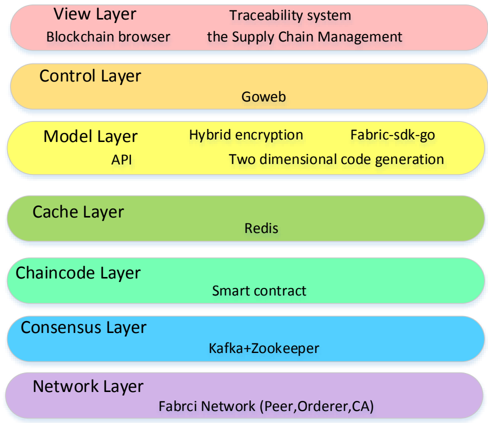

Fig. 2. Logic layers

B. Supply chain design

This study divides the agricultural product supply chain into five links, as shown in Fig. 3, namely manufacturers, processing factories, packing factories, logistics companies, and sellers. A supply chain organization represents a physical node in the blockchain, and each node has a complete ledger record. Before the products are delivered to following links, relevant information about the link shall be recorded in the blockchain. When the products are delivered throughout the supply chain, the complete information about products is recorded in the blockchain.

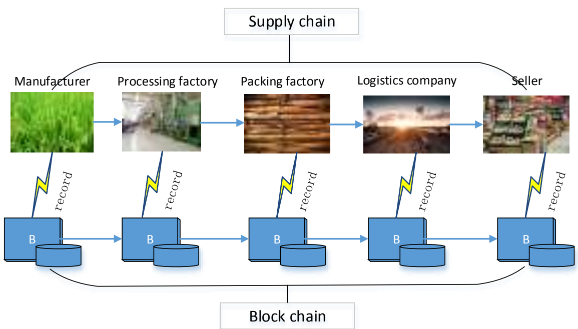

Fig. 3. Agricultural product supply chain

C. System design

In line with the links in the agricultural product supply chain, five organizational structures and a supply chain structure for product tracing are defined in the smart contract. As shown in Fig. 4, each organizational structure has several attributes and an operation for data recording data. The supply chain structure has all attributes of the supply chain structure, and five methods to display information about each link of the supply chain. The production, processing, packing, and transportation services are provided by one designated service providers, and the sales services can be provided by several designated service providers.

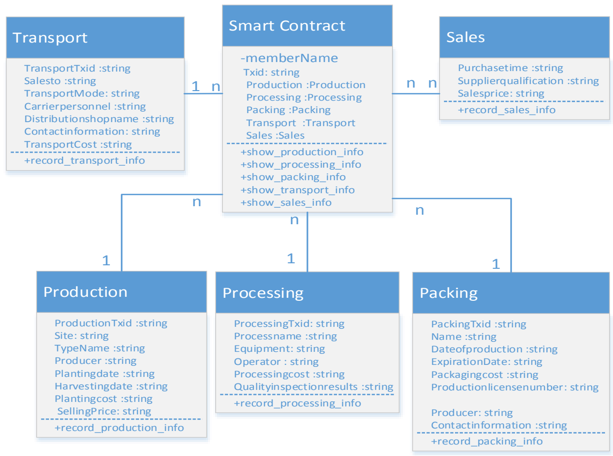

Fig. 4. Class diagrams of organizations in the supply chain

User query happens in three stages: send a query request to the system via user client, check whether K value exists in Redis (as shown in Fig. 5, if yes, return data to the client; if not, continue to query in the blockchain, return the results to the client and write them into Redis as pairs); offer the user with the query results via client. Redis acts as a cache mechanism.

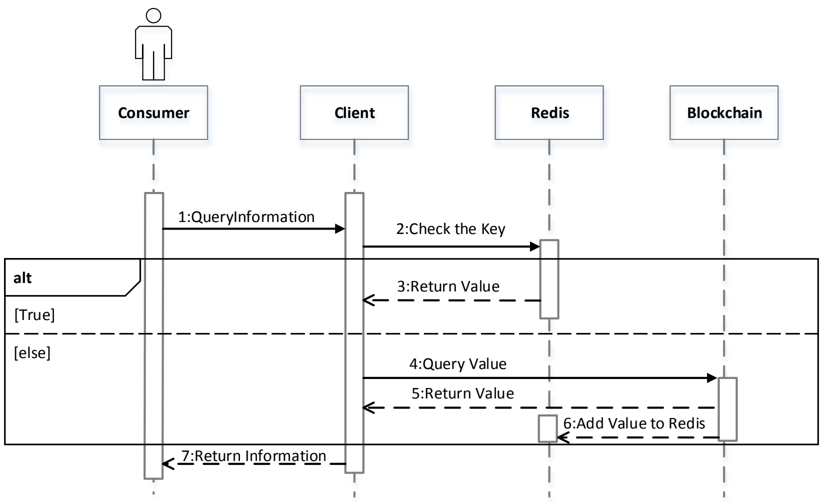

Fig. 5. Query sequence chart

As shown in Algorithm 1, the Bool function of Redis is requested. Check whether the data exist in Redis based on the key. If yes, read the data from Redis and perform the deserialization task; if not, check the data in the blockchain and return value after deserialization. The data is transmitted in Json and stored in Redis and the blockchain as key-value pairs.

Algorithm 1 Information Query

Input: Key

Output: Value

if redis.Bool("EXISTS",Key) **then**
    $data \leftarrow redis.Bytes("GET", Key)$;
    $Json.Unmarshal(data, Value)$;
else
    $data \leftarrow Query(Key)$;
    $Json.Unmarshal(data, Value)$;
end if
Return $Value$;

D. *Multi-hosts deployment*

The agricultural product tracing system is developed based on Fabric. As shown in Fig. 6, 3 Orderer nodes, 4 Kafka nodes and 3 Zookpeer nodes are configured in three hosts to form a cluster for block sorting. Each organization has a server and runs multiple peer nodes. Each organization is configured with the Ngnix service and generates a virtual IP via Keeplived for user access. A network of multiple hosts and nodes is thus established, achieving fault tolerance of the Orderer node, and load balancing and high availability of peer nodes [10].

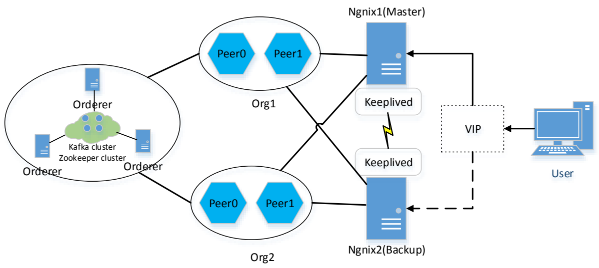

Fig. 6. Multiple hosts deployment

III. EXPERIMENT AND DISCUSSION

A. *Experiment environment*

There are single host and multiple hosts of the experimental environment, with the configuration shown as below:

Operating system: Ubuntu 16.04 64-bit; CPU: 2 cores; Memory: 2GB; Broadband: 1Mbps; Programming language: Golang.

The single host environment uses one server to create a 1-organization, 2-nodes network; and the multiple hosts environment uses 2 servers to create a 2-organizations, 4-nodes network.

B. *Single host experiment*

In the single host environment, the read performance of the Redis and the traditional databases (without Redis) was measured. As shown in Fig. 7, with Redis, the curve grows slowly along with the increase in the number of reads; while with the traditional databases, the curve grows rapidly. The read speed of Redis is at least 4 times faster than that of the traditional databases. As the number of reads increases, the gap widens.

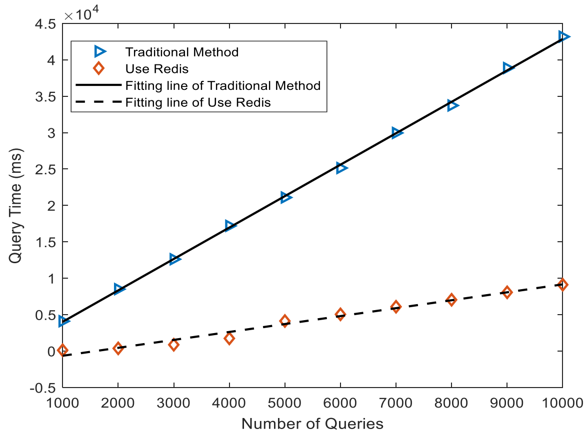

Fig. 7. Test comparison of single host query performance

C. *Multi-hosts experiment*

In the multi-hosts environment, the read performance was tested as well. As shown in Fig. 8, the changing trend of the curves is similar to those in the single host environment. Changes in the traditional database are more intensive, caused by the transmission delay of different nodes in the multi-hosts environment. The results suggest that Redis is over 20 times more efficient than that of the traditional databases. Therefore, Redis has enormous application value in the multi-hosts environment.

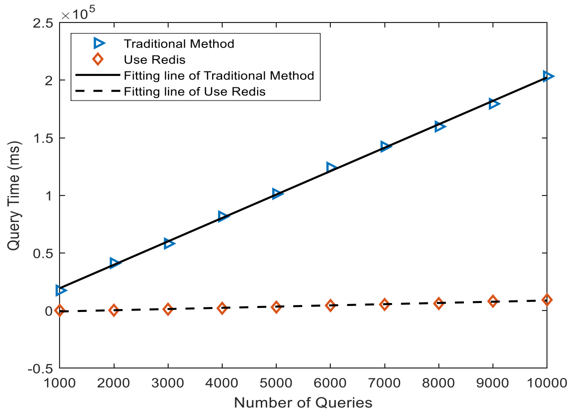

Fig. 8. Test comparison of multi-hosts query performance

IV. CONCLUSION

The study comes up with an agricultural product credibility tracing system that covers the complete supply chain, removing the data barriers among organizations and providing reliable quality control for consumers. The introduction of Redis into the blockchain tracing system optimizes its read performance and supports efficient tracing of agricultural products.

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