Research Article
doi: 10.1590/01047760202329013259
vol(29), 2023

CERNE

Forest resource management system based on blockchain

Lina Zhang[1✤], Hepeng Qu[1], Kun Liu[1], Yandi Wang[1]

[1]Jilin Agricultural University, China

FOREST MANAGEMENT

ABSTRACT

Background: With the reduction of global forest resources and the intensification of environmental problems, it is particularly important to seek new solutions for forest resource management. This paper proposes a forest resource management system based on blockchain technology to realize data security sharing and traceability of forest ownership. Through drone on-site verification and blockchain technology, management credibility and efficiency are improved and costs are reduced. The system provides innovative solutions in terms of data credibility, cooperation mechanism, intelligent decision-making, sustainable development, etc., and defines the future development direction.

Keywords: blockchain; smart agriculture; smart contracts; forest resource management; illegal logging.

HIGHLIGHTS

This article designs a blockchain based forest resource management system, which achieves real-time supervision and scheduling of forest resources through blockchain technology.
The system can be optimized in terms of block size, consensus algorithms, throughput, and other aspects. Improve the usability of the system.
The forest resource management system based on blockchain has broad development prospects in the future.
More efficient and reliable forest resource management can be achieved by strengthening data collection and monitoring capabilities;
The implementation of these development directions will provide important support for the sustainable utilization and protection of forest resources.

QU, H.; WANG, Y.; LIU, K. Forest resource management system based on blockchain. CERNE, v.29, e-103259, doi: 10.1590/01047760202329013259

✤Corresponding author: zhangln@jlau.edu.cn
Received: April, 23/2023 Accepted: July, 10/2023

Open Access
CERNE ISSN 0104-7760
UNIVERSIDADE FEDERAL DE LAVRAS

INTRODUCTION

At present, smart agriculture mainly includes five systems: three-dimensional perception, collaborative management, ecological value, livelihood services, and comprehensive management. Due to the diversity of forestry system data, the statistical and analytical models of forestry systems urgently need to be improved. It is necessary to establish a simple, efficient, stable, and scalable forestry resource management system through unified planning and improved regulatory models. Blockchain, with its characteristics of immutability, autonomy, security, and blockchain storage mechanism, provides high error tolerance and scalability requirements for the implementation of forestry regulatory systems, providing solutions.

Traditional forest resource management systems have been widely studied and applied. The research on this management system mainly focuses on the following aspects: research on forest resource monitoring indicator system, research on forest resource protection and utilization management strategies, and research on forest resource management and informatization. For example, Millikan et al. (2019) used airborne laser scanning data to automatically detect individual trees in the Amazon tropical forest, evaluate and detect four types of trees; Bugday et al. (2019) used neural networks to predict the relationship between land cover and population flow, and provided suggestions for forest and land planning; Felipe et al. (2019) used remote sensing technology to evaluate the relationship between leaf quantity and nutrients, providing a theoretical basis for monitoring the growth status of forest resources; Rosado et al.; (2019) developed a multivariate model using near-infrared spectroscopy to study the potential of plants to cope with different environmental pressures. By applying this model, it is possible to analyze the environment in different regions and select more suitable seedlings. Researchers studied the relationship between durability testing and resistance of commercial wood (Oliveira et al., 2019). Özçelik et al. (2019) established a cone model of Oriental spruce to detect trunk contour and volume, while Gyenge et al. (2019) established a forest density management map to improve pulp production, achieving excellent results.

At present, the research summary of forest resource management systems is as follows: Mortved et al. (2022) has developed the application of unmanned aerial vehicle photogrammetry data in forest genetics experiments: using cost-effective and time-efficient alternative methods to measure the height, growth, and phenology of Norwegian spruce trees. Figorilli et al. (2018) is the first to introduce blockchain technology combined with RFID sensors to enable electronic traceability of wood from standing logs to end users. Figorilli et al. (2018) and his collaborators proposed a blockchain implementation prototype of wood electronic open source traceability, which provided a theoretical basis for the application of blockchain technology. Wang et al. (2020) proposed the exploration of using blockchain technology to trace the legality of timber sources. The regulatory department stores, transmits, verifies, and analyzes product information, and transfers it among different departments to achieve unified vouchers and full-process records, effectively solving the multi-party participation in corporate credit reporting, information fragmentation, and repeated review and circulation links. Validated the feasibility of drone exploration in forest resource data, with high accuracy when the characteristics and conditions of the target tree are combined (Mortved et al., 2022). Tessa et al. (2020) collected data on forest society, tested the relationship between humans and forests, and used photos of forest index plots centered around four categories integrated forest features and incorporated them into deep forest detection in society. Jakobsson et al. (2021) studied the impact of sustainable forest management in Sweden, summarized the technical and political conflicts in forestry practices, and emphasized the necessity of government outcomes using different methods to manage forest resources. The research results of Hyrinen et al. (2020) indicate that wood, as a building material, has a positive psychological impact on health, leading to an increase in consumer appreciation of wood and wooden materials. Therefore, tracing the origins of forest resource management and timber trafficking processes has practical significance. Oliveira et al. (2009) analyzed the views of Brazilian Uba MG furniture center manufacturers on the use of eucalyptus in furniture production. After reasonable planning of oak resources, enterprises can obtain reasonable prices and information, and will use eucalyptus trees to produce furniture. This indicates that reasonable planning of forest resources can not only protect the environment, but also improve economic benefits (Oliveira et al., 2009). Frosini et al. (2009) introduced sustainability indicators in the selection of forest restoration sites in the Klenbatai River Basin, achieving a reforestation site selection method based on water sustainability indicators. The research results indicate different aspects of watershed sustainability. An example is provided for implementing a blockchain based forest management system (Frosini et al., 2009). Fiedler, et al. (2020) analyzed the entire process cost of forest planting operations by studying variables related to agricultural planting mechanization, and found that the consumption cost of subsoil is the highest, indicating the need for rational utilization of existing forest areas, which can to some extent reduce the cost of seedling cultivation. This will directly affect the survival rate of afforestation and the newly formed forest area in forest resource management.

The main purpose of this paper is to develop a blockchain-based forest resource management system. Provide efficient and simple solutions to problems encountered in forest resource management such as tree identification records, data abnormal alarms, data sharing, afforestation survival rates, and acquisition of newly added forest areas; the system can realize forest resource information collection and forest resource sales traceability; the method and traceability process of data on the chain are given, which improves the accuracy and security of information; the method of storing data using hash in the system, when the amount of data is large, the transaction cost of Ethereum is significantly reduced; the role of the system is rare in the existing system, and the data collection and business collaboration methods of Taolin forest households in the system.

Literature review

Blockchain technology

The blockchain is a distributed ledger system, and the collaboration of all parties can be directly connected without the intervention of a third party. For the safety of the collaboration, the system will broadcast the operations of each participant to all participants, ensuring The security and transparency of the collaboration process (Guo et al., 2022). At present, it is widely used in fields such as medical care, agriculture, education, and banking. The structure of the blockchain is shown in Figure 1.

It can be seen from the figure that there are multiple blocks on a blockchain, and each block includes a block header and a block body, including block casting, migration block hash value, timestamp, target hash, merkle root, block and block are connected through the serial hash value of the parent node, the timestamp is the record of each transaction to ensure the authenticity of the record, and record the ledger information through the merkle tree (Alber at al., 2022).

Merkle tree is a common data structure used to store key value pairs in a blockchain. There are three types of nodes in the merkle tree: branches, leaves, and extensions. Each leaf node uses a hash value as a marker for the data block, and each non leaf node uses the hash value of its child nodes as a marker. As shown in the figure, the hash values of two leaf nodes generate the hash values of their parent nodes (Rongxu et al., 2021). When data information is tampered with information errors can be quickly detected.

The overall transaction process of blockchain is shown in Figure 2. The client node constructs a transaction proposal and selects an endorsement node to submit it. The multiplier node simulates the execution of the proposal and generates a signature, and returns the results to the client (Zhang et al., 2021). The client submits the transaction, and the sorting node sorts, packages, and broadcasts the transaction to the blockchain. The main node updates the status of the transaction at this time and synchronizes the block through gossip within the organization, bookkeeping node saves data and updates status (Myles et al., 2021).

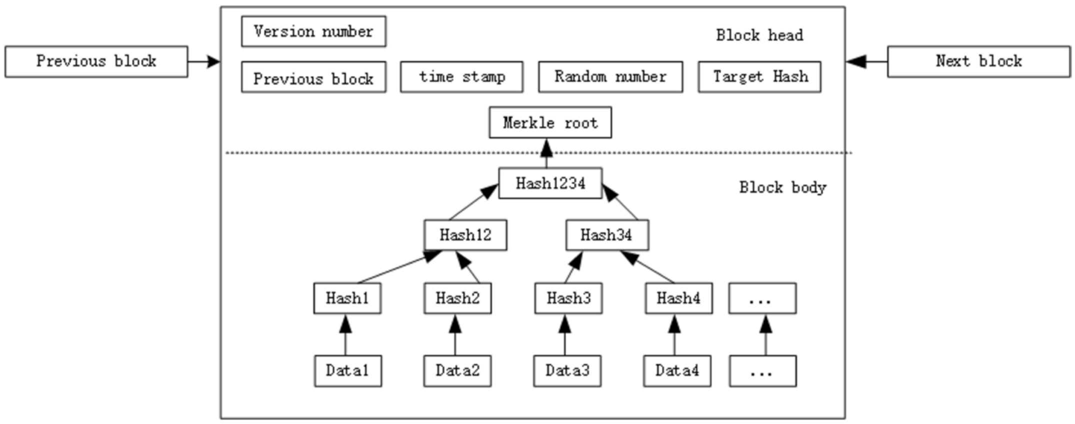

Figure 1. Blockchain structure.

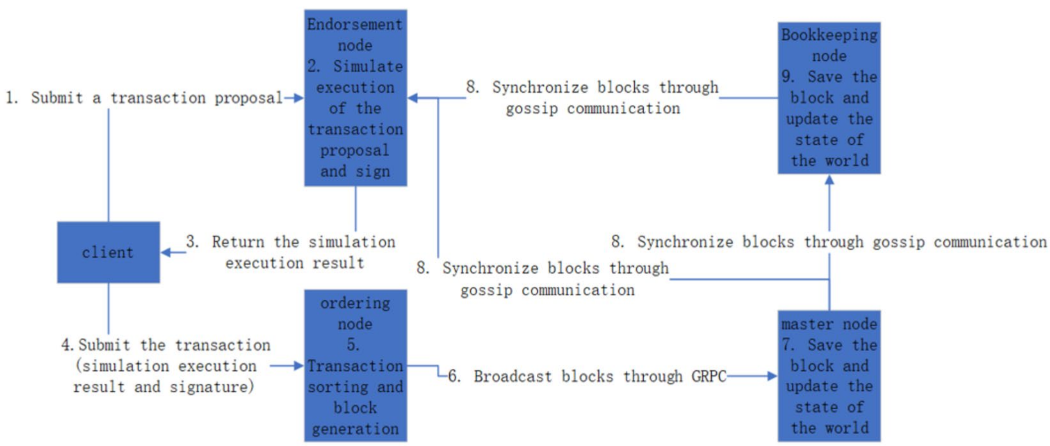

Figure 2. Blockchain transaction flow chart.

Hyperledger

Hyperledger is an open source project developed by IBM for enterprise customers. Using smart contracts, a system in which transactions are managed by participants, but not fully decentralized, members who want to join need to register from a trusted membership service provider. The ledger is shared by multiple participants, each of whom has a stake in the system. The ledger can only be updated if all participants reach a consensus, and once updated it cannot be changed, and every recorded event can be verified using cryptography based on the consensus proof of the participants. Transactions are safe, private and confidential (Jha et al., 2021). Each participant registers with the network membership service using proof of identity to gain access to the system. Participants generate transactions using untraceable export certificates and can remain completely anonymous in the network.

Hyperledger includes three major components: blockchain, chain code, member authority management, forest resource management system based on blockchain, which packs transactions in the system into blocks, and multiple blocks form a blockchain, representing the ledger. The historical process of state machine changes. By calling the interface provided by the chain code, that is, the smart contract, the state of the world in the block is changed (Li et al., 2021). For members who access the forest resource management system, KPIs are used to restrict access to government departments, merchants and other nodes. The Hyperledger architecture is shown in Figure 3.

The application implements the logic of the business by calling the smart contract, which is closer to the user end, and the application is more flexible. It can run on the network nodes of the blockchain or on the centralized server, but it must be guaranteed to be accessible Smart contract API and good network. Application development is shown in Figure 4.

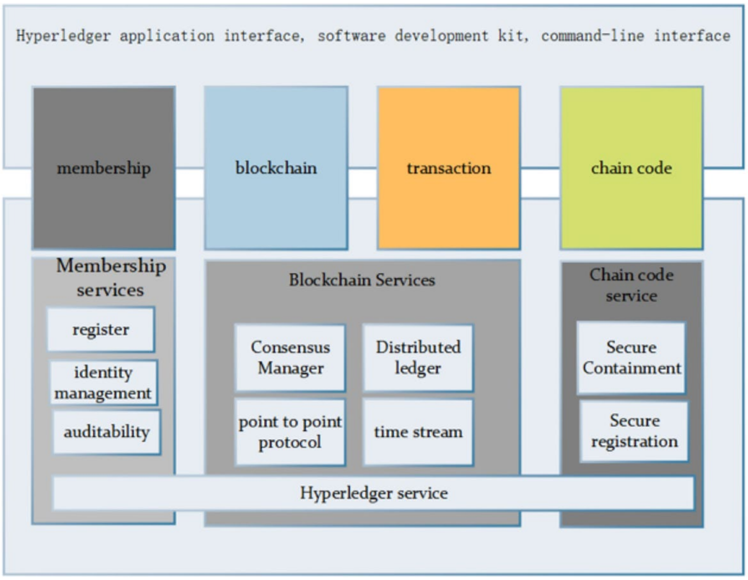

Figure 3. Hyperledger architecture diagram.

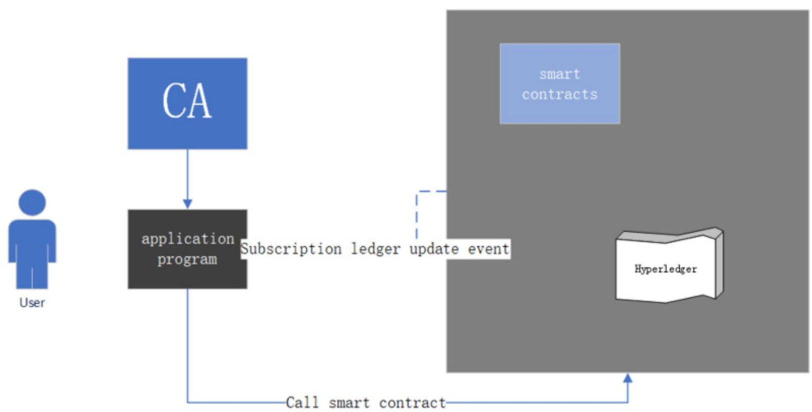

Figure 4. Application development example diagram.

Blockchain and Forest Resource Management System

Forest Resource Management System

The forest resources management system is a management system that utilizes modern information technology to realize the digitization, visualization and traceability of forest resources. By integrating multi-source data, including remote sensing data, manual survey data, etc. a complete forest resource information database is constructed to provide dynamic monitoring of forest ecosystems and decision support for forest resource management. The system has a variety of functional modules, including data acquisition, data storage, data management, data analysis and application decision-making, etc, which can realize comprehensive, accurate and real-time monitoring and management of forest resources (Noah et al., 2022).

In terms of data collection, the forest resource management system uses a combination of remote sensing technology and manual surveys to collect various data on forest resources, including forest geographic information, forest types, and forest ecosystem indicators. In terms of data storage, the system uses distributed database technology to store data on multiple nodes to ensure data security and reliability. In terms of data management, the system uses technologies such as data cleaning, data normalization, and data mining to process and analyze data and extract valuable information (Sun et al., 2023). In terms of data analysis, the system uses data visualization technology to present data as intuitive and easy-to-understand charts to help users deeply understand the data and make decisions (Santopuoli et.al., 2020). In terms of application decision-making, the system provides a variety of decision-making support tools and services, including forest resource assessment, forest resource planning, forest resource monitoring, etc (Huang et al., 2023), to help users better manage forest resources.

The forest resources management system has a wide range of applications and can be applied to the management and protection of various forest resources, including state-owned forests, private forests, nature reserves, forest parks, etc. This system can help the government and enterprises manage and monitor forest resources more accurately, protect and maintain the ecological environment, and promote sustainable development (Jiax et al., 2021).

In order to solve the current problems of information collection and management of forestry resources and realize the informatization of forest resources management, the framework of the forest resource system is proposed based on blockchain technology. Figure 5 shows the entire system framework. The application of blockchain technology has improved the quality of the data makes the whole system more reliable.

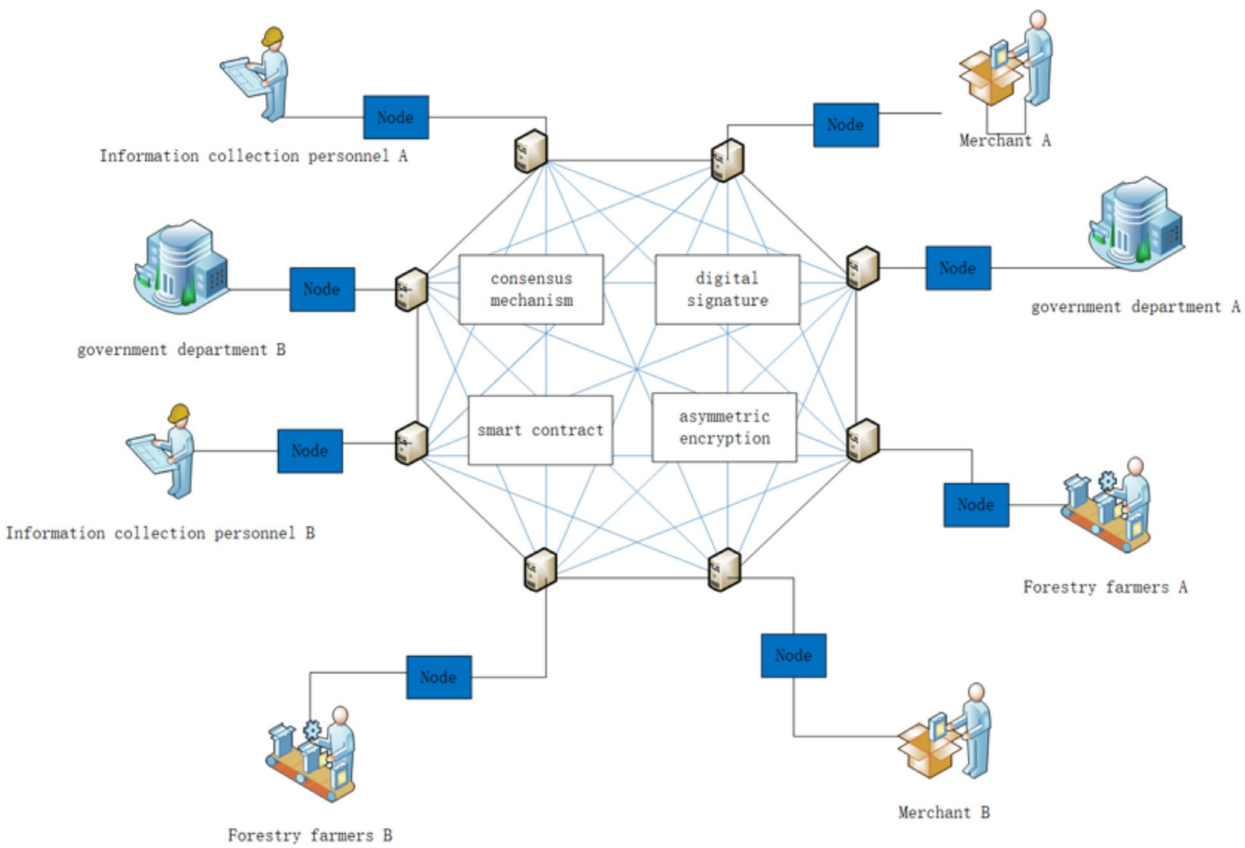

Figure 5. Blockchain network framework.

When the amount of data is large, the consumption of storing information and obtaining information on the blockchain is too high. The mixed use of blockchain and database is adopted, and efficient space operation functions are used to optimize the query. It will be explained in detail in the Optimizing Search section.

System design

The data mobile device uses drone image transmission technology and H.265 encoding technology to obtain coordinates and image information within the collection area. The drone terminal establishes a connection with the image transmission device through a WiFi module, controls in both directions, and transmits image information to the image storage server. The image processing server processes the images of the image storage server and uploads the longitude, latitude, and image information of the collection area to the blockchain. The overall design of this program is shown in Figure 6.

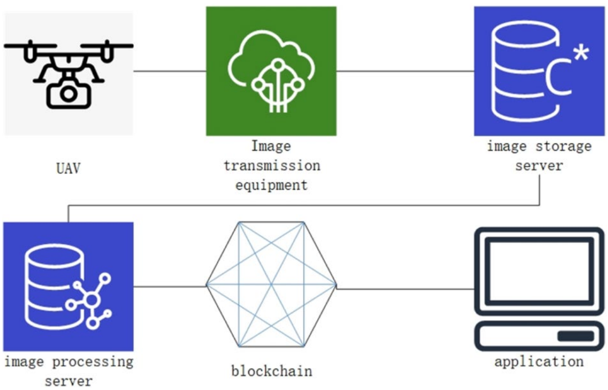

Figure 6. System design diagram.

System structure

The deep forest resource management system based on the blockchain can manage the data of the video processing server, ensure the accuracy of the data through automatic collection and manual input, unify the standard and coding format of the database, and facilitate multi-departmental data sharing and analysis and decision-making. Manage and control forest resources, based on the decentralization and security of the blockchain to ensure the stability, sharing, traceability of forestry data, and according to the actual requirements of the data system, perform operations such as transmission, storage, analysis and integration of data, the block chain-based resource management system architecture diagram (Figure 7), which is mainly divided into four steps.

The combination of blockchain and traditional relational databases not only preserves the original characteristics of blockchain decentralization, but also enables blockchain to support more application scenarios and alleviate the problem of increased time consumption caused by the need for all nodes to participate in transactions in blockchain. Store the data on the chain in a traditional database. Using node monitoring blockchain, when the data within the node is updated, the monitoring program extracts or updates the data to the traditional database; after the application sends a query request, it obtains the database configuration file information according to different nodes through the smart contract. Each node of the program connects to the corresponding database, reducing the program time consumption, and uses dual verification to verify the data and verify the data security. When users query data, the API obtains the connection information according to the node information, and queries the traditional database by creating a Connection pool, and return the results to the application. The optimal retrieval system model is shown in Figure 8.

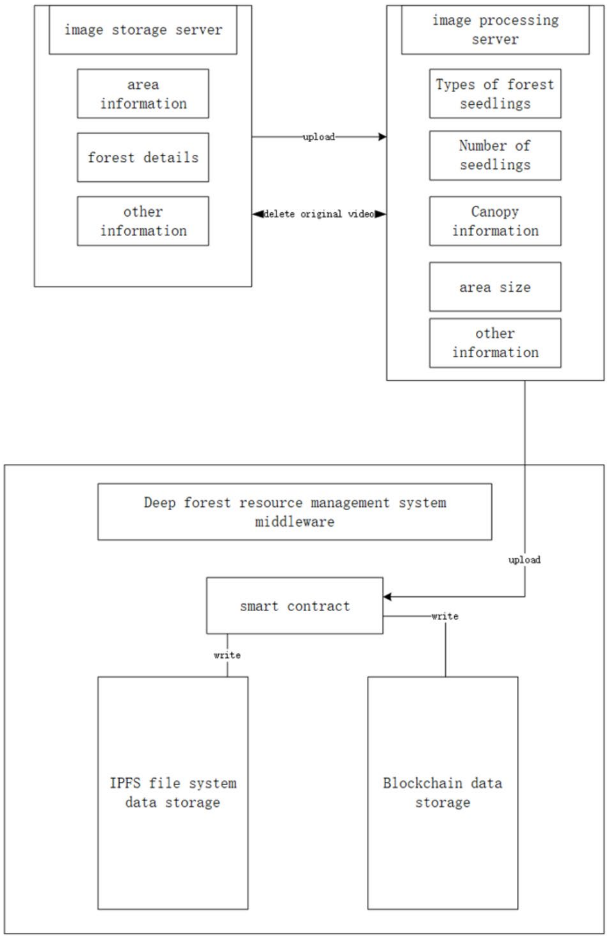

Figure 7. System architecture diagram of forestry resource management system optimized search.

Implement

Information on-chain process

Taking the upload of an information collector as an example, as shown in Figure 9, the data collection personnel upload the data to the image storage server through drones and manual input. This program processes images and creates a JSON object that contains information such as forest area, species, average age, and uploader ID. Upload information through the corresponding modules in the forest resource management system and broadcast the information to the blockchain; Government departments can update, integrate, and analyze corresponding information; Users can view forest distribution information through the application program; The information on the chain is shown in Table 1.

Information traceability process

Taking the traceability process of timber trading as an example, Figure 10 shows the traceability process of seedling purchase. Government departments or merchant groups want to query the historical records of a certain transaction. By entering the transaction ID and block height to obtain all records, the traceable records of the supply chain can be realized. It is also possible to query relevant information in the Hyperledger browser through the transaction hash very convenient. The historical result information is shown in Table 2.

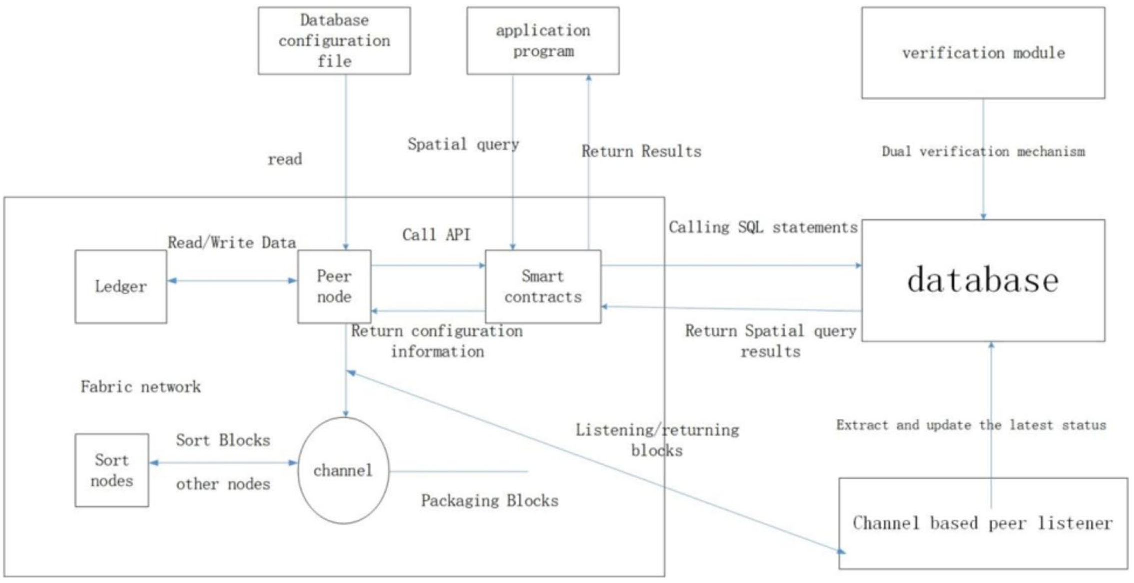

Figure 8. Optimizing the retrieval system model.

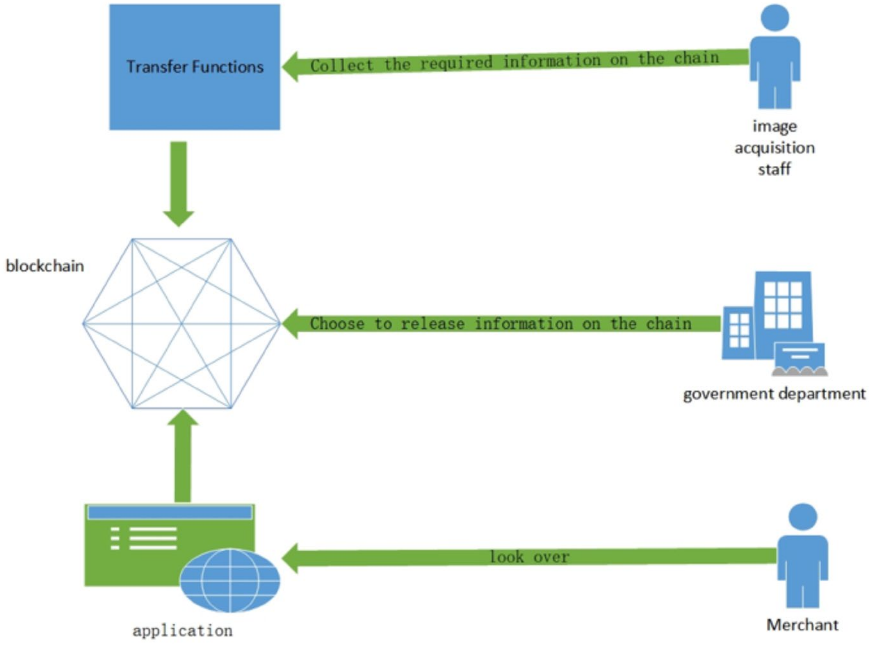

Figure 9. Information on-chain process.

Table 1. Information on-chain process.

Forest tree information node	Information
Regional latitude and longitude	*24.711526, 52.335262*
Average height	18 M
Number of years	170 year
Diameter	0.4 m
Type	Beauty pine
Quantity	352 trees
Is there any disease	Yes

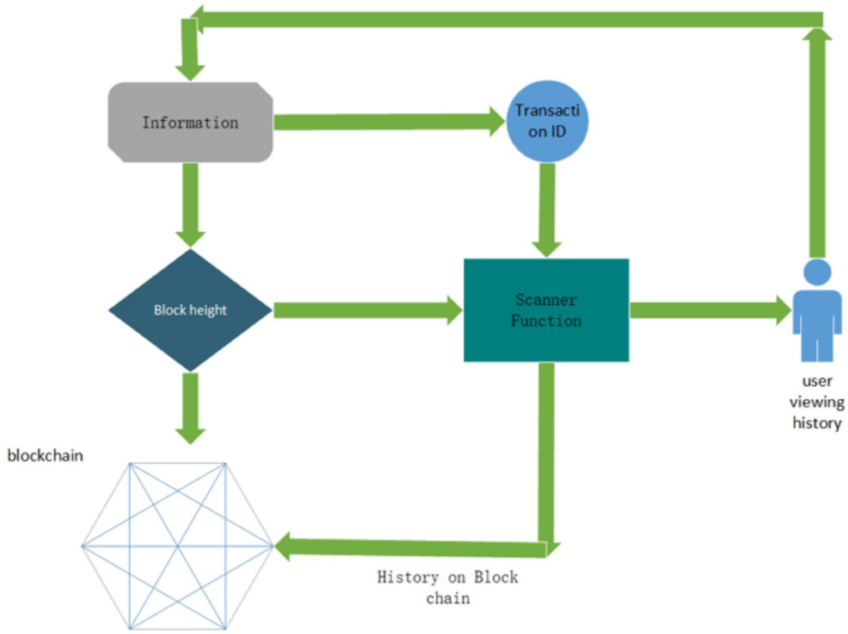

Figure 10. Traceability flow chart.

Table 2. The historical result information.

Txn Hash	Block	Age	from	to
0xm3zgsogn...	12408510	4hrs ago	0xmpupueka...	0xfxcwwhqd...
0xmivjda3i...	12408503	6hrs ago	0xjtlcpwyr...	0xg2clyheh...
0x164ppgn6...	12398440	1days 16hrs ago	0xn38y9js7...	0x8crltgqn...
0xgx84Lypl...	12398421	1days 20hrs ago	0xnd7xjrng...	0xmqi3yv8j...

CONCLUSION

This article designs a blockchain based forest resource management system, which achieves real-time supervision and scheduling of forest resources through blockchain technology. It can improve the accuracy and supervision effect of resource utilization, optimize resource scheduling and configuration, and improve resource utilization efficiency and value. Managing the entire process of forestry resource information collection, transmission, and analysis, improving the sharing of information among various forestry departments, as well as the accuracy and security of forestry data, has achieved the legitimacy, rationality, and traceability of exploitable forestry resources, and solved the problems of difficult information sharing and redundant data in current forestry resource management. The current system is in the initialization stage, and in the future, the system functions can be improved according to actual needs, such as increasing various forestry data resources, approving wild plant picking certificates, and designing system permissions. The system can be optimized in terms of block size, consensus algorithms, throughput, and other aspects. Improve the usability of the system. The forest resource management system based on blockchain has broad development prospects in the future. More efficient and reliable forest resource management can be achieved by strengthening data collection and monitoring capabilities, promoting cross-border cooperation and data sharing, introducing smart contracts and sustainable development mechanisms, strengthening security and privacy protection, and integrating artificial intelligence and Big data analysis. The implementation of these development directions will provide important support for the sustainable utilization and protection of forest resources.

AUTHORSHIP CONTRIBUTION

Project Idea: HQ

Funding: KL

Processing: YW

Analysis: HQ; LZ

Writing: HQ

Review: KL

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