Construction of Financial Data Supervision Mode Based on Blockchain Technology

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Abstract: To address the issues of low system throughput and poor financial data sharing in traditional enterprise financial data management systems, a financial data supervision model based on blockchain technology is proposed. This model utilizes Internet of Things (IoT) technology to establish a data sharing system consisting of a perception layer, network layer, data layer, and application layer. The RESTful architecture of REST information sharing services (ROA) is chosen to provide the sharing services for the system. The system collects enterprise financial data using sensing devices, and the collected data is transmitted to the data layer through a gateway composed of certificate management, data reception, and Fabric SDK. The data layer preprocesses the collected data for storage and sharing, while ensuring the security of data storage and sharing within the system through decentralized blockchain technology. The design of the enterprise financial data sharing system is completed. The testing results indicate that the designed system enables effective sharing of financial data and improves the performance of the financial data management system.

Keywords: low system throughput, a financial data supervision model, blockchain technology, enterprise financial data

1 INTRODUCTION

Blockchain technology offers diverse and high-value advantages that enable comprehensive management of enterprise financial data and enhance financial management efficiency. Rail transit enterprises involve various technologies such as operation maintenance and vehicle data, with extensive data distribution and high interconnectivity between different data sources. The relevant data in rail transit enterprises exhibit certain regularity and heterogeneity, making the application of information management methods highly suitable for financial data management in rail enterprises. By integrating IoT technology, rail transit enterprise financial data can be consolidated into a shared system. This system facilitates information and data sharing, transforming financial data into actionable insights, and improving the efficiency of financial data management in rail transit enterprises[1,2].

Enterprises encompass numerous industries and generate massive amounts of information, making data and information management crucial. The level of digitization and informatization directly impacts the business models and efficiency of enterprises. For instance, in the case of rail transit enterprises, the sheer magnitude of financial data poses challenges, and the lack of advanced analytics and management capabilities hinders business

ICIDC 2023, June 02-04, Nanchang, People's Republic of China

DOI 10.4108/eai.2-6-2023.2334674

expansion. The information of financial data in rail transit enterprises can enhance overall management[4,5].

In recent years, there has been extensive research on blockchain-based regulatory models for financial data management. Wang et al[6]. have applied blockchain identity technology and cloud computing technology to the sharing of photovoltaic data and enterprise financial data. Concurrent workflow technology can also be utilized for regulatory purposes. Currently, data integration technology, grid technology, concurrent workflow, and distributed workflow have laid the foundation for financial supervision within corporate groups. Although the research enables fast transmission and sharing of financial data, the effectiveness of sharing is unsatisfactory, and there exists the problem of information silos in the research[7].

To address this issue, this paper proposes a regulatory model for enterprise financial data based on blockchain technology. It integrates Internet of Things (IoT) technology into the financial data sharing system of rail transit enterprises to enhance the performance of financial data sharing. The designed system is experimentally validated to have high applicability and effectively improve the financial data sharing performance of rail transit enterprises[8].

2 CONSTRUCTION OF ENTERPRISE FINANCIAL DATA SUPERVISION MODE

2.1 Overall system architecture

The overall structure of the designed enterprise financial data sharing system is illustrated in Figure 1.

From Figure 1, it can be observed that the designed enterprise financial data system consists of four main components: the perception layer, network layer, data layer, and application layer. The system utilizes sensing devices in the perception layer to effectively sample diverse and heterogeneous financial data from multiple sources. It tracks various data collection terminals in the perception layer to ensure data monitoring and enables data sharing and intelligent management. The collected data is transmitted to the data layer through a gateway composed of certificate management, data reception, and Fabric SDK. The data layer receives massive and diverse financial data from rail transit enterprises and transfers the received data to internal and external applications through preprocessing and blockchain technology, thereby providing diverse financial data sharing services for the system. The system achieves interconnectedness of financial data in rail transit enterprises through the data layer[9].

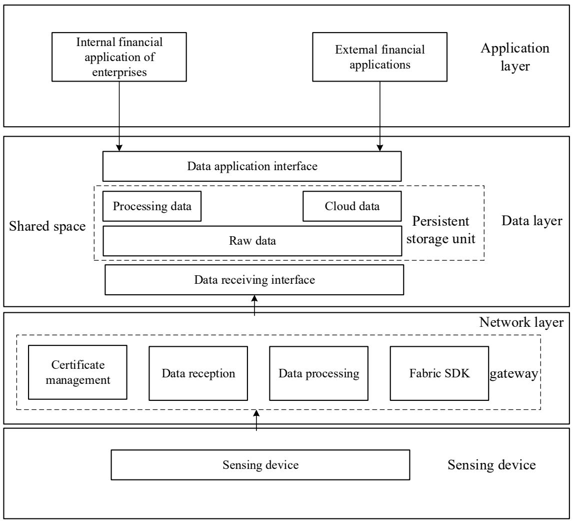

Figure 1. System overall structure System overall structure

2.2 Design of REST information sharing mechanism

Solving the problem of financial data sharing in the system through financial data acquisition, data abstraction, and data localization. Selecting REST for information sharing services to achieve effective sharing of enterprise financial data. In the REST architecture, Representational State Transfer (REST) Object Architecture (ROA) serves as a typical example that can be utilized to describe actual sharing problems using REST, making the system architecture simpler[10]. By selecting the ROA architecture within the REST information sharing service, the Internet of Things (IoT) is leveraged to provide services for the sharing system.

In the REST information sharing service, all named entities are represented as resources. Perception networks, perception data, and access gateways can all be represented by resources. The system's Internet of Things architecture utilizes knowledge resources, object resources, and index resources to represent all resources. Independent data collections are recorded as object resources, while knowledge resources are obtained from object resources using filtering, aggregation, and other methods. One type or collection of data is represented as an index resource, which can be accessed through a resource listing to access object resources[11]. The relationship between resource hierarchy and resource types in the ROA architecture is shown in Figure 2.

From Figure 2, it can be observed that index resources are used to identify the transfer of states between different resources. By utilizing state transitions, knowledge and resources between objects can be obtained. Knowledge resources and object resources can be extracted in a fixed manner to acquire perceptual knowledge resources using states. The transfer paths of different types of resources in the system can be replaced by another index resource, allowing flexible organization and sharing of different types of enterprise financial data resources in the system[12].

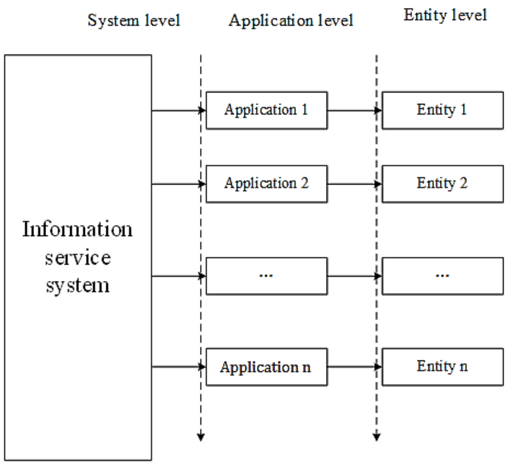

Figure 2. Relationship between resource types and hierarchies

2.3 Data preprocessing

Data blockchain technology is an important technique that utilizes collected data to establish a data ledger. Blockchain technology can enhance data reliability. The Internet of Things architecture utilizes sensor devices to collect financial data from railway transportation enterprises. When using blockchain technology to process massive data, it is necessary to preprocess the collected data for subsequent classification, storage, and sharing. The structure diagram of the data preprocessing mechanism is shown in Figure 3.

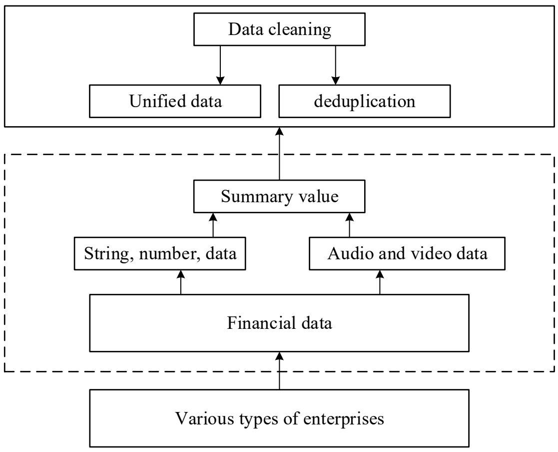

Figure 3. Data preprocessing mechanism

Data preprocessing starts by compressing multimedia data to reduce the storage capacity required for shared data in the system. Once the compression of multimedia data is completed, data fusion is performed to combine the data, thereby reducing the system's data size. To facilitate data sharing, a standardized data representation is adopted for data storage.

Distributed storage is used to store processed data, ledger data, and outsourced data separately. These data are stored on various system nodes and fog nodes. When users need to use the data, they can download it from the shared system at any time, enabling data supervision[13].

3 SYSTEM GATEWAY DESIGN BASED ON BLOCK CHAIN

Implementing communication using a gateway. The gateway consists of certificate management, data reception, and Fabric SDK. The certificate management module and the data reception and processing module are used for certificate application, storage of IoT device certificates, as well as receiving and processing collected data[14]. The communication within the blockchain network is achieved using the Fabric SDK. The device gateway registration process based on blockchain technology is shown in Figure 4.

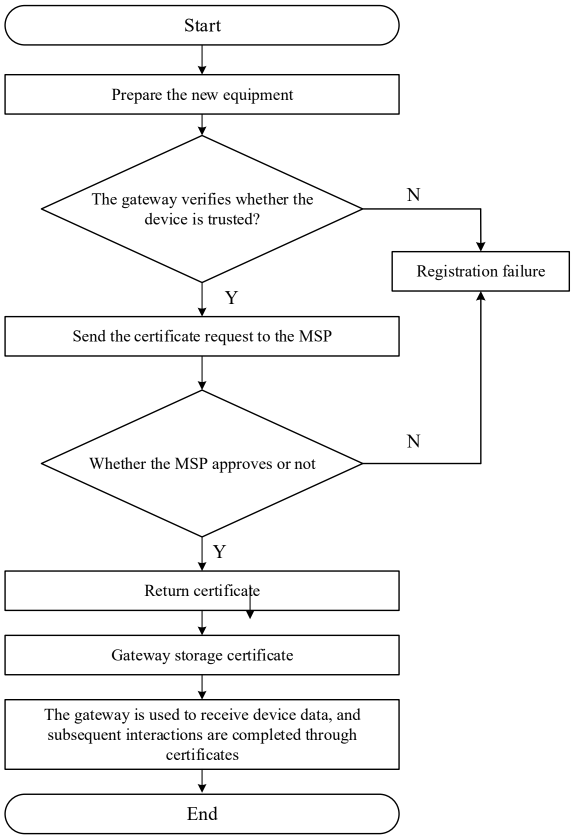

Figure 4. Flowchart of device gateway registration based on blockchain

The device gateway registration process is as follows:

1) When the system receives data from a new IoT sensor node, it needs to verify the device's identity through the gateway to determine its trustworthiness. If the device is deemed trustworthy, the gateway utilizes the certificate management module to send an HTTP POST

request to the corresponding MSP (Membership Service Provider) based on the user's request. This process facilitates the registration application for the IoT sensor device's identity certificate.

2) After receiving the request, the MSP verifies its legitimacy. If the request is deemed valid, a new certificate is generated and sent to the certificate management module. However, if the request is found to be invalid, it is returned to the sender. The sorting service, nodes, and channel configuration in the blockchain network are authorized by the MSP. The certificates sent by the MSP can be applied within the IoT network[15].

3) After the certificate is sent to the certificate management module, the local database needs to encrypt, store, and process the received certificate. It is essential to maintain an effective record of the corresponding relationship between the IoT device and the sent certificate.

4) The data collected by IoT sensor devices needs to undergo processing using the data reception and processing module. This module is responsible for cleansing the received data, converting its format, and transmitting the processed data to the Fabric SDK.

5) The certificates of IoT sensor devices are utilized for signing using the Fabric SDK. After signing, the received data is encapsulated into a transaction proposal and then transmitted to various nodes within the IoT channel.

The blockchain network consists of numerous events such as block events and channel events. The gateway can effectively monitor data transmission, facilitating subsequent operations.

4 THE DEGREE OF DECENTRALIZATION BASED ON BLOCKCHAIN TECHNOLOGY

Decentralization is at the core of blockchain technology, where entities in the blockchain network are unable to control the network's rights. When applying blockchain technology to a shared system, data sharing and storage rely on consensus nodes. Consensus nodes play a crucial role in the blockchain network. Blocks can be added to the blockchain by verifying the blocks of consensus nodes. The degree of decentralization in a blockchain network is determined by the validation of nodes. Additionally, the level of decentralization is influenced by the fluctuation in data storage by consensus nodes. The more diverse the data storage volume in the blockchain network, the more centralized it becomes. The decentralization of a blockchain network is determined by the proportion of consensus nodes, data storage fluctuations, and node validation.

The storage situation of enterprise financial data in consensus nodes determines the variability of data storage. Let's represent the pending shared financial data files within the same consensus period as $F = \{f1, f2, ..., f|F|\}$, where $|F| = NF$. The enterprise financial data files are of equal size and are represented by $x_{c,f}$ belonging to {0, 1}, where $x_{c,f} = 0$ and $x_{c,f} = 1$ indicate that the data file f is stored and not stored in consensus node c, respectively. Within the same consensus period, the storage status of enterprise financial data files in consensus nodes can be expressed as:

$$\psi = \begin{bmatrix} x_{1,1} & \dots & x_{1,|F|} \\ \dots & \dots & \dots \\ x_{|c|,1} & \dots & x_{|c|,|F|} \end{bmatrix} \quad (1)$$

The number of railway transportation enterprise data files stored in consensus node ci can be represented as:

$$\psi_{i,|F|} = x_{i,1} + x_{i,2} + \dots + x_{i,|F|} \quad (2)$$

Here, F represents the stride between enterprise data files.

The enterprise data file fj can be stored simultaneously in multiple consensus nodes to prevent the loss of stored data files. The formula for the number of replicas of the stored railway transportation enterprise data file fj can be expressed as:

$$\psi_{|c|,j} = x_{1,j} + x_{2,j} + \dots + x_{|c|,j} \quad (3)$$

The variance (var) represents the disparity in the quantity of railway transportation enterprise data files stored among consensus nodes. The differences in storing shared data files among consensus nodes increase as the variance (var) becomes larger. The formula for variance (var) can be expressed as:

$$\text{var} = \frac{\sum \left(\psi_{i,|F|} - \frac{\sum \sum x_{i,j}}{N_c} \right)^2}{N_c - 1} \quad (4)$$

Here, Nc represents the variance value of the original data.

The formula for measuring the degree of decentralization in a blockchain network is represented by formula B:

$$B = \frac{\beta_1 F_{con} + \beta_2 F_{VER}}{\text{var}} + \kappa \quad (5)$$

In the formula, κ represents the error parameter, while β_1 and β_2 represent system parameters. *Fcon/Fver* represents different decentralization data term frequency factors. The degree of decentralization in a blockchain network increases as the obtained value of B becomes higher.

Normalizing the degree of decentralization B and block propagation latency τ facilitates balanced analysis of the relationship between the two. The formula for normalizing block propagation latency is as follows:

$$\tau = \frac{\tau - \tau_{mean}}{\tau_{\max} - \tau_{\min}} \quad (6)$$

In the equation: τmax and τmin represent the maximum and minimum block propagation delays, respectively; τmean represents the average block propagation delay in the system.

The formula for normalizing the degree of decentralization is as follows:

$$B = \frac{B - B_{mean}}{B_{\max} - B_{\min}} \quad (7)$$

In the equation: Bmax and Bmin represent the maximum and minimum values of decentralization degree, respectively; Bmean represents the average value of decentralization degree.

Set a threshold φ such that $\varphi = \tau_{->1} - B_{->1}$. The threshold can be dynamically adjusted based on the real-time performance requirements of the rail transportation enterprise's financial data sharing system. When the system requires high decentralization or low latency, set $\varphi < 0$ and $\varphi > 0$ respectively.

The implementation steps of the financial management system based on blockchain technology can be divided into three stages during its application and development, as shown in Figure 5. In the first stage, enterprise nodes submit transaction information to the accounting nodes in the blockchain for calculation, generating specific blocks within the blockchain. These blocks are stored in distributed storage space for subsequent querying and processing. In the second stage, enterprise nodes not only provide transaction information but also provide business demand information to the accounting nodes, which is written into smart contracts. Once other enterprises meet the business requirements, automatic matching and business transactions can be achieved. In the third stage, accounting nodes can also provide recommendations for enterprise financial management decisions and business operations to the enterprise nodes, helping the enterprises to develop better and cope with potential risks.

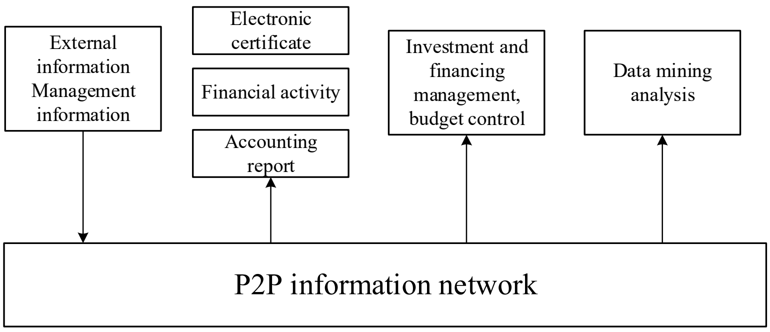

Figure 5. Implementation steps of enterprise financial management system based on blockchain

5 THE DEGREE OF DECENTRALIZATION BASED ON BLOCKCHAIN TECHNOLOGY

5.1 Experimental scheme

Applying the designed blockchain-based enterprise financial data supervision model system to a specific rail transportation company, we validate the effectiveness of the system in terms of financial data sharing. We select two comparative systems to visually demonstrate the effectiveness of data sharing in our system.

Table. 1. Parameter setting

parameter	2007
Channel capacity	120bit/s
Verify the proportion of nodes in consensus node recruitment	0.3
Check the storage capability threshold of the node	64GB
CPU cycles	1/64
Block size	214bit
Average round-trip time	120ms
Minimum computing capability of a node	1200Hz

The designed system adopts the Internet of Things architecture and uses blockchain technology to realize communication and data sharing. The system parameters are set as shown in Table 1.

5.2 Result analysis

Comparison of the storage of byte counts in different blocks within the system proposed in this paper, the system described in Reference [6], and the system described in Reference [7] was conducted in the experiment. The comparison was carried out based on varying block sizes. The results of the comparison of block propagation delays in the IoT architecture for different block sizes are shown in Figure 6.

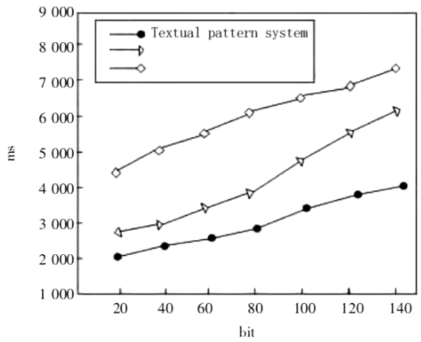

Figure 6. Propagation delay analysis of different system blocks

From Figure 6, it can be observed that when the block size is fixed, the block propagation delay of the system proposed in this paper is lower compared to the other two systems. The main reason for this is that the system in this paper applies blockchain technology to the IoT architecture. In the proposed block propagation scheme, both the consensus node layer and the validation node layer require consensus nodes to facilitate block transmission, effectively reducing the block propagation delay in the shared system. When the block size is changed, the block propagation delays of the system vary accordingly. As the block size increases, the number of pending verification blocks increases, leading to an increase in propagation delay.

The results of decentralizing enterprise financial data using blockchain technology for the three systems under different levels of consensus nodes are shown in Figure 7.

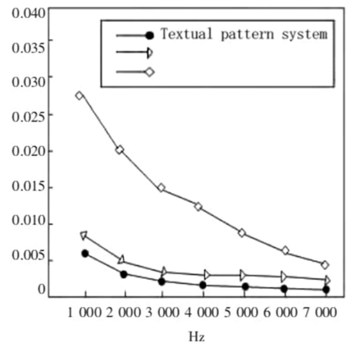

Figure 7. Results of decentralization of financial data in different systems

The results from Figure 7 indicate that as the thresholds for the computing power and storage capacity of consensus nodes increase, the decentralization levels of different systems in managing financial data decrease. The main reason behind this is that the validation nodes and consensus nodes in the blockchain decrease with the increase in the threshold for computing power, resulting in a reduced level of decentralization. Additionally, the proportion of consensus nodes in the IoT decreases as the thresholds for computing and storage capacity increase, further reducing the decentralization level of the blockchain and improving the security of the shared system.

To further validate the effectiveness of the proposed system, an experimental analysis was conducted on the throughput of the three shared systems. The tests were repeated 10 times under different block formation times, and the results are presented in Figure 8.

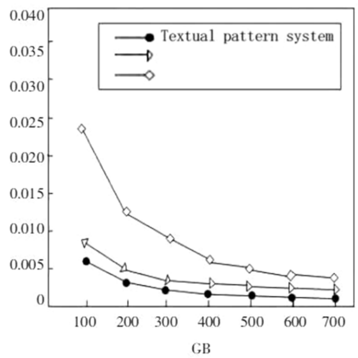

Figure 8. Throughput test results of different systems

From the experimental results in Figure 8, it can be observed that the throughput of the system proposed in this paper is consistently above 10,000 transactions per second (tps) for different block formation times. This indicates that the proposed system possesses a high throughput capability, making it suitable for meeting the financial data sharing requirements of railway transportation enterprises when applying IoT technology.

6 CONCLUSION

Enterprises often deal with massive volumes of diverse and heterogeneous financial data, making secure data sharing a challenging task. Therefore, designing a regulatory model system for enterprise financial data based on blockchain technology can enhance the intelligence, digitization, and informationization of enterprise management. The application of IoT technology in the field of data processing has been rapidly advancing the digitization of information technology. In previous attempts to apply IoT technology in shared systems, the lack of effective credit guarantee mechanisms during the data sharing process often led to the formation of information silos. By incorporating blockchain technology into IoT architecture, the effectiveness and security of data sharing in IoT technology can be significantly improved. Blockchain technology can prevent unauthorized personnel from tampering with shared financial data within the system.The designed system can facilitate effective management of enterprise operations and provide valuable data support for the smooth functioning of businesses.

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