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The Application of Blockchain Technology in Engineering Project Archive Management

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Abstract: Blockchain is a distributed ledger technology that became widely known with the development of virtual currencies, and is often applied in fields such as finance, logistics, and government that require high data security. Engineering project archives belong to commercial confidential documents, and there are strict regulations for the establishment and circulation of archives. Engineering project archives are technical documents formed during engineering planning, construction, and management activities, and their authenticity and immutability are crucial. In order to address the security and credibility issues in traditional project archive management, this paper proposes a digital management solution for project archives based on blockchain and smart contract technology, which reduces the possibility of human operation in archives and aims to make the archive management process more reliable and intelligent.

1. Introduction

Blockchain is a distributed ledger technology that enables decentralized, tamper proof, traceable, collectively maintained, and publicly transparent data storage processes. A Smart Contract is a program implemented on blockchain technology that automatically enforces the terms of a contract. It allows contractual agreements to be defined, validated and enforced in the form of code without a third-party intermediary. It is a set of digital protocols that ensure that the contracting party executes predetermined commitments.

Generally, engineering project archives mainly include the following contents: firstly, planning schemes in project feasibility study reports, project overview documents, and other documents; Secondly, progress control information in documents such as monthly supervision reports, construction logs, and construction schedule application forms; Thirdly, cost control information in bidding notices, various contracts, engineering change notices, and other documents; Fourthly, the quality control information in documents such as drawings, material and equipment inspection forms, equipment installation records, and on-site test summaries; Fifth, resource information in documents such as material and equipment inspection lists, concealed engineering acceptance records, etc; Sixth, the summary table of entry tests, inspection reports, engineering change reports, etc. [1]

2. Current Status of Project Archive Management

At present, many enterprises have successfully transitioned to the electronic file management mode, but in the actual operation level, still face many challenges, the urgent need for innovative thinking and advanced technology to optimize and strengthen the file management process. Traditionally, most of the project file management system is built on a relational database, the inherent disadvantages of this approach include data duplication, frequent conflicts, information security loopholes, uncontrolled modification of permissions and susceptible to hacking. The inconsistency of archive data and the uncertainty caused by human operation will not only jeopardize the trust between archive users and management, but also become the source of disputes. Therefore, it is important to explore more efficient and secure archive management solutions. Specifically, it can be summarized as the following points.

(1) The reliability issue of archives

In the various stages of the creation of project files, information recording means, even if the final electronic form of archiving, the initial period also often rely on paper document records and flow, which undoubtedly increases the risk of inconsistent content or entry errors. Once such a problem occurs, the traceability often still need to rely on the original paper files, invariably returning to the traditional management process. In addition, the preparation of the content of the file is often based on the policy guidance documents of a particular period, which means that, in order to ensure the authenticity and trustworthiness of the file, the associated policy documents must also be properly preserved; otherwise, the effectiveness of the file will be greatly reduced. Therefore, the integration of electronic and paper archive management processes, together with the establishment of a sound preservation mechanism for policy documents, is essential to improving the accuracy and efficiency of archive management. [2]

(2) The retrieval of archives is inconvenient

Due to the fact that project archives involve many different departments of the company, information is scattered and stored in the archive information systems of each department, which is not conducive to quickly and comprehensively obtaining archive information. The development platforms and data structures of various information systems are also different. Some information systems are in disrepair for a long time, making it difficult to integrate and utilize data between systems, forming information silos. The login and authentication methods for archive systems vary among departments, and some even require paper proof to access archives, which reduces the efficiency of archive retrieval. [3] [4]

(3) The update of archives is not standardized

The accumulation and improvement of archives is a continuous and lengthy process, and the information contained therein may need to be updated or adjusted in due course as time passes and the external environment changes. Relying on manual methods for the maintenance of such archival information is not only a heavy task, but also prone to the introduction of subjective errors, making it difficult to ensure the standardization and consistency of archival management work. Therefore, exploring automated or intelligent mechanisms for updating archives to reduce reliance on human resources and enhance the process of controllability is particularly critical to promoting the transformation of archive management into a more standardized and efficient model. If it is a paper file, updating the file information can be more complicated, and frequent updates may also lead to unclear or even damaged file content; The update of digital archives will be relatively easy, but the update operation is not easy to leave traces, which will reduce the credibility of the archive content [5-6].

3. Top-Level Architecture Design

In order to effectively address and revolutionize the existing challenges of project file management, this solution integrates blockchain and distributed technologies to craft an advanced project file management system architecture. The architecture is built hierarchically, consisting of interface layer, logic layer and data layer, and its comprehensive layout is shown in Figure 1.

The interface layer presents a friendly and intuitive graphical user interface using a modern browser or customized client. Users can easily enter information through this interface, which is then passed to the logical layer to be processed and receive feedback for viewing or further action.

The logical layer is not only the heart of the system's functionality, but also the center of user role and permission management. Its core components include:

CA (Certificate Authority) module, responsible for generating user digital certificates and encryption keys to ensure the security of information exchange.

System Administrator Module performs system initialization configuration, sets core parameters and ensures stable operation of the system.

Company Administrator Module is responsible for user role configuration, permission setting, initial account import, and creation and review of smart contracts to ensure clear division of authority and orderly management.

The project team management module is responsible for uploading policy documents, training plans, project schedules, and designing business-critical smart contracts based on current workflows to promote information transparency and process automation.

The supervision module records project progress, quality inspection standards and construction specifications, and uses smart contracts to objectively evaluate project execution and improve supervision efficiency.

The construction module enables the constructor to conveniently query the construction records and evaluation results, and complete the business process by invoking smart contracts to enhance operational efficiency.

The data layer, as the underlying support, is responsible for storing and retrieving blockchain data, ensuring real-time synchronization of data communication among nodes, and maintaining the integrity and consistency of the blockchain network.

With the above layered design and the advantages of blockchain and distributed technology, this solution aims to build an efficient, secure and transparent project archive management system, completely change the limitations of traditional archive management, and lead the industry into a new era of digital management. [7-8]

Based on the responsibilities and permission levels of users, the interface layer clients are subdivided into three types to accommodate different roles:

Ordinary Node Client: oriented to the basic user group with more limited privileges, it mainly allows users to create and publish daily business operations and ensures that each participant can effectively contribute and view the profile information related to them within the scope of privileges.

Business Management Node Client: Designed for middle-level managers with a wider range of permissions, in addition to all the functions of an ordinary node, it also further confirms the validity of business operations, inquires about business details, and performs business validation, etc., so as to ensure the smooth advancement of business processes and the accuracy of data.

System Management Node Client: Designed for senior management or IT operation and maintenance team, it has the widest range of privileges. This client is not only able to monitor the transaction volume in the business validation pool in real time to ensure the efficient operation of the system, but is also responsible for packaging and publishing the accumulated business data to the blockchain network, realizing distributed storage and tampering of the data, which greatly enhances the security and trustworthiness of the data.

Business refers to a collective term for an activity in a system, such as a project manager releasing tasks and a construction team completing tasks. There are two working modes for the client: full node mode and light node mode. All nodes store all information of the blockchain, and can query and verify the information of all blocks, requiring large hard disk storage space and strong data processing capabilities; Light nodes only store the header information of the blockchain and can query partial block information, but can verify the integrity of all blocks.

The system management nodes are undertaken by the server cluster and work 24 hours a day in full node mode to ensure the normal operation of the system 24/7. The business management node generally runs in full node mode on a regular PC and can complete operations such as smart contract preparation, business initiation, and business confirmation. When it is not working, it can be shut down and taken offline. Ordinary nodes run in a light node mode on various intelligent terminals, only downloading blockchain block header information for creating, publishing, and verifying business. This not only ensures the information privacy of the project team, but also reduces the data storage and computing pressure on the terminal.

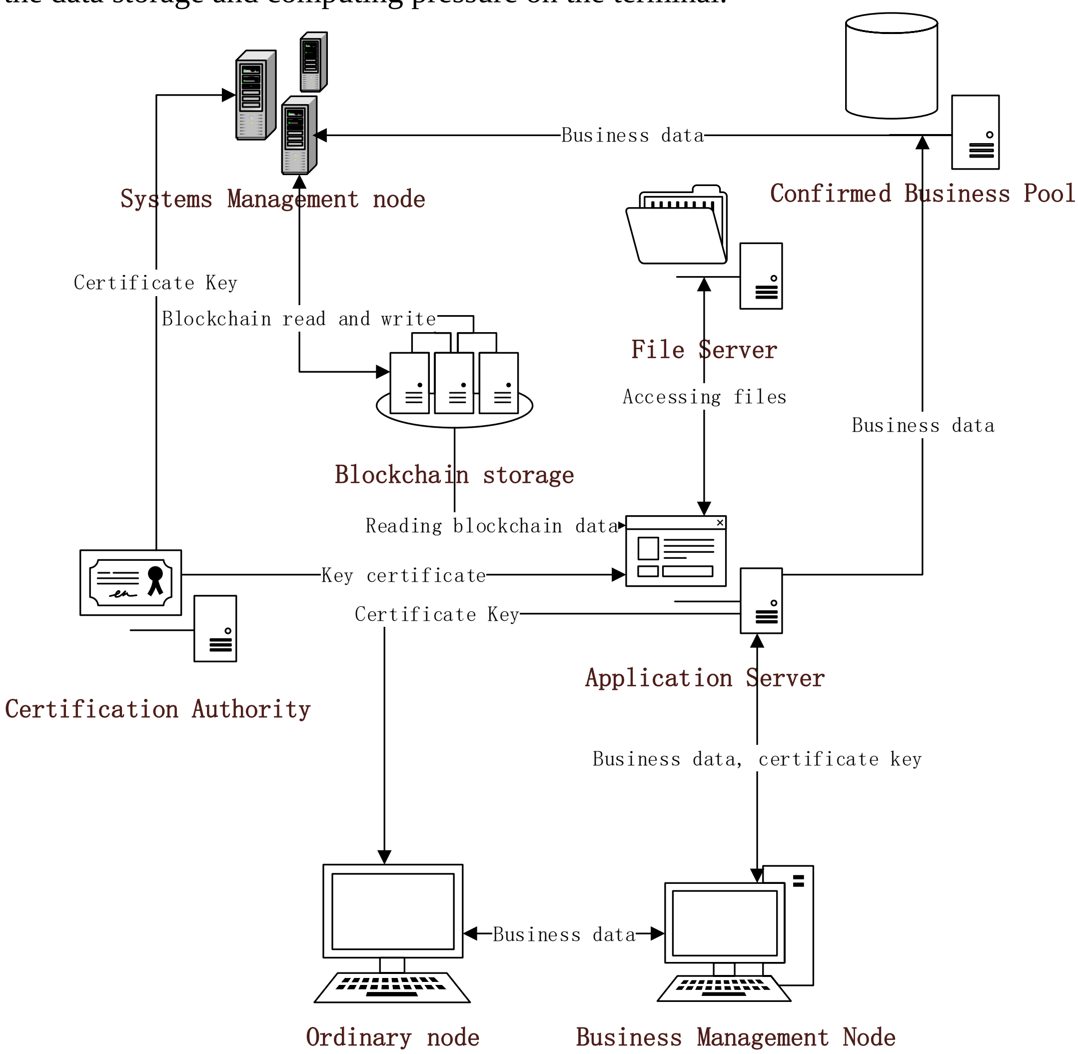

Figure 1: System Deployment Diagram

4. Key Technologies for Implementation

4.1 Main Data Structures

The data structure of a block mainly includes the block body and block header. The block body stores business data, while the block header stores the main information of the block, including block number, timestamp, block header hash, pre block pointer, block body hash, random value, etc. The business in the block body is saved in a tree structure, and the leaf nodes at the bottom of the business tree store the specific content of the business. Based on the category of the business, they are aggregated into higher-level nodes and the node hash value is calculated. Then, based on a larger range of category grouping, higher-level nodes are generated and the node hash value is calculated until the root node is generated. The hash value of the root node is saved in the "Block Body Hash" field at the block head. The data structure of a business includes business number, business time, business initiator, business receiver, business data, business signature, and random value.

4.2 Storage of files and smart contracts

The project rules and regulations documents are published in the form of business, and the content and related information of the documents are packaged into business and saved in the blockchain. If the file is too large, only the file name, file version number, issuing unit, issuing time, digital signature, file hash value and other information can be stored on the blockchain. The file itself is saved in the file server of the permanent node for users to read. The integrity and legality of the file can be verified through the file's hash value and digital signature.

Smart contracts, as code snippets that automate the execution of protocols, also reside on the blockchain platform in the form of business records, each marked with a clear release timestamp and a unique version number. When the logic or terms of a smart contract are revised, the system generates a new business that encapsulates the updated smart contract code to reflect the latest version. It is important to note that for collections of smart contracts that perform similar functions, the system mechanism allows the user to activate and execute only the most recent smart contract in the sequence of version numbers, ensuring that all interactions are based on the latest and most accurate contractual rules, thus preserving the consistency and compliance of the business process.

4.3 Business Generation

When creating a business, the business initiator first sends the business information and its signature data to the business receiver. If encrypted transmission is required, the business initiator encrypts the data with the public key of the business receiver before transmitting it. After the business receiver receives the encrypted data, they can decrypt it with their own private key. The business recipient verifies the integrity of the business content with the initiator's public key, and after verification, signs the business with their own private key to indicate recognition of the business content. Then, the business content and signature data from both parties are sent to the management node together. After receiving the business content and signature data, the management node verifies the business content with the public keys of both parties. After confirming that there are no errors, the business is stored in the business confirmation pool. When a user needs to initiate a critical business, they need to use the corresponding smart contract to complete the operation. The user first requests the smart contract address from the management node, and then calls the smart contract through the address. The smart contract checks whether the current user meets the conditions required for the business. If it meets the requirements, the business operation is executed. If it does not meet the requirements, an error message is returned. [9]

4.4 Generation of Blocks

The system management node continuously monitors the accumulation of transactions in the business acknowledgement pool, and once the number of pending transactions hits a preset threshold, the system instantly consolidates the transactions into a new block and broadcasts it to the blockchain network. This process is designed to maintain the efficiency of data processing and the timeliness of system response.

In order to adapt to the dynamically changing business volume, the system is designed with an intelligent adjustment mechanism that flexibly adjusts the expected value of the number of businesses to be included in a single block according to the current block generation rate of the blockchain. This not only ensures the continuity and efficiency of data processing, but also avoids overconsumption or idleness of resources.

Given that this blockchain platform is an internal private chain, which mainly serves the internal management and information exchange of the organization, there is no need to adopt highly complex mining algorithms or set excessive computational difficulty in its design, which not only alleviates the demand for computational resources, but also reduces the sensitivity to changes in the external environment, and ensures the stable operation of the system and the effective control of maintenance costs. At the same time, due to the closed and controllable nature of the private chain, the need to frequently adjust the calculation difficulty is greatly reduced, making the system management easier and more efficient.

4.5 Query and Verify Transactions

When a user initiates a request to query a transaction, the system first verifies the user's privileges through the management node to confirm whether he or she has the right to view the transaction information. Once verified, the management node will retrieve the transaction record from the blockchain. For information security, the content of this transaction is encrypted using the public key of the requester, and the encrypted data is then securely transmitted to the requester.

The requester, who receives the data, is required to decrypt the encrypted content using the private key he or she holds so that he or she can view the specific details of the transaction. This process ensures the confidentiality and integrity of the transaction information during transmission, and only legitimate requesters can access the relevant information, thus maintaining privacy protection and data security within the system. [10]

When a user requests validation of a particular transaction, the management node will summarize the necessary validation information and transmit it to the requestor's end, which includes a summary of the content of the transaction, the digital signatures of the participants, the tree structure of the exchange in the block, and the hash values of all relevant nodes on the path of that transaction. In this way, the data requester is able to ensure that the transaction is reliable and untampered with by verifying the digital signatures and transaction integrity checks.

5. Conclusion

With the acceleration of urbanization in our country, the functionality of knowledge services in archives, as a carrier of information, has become increasingly prominent. Various levels and types of users also have diversified demands for archive information in construction projects. [11] This article applies emerging technologies such as blockchain and distributed technology to the field of archive management, and designs a blockchain based project archive management solution. Multiple signatures are used during archive creation to reduce errors and avoid arbitrary modifications after archive formation. Data updates are completed in the form of new additions. The data operator signs with their own private key, which neither denies changes to the data nor preserves the process of data updates, making archive data operations transparent and trustworthy. When conducting critical business, users need to call smart contracts to complete it, and smart contracts are written based on relevant rules and regulations, which are effective after multiple signatures from different reviewers, ensuring the fairness and impartiality of smart contracts. By utilizing blockchain and smart contract technology, the credibility of project archives is further ensured, reducing the possibility of archive fraud and project disputes, and improving archive management efficiency.

References

[1] Dong C J. Research on Archival Management of Construction Projects from the Perspective of Knowledge Management [J]. Lan Tai Neiwai, 2024 (16): 61-63.

[2] Ding J. and Y Su. A teaching management system for physical education in colleges and universities using the theory of multiple intelligences and SVM. Soft Computing, 2024. 28(1): p. 685-701.

[3] Feng C and S Liu. Blockchain Adoption in University Archives Data Management. 2022. Xi'an, China: Springer Science and Business Media Deutschland GmbH.

[4] Alsudani, M. Q., et al., Blockchain-Based E-Medical Record and Data Security Service Management Based on IoMT Resource. International Journal of Pattern Recognition and Artificial Intelligence, 2023. 37(6).

[5] He Y. et al. Cloud computing data privacy protection method based on blockchain. International Journal of Grid and Utility Computing, 2023. 14(5): p. 480-492.

[6] Aruna, A., et al. Critical Analysis of Blockchain-based Security for The Internet of Things in Enhancing the Future Technology. 2023. Hybrid, Imphal, India: Institute of Electrical and Electronics Engineers Inc.

[7] Hu R. et al. EduASAC: A Blockchain-Based Education Archive Sharing and Access Control System. Computers, Materials and Continua, 2023. 77(3): p. 3387-3422.

[8] Tang Q. et al. Research on Epidemic Material Management Method Based on Fabric Blockchain. 2022. Shenzhen, China: Institute of Electrical and Electronics Engineers Inc.

[9] J. Chen, J. Zhan and F. Tian. Research on the Construction of a Data Warehouse Model for College Student Performance. 2023. Harbin, China: Springer Science and Business Media Deutschland GmbH.

[10] J Yu, F Xu and Y Li. Research and design of student archives management system based on consortium blockchain. Journal of Computational Methods in Sciences and Engineering, 2023. 23(5): p. 2313-2322.

[11] Mardisentosa, B., et al. Sustainable Learning Micro-Credential using Blockchain for Student Achievement Records. 2021. Virtual, Jakarta, Indonesia: Institute of Electrical and Electronics Engineers Inc.