Hindawi
Mobile Information Systems
Volume 2022, Article ID 7512692, 14 pages
https://doi.org/10.1155/2022/7512692

Research Article

A Scientific Research Information System via Intelligent Blockchain Technology for the Applications in University Management

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Received 12 April 2022; Revised 7 May 2022; Accepted 12 May 2022; Published 27 May 2022

Academic Editor: Liping Zhang

The scientific research information system plays an essential role in improving management efficiency and promoting technological innovation in universities. With the increasing computational demand for human-centric research management, blockchain technology, with distributed storage, consensus sharing, and security traceability, has efficiently assisted the research information system in dealing with various issues such as big-data scale, information security, interconnection, rapid response, and private security. A novel scientific information system framework based on intelligent blockchain technology is proposed to promote university scientific research's information level and management efficiency. Moreover, four smart data contracts, including data collection, verification, sharing, and supervision, are custom-designed under an efficient scientific research information system. Those intelligent contracts provide reliable data security and traceability algorithms to guarantee the practical application of the scientific research information system. The results show that the constructed system can relieve the centralized storage pressure of scientific research information and solve the cross-subject sharing obstacle of massive safety data among different systems. Thereby, the system increases the transparency of scientific evaluation and realizes the credible supervision of scientific research information, which provides a way to promote the innovative application of blockchain technology in scientific research management in colleges and universities.

1. Introduction

In recent years, computational intelligence technology has formed a new human-centered field in which people are the primary target and service object of intelligent information systems. In the field of education application, human-centered computational intelligence technology and the establishment of an education intelligent information system can realize the transformation of personnel from the operating subject to the served object. Universities are an essential part of the natural scientific and technological innovation system, and their scientific output and transformation applications play an essential role in promoting economic and social development [1, 2]. Universities' scientific research information system is the storage and operation carrier of scientific research project management, scientific research achievement management, scientific and technological evaluation management, etc. [3–5].

With the expansion of scientific research fields and project sources, as well as the increasing demand for gradual enrichment and information sharing, scientific research management is faced with the challenges of expanding data scale, increasing complexity of management processes, improving work efficiency, and increasing interconnection requirements [6]. Scientific research in universities has experienced a development process from paper materials and semi-informatization to informatization [7–9]. However, current scientific research information systems applied in universities' management and analysis are still relying on separate personal account pattern [10, 11]. Under this

system framework, there are mainly three types of account topics, including university administrators, scientific research secretaries in secondary management departments, and massive researcher and teacher users, participating in the entire scientific research information management from collection, review, statistics, release, and submission [12–14]. Problems such as error-prone data, long execution cycles, untimely response, high duplication of work, and difficulty in sharing often exist in the management process [15]. Some colleges and universities have optimized the scientific research information system [16, 17]. Sharing and real-time performance have been improved to a certain extent, the scientific research management information technology has not yet achieved breakthroughs due to the barriers of traditional information technology [18, 19].

As a novel decentralized architecture and distributed computing paradigm, blockchain was initially used in the field of digital currency and information sharing [20]. Since blockchain-based codes can automatically record the whole process according to business rules set, blockchain provides effective solutions for information transferring issues related to centralization, security, and traceability, having significant advantages in network-wide records, low cost, high efficiency, safety, and reliability [21–23]. Ling et al. proposed a trusted permissionless IoT access protocol using blockchain and radio access network [24]. Singh et al. proposed a blockchain-based cyber-physical system security mechanism to ensure the secure transmission of information between UAVs [25]. In the past years, blockchain technology has also been introduced into the scientific management of universities and research institutes to explore some practical applications in the management of intellectual property rights, laboratory security, and library resources [26, 27]. Especially in some European and American countries with developed education, education management system based on blockchain technology has been widely explored and achieved remarkable results. For example, at the Massachusetts Institute of Technology and Holberton College, blockchain technology is used for university degree management, learning result evaluation, degree records, certificate storage access, etc. [28]. On the characteristics and advantages of blockchain technology, applying blockchain to scientific research management in universities can effectively eliminate information asymmetry, achieve information synchronization between nodes, and enhance the credible sharing of information [29]. It provides a feasible way to solve the problems of traditional scientific research information systems and has important practical significance for promoting the management efficiency and scientific and technological innovation of colleges and universities. However, many existing universities are only stop at establishing the original management model to improve the efficiency and level of scientific research management. Some have deployed customized functions under the support of the unit's information technology department and professional technology companies. Other universities directly developed independent scientific research information systems, which have played an essential role in supporting discipline construction and scientific management [30, 31]. There are many difficulties in completing university scientific research information system by using blockchain technology as follows:

Firstly, internal relevance is poor. Current layered architecture is adopted by university scientific research information systems, such as B/S architecture, C/S architecture, MVC architecture, SOA architecture, SSH architecture, etc. [32]. Although the layered architecture can meet the management needs within a specific time frame within the department, it is not easy to exchange data with other department, which leads to isolated islands of information between departments, resulting in redundant and duplication of business work, and inevitable risks such as information irregularities and errors.

Secondly, it is difficult to communicate with the outside world. Due to the requirements of data format standardization and network security, most scientific research information systems are limited to the internal use of universities. There is little information interaction with external systems, and it cannot connect with the competent department or other universities, cooperative units, etc. External reporting of information is still mainly manual, which leads to problems such as narrow coverage and poor timeliness of information transmission.

Thirdly, data storage is limited with poor traceability. Studies have found that the amount of scientific research information kept is increasing at 127% every year [33, 34]. University scientific research data face tremendous storage pressure, and historical data have poor traceability. There is no unified standard for data storage formats at different stages because scientific research policies, rules and regulations, and evaluation standards are regularly updated. A lot of time and energy is spent on data calls, and there is even a phenomenon of data loss.

Fourthly, security is difficult to guarantee. One of the reasons why it is difficult for scientific research information systems to be interconnected is that the existing system architecture has deficiencies in privacy security, identity authentication, and authority management and control. Unlawful access to or public disclosure of scientific research data will cause irreparable losses. In addition, there are problems such as the difficulty of opening the information channel for the transformation of scientific and technological achievements and the time difference between the update of scientific research data and the needs of management departments.

To end the above problems, this study proposes a novel way to integrate blockchain technology into university scientific research management, aiming to promote the work efficiency and intelligence level of intelligent management systems. With reasonable framework design and smart contract optimization, our system approach can achieve better administration performance for massive scientific research information in terms of security, traceability, and robustness, which is more suitable to complex practical applications for universities and research institutes.

The rest of the article is organized as follows: in Section 2, related researches done with blockchain technology are introduced towards university scientific research

information systems. The details of the proposed system architecture design and smart contract algorithms are explained in Section 3. Section 4 presents contrastive experimental results and performance evaluation. Finally, Section 5 concludes the whole work with future research prospects.

2. Related Work

2.1. Intelligent Blockchain Technology Development. Intelligent blockchain originated from Bitcoin and is the underlying support technology of Bitcoin. People know it with the white paper "Bitcoin: A Peer-to-Peer Electronic Cash System" published in 2008 [35]. Blockchain technology has the characteristics of decentralization, transparency, openness, autonomy, and information immutability, including point-to-point transmission, distributed storage, cryptography, and consensus algorithms [36, 37]. According to the network scope, blockchains are mainly divided into the public, alliance, and private chains. Public chain is represented by Bitcoin. Nodes are independent of each other, and the trust between the nodes is maintained through a consensus mechanism [38]. A private chain is a blockchain system used internally by an enterprise or organization. Read and write administrators control the permissions of the blocks in the organization. Although the private chain uses blockchain technology, it still has the characteristic of "centralization" in essence. Alliance chain is a blockchain controlled by a consortium composed of multiple enterprises or organizations. In the alliance chain system, only nodes authorized by the alliance have the power to keep accounts [39]. This kind of blockchain technology is essentially "partial decentralization" or "multi-centralization" to ensure information security and operational efficiency [40]. Compared with the traditional centralized management method, it is safer and more reliable.

Currently, blockchain technology is divided into three stages by academia. Blockchain 1.0 era is applying blockchain technology in the currency field, that is, programmable currency in currency payment. Blockchain 2.0 era is a field where blockchain technology is applied to the combination of digital currency and smart contracts. In the era of blockchain 3.0, blockchain technology is no longer limited to the financial field, which has gradually expanded to various applications in all walks of life. Nowadays, blockchain technology is considered the result of the fourth industrial revolution after steam engines, electricity, and the Internet. A large number of experts and scholars from all over the world are exploring and researching [41].

2.2. Blockchain Realization on University Scientific Research Information System. In recent years, many universities and research units have made many attempts to apply blockchain and other advanced technologies to solve problems such as scientific research information storage, sharing, intelligent analysis, and decision management. For example, Altowaijri suggested the application of blockchain technicality because of its tremendous technical and systemic payoff in improving the sharing of management experience across the Saudi higher education system, particularly at Qassim University [1]. Alammary et al. pointed out that blockchain can bring significant benefits to education, including providing a secure platform to share student data, reduce costs, and increase trust and transparency [5]. Daraghmi et al. designed UniChain to improve the current management system as it provides interoperable, secure, and efficient access to EARs by students, universities, and other third parties while maintaining student privacy [6]. From the perspective of design ideas and implementation means, these system construction works for universities' scientific information management roughly reflect the following aspects:

(1) Distributed storage technology of blockchain can alleviate the pressure of centralized storage of scientific research data. Distributed storage of the blockchain is essentially a kind of account data maintained by multiple nodes, different physical addresses, or multiple members. Thereby, it is used to realize the decentralized database of data sharing, synchronization, and value assignment. The method of combining on-chain and off-chain storage is adopted by university scientific research data storage. Scientific research information index and the data summary of crucial information are first hashed and then stored on the chain. Complete scientific research materials are stored in an off-chain database that maps to the on-chain. Smart contracts are used to verify the authenticity of scientific research data to achieve data verification, query, and invocation.

(2) Blockchain cryptography technology is used to ensure the security of scientific research data. Cryptography is the core of blockchain privacy security. Cryptographic algorithms involved in the blockchain include asymmetric encryption algorithms, Merkel trees, and hashing algorithms. Different encryption technologies are used to ensure the reliability and security of scientific research data transmission, submission, and sharing. In addition, cryptography provides technical support for the direct connection of cross-departmental information, such as project fund revenue and expenditure associated with the financial department, teaching project management associated with the educational administration department, student science and technology competition associated with the student department, teacher performance evaluation associated with the personnel department, etc. Cryptography technology fully realizes the secure collaboration of scientific research data.

(3) Blockchain architecture model can realize data sharing across the primary scientific research information system. Competent authority can plan the scientific research chain in a regional scope and form a distributed node of the blockchain. Scientific research chain is different from the conventional blockchain in that it only stores scientific research

data abstracts and data specifications. Scientific research management department can be used as a node to establish an alliance chain. The front-end processor of the scientific research chain is used by the provincial science and technology commissions (bureaus), education commissions (bureaus), science and technology associations, and other government departments to realize the data association between the access requirements and the node scientific research information system. University scientific research information system realizes a top-down structure's selective sharing of scientific research information among different subjects. Cross-chain technology is used in different regions to realize the interconnection and intercommunication of scientific research data of universities in multiple regions.

(4) Blockchain consensus mechanism can be used to realize the transparency of scientific and technological review and evaluation. Blockchain consensus mechanism is that multiple hosts form a network cluster through asynchronous communication. It requires state replication between hosts to ensure that each host reaches a consistent state consensus, thereby safely updating the data state in the distributed network. Election consensus algorithms such as PBFT and Kafka are used by scientific research information system in universities to achieve paperless and anonymous scientific research results such as peer review of scientific research results, scientific and technological project review, and scientific research funding audit to ensure fair and impartial scientific and technological review and evaluation. Furthermore, the traceability based on the chain structure is used to realize the whole process of the review and evaluation process is well-documented.

(5) Smart contract algorithms can expand the functions of scientific research information systems in universities. Smart contracts have the characteristics of self-verification, decentralization, and automatic execution to set execution conditions with automatic trigger operations, which can be introduced to implement functions such as information interaction and value transfer provided by users in the blockchain network. Applications of smart contracts to verify the personnel indentations of various departments is a significant improvement over the traditional manual approval verification in the scientific research information system. Smart personnel contracts in different departments trigger different conditions to realize that the corresponding personnel will match the corresponding permissions.

(6) Through the customized deployment of smart contracts, functions that are difficult to achieve by traditional scientific research information systems are realized. For example, remote identification of scientific research projects can be realized through smart contracts and digital signature technology. Then, transformation and docking of scientific research results can be realized through intelligent contracts and encryption technology.

In addition, blockchain technology can also realize the credible supervision of scientific research information in universities. Supervisory department can be used to comprehensively grasp the information on scientific research projects, scientific research results, fund execution, scientific research personnel, etc. Once a problem is discovered, relevant departments and personnel can supervise the entire process through the chain storage of data, contract execution records, and system operation logs. At the same time, scientific research information system constructed by the application of blockchain technology can provide real-time scientific research statistical information to the competent department or regulatory department as well as assist in grasping the status quo and development trends in scientific research among various universities. In summary, the application of blockchain technology effectively solves the problems in the construction of universities' scientific research information systems and overcomes the shortcomings of existing information technology for broad application prospects. However, the existing information systems based on blockchain technology have the following problems. Firstly, most of the existing information systems take "data" as the first consideration factor, and there is a lack of people-oriented information system research. Secondly, the existing research on information systems based on blockchain is mostly theoretical research, and there is a lack of specific implementation methods for information systems based on blockchain. Thirdly, storage capacity of blockchain is limited, and the delay and scalability of information system research based entirely on blockchain are low. Therefore, this study builds a people-oriented university scientific research information system, aiming to break through the barriers of information exchange between universities and departments and between departments through blockchain and customize smart contracts to serve the needs of users. This study adopts the "on-chain + off-chain" dual-mode storage mechanism to alleviate the high latency of the system and enhance the scalability of the system.

2.3. Blockchain-Based Architecture of University Scientific Research Information System. Innovation blockchain architecture consists of five important parts, including the application, contract, incentive, consensus, network, and data layers. On the general blockchain architecture, blockchain technology is applied to the construction of scientific research information systems in universities, and a certain degree of adjustment and optimization is needed. For example, the admission subject needs to perform identity verification, and election consensus is adopted in the consensus mechanism. Figure 1 shows the architecture of scientific research information systems in universities based on blockchain technology.

This study proposes a university scientific research information system architecture based on blockchain

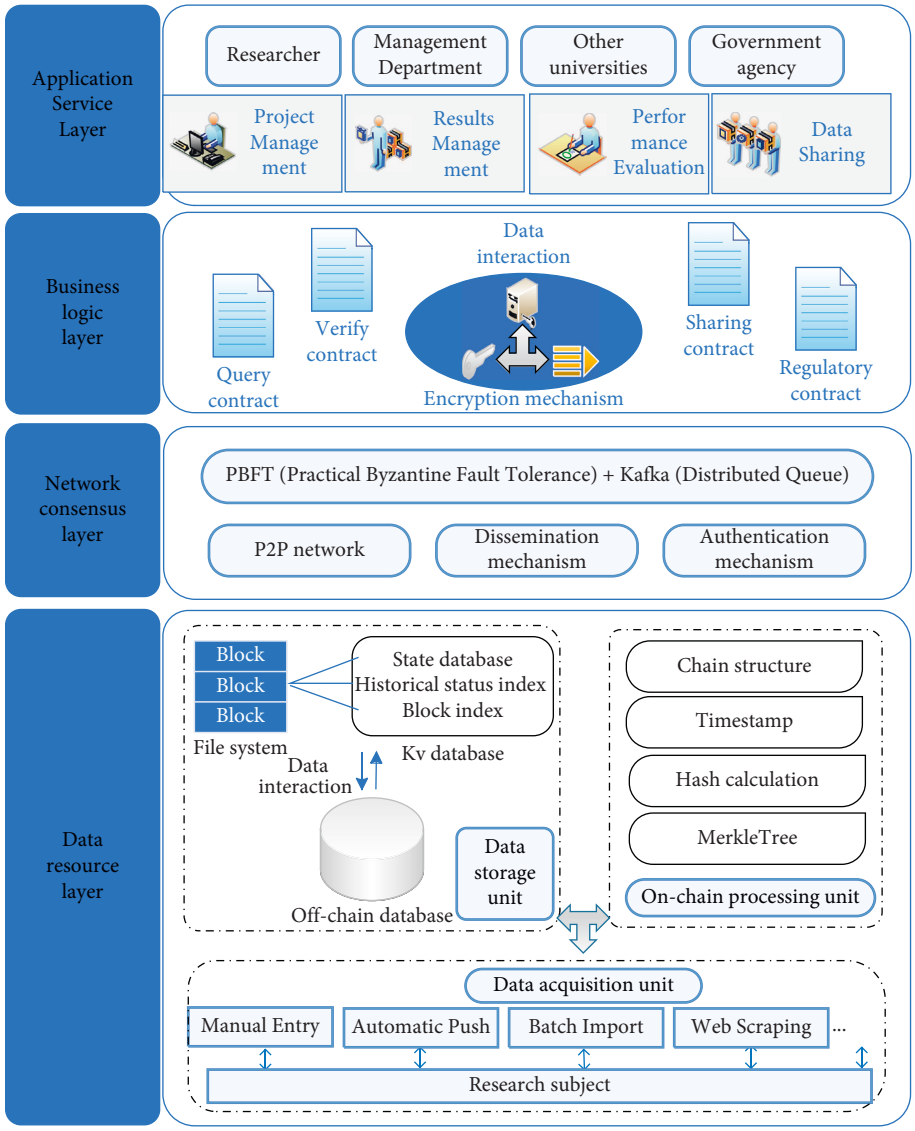

Figure 1: University scientific research information system architecture based on blockchain technology.

technology, which includes a data resource layer, a network consensus layer, a business logic layer, and an application service layer. At the data resource layer, this study innovatively applies the "on-chain + off-chain" data storage method to realize dual-mode data storage and reduce the complexity of data storage on the blockchain. Through the combination of on-chain storage and off-chain storage, it jointly serves the safe and efficient interaction of scientific research information in universities. In the network consensus layer, this study adopts the electoral consensus algorithm PBFT based on the demand for the exchange of scientific research information in colleges and universities to serve the consensus of user nodes in the scientific research information system of colleges and universities. In the business logic layer, this study customizes four smart contracts for data collection, verification, sharing, and supervision and uses asymmetric encryption to ensure the data flow of the university's scientific research information system. In the application service layer, university scientific research information system proposed in this study serves scientific researchers, management departments, other universities and government departments, etc., and truly realizes the reliable data sharing of university scientific research information between and within universities.

2.4. Data Resource Layer. Data resource layer includes three parts, namely data collection unit, on-chain processing unit, and data storage unit, which are mainly used to realize the collection, storage, integration, and release of scientific research data. The data collection unit uses manual entry, automatic push, batch import, and network capture to collect various forms of scientific research data. The on-chain processing unit includes chain structure, timestamp, hash calculation, MerkleTree, etc. In particular, the chain structure defines the on-chain storage method of the system; the timestamp is a chain based on the timeline to provide support for the traceability of scientific research

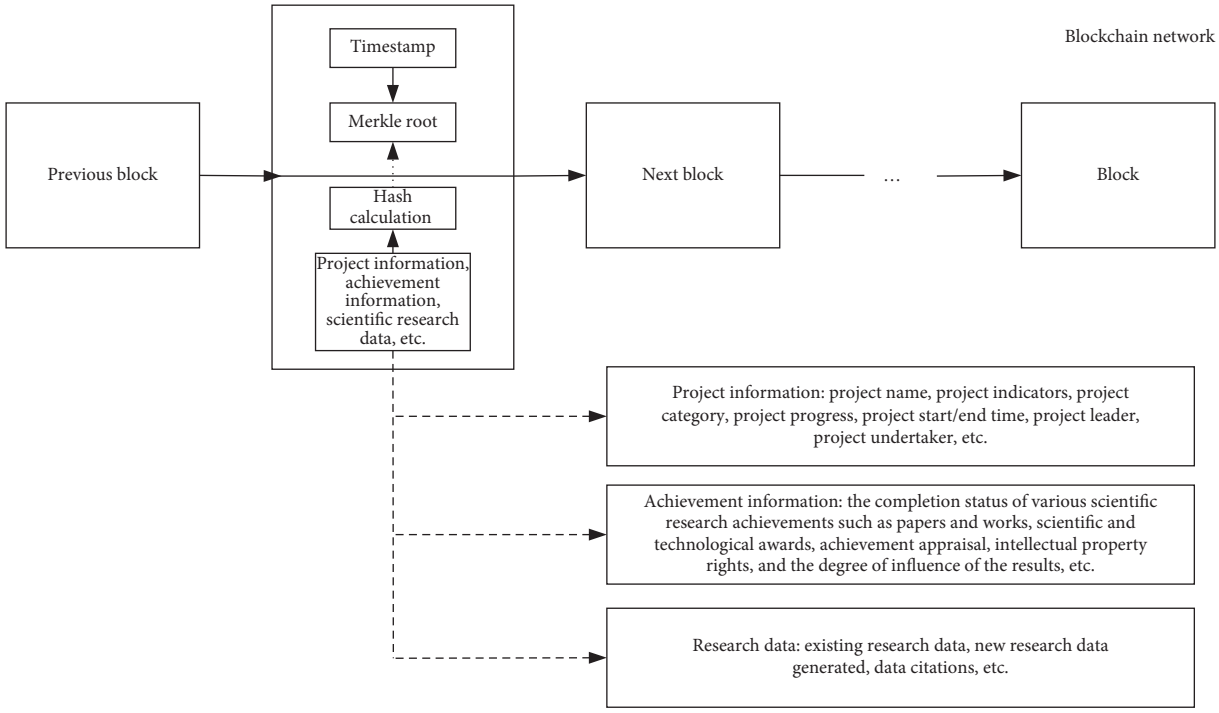

Figure 2: Blockchain structure of university scientific research information system.

information; hash calculations are mainly used for scientific research information encryption, adjacent block associations, ensuring information integrity, etc.; and MerkleTree can effectively prevent malicious tampering of information, because it can search Tree similar structure. Blockchain network structure of the upper chain processing unit is shown in Figure 2. Data storage unit includes an off-chain database, a file system, and a kv database. Off-chain databases generally use conventional relational or nonrelational databases, which are used to store complete scientific research information. File systems generally use distributed file systems such as the Interplanetary File System (IPFS), which are used to store essential information and data summaries, and smart contracts. Kv database is a key-value database that stores data in key-value pairs. For example, Level DB, developed by Google, stores data indexes and provides mapping associations for the interaction between various types of data.

2.5. Network Consensus Layer. Network consensus layer includes a network layer and a consensus layer. Firstly, network layer is the basis of distributed storage, since it encapsulates the blockchain networking mode, message dissemination mechanism, and data verification mechanism. Message dissemination and data verification mechanism can be customized according to application requirements. Secondly, consensus layer guarantees mutual trust between blockchain nodes because it encapsulates various consensus mechanisms. From the perspective of security mechanisms, the PBFT (Practical Byzantine Fault Tolerance) consensus algorithm can be used by university scientific research information systems. Requester sends a

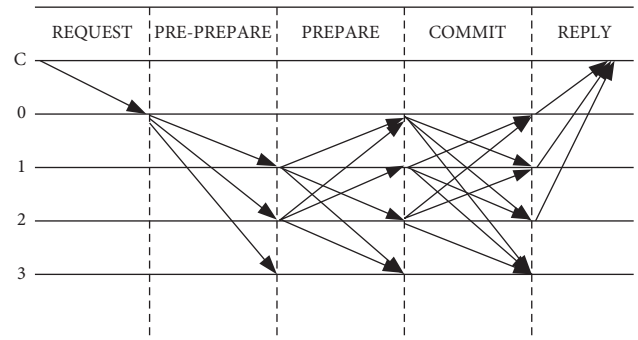

Figure 3: PBFT consensus algorithm.

request to the controller node, and the controller node broadcasts the request to the agent node after receiving the request. After receiving the request, the agent node records and broadcasts it again. If it receives more than a certain number of the same request, it enters the next stage. If one of the nodes receives more than a certain number of identical requests, it initiates feedback to the requesting end. In addition, election consensus algorithms such as Kafka (distributed queue) can also be completed to optimize network request efficiency. Furthermore, 1/3 of the fault tolerance can meet the security requirements. Compared with another reward-type consensus, it has the advantages of less computing power and high efficiency. In the scientific research information system of colleges and universities, for the interaction of internal data of colleges and universities, this study designs the internal consensus algorithm of the system based on the PBFT consensus mechanism. Schematic diagram of the PBFT consensus algorithm is shown in Figure 3.

Consensus of the internal nodes of the university scientific research information system based on blockchain technology is divided into five stages, which correspond to Request, Pre-prepare, Prepare, Commit, and Reply in the PBFT consensus mechanism. The specific flow process of each stage is as follows:

Request: a faculty member of the scientific research information system of a university initiates a request C from the system client and sends the request to the system master node, which is represented as a 0 node. The master node here is not unique. When an error occurs on the master node, the university scientific research information system will replace the new node as the master node. The consensus stage goes from entering to the Request stage.

Pre-prepare: after receiving the request, the system master node broadcasts the message through the P2P network immediately. The broadcast range is all other nodes in the system, which are expressed as 1, 2, and 3 nodes here. The consensus stage enters the Pre-prepare stage.

Prepare: after receiving the request, all other nodes in the system first record the content of the request, and broadcast it again relying on the P2P network. The broadcast range is all nodes except this node, expressed as: 1->0, 2, 3, 2->0, 1, 3. To prevent master node 0 from sending requests with different intentions of the faculty and staff from other nodes, it is set that node 3 cannot perform P2P broadcast on the received request C. The consensus stage enters the Prepare stage.

Commit: when all nodes in the university scientific research information system receive more than 2/3 of the same requests from all nodes in the system in the Prepare stage, the consensus stage enters the Commit stage.

Reply: when a node in the system receives one more request than 2/3 of the same requests of all nodes of the university scientific research information system in the Commit stage, the consensus stage enters the Reply stage. Feedback the consensus results to the faculty.

2.6. Business Logic Layer. Business logic layer includes the contract units and data encryption interaction mechanisms. Data encryption interaction mechanism adopts asymmetric encryption method to encrypt data transmission. Specifically, the system will generate a unique pair of public key and private key for each user, the public key will be broadcast to the blockchain network, and the private key will be kept secret for the user. When the data are used, the data owner uses the data applicant's public key to encrypt and transmit, and the data applicant uses his own private key to decrypt the data. Various script codes, algorithms, and smart contracts of the blockchain system are encapsulated in the contract unit. This is the core extension technology of blockchain network applications. Business logic layer is based on smart contracts, which are used to ensure the system's efficient operation while invoking the data encryption interaction mechanism to ensure the privacy and security of data throughout the system's life cycle. According to the business needs of university scientific research, information system construction, data collection, data verification, data sharing, data supervision, and other contracts can be adopted. Logical design of the smart contract is shown in Figure 4.

Collection of scientific research data, scientific research personnel information, achievement data, and financial data are mainly realized through data collection contracts. It mainly includes manual entry, network capture, batch import, automatic push, and other methods to ensure the traceability of data. This study makes a customized design for the data collection contract, as shown in Algorithm 1.

Authenticity of the data, the original verification, and the verification of the data caller are mainly realized through the data verification contract, which is used to ensure the security of the data. This study makes a customized design for the data verification contract, as shown in Algorithm 2.

Data sharing contract is used to set the procedural flow of data interconnection. The purpose of the contract is to realize multi-platform data sharing, break the information barriers of traditional scientific research systems, and get rid of the problem of information islands. This study makes a customized design for the data sharing contract, as shown in Algorithm 3.

Supervision contract is a necessary contract for all-round supervision of the entire scientific research system. Relying on the immutability of smart contracts, supervision contracts can realize credible supervision of the data of the entire system. In this study, supervision contract is customized, as shown in Algorithm 4.

2.7. Application Service Layer. Application service layer provides complementary services in the form of web pages and mobile apps to scientific researchers, management departments, other universities, government affairs departments, etc., and also provides data interaction services according to users' different permissions, including project management, result management, performance evaluation, and data sharing. Project management includes project declaration, initiation, change, acceptance, funding, and other modules. Then, achievement management includes management modules such as papers, scientific and technological awards, achievement appraisal, intellectual property rights, etc. Performance evaluation includes a subitem and comprehensive evaluation of teachers' scientific research performance. Finally, data sharing is designed to realize the interactive sharing of information such as scientific research projects, technological achievements, and performance evaluations of universities with other universities or government departments.

3. Results and Analysis

3.1. System Implementation. Blockchains are usually divided into public, consortium, and private chains. Public chain is entirely open, and anyone can conduct

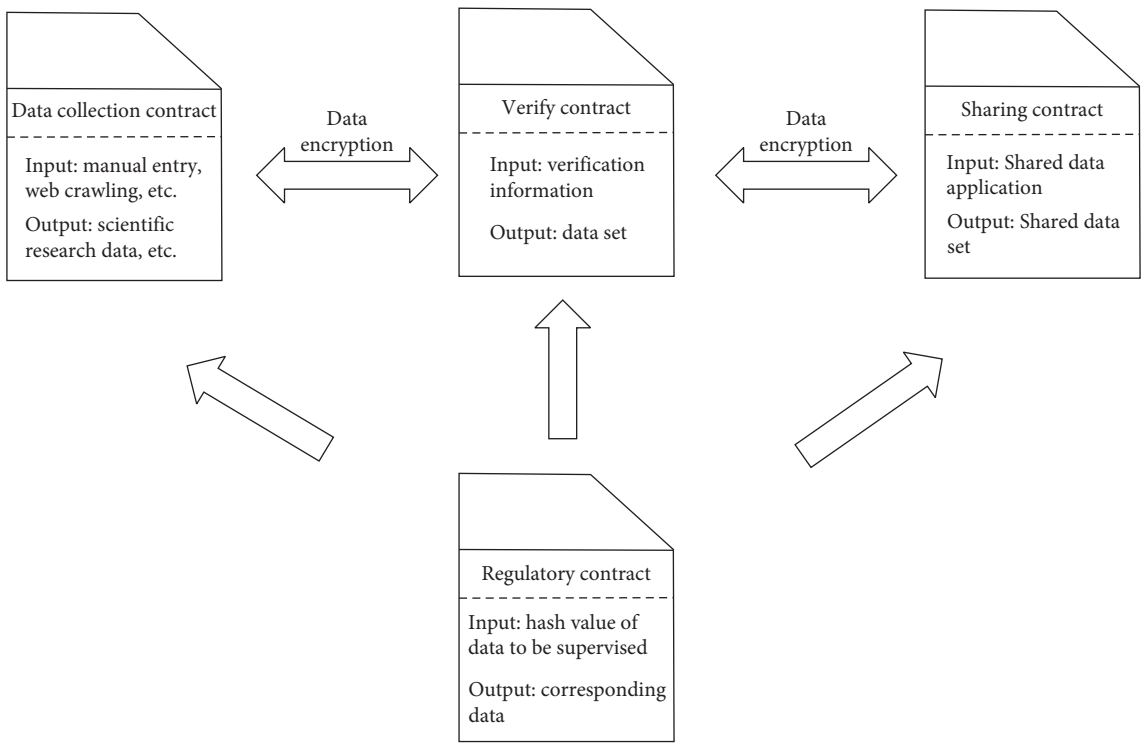

Figure 4: Logic diagram of smart contract of university scientific research information system.

```
    Input: Manual entry data, Web crawling data, Batch import data, Automatic push data
    Output: Research data, research staff information, achievement data, and financial data
(1) Manual entry data, Batch import data//Manually entered data, and Batch import data are stored in the blockchain
    If verification(User)//User authorization authentication
      Standardization(Data)//input data standardization
      If verification (Data)//data verification
        Return Dataencryption—>P2P//data encryption broadcast
      Else exit
      Return Data—>Blockchain//Data storage to the blockchain
    Else
      false
(2) Web crawling data, Automatic push data
    If verification(Data)//Data authorization authentication
      Standardization(Data)//input data standardization
      Return Data—>Blockchain//Data storage to the blockchain
    Else
      false
    Output: Research data, research staff information, achievement data, and financial data
```

Algorithm 1: Data collection smart contract.

transaction operations on the public chain, represented by Bitcoin, Ethereum, etc. Alliance chain is composed of some enterprises or organizations, and the organizations on the chain must approve its joining and exiting. Moreover, it has the characteristics of partial decentralization, represented by Hyperledger. The private chain is generally used within a company or organization. Operation authority on the chain is controlled by an organization, which is mainly used to manage internal work. While, public chain consensus is based on PoW (Proof of Work), which is unsuitable for nonfinancial fields such as supply chains where frequent transactions and information interaction are the mainstays. At the same time, as a consortium chain platform, Hyperledger has more evident advantages in high availability, high performance, and privacy protection. Therefore, this study chooses the Fabric platform under Hyperledger to build a university scientific research information system. System is based on the network technology of the TCP/IP protocol, combined with blockchain, database, software engineering, data

```
    Input: Verification information
    Output: Dataset
(1) Request input()//User input request
    If permissions ()//Authority determination
      compare personnel permission database
      If the request type meets the standard
        Return allow and Data set
      Else refuse
    Else
      false
(2) Data input()//data validation
    If Compare database data types
      Return allow
    Else false
    Output: Dataset
```

Algorithm 2: Data verification smart contract.

```
Input: Shared data application
Output: Shared dataset
If Authority determination()//User authority identification
  Call Data validation smart contract
  If Receive allow notification
    Return Asymmetric encryption(Data)
    Shared dataset <—Public key//data encryption
  Else refuse
Else false
Output: Shared dataset
```

Algorithm 3: Data sharing smart contract.

```
Input: Regulatory request
Output: Regulatory data
If Authority determination()//User authority identification
  Call Data validation smart contract
  Return true
  If Get the private key of the regulatory data owner
  Return Decrypt regulatory data
  If Database comparison()//Regulatory process
    Return result—> regulator
  Else
    false
  Else
  refuse
Else
  false
Output: Regulatory data
```

Algorithm 4: Supervision smart contract.

coding, etc., with Hyperledger Fabric as the blockchain platform, MySQL as the cloud database, and Go, JavaScript, Html, CSS as the development language. System is developed using framework such as Nodejs and Bootstrap, and the data are processed and sent uniformly in JSON format. System adopts a browser/server (B/S) structure and runs in a wide area and local area network. Blockchain-based university scientific research information system mainly provides users with a more secure data storage mode, data sharing across the platform, and highly transparent review and evaluation, and dramatically enhances the system's scalability.

Figure 5: System implementation interfaces.

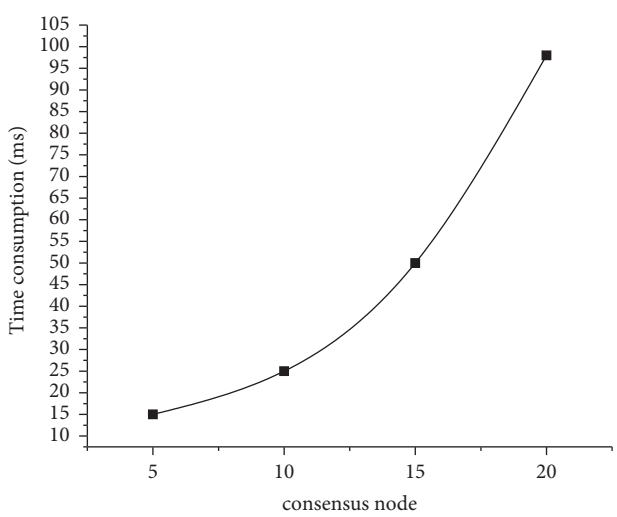

Figure 6: Consensus time consumption.

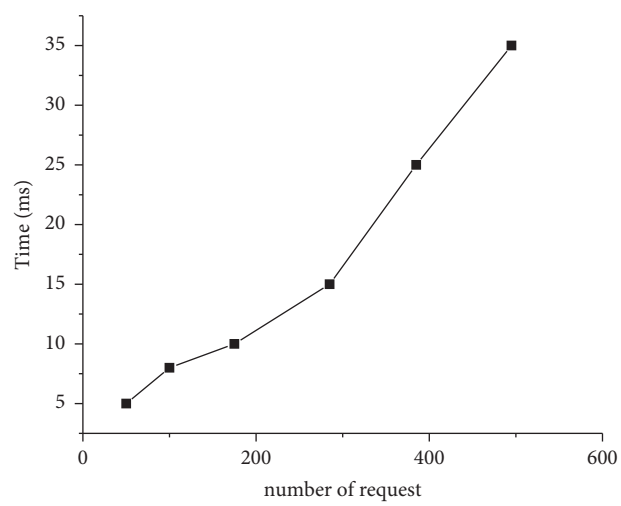

Figure 7: Data read latency.

The login interface of the prototype system is shown in Figure 5(a). System provides a variety of login channels for different personnel, and the user can select the corresponding category to match the corresponding functional authority. Login method system takes the form of an account and password to log in. Before logging in for the first time, users can register for an account through the link at the bottom of the website. Taking the management department as an example, the entire system consists of five submodules for the management department, namely homepage, project management, result management, performance evaluation, and data sharing. The homepage of the prototype system is shown in Figure 5(b). At the top of the interface is a carousel of campus scenery, and the middle part uses tables and charts to make statistics and visual displays of the school's semiannual scientific research results. Below is a graph of the dynamic changes in department performance and the latest notifications. Project management interface is divided into five functions, namely project declaration, project establishment, project change, project acceptance, and project funding, by the steps of the project declaration as illustrated in Figure 5(c). Users can fill in relevant information to declare the project. As shown in Figure 5(d), the results

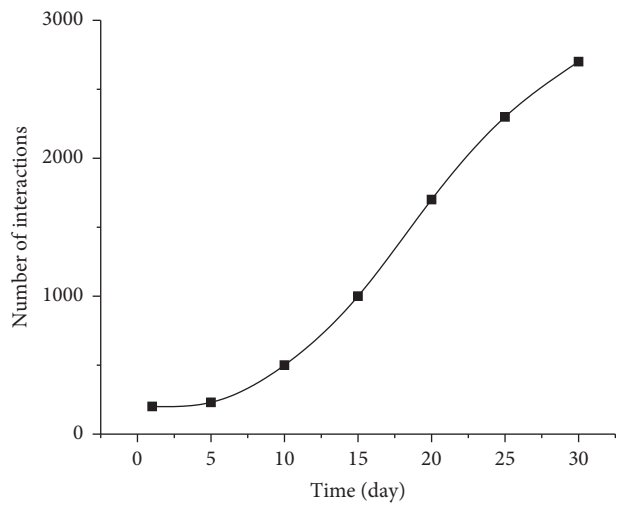

Figure 8: Statistics on the number of system interactions.

management contains four essential management functions: thesis and work, scientific and technological awards, achievement appraisal, and intellectual property rights. Users can select the corresponding link and enter the corresponding management interface.

3.2. Experimental Performance Analysis. We carry out numerical analysis on three aspects of fault tolerance rate, consensus consumption, and delay of scientific research information system in colleges and universities. In terms of fault tolerance rate, this study applies the PBFT consensus mechanism to the scientific research information system of colleges and universities. In the model, if there are f faulty nodes and f problem nodes, in the worst case, the faulty node and the problem node are different nodes. According to the principle that the minority obeys the majority, the normal nodes in the model should be larger than the faulty nodes and the problem nodes, so $f+1$ normal nodes are needed. The model summary point is n. According to the following expression, we can see that the maximum fault-tolerant node of this model is $(n-1)/3$.

$$f + f + f + 1 = n \longrightarrow f = \frac{(n-1)}{3}. \tag{1}$$

In terms of consensus consumption, this study uses the number of nodes as a variable. When the total number of nodes is 5, 10, 15, and 20, the time it takes for nodes to reach consensus is shown in Figure 6. As the number of nodes increases, the number of requests broadcast by each node in the model increases, and the response time of each node to the request increases gradually, resulting in an increase in consensus time consumption.

In terms of data latency consumption, we count the time interval between when a request is initiated and when the request receives a response. Taking the number of requests as a variable, when the number of requests is 50, 100, 200, 300, 400, and 500, the data read delay is shown in Figure 7. Since the model adopts the "on-chain + off-chain" dual-mode storage mechanism and adopts the PBFT consensus

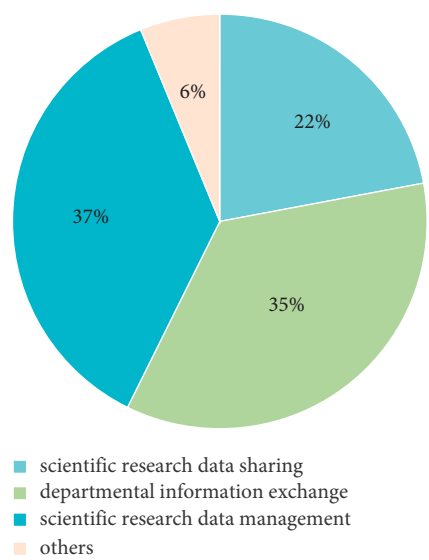

Figure 9: Interaction type statistics.

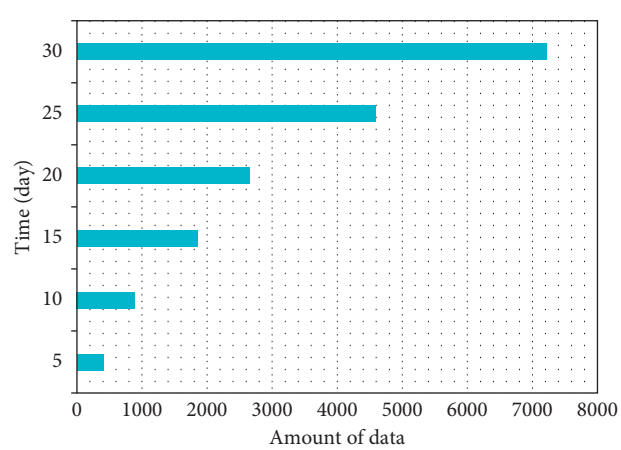

Figure 10: Statistical chart of data.

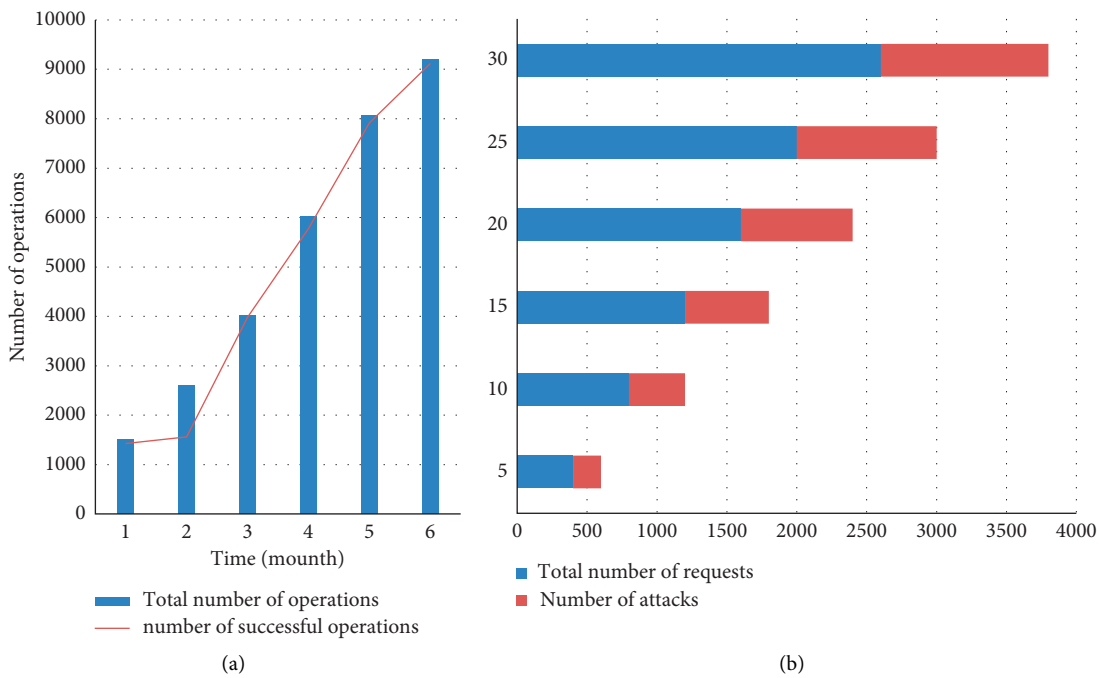

Figure 11: Research data management statistics chart.

mechanism, the data read delay increases as the number of requests increases.

3.3. Application Case Analysis. After conducting on-the-spot research on several universities, we initially chose to apply the system to a university in Beijing, China, to verify the effectiveness of the system. The university adopts a centralized storage mechanism, and the data security cannot be guaranteed; there are information island barriers between the scientific research information of faculty and students, and it is difficult to share scientific research data; transparency of scientific research evaluation and evaluation process of the university is low, and credibility of the evaluation and evaluation results is low. Therefore, the university scientific research information system developed in this study is used for optimization.

To verify the actual application of the system, we made statistics on the data interaction of the system within month, as shown in Figure 8. After we use blockchain technology to optimize the scientific research information system of colleges and universities, in the initial stage, due to publicity and popularization reasons, the use of scientific research personnel in colleges and universities is less. Over time, the number of data interactions within the system increases. On this basis, we classify the data request types in the system, as shown in Figure 9. Scientific research data sharing, departmental information exchange, and scientific research data management are the main interactive contents, which have played a good demonstration role in the digital transformation of scientific research information in universities.

Blockchain-based university research information system can enhance the ability of school administrators to manage research data. We conducted statistics on the data stored to the blockchain 1 month after the application of the system, as shown in Figure 10. Data stored on the blockchain grew incrementally with time, and when the system was put into use on the 20th day, the amount of data on the blockchain already exceeded the amount of data in the traditional system for nearly 6 months.

We have counted the management behaviour of school administrators in 6 months, as shown in Figure 11(a). There is a gap between the total number of management requests and the total number of actual completed requests, and the system can achieve trustworthiness and transparency in research management. In the second month of testing, we tested the tamper-evident capability of the system, as shown in Figure 11(b). We performed more than 1200 attacks on the system in 1 month, and the system was able to identify and block them accurately.

4. Conclusions

Based on summarizing the existing problems in universities' scientific research information systems, we elaborated on the advantages of applying blockchain technology to construct scientific research information systems in universities. We analyzed the idea of implementing blockchain technology in universities' scientific research information systems and proposed a general framework for university research information systems based on blockchain technology. Our research provides an innovate scientific information system framework based on intelligent blockchain technology to promote university scientific research's information level and management efficiency. There are two major contributions to solve the challenges faced by the current scientific

research information system: firstly, the formulation of scientific research management blockchain technical specifications and top-down implementation are used to ensure the interconnection and intercommunication of cross-subject scientific research information and honestly give full play to the advantages of blockchain technology. Secondly, four smart data contracts, including data collection, verification, sharing, and supervision, are custom-designed to optimize the scientific management process, which no longer just staff personnel operations but also offer solutions to strengthen professional requirements of scientific research managers. Validation experiments and analysis demonstrates the better efficiency and robustness of the proposed information system, which meets the practical demands of scientific research management in different university and research institute applications. In the future, the proposed approaches in the study can combine other advanced information technologies such as artificial intelligence and big-data mining algorithms to study pattern recognition problems of linear and nonlinear systems, and can be applied to other fields such as time-series forecasting and engineering application systems [42–47].

Data Availability

The authors declare that the data supporting the findings of this study are available with the authors.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This research was funded by the general project of National Social Science Foundation "Research on Improving Ability Development and Innovation Performance of Scientific Research Team" (Grant no. 18BGL138).

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