Discussion of College and University Laboratory Safety Management System Using Blockchain

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ABSTRACT: Laboratory safety management in colleges and universities is an important task in daily management. It is related to the life safety of teachers and students and the safety of state property, and it guarantees the normal progress of experimental projects and experimental teaching. Constructing a laboratory safety management system (LSMS) is an important way to realize the informatization and modernization of laboratory safety management. An efficient, reasonable, convenient, and open LSMS can prevent accidents, effectively supervise the disposal of wastes, and stimulate the passion of teachers and students for experiments. In this work, an LSMS based on a blockchain model is presented. By integrating safety education, equipment management, waste disposal management, and other aspects into an organic arrangement, it can be effectively implemented and provide reference for the application and implementation of blockchain technology in the field of safety management.

CCS Concepts
\begin{itemize}
  \item Applied computing \rightarrow Computer forensics
  \item Applied computing \rightarrow Education \rightarrow Learning management systems
  \item Computer systems organization \rightarrow Architectures \rightarrow Distributed
\end{itemize}
1. INTRODUCTION
The laboratories of colleges and universities are the main place for carrying out scientific research work in those institutions. They provide an important practice base for cultivating talent, but they are also places where security incidents can easily occur [1]. Therefore, the safety work of college and university laboratories is not only an important part of laboratory construction and management, but also a necessary guarantee for the normal development of teaching, scientific research, and social services. In recent years, the frequent occurrence of safety accidents in colleges and universities [1, 2] has brought huge losses to individuals, families, universities, and society, and it has also made research and teaching difficult. According to investigation and statistics, most of the laboratory safety management in colleges and universities has problems, such as weak safety consciousness, lack of safety education, imperfect management mechanisms, irregular safety management, lack of professional personnel, lack of experimental equipment, cumbersome management procedures, improper management of dangerous chemicals, improper disposal of waste liquid, and insufficient resource investment [1-3]. The information management of university laboratory safety management can help improve the level of laboratory safety management services in universities and improve contact among various safety management departments to facilitate the assessment of safety management work. Blockchain technology is an encrypted distributed chained storage system with such features as decentralization, time series data, collective maintenance, programmability, and being secure and trusted [4]. According to the characteristics of a blockchain, a university laboratory safety management system (LSMS) based on blockchain is described. Various safety management functions are effectively integrated, the safety standard process from safe education to safe operation is reconstructed, and a complete, efficient, and modern university LSMS is constructed. It can solve the difficulties of university laboratory safety management and protect the life safety of the majority of scientific research workers and the security of national property. It also provides new application scenarios for blockchain technology.

2. RELEVANT TECHNOLOGY

2.1 Features of Blockchain
Blockchain technology was proposed by Nakamoto in "Bitcoin: A Peer-to-Peer Electronic Cash System", which was published online in 2008 [5]. A blockchain is a distributed chained storage data model with decentralization, sequential data, collective maintenance, programmability, and secure and trusted features [4, 6]. Blockchain technology can not only be successfully applied to the field of digital cryptocurrency, but it also can be widely used in economic, financial, electrical energy, and social systems [5, 7, 8], which properties, when combined with its various modules, provide an important, feasible, and technical path for an LSMS.

2.2 Smart Contract
Smart contracts are commitments that are developed in a trusted execution environment based on blockchain technology and defined in digital form, including agreements on which contract participants can implement these commitments. Through smart contracts, various protocols can be flexibly formulated with the blockchain model for supervision, management, and resource allocation.

3. SYSTEM DESIGN
The LSMS based on blockchain technology consists of five layers: data layer, network layer, consensus and incentive layer, contract layer, and application layer (see Figure 1). The data layer encapsulates the underlying data blocks, such as student information, teacher information, security
course information, device information, and other relevant data encryption and timestamp technologies. The network layer includes a distributed network and terminal access mechanism. It also includes mechanisms for data dissemination, sharing, and validation. The consensus and incentive layer mainly includes the consistency algorithm and incentive allocation system related to laboratory security management among all network nodes. The contract layer is mainly the intelligent contract. The application layer is interface of the LSMS.

3.1 Data Layer
The data layer stores and provides basic data required for safety management, including student information data, teacher information data, experimental data, equipment operation data, and safety course data.

The student information data are created by the student node, which includes comprehensive and accurate digital information, such as student number, major, grade, safety course learning information, and equipment use information. Timestamps can help keep track of students after updating information (learning information, device usage information, and so on).

The teacher information created by the teacher node is a comprehensive and accurate digital identity information, including job number, education background, major, professional title, safety course learning information, equipment use information, and project information and. The timestamp is added to facilitate the establishment of the teacher's laboratory usage track in the time series after the information is updated.

![Diagram of LSMS based on blockchain](image-url)

Figure 1. Basic framework of LSMS based on blockchain.
Device management information is created by the device administrator node, including device parameter information and device usage information. Each time the device is used or repaired, a timestamp is added to the blockchain to track the use of the device.

Reagent drug and waste information is created by the reagent drug and waste management node, including reagent purchase source, reagent parameters, waste disposal time, and waste disposal person information. Each piece of information can be timestamped to trace the source of reagents and waste disposal accurately.

3.2 Network Layer
The network layer defines the basic elements of the LSMS networking, message dissemination protocol, and data sharing and verification mechanism. The access to each node must be verified and approved by the funding agency node and recorded on all nodes of the whole network. Access to each node requires verification and approval by the funding agency node. The attributes and permissions of the node are published across the network and recorded in each node.

The LSMS uses a private blockchain model, which is a weakly centralized blockchain. Owing to the features of the LSMS and union blockchain, the permissions of each node are different. Based on the permissions and attributes of each node, the nodes of the entire LSMS are divided into student nodes, teacher nodes, reagent drug and waste management nodes, equipment administrator nodes, and so on.

The reagent drug and waste management nodes and equipment administrator node have the highest authority and can determine whether to allow the use of the laboratory. The student node only has the right to apply for the use of laboratory, study for the safety course, and record experimental data. In addition to the full authority of the student node, the teacher node has the authority to manage the student node. After various types of node create the data of this node, they add it to the blockchain, publish it to the whole network, and record the data to the data layer of this node according to the permissions of this node.

3.3 Consensus and Incentive Layer
In a distributed system, the nodes must be able to reach an agreement efficiently. The entire LSMS is divided into several types of node. Each node independently verifies the state of the security management data related to itself and publishes the verification results to the entire network, which shares them. Nodes with relevant permissions integrate the results into a unified result and add it to the block chain. The verification of data by nodes is judged according to the overlapping time area of the data. There is time correlation between the safety course learning data, experimental record data, equipment use data, reagent data, waste disposal data, and other information. The verification nodes verify each other based on the overlapped information to reach a consensus that the forged information can be accurately identified and the security of the entire LSMS can be enhanced.

The purpose of security management is to establish not only a simple process and data record but also a responsibility mechanism and contribution mechanism. Each node user pursues her/his own interest maximization, and the distribution of interests must be achieved through workload proof. According to the workload, the node gets the corresponding contribution value, and the resource allocation is based on the contribution value. The workload proof of the LSMS is different from that of the bitcoin system. Bitcoins are proven to work by computing hash values. The LSMS workload proof is based on the actual amount of work to be proven, such as safety course learning, equipment use records, and experimental data records; through the completion of these tasks, it can obtain the corresponding contribution value. Contribution values are different for each node. For faculty, contribution is associated with employee performance, and for students, contribution is associated with student credit. Once a node is found to be cheating, its contribution value is cleared.
3.4 Contract Layer
The contract layer, mainly to sign smart contracts, encapsulates the data validation and tracking algorithm. After the smart contract is signed, it is stored in the data layer of the LSMS in the form of program code, which is recorded in the blockchain after peer-to-peer network propagation and node verification. Smart contracts encapsulate the predefined process-flow state, the corresponding transition rules, the scenarios that trigger contract execution, and the response actions in specific scenarios. Each node of the LSMS monitors the execution of smart contracts related to this node in real time and activates and executes contracts by receiving and verifying external data sources and confirming that trigger conditions that meet the requirements of smart contracts are met.

For the LSMS, smart contracts primarily encapsulate transformation conditions related to workload proof and contribution values. For example, it is necessary to take a certain number of hours of safety courses before conducting experimental operations using equipment and obtaining reagents. The smart contract of the relevant nodes monitors the safety course learning of teachers and students in real time, automatically converts the class hour into workload, and then converts the workload verified by relevant nodes into the corresponding contribution value. If the contribution value reaches the minimum threshold required for experimental operation, the student node and teacher node can sign the intelligent contract for experimental equipment and reagent application. The intelligent contract can thus effectively control the risk of laboratory safety management.

3.5 Application Layer
The back-end of the LSMS is established on the node server, and the underlying code is optimized for the programming of multiprocessor system applications by the Go language, which is more secure and supports parallel processes. The user interface uses mainstream front-end development technology, such as HTML, CSS, and JavaScript, which can be used in PC, tablet computer, and mobile phone applications, to provide more personalized and friendly services, making it convenient for teachers and students to use the LSMS.

4. CONCLUSION
The objectives of this research included 1) a college and university LSMS and several other related topics and 2) refactoring workload proof and contribution values for the LSMS. Based on a private blockchain, a construction model of a management platform for safety management was proposed. The LSMS is not only an innovation of the traditional laboratory safety management mode but also optimization of laboratory safety management service. It is also an organic consolidation of all departments. The LSMS only involves safety course learning for simple equipment and reagents and for waste management, and it does not involve deeper operation and more involvement of management departments. Further development is planned to meet the needs of the new era of university laboratory safety management.

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