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Article

Blockchain technology empowers physical fitness test of students in colleges and universities: Study on the uploading of multiple statistical indicators

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Abstract: This study investigates the groundbreaking application of blockchain technology in the realm of student physical fitness testing within colleges and universities. The focus is on constructing a secure, transparent, and traceable data management system to enhance the accuracy and reliability of physical fitness assessments. Using literature review to establish a theoretical basis, logical analysis to clarify technical principles, and cross-disciplinary methods to integrate various perspectives, the study provides an in-depth analysis of how blockchain can be seamlessly incorporated into the student physical fitness testing framework. Physical fitness testing in colleges typically includes evaluations of various health metrics such as aerobic capacity, muscular strength, flexibility, and body composition. Traditional methods for recording and managing these tests often face challenges related to data accuracy, tampering, and privacy. Blockchain technology, with its immutable and decentralized nature, offers a solution by ensuring that fitness test results are securely recorded and cannot be altered once entered into the system. The proposed blockchain-based system incorporates several key components tailored to the needs of student physical fitness assessments. The system includes an authentication module to verify basic student information and a management module to handle test scores and related health data. By employing advanced encryption methods and blockchain platforms like Bei-hang Chain, the system provides robust data protection, ensuring both the privacy of individual student records and the integrity of the test data. One of the system's innovations is its ability to offer real-time access and verification of fitness data for all relevant stakeholders-students, educational institutions, parents, and regulatory bodies. This transparency helps in monitoring students' health trends and in making informed decisions about physical education programs and health interventions. Furthermore, the decentralized nature of the system reduces administrative overhead and mitigates risks associated with centralized data storage. The integration of blockchain technology addresses significant issues inherent in traditional physical fitness testing systems, such as data tampering, unauthorized access, and inaccuracies in test results. By ensuring that fitness data is accurate, unalterable, and accessible, the system provides a reliable basis for evaluating and improving student health and fitness. This advancement not only supports more accurate assessments of students' physical fitness and health but also facilitates the development of evidence-based policies and programs aimed at enhancing student wellness. In summary, the blockchain-based physical fitness testing system represents a transformative approach to managing student health data. It not only provides strong support for accurately reflecting the physical fitness and health status of contemporary college students, but also provides a solid data basis for the government and relevant departments to make more scientific and reasonable health policies and decisions, and has far-reaching positive significance for improving the physical fitness level of college students.

Keywords: blockchain technology; college and university students; physical fitness test; data

security; biomechanics

1. Introduction

1.1. Purpose of the study

Blockchain technology empowers the students' physical fitness tests in colleges and universities by addressing key challenges related to data security**,** transparency**,** and traceability. Through blockchain, students' physical fitness data can be securely stored and managed, reducing the risks of tampering and leakage. Additionally, the decentralized nature of blockchain allows for real-time access and validation by all stakeholders (e.g., schools, students, parents, and relevant organizations), enhancing transparency and trust in the data.

1.2. Challenges in managing physical fitness test data

Current systems for managing college students' physical fitness data face three key challenges:

(1) Data Security and Integrity: Centralized databases are vulnerable to unauthorized access, hacking, and tampering, which compromises student privacy and data reliability.

(2) Limited Transparency and Collaboration: Existing systems lack transparency, making it difficult for students, parents, and educators to verify the accuracy of fitness data. Additionally, inconsistent data sharing across institutions hampers collaboration and limits progress tracking.

(3) Manual Errors and Lack of Long-term Access: Heavy reliance on manual data entry introduces errors, while students often lose access to their fitness records after graduation, restricting their ability to monitor long-term progress.

1.3. The current challenges faced by college student physical fitness test data management in China include

(1) Data Tampering and Security: Traditional centralized systems are vulnerable to data tampering and unauthorized modifications, particularly concerning the manipulation of fitness test pass rates. Ensuring the authenticity of these rates and preventing data interference is a critical issue.

(2) Pressure on Pass Rate Metrics and Re-testing Traceability: Due to the pressure to meet pass rate requirements, some schools may face the temptation to falsify data. Additionally, the tracking and traceability mechanisms for re-testing students who failed the initial test are weak, leading to a lack of data continuity and reliability, which affects the overall accuracy of evaluations.

(3) Privacy Protection: Fitness tests involve sensitive health data, yet existing systems fail to adequately protect student privacy during data sharing, particularly in the context of multiple tests and cross-institution data transfers.

(4) Cross-Institution Data Sharing: Inconsistent test standards between institutions hinder the seamless sharing of fitness test data during re-testing or student transfers, leading to inefficiencies and delays in data management.

1.4. Innovative

1.4.1. The innovation of students' physical fitness test improves the security of data

The integration of blockchain technology into student physical fitness tests has led to major innovations in data security. Blockchain provides a decentralized storage system that can effectively protect fitness data from tampering or unauthorized access. In addition, through blockchain, students' fitness test results can be transparently recorded, with each data entry traceable and a full history of changes available for verification. This improves the reliability of the data and ensures the accuracy of the data. In addition, blockchain facilitates the sharing of data between universities as well as between educational institutions and medical organizations, facilitating collaboration and research in health management.

1.4.2. Students' physical fitness test content innovation

The application of blockchain extends to physical fitness test content, enabling personalized health management. Analyzing fitness data stored on the blockchain can provide tailored health advice to students, helping them optimize their exercise habits and overall health. At the same time, blockchain technology can also support the creation of incentives through smart contracts to encourage students to actively participate in fitness tests and improve their health awareness.

2. Review of relevant research at home and abroad

2.1. A review of the current status of relevant studies abroad

Blockchain technology started earlier in other countries, and their Internet companies and research institutes have explored and applied blockchain technology, and its application involves many fields such as healthcare and education, etc. Vujičić et al. [1] introduced the principles of Bitcoin and Ether blockchain technology platforms, studied and analyzed the structural differences between the two and their applications. Divya et al. [2] proposed a blockchain model based on directed acyclic graphs for blockchain-based Internet of Things (IoT) applications. Watanabe et al. [3] proposed a blockchain-based contract recording method, through which users can confirm the identity of contractors and whether they are licensed or not, and can trace their contract documents through blockchain technology.

2.2. A review of the current status of relevant studies at home

Recently, General Secretary Xi Jinping emphasized the importance of blockchain development at the Political Bureau of the Central Committee conference, and the application of blockchain has been rapidly expanding from the initial financial field to energy, healthcare, education and so on. Yuan et al. [4] integrated the infrastructure model of blockchain system through studying the core elements of blockchain, and discussed the concept, application and significance of smart contract. Zeng et al. [5] analyzed the principle of blockchain, designed a hierarchical blockchain technology architecture, and gave the frontier application direction of blockchain such as smart city and industrial internet. Shao et al. [6] provided a more detailed architecture of blockchain. Blockchain, as a decentralized, tamper-proof, traceable, and multi-party

co-maintained distributed database, can establish a reliable trust between multiple parties who do not know each other, and epochally realize credible data sharing and peer-to-peer value transmission without the coordination of third-party intermediary institutions, and it is an advancement of human technology. In the field of sports, Huang et al. [7] are leading a new round of global technological and industrial reform, and blockchain technology's decentralization, non-tampering, anonymity, and other characteristics bring a new impetus to the development of the sports industry. Song [8], starting from the latest blockchain concept and its corresponding technology path, carried out exploratory research on the big data platform and its application and development prospect in the field of sports.

2.3. Problems of relevant research at home and abroad and the entry point of this research

According to relevant research at home and abroad, blockchain is transparent in system, tamper-proof in data, and has been widely applied in many fields such as finance, information security, sports industry and so on. Research in the field of sports is more on the referee black whistle, sports industry-driven, while research on college students' physical fitness test scores data, uploading in blockchain is still in the primary and blank stage. As the reported data of students' physical fitness test is often tampered with, the National Physical Fitness Monitoring Center needs to grasp the real data, and urgently needs a supervision and measurement tool that can truly reflect students' physical fitness status, so that it can be applied to grassroots units such as colleges and universities, and that students' physical fitness test data can be integrated into the blockchain. As a result, the decentralized and highly confidential characteristics of the data transmission of the blockchain can be utilized to guarantee the authenticity and validity of students' PE scores and effectively avoid and prevent certain school staff from artificially tampering with students' physical fitness test data. On September 5, 2022, the Institute of Sports Science of the State General Administration of Sport conducted a seminar on Construction of Scientific Fitness Knowledge Base and Application of Blockchain Technology, which strongly recommended the introduction of blockchain to the public. Director Hong Yuan stressed that accelerating the promotion of 'improving the physical fitness of all people', and network's and information technology's playing important roles in the development of public fitness and sports industry are significant spirits of national strategies such as the "Healthy China 2030" planning outline. For that reason, there is an urgent need to introduce blockchain technology into students' physical fitness test to fill the gap. In this regard, our group will make use of the decentralization and data encryption characteristics of blockchain to make it widely used in the field of students' physical fitness test, to maximize the authenticity of students' physical fitness test data in grassroots schools, and to provide a solid basis for the country to formulate the paths and means of improving students' physical fitness effectively.

3. Research object and methods

3.1. Research object

This research focuses on exploring the integration of blockchain technology with students' physical fitness testing systems. The objective is to provide a framework for the informatization of physical fitness testing and the application of blockchain within educational contexts.

To enhance the representativeness of the study, the sample selection criteria include:

(1) Institutions: The research will involve a diverse range of educational institutions, including universities and colleges across different regions, with a focus on both urban and rural settings. A minimum of 5 institutions will be selected to ensure varied perspectives and practices in fitness testing.

(2) Sample Size: The study will target approximately 1,000 students from the selected institutions, encompassing various demographics, such as age, gender, and academic backgrounds. This will allow for a comprehensive analysis of how blockchain can address the unique needs and challenges faced by different student groups.

3.2. Research methods

3.2.1. Literature research method

Sort out and identify the current research progress of blockchain and the status quo of college students' physical fitness test, and leave literature with high relevance to the subject for reference.

3.2.2. Logical analysis method

This method supports the necessity and feasibility of integrating blockchain technology with health test system by analyzing previous research results.

3.2.3. Cross-research method

Use blockchain technology to conduct model innovation and value research on the measurement and data organization of college students' physical testing. The use of Bei hang blockchain technology and its internal branch technology [9]: distributed ledger, decentralization, etc., can effectively organize and store college students' physical test data, avoiding the problem of data tampering and forgery. Therefore, interdisciplinary applied research can better promote the country's rapid development and academic integration [10].

Bei hang Chain offers distinct advantages in educational applications compared to Ethereum and Hyperledger:

(1) High Throughput & Low Costs: With a heterogeneous blockchain architecture, Bei hang Chain boasts higher throughput (up to 200 TPS) and lower operating costs. This is significantly higher than Ethereum's throughput, which is typically just two to three times Bitcoin's 7 TPS.

(2) Efficient Data Management: It effectively reduces storage costs and provides a reliable, integrated, and secure cloud system for data management, making it cost-effective for processing large educational datasets.

(3) Smart Contracts: Bei hang Chain supports smart contracts, enabling automated transactions and management, which enhances efficiency and control in educational applications.

(4) Adaptability & Privacy: It adapts to various educational needs and meets specific country data privacy requirements, demonstrated by Net Dragon Web soft's eLMTree ecosystem.

(5) Security: Bei hang Chain's decentralized storage and management mechanism mitigate security risks such as 51% attacks, providing a safer alternative.

In summary, Bei hang Chain's higher throughput, lower costs, efficient smart contract support, and robust privacy protection capabilities make it a potent tool for educational applications.

4. Findings and analyses

4.1. Analysis of blockchain and student physical fitness management system

4.1.1. Module for authentication of basic student information

(1) System Business Function

The system business function module encompasses three key components: the student basic information module, the results management module, and the professional management module. These components are designed with a unified architecture, allowing the system to be adjusted based on specific requirements to ensure stability and balance.

(2) System Business Function Design

The student basic information management system is divided into two modules:

Basic Information Entry Module: This module requires manual entry of student data. Administrative personnel will input essential details such as name, identification number, and contact information.

Student All-in-One Card Access Module: This module utilizes a student's all-in-one card to streamline the entry of basic information. When students use their cards, the system automatically retrieves and inputs their basic data into the database. This process is verified through blockchain technology, which ensures that each entry is time-stamped and immutable, preventing tampering.

4.1.2. Privacy protection measures

(1) Data Encryption: All student information transmitted via the all-in-one card access module is encrypted, ensuring that intercepted data remains unreadable without the proper decryption keys.

(2) Access Control: Role-based access controls are implemented to limit visibility and modification capabilities to authorized personnel only, safeguarding sensitive student information.

(3) Anonymization of Data: Personal identifiers are anonymized during data storage and processing, allowing for analytics without compromising individual privacy.

(4) Blockchain Auditing: A complete audit trail of data access and modifications is maintained on the blockchain, enabling traceability and accountability for unauthorized access attempts.

These privacy protection measures collectively ensure that students' personal information is handled responsibly and securely within the student physical fitness management system.

4.2. Student physical fitness test results management system

4.2.1. System architecture

(1) Network architecture

The network architecture is an indispensable component in the construction of a student physical fitness management system for higher education, as shown in **Figure 1**. When designing this architecture, three main elements should be considered: decentralization, security and scalability. Firstly, to achieve the goal of decentralization, a distributed network architecture is adopted. This architecture ensures that all nodes in the system participate equally and work together to maintain the data integrity and trustworthiness of the blockchain. This is designed to avoid a single point of failure and thus enhance the robustness of the system. Secondly, security plays a central role in the design of the network architecture. Encryption, authentication and access control are used to ensure that only authorized users can access and modify data on the blockchain. Meanwhile, the inherent characteristics of blockchain immutability can effectively prevent data from being maliciously tampered with or forged. Finally, the scalability of the system is also an important consideration in the design of network architecture. As the number of users increases and business demands evolve, the network architecture must be able to flexibly scale to support more nodes and higher concurrency of data processing.

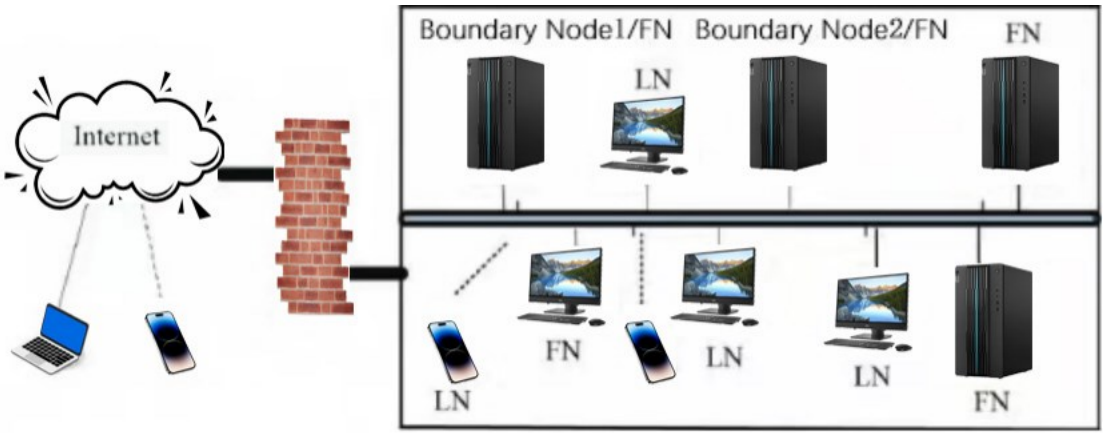

Figure 1. Network structure of teaching management chain in trusted universities.

(2) System architecture

A credible student physical fitness test management system is an application based on blockchain technology and its underlying architecture is blockchain technology as shown in **Figure 2**.

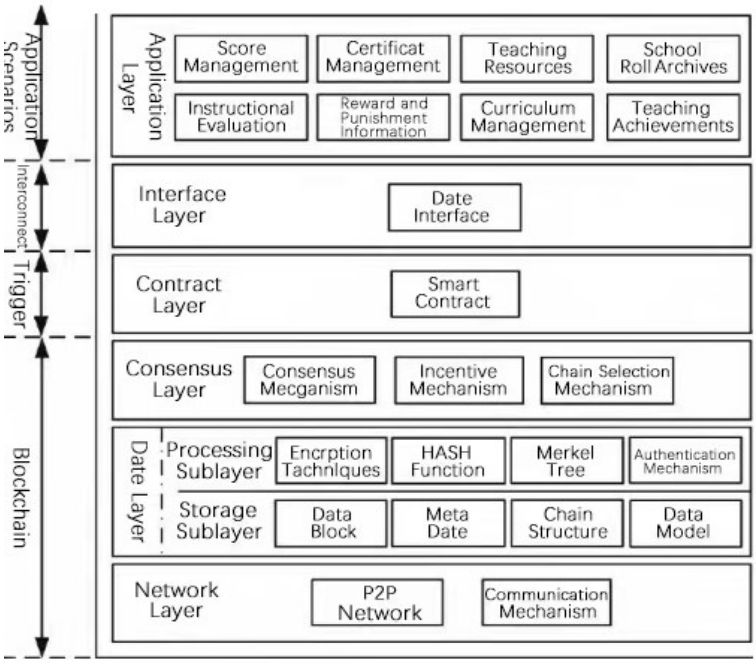

Figure 2. Credible student physical fitness test management system.

The architecture of blockchain's college student physical fitness test management system detailedly plans the various components in the system and their interrelationships, ensuring the orderly operation and efficient management. In the process of building the system architecture, the primary focus is on the core system functions, which includes key aspects such as student information management, course management and scores management. Around these core functions, the corresponding modules and components are elaborately designed, and the interaction mode and data flow among them are clarified to ensure the smooth transmission and efficient processing of information. In terms of data storage, blockchain technology is adopted to realize data distributed storage and sharing. Through the consensus mechanism among multiple nodes, data consistency and credibility are ensured, providing solid data support for the student physical fitness test management.

4.2.2. Consensus mechanism

In blockchain-based college student physical fitness test management system, the consensus mechanism is the key to ensure data consistency of all nodes and system security. Among various consensus algorithms, the Practical Byzantine Fault Tolerance (PBFT) algorithm is often used in coalition chain scenarios due to its efficiency and applicability.

PBFT consensus algorithm

PBFT algorithm, proposed by Miguel Castro and Barbara Liskov in 1999, addresses the inefficiency of traditional Byzantine Fault-Tolerance algorithms by reducing the complexity of the algorithm from exponential to polynomial level, which makes it more efficient in practical system applications. The algorithm further enhances system security by limiting the damage that can be caused by failed clients through clustered access control, auditing the clients and preventing them from initiating operations that they are not authorized to perform.

In PBFT algorithm, the role of nodes in the system is divided into Primary and Backup nodes. The primary node is responsible for processing client requests and broadcasting the results to other nodes. The backup node is in charge of verifying the primary node operations and participating in the consensus process if necessary.

The PBFT consensus process covers the following key steps:

Request Phase: the client sends a request to the primary node, which broadcasts it to other backup nodes after receiving it.

Pre-preparation phase: Once the backup node receives the request, its first task is to verify its legitimacy. Once verified, the node forwards the request to the other backup nodes and generates a unique sequence number, which is stored with the request as a pre-prepared message. Subsequently, this pre-prepared message will be broadcast to all nodes.

Preparation phase: Once the node receives the pre-prepared message, it verifies its legitimacy again and stores it as a prepared message. When a node receives the same prepared message from a sufficient number of different nodes, it sends a prepared message. This message contains information such as node number, sequence number, and request summary.

Commit phase: When a node receives the same prepared message from a sufficient number of different nodes, it sends a commit message. This message contains the node number, sequence number, request summary, and a signature for the request. Once a node receives a sufficient number of commit messages, it executes the request and broadcasts the result to other nodes and clients.

Comparison with Other Consensus Algorithms

While the PBFT algorithm is effective for the specific needs of this management system, it's valuable to contrast it with other common consensus algorithms:

(1) Proof of Work (PoW): PoW, used by Bitcoin, relies on solving complex mathematical problems to validate transactions, consuming significant computational resources and energy. This makes it less suitable for real-time applications like fitness data management, where efficiency and speed are critical.

(2) Proof of Stake (PoS): PoS selects validators based on the number of coins they hold and are willing to "stake." While it reduces energy consumption compared to PoW, PoS can introduce centralization concerns and may not guarantee immediate consensus in a network with limited participants, making it less reliable for the dynamic interactions required in fitness testing.

(3) PBFT: In contrast, PBFT provides a highly efficient consensus process with low latency, suitable for environments with a limited number of trusted nodes, such as educational institutions. Its ability to maintain data integrity and security even in the presence of faulty or malicious nodes makes it particularly well-suited for managing sensitive fitness test data.

Throughout the consensus process, the PBFT algorithm ensures the data consistency and security of the system nodes through multi-stage message interaction and verification. Even in the case of Byzantine failure (i.e., the nodes may have malicious behaviors or failures), the PBFT algorithm is still able to maintain the consistency of the system.

4.2.3. Block structure

The block structure is the core component of the blockchain based on the blockchain technology application in the college student physical fitness test management system. Each block contains specific components: block header, which covers the block metadata information, such as time stamp, hash value of the previous block and hash value of this block. This information is crucial for maintaining the integrity and security of the blockchain system. The block body, on the other hand, is responsible for storing the actual teaching management data, such as student information, course records and score data. These data are stored in a specific encoding format to ensure data accuracy and readability [11]. With the design of block structure, the system realizes the distributed storage and updating mechanism of the data to ensure data integrity and reliability.

4.2.4. Scalability of the student physical fitness test results management system

The student physical fitness test management system is designed with scalability as a core feature to ensure that it can accommodate future growth, including the addition of new test items and increased data volumes. Here's how the system addresses scalability:

(1) Modular Architecture: The system is built with a modular structure, allowing for easy integration of new physical fitness test items without disrupting the existing framework. Each test item is treated as a separate module that can be added or modified as needed, facilitating future updates.

(2) Flexible Data Schema: The blockchain architecture employs a flexible data schema that supports a wide variety of data formats. This ensures that the system can store and process different types of test results—whether new fitness metrics or complex biometric data—without requiring significant changes to the underlying system.

(3) Distributed Ledger Expansion: As the number of students and test items grows, the distributed ledger system can scale horizontally by adding more nodes to the network. This increases the system's capacity to handle higher data throughput and maintain efficiency in processing new test items.

(4) Smart Contracts for Automation: Smart contracts can be updated or added to automatically handle new test items, streamlining the process of recording and verifying new data. This enhances the system's ability to adapt to evolving requirements without manual intervention.

By designing the system with scalability in mind, it can seamlessly accommodate future changes, ensuring long-term usability and adaptability in managing student fitness data.

4.3. Student physical fitness test results management module

4.3.1. Student physical fitness test result management function

The function of this module is mainly to query and modify. In order to improve the request response speed and reduce the storage space occupied by blocks, the query function does not use blockchain, and only the query request is filtered by authority [12]. No block is built for query operation.

4.3.2. Student physical fitness test result management design

The student physical fitness test machine automatically records test results into the module and timestamps the information. Students will be guided by teachers to perform measurements sequentially, with the machine automatically inputting results into the blockchain database.

To ensure that only authorized personnel can modify or delete data, the system implements the following measures:

(1) Access Control: Role-based access control (RBAC) is enforced, granting modification and deletion rights only to designated staff members, such as administrators or health personnel. Each user must authenticate their identity through secure login procedures before accessing the module.

(2) Audit Logging: All actions involving data modification or deletion are logged in an immutable audit trail on the blockchain. Each log entry includes details such as the user ID, timestamp, action type (e.g., modify or delete), and a summary of the changes made. This audit log is crucial for ensuring accountability and transparency.

(3) Change Approval Workflow: For sensitive data modifications, an approval workflow can be implemented where changes require validation by a secondary authorized user before being executed. This additional layer of oversight helps prevent unauthorized alterations.

(4) Data Recovery Mechanisms: In the event of unauthorized changes or deletions, data recovery mechanisms are in place, allowing the system to restore previous versions from the blockchain, thus ensuring data integrity.

By incorporating these security measures, the module maintains a secure and reliable environment for managing students' physical fitness test results while ensuring accountability and traceability of all modifications.

4.4. Implementation of blockchain-based student physical fitness test system

4.4.1. Blockchain development technology working principle analysis of Bei hang chain

The blockchain development technology, Bei hang Chain, was originally designed as a blockchain for education and financial services. It is characterized by the inclusion of a node credit system, which speeds up information processing by concurrent Byzantine Fault Tolerance. It also adopts a dual-chain structure of account blockchain and transaction blockchain, which improves system scalability and throughput, and reduces latency and privacy leakage risks. The Bei hang chain architecture has five layers: application layer, on-chain code layer, interface layer, blockchain service layer and storage layer. The application layer deploys applications, the on-chain code layer provides contract-related services, the interface layer provides external and internal API interfaces, the blockchain service layer deploys the block dual-chain system, and the storage layer includes the operating system and database services.

4.4.2. Result management module architecture design

The result management module is divided into four layers:

(1) Application layer: send the user's operation request and private key to the on chain code layer for the next step.

(2) On chain code layer: decrypts and verifies the private key sent by the user, if the verification is valid, then proceed to the next step according to the operation mode. Otherwise, access is denied.

(3) Blockchain service layer: create blocks according to the operation data sent over by the user, with time stamp, pre hash and Merkle root, perform the database operation requested by the user, and return the result to the frontend for display [13].

(4) Storage layer: used to store user data and respond to user requests for operations.

4.5. Blockchain design for student physical fitness test system

4.5.1. Block header

Including time stamp, pre block hash and Merkle root. Merkle root is to let all the transaction records in the block have two hash operations, the result of which, as a child node of the Merkle root, recursively hashes two neighboring nodes until the last hash result is got, this hash value is the Merkle root.

4.5.2. Block body

Including operation type, pre-operation information, post-operation information and operator.

(1) Operation type: categorized by user intent: create, insert, update and delete.

(2) Pre-operation information: Record the raw data of the object the user is about to operate.

(3) Post-operation information: Record the data after the user operation is completed.

(4) Operator: record the user who initiated the operation.

4.5.3. Key point to the overall system technology

Bei hang Chain System provides the technology development toolkit-OBCC, therefore, how to apply the technology development toolkit OBCC to the student physical fitness measurement system is the key technology of this system. The details are as follows:

Functional module interface design: the storage layer of the Bei hang chain system uses Level DB database and Mysql database. The calling interfaces include user IP configuration module, calling request module, communication module, service calling module, and the API of system calling is shown in **Table 1**.

Table 1. Functional module interface design.

API function prototypes	Return value	Remark
Insert (Srting tx, String tbc Name)	OBCC Result	Adding transactions to the blockchain system
Select (String tbc Name, String condition)	OBCC Result	Query Transactions by Index Fields
Create Tbc (String tbc def)	String	Create Block
Create lndex (String column Name)	String	Create Index

Block encryption and algorithms in blockchain: SHA256 is used in blockchain encryption and algorithms, which maps an input value of any length to a binary value of length 256, and is used to verify the integrity of the data; the company key encryption and decryption use elliptic curve encryption algorithms, which ensures the authenticity of the user's identity; the consensus mechanism adopts the concurrent Byzantine Fault Tolerance, CBFT, which parallelizes transactions and votes to improve performance; the time stamp service solves the "duplicate payment" problem; blocks are stored in Merkle trees, which are mainly used to check the block speed and data transmission, as well as data calculation complexity.

Embedding blockchain encryption technology into the existing student physical fitness test system ensures the authenticity of the student physical fitness data. For this reason, we carry out blockchain encryption algorithms to implement time stamping during the transmission of the machine measurements to the computerized database to make clear the exact time of the database transmission to ensure that the data authenticity can be queried and identified at any time and place [14]. Therefore, we also have to embed blockchain confidentiality technology to find the encryption key of the student physical fitness test program in order to open all the system programs to ensure the stable and balanced system operation.

Cross-school data sharing and validation in the student physical fitness test system, particularly in cases like student transfers or inter-school competitions, can be achieved through several mechanisms:

(1) Permissioned Blockchain Consortium: Schools within the consortium can have nodes on the blockchain. Each school has authorized access to the relevant student data, ensuring secure and efficient cross-school data sharing.

(2) Interoperability Protocols: The Bei hang Chain system can be designed to support interoperability between different schools' fitness management systems. Smart contracts and APIs enable seamless data exchanges, allowing for real-time access to verified student performance data.

(3) Data Validation via CBFT: When a student transfers or participates in competitions, their fitness data can be validated through the concurrent Byzantine Fault Tolerance (CBFT) mechanism. This ensures that each school's data on the blockchain is consistent and verified without needing central authority approval.

(4) Privacy Protection and Access Control: Role-based access control and encryption methods (like elliptic curve encryption) ensure that only authorized personnel can access or modify sensitive data, even during cross-institutional sharing.

These mechanisms ensure smooth and secure data sharing while maintaining the authenticity and privacy of student fitness records across different schools.

5. Conclusion

In conclusion, the application of blockchain technology in managing student physical fitness test data not only enhances data security and integrity but also facilitates seamless sharing and integration of health information. This innovation can significantly improve the accuracy of student health assessments and assist in better decision-making by governmental and educational institutions.

Future Research Directions:

Future research can explore several promising avenues:

(1) Integration with Educational Management Systems: Investigating how to integrate blockchain-based fitness data management with existing educational management systems could create a more holistic view of student health and academic performance. This could enable real-time tracking and comprehensive analyses, improving student support services.

(2) Scaling for Larger Applications: Exploring the scalability of this blockchain solution to larger educational networks or even national databases can enhance its utility. This could include the potential for real-time health monitoring and data sharing across multiple institutions, fostering collaborative health initiatives.

(3) Interoperability with Health Systems: Future studies could focus on developing standards for interoperability between blockchain health records and traditional health management systems. This would ensure seamless data exchange between educational institutions and healthcare providers, promoting a more integrated approach to student health management.

(4) Enhanced Analytics and Machine Learning: Incorporating advanced analytics and machine learning techniques could optimize the interpretation of fitness data. This could lead to personalized health recommendations for students, thereby improving overall health outcomes.

By pursuing these directions, researchers can further leverage blockchain technology to enhance the management of student physical fitness data, ultimately contributing to a more effective and secure educational ecosystem.

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