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A Blockchain-based Educational Digital Assets Management System

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Abstract: A variety of heterogeneous information is produced after the application of various emerging technologies in education, which is of great research value as educational assets. The traditional educational asset management system has emerged. In view of the disadvantages of traditional system centralization process, people begin to use decentralized blockchain technology for innovation. This paper proposes an educational digital asset management system architecture based on blockchain 3.0 technology system, which forms various data formed by students in and out of class learning process, courseware and experience data generated by teachers in the process of teaching into educational digital assets, and carries out the right confirmation and storage on the blockchain. The system can use a variety of heterogeneous data in digital assets to analyze the development status of school users, achieve the teaching purpose of teaching students according to their aptitude and different people.

Keywords: blockchain; blockchain system; digital assets; educational technology; decentralized systems.

1. INTRODUCTION

Technological advancement in Internet, cloud computing, big data, edge computing, 5G, artificial intelligence and blockchain has significantly changed the ways of teaching and learning. For example, learning can happen anytime and anywhere through networked platforms, where various teaching resources in the digital format are stored, updated, distributed and shared in a timely manner. Doing so, much data about students and teachers are isomerized and fragmented on the Internet, and/or personal computers, and/or school systems. In fact, such information is valuable digital asset that can be utilized via data analytical technology for teacher/student assessment. Its existence and accumulation in the education system calls for an effective educational data asset management system.

The traditional education digital asset management system (Fig. 1) usually has a centralized datacentre to store large files such as courseware and/or videos of teaching materials; while the data, such as students' scores and evaluation records, is generally stored in a structured database. The high level of data centralization might cause a series of security risks, such as data leakage, hardware failure and damage. This form of centralized storage makes it challenging for networks to support large-scale data transmission. As a result, the traditional system has many problems, such as low efficiency, high cost, insufficient use of data value and so on.

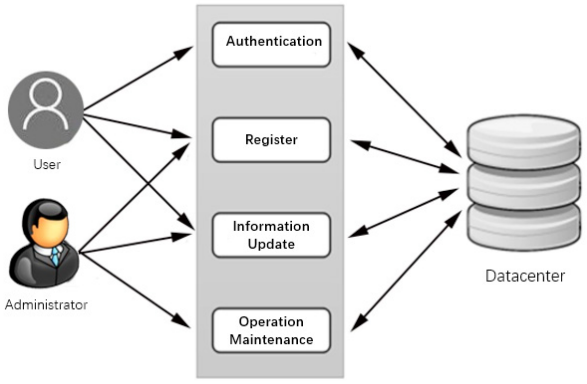

Fig. 1. A traditional education digital assets management system

The emergence of blockchain technology brings new opportunities for the management of data assets. Through the distributed storage mode, different data are stored in a wide range of blockchain networks. Its storage form is simple and easy to expand, and its degree of decentralization can ensure the existence of data, even after the damage of single hardware. The high availability of the blockchain network ensures the data assets' security. And various security protocols in blockchain, such as zero knowledge proof, homomorphic encryption and so on, can guarantee the rights of owners to these data assets. The privacy of data assets can be guaranteed by using appropriate encryption methods. Only

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authorized users or users with specific permissions can access the corresponding assets.

The education digital assets management system based on blockchain can realize the privacy protection and security protection of data assets based on blockchain technology. Its distributed feature is convenient for different types of users to upload and access their related heterogeneous data information, such as: images or videos, text records, various audio media and other data. At the same time, the information possessed by the system can be used as a big data source for relevant analysis, so as to provide teaching reference for schools or educational institutions, and its zero-knowledge proof and other privacy protection law can also ensure data security. Based on blockchain technology, digital asset management system can meet the needs of multi-institution, multi-school and multi-user digital asset creation and transaction. Through the transaction between data, it reflects the value attribute of digital assets and forms the credit value network.

Motivated by the above remarks, this paper proposes an educational digital asset management system architecture based on blockchain 3.0 technology. Various data, such as courseware, teaching videos, student behaviors in and out of class, is stored and confirmed on the chain. At the same time, considering the human factor in blockchain that causes various credibility of the assets being uploaded, our system integrates data analysis, data prediction, management and regulation to form a cyber-physical-social-system-based educational blockchain digital asset application system. The system can use a variety of heterogeneous data in digital assets to analyse the behaviors of student users via artificial intelligence, so as to offer personalized learning in accordance with individual student's aptitude and talents. In a similar fashion, the system can provide curricular reform strategies that fit the needs of schools and educational institutions, and help them carry out effective teaching assessment.

The rest of this paper is organized as follows: Section 2 introduces the development of blockchain technology and the development status of education blockchain; section 3 proposes the framework of educational blockchain digital asset management system, followed by the summary and future directions in Section 4.

2. DEVELOPMENT AND STATUS OF RELATED TECHNOLOGIES

2.1 Development of blockchain Technology

Blockchain has not been more than 10 years since the first application bitcoin developed by Nakamoto in 2008 as the symbol of its birth. Compared with artificial intelligence with hundreds of years of theoretical support and Internet and cloud computing developed for decades, the research on blockchain is still in the initial stage. Blockchain was first created as an application in the financial field only. It was then being widely recognized after the popularity of the wealth making campaign. Yuan and Wang (2016) systematically analysed the infrastructure model of blockchain in the academic field, and elaborated the basic principles and technical methods of blockchain. It is pointed out that blockchain technology has the characteristics of decentralization, sequential data, collective maintenance, programmability, security and credibility. Blockchain technology is suitable for the construction of programmable monetary system, financial system and even macro social system.

The second generation blockchain technology is represented by the emergence of Ethereum, EOS and private chain systems with limited programmable smart contract functions. Wang *et al*., (2019) proposed the infrastructure model of smart contract, and elaborated the operation mechanism and infrastructure of smart contract based on this research framework. It is pointed out that smart contract can flexibly embed all kinds of data and assets, help to realize safe and efficient information exchange, value transfer and assets management. Finally, it is expected to deeply change the traditional business model and social production relations, and lay the foundation for the construction of programmable assets, systems and society. The smart contract function innovated by the second generation blockchain technology enables blockchain with more practical functions to be applied to real-world cases, such as Benet (2014) the IPFSDATA (InterPlanetary File System data storage). With the emergence of the second generation blockchain technology, people began to think how to apply the decentralized blockchain to the centralized and intensive real world, forming a weak centralized blockchain architecture, which is the third Generation of blockchain technology.

With the reform of public chains, new blockchain mechanisms arise. Consortium blockchain is the representative of the third generation blockchain technology, where various access mechanisms evaluates the qualification and levels of super management nodes. Those nodes usually have the highest authority in the chain, corresponding to the management department in the real world. Consortium blockchain, widely serving enterprise, institution or organization, overcomes the shortcomings of public chains that cannot offer customized functions for a large range of public users. Two examples of such consortium blockchains are IBM's Hyperledger and FISCO BCOS in the financial area. Hyperledger is driving blockchain innovation across enterprises in every part of the world. FISCO BCOS is a safe, reliable and efficient platform of blockchain.

2.2 Application status of education blockchain

Under the existing education theory and teaching form environment, a variety of education block chain driven intelligent education system has been formed. Especially after Comrade Xi Jinping's speech in October 24, 2019, a wave of learning and application block chain technology emerged in China. Internationally, Sony has launched a blockchain based learning system. Scholars from UAE University have compared a variety of blockchain technologies, deployed and tested the performance of education blockchain in UAE University, and confirmed that

the large-scale deployment of blockchain network in education system is feasible. In addition, MIT also has a software blockcerts wallet based on blockchain technology, which realizes the authentication of students' e-certificates and the issuance of diplomas. Students can obtain the corresponding e-diploma through the smart phones installed with the software. At present, there are many education type blockchain systems in operation, and the application of blockchain technology in all stages of development exists. Sharples and Domingue (2016) proposed a private chain based, persistent distributed personal achievement record and reputation reward blockchain system. Yang *et al.,* (2017) discussed the application mode and practical challenges of blockchain technology in education field, and proposed several application modes of blockchain in education industry. Wang (2004) first proposes parallel intelligent theory based on ACP (A: Artificial Society + C: Computational Experiments + P: Parallel Execution) for CPSS (Cyber-Physical-Social Systems). Yuan and Wang (2017) elaborated the concept framework, basic theory and research method system of parallel blockchain based on parallel intelligence theory and discussed the connotation of parallel blockchain. Gong *et al*., (2018) on the basis of parallel intelligence theory and parallel blockchain, a parallel education blockchain based on public chain system and private chain is proposed. Its driving mechanism, function distribution, data transmission, application scenarios and related issues are described. An education blockchain system architecture based on parallel intelligence theory is proposed, which uses the dual functions of distributed and centralized in storage The results, credits and rewards of formal education are stored in the distributed ledger, while the scores, credits and rewards of informal education involving a large number of video, audio and image data resources are recorded by the distributed and central storage mechanism. Mo (2019) believes that science and technology are enabling future education and pushing education into a new development stage. In the 3.0 school education organization ecology, blockchain technology has an important impact on the new mode of education. In digital schools and even cloud schools, "artificial intelligence + blockchain" will have more functions in the combination of inside and outside the school.

With the development of blockchain technology, consortium blockchain has gradually come into people's vision. In the public chain system, all nodes are equal, relying on consensus algorithm to reach an agreement, which may consume huge computing power and energy, or need to synchronize hundreds of g of ledger data. This is obviously unrealistic for ordinary users. However, in the whole education system, the relationship between all users is not completely equal. Teachers and students as well as education administrative departments have their own roles and responsibilities. The access rights and user functions of these people should be different. Consortium blockchain system can achieve data sharing instance by building channels, and realize authentication and audit through certificate authentication and authority authentication, which is relatively consistent with the current digital asset management model of education system. At the same time, the consortium blockchain can run different chain codes (smart contracts) in different channels, which provides different functions for different channels. Therefore, we choose consortium blockchain system to build an education asset management system.

3. THE EDUCATIONAL BLOCKCHAIN DIGITAL ASSET MANAGEMENT SYSTEM FRAMEWORK

Based on the above analysis, combined with the consideration of privacy protection and safe operation of the education blockchain digital asset management system, it is not appropriate to build a public chain system that all people may join at will. Correspondingly, a consortium blockchain system composed of the internal industries of the education ecosystem can be constructed. On the basis of this system, the user access mechanism, node authority management, transaction user management, system contract installation and call execution are realized.

3.1 Organizational structure of educational digital asset consortium blockchain nodes

The main users of the system are schools, teachers and students, education administrators, some educational institutions, community organizations and students' families etc. In consortium blockchain, peers are authorized and authenticated with the certificate of blockchain. At the same time, different types of units can be divided into different channels, so that different types of units can be divided into a group. It can access authorization data and coordinate with each other. The whole education blockchain digital asset management system implements the overall framework of consortium blockchain (Fig. 2), including all units of each alliance node. For example, school unit alliance node does not refer to a school, but refers to all the same type of schools that join the alliance and are qualified to participate in teaching.

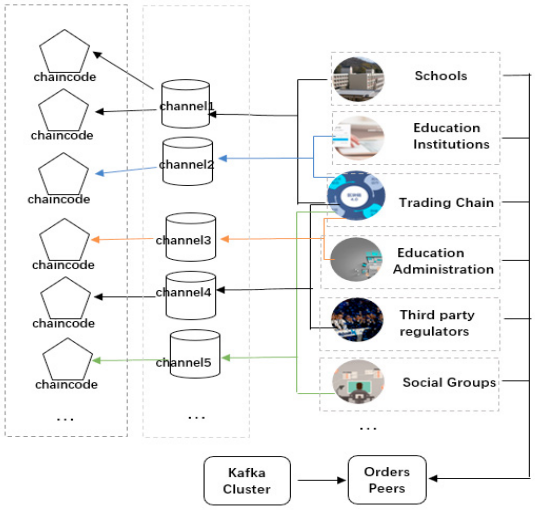

Fig. 2. The organizational structure of educational digital asset consortium blockchain nodes

The data asset transaction within the alliance is usually composed of nodes with the same channel as the transaction chain. The transaction chain combines several types of alliance nodes to form different channels, which can conduct data transaction with each other. Each channel is equivalent to a new blockchain, and each node in the channel has a copy of the current channel's ledger data. In different consortium blockchain channels, one or more smart contracts may be run. For example, the school can execute the smart contract of student development level evaluation and the smart contract of teacher teaching level evaluation. When students and teachers upload data, the data is encrypted and stored. One is for the integrity of user data, the other is to prevent the leakage of user's privacy information. Homomorphic encryption and other cryptographic encryption methods can ensure that the ciphertext can be calculated arbitrarily without decryption, so it can solve the problem of data privacy security immediately. The system can analyse user data without decrypting user data, and provide source data for subsequent artificial intelligence analysis model.

The Federation nodes in the federation chain are not immutable. They can be restricted to enter the system by revoking their certificates. When the role of some coalition nodes is relatively weak or destructive, these nodes can be required to exit the consortium network. For example, some educational institutions may have similar functions, and their relationship is a competitive relationship. When some educational institutions are facing bankruptcy or closure due to declining performance, they can choose to issue certificates to other newly established but not qualified educational institutions to introduce into the alliance and eliminate those inferior products from the alliance.

3.2 Infrastructure model of consortium blockchain

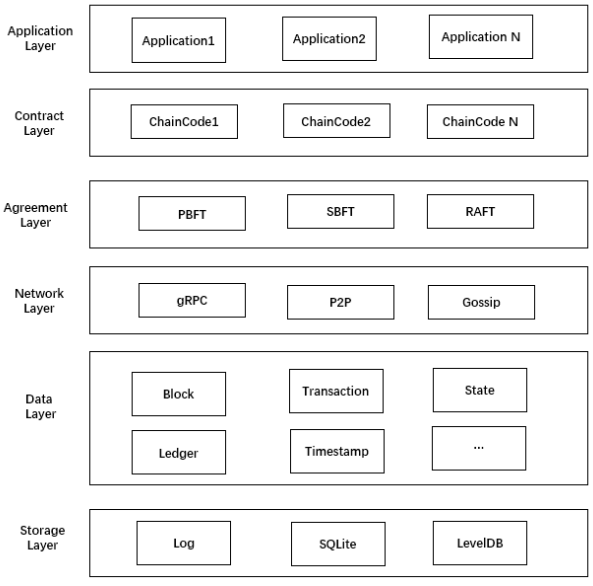

Fig. 3. Infrastructure model of consortium blockchain.

We divide the bottom layer of the blockchain into six layers (Fig. 3), which are storage layer, data layer, network layer, consensus layer, contract layer and application layer from bottom to top.

As the bottom layer of the system, the storage layer is mainly used to store the system running log and transaction related content. The system log contains a record of the system events that indicates how the system processes. There are several levels you can choose: such as debug, error, info, warn. Among them, the system log is implemented based on logback, the related contents of the transaction are stored by the built-in SQLite database, and the metadata information of the transaction is stored by LevelDB or CouchDB.

The data layer consists of blocks and ledgers. This layer encapsulates the key information of the blockchain, including specific block information, ledger information, timestamps, and so on. The block also involves the storage of transaction list in Merkle tree and the calculation hash value of parent node. The ledger holds facts about the current and historical state of a set of business objects. Data asset information is also encrypted and stored here. Generally speaking, there are many types of nodes in the consortium blockchain. In order to effectively manage node data and ensure data security, different public and private keys can be assigned to different nodes for encryption.

The network layer mainly provides the underlying support of data communication to the system. In the blockchain, each node is both the sender and the receiver of data. It can be said that each node is both a client and a server, so it needs to be implemented based on long-lived connection. We can establish long connection in native way based on websocket, or implement it based on long connection third-party toolkit.

The consensus layer can choose to adopt PBFT (Practical Byzantine fault tolerance) or a simplified version named SBFT (Simple Byzantine fault tolerance), or any other consensus algorithms. Different from the mining mechanism of public chain, the consortium blockchain pays more attention to the information integrity with all the peer. Therefore, the consortium blockchain system does not need to consume huge energy to reach consensus, and it will go straight to reach consensus.

Many different smart contracts running on contract layer. Smart contract defines the executable logic that generates new facts that are added to the ledger. By these smart contracts, the agreed automatic data operation is realized. For example, when a student submits a certain certificate or examination qualification, and after endorse peers confirm its authenticity, the smart contract can automatically perform a series of operations, such as student quality improvement, Certificate Award, point increase update and record these action results in the student information table.

The application layer is mainly the landing development of each application in the consortium blockchain. The various applications provided here can directly face the node user client and provide users with various functions such as query, upload, update and transaction.

3.3 System authority management of consortium blockchain

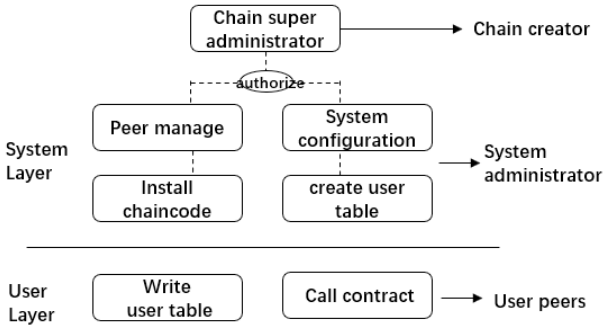

Fig. 4. The system authority management of consortium blockchain.

In consortium blockchain system, only nodes in the same channel are decentralized compared with other nodes, while different channels are isolated. The core management organization in the alliance has high-level authority to manage the whole consortium blockchain. It can manage the node type of the consortium blockchain by distributing certificates. At the same time, the chain administrator at the top of the consortium blockchain management can set up a system administrator. The system administrator can adjust the system parameters, deploy the chaincode smart contract, and create a new database storage table. Therefore, the whole chain management department must run under the guidance of the core departments of the alliance. The members of the core departments of the alliance are generally considered to be appointed by a third-party organization, or elected offline according to the alliance creation agreement within the alliance.

3.4 Jointly generate evaluation indicators to determine the smart contract

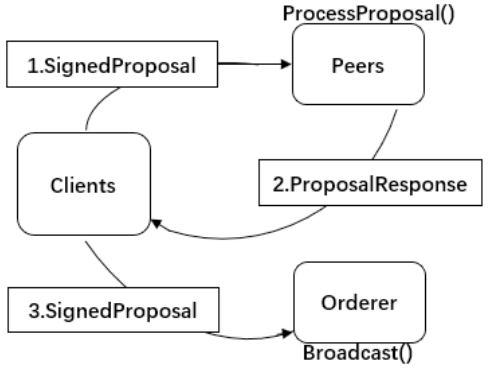

Fig. 5. The call process of smart contract.

All nodes in the same type of alliance nodes have equal status. After students and students from other schools upload data, the age and stage of students are completely eliminated. In this case, the data provided by students should be analysed and scored first, and then the smart contract based on some evaluation standard is used to automatically update the score. This smart contract should be reached through the school node or the school node led by the education administration department to discuss and propose the index evaluation system, which will be deployed in the system after reaching a consensus. As long as the user meets the starting conditions of the smart contract, the smart contract will automatically execute and record the information to the blockchain, and this process does not need manual intervention.

3.5 Construction of artificial consortium education blockchain based on CPSS

We can build many artificial blockchains by formal description of static characteristics and dynamic behavior of core elements (peer type, chaincode, consensus algorithms, etc.) of blockchain systems. Analyse specific blockchain scenarios. Optimize the decision by the closed-loop feedback between artificial blockchains and actual blockchain system. For example, we can analyse the operation status of network communication and blockchain when the blockchain is under attack and the management node is offline, as well as what coping strategies need to be selected to prevent attacks. When such problem scenarios occur in real society, the prepared solutions can be used directly. But so far, it is not easy to model the blockchain, it is difficult to simulate the real scene, and the system situation is complex. The calculation experiment still needs new technical means to realize.

3.6 Investigation of the third-party evaluation unit

The characteristics of the blockchain system can ensure the integrity and reliability of the data after being put on the chain. However, a third-party organization needs to evaluate whether the data on the chain is normal or not and whether the data is fake or not. We call it a third-party evaluation agency. The establishment of the organization is mainly to make up for the authenticity of the front-end data. It may work in a variety of ways, such as on-site inspection, periodic inspection, assessment and supervision. For example, evaluation experts can check the indicators recorded in the blockchain on site, evaluate the teaching level of teachers, and evaluate the ability of students.

In addition, there is another type of functional assessment. Through the various data stored in the blockchain, the system can call the trained artificial intelligence model to carry out data value evaluation, user performance evaluation, student performance evaluation and other assessments. In order to ensure the accuracy of the data results, the third-party evaluation unit can make the evaluation while the system automatically evaluates, and finally compares and combines the results with each other. Due to the automatic execution function of smart contract, the third-party evaluation unit will receive the big data information of evaluation students, and can use the evaluation platform to conduct big data analysis on the selected data. The analysis results are compared with

the results of automatic evaluation in the system. If the gap is too large, a new round of re-evaluation will be started. It also includes the evaluation of data assets provided by teachers and students. The evaluation is dynamic, and the designation of each evaluation index is approved by the index evaluation units in the consortium blockchain by consensus.

4. THE SUMMARY AND FUTURE PROSPECTS

Although the educational digital asset management system based on blockchain has great foresight and adaptability in practical application, its specific application is extremely difficult for the education ecosystem. First of all, it needs to coordinate among many different units, even including the participation of government functional departments such as education administrative departments. In addition, a lot of preparatory work needs to be prepared, such as in the industry it is a hard work to develop standardized and reasonable digital asset management regulations; training the internal staff of the consortium blockchain nodes involved in the education system; training the students how to use the system; the research and development of the system and the investment of human and material resources are great challenges.

The operation of traditional digital asset management platform tends to be stable. Under the premise of stable operation, no user can easily choose to use other digital asset management systems. In addition, blockchain technology, as an emerging technology, its practice and theoretical research are in the promotion stage. Although the current research is relatively mature, there are many defects that cannot be easily solved. For example, in terms of the performance of the blockchain, there is an impossible triangle, and the storage performance, transaction performance and scalability of the blockchain cannot be improved at the same time. Other aspects, such as the low transaction rate, the limited number of transactions completed per unit time and the limited number of bookkeeping, are a major defect of the current blockchain; in the development of smart contracts, there is a lack of effective audit and maintenance of smart contracts, and many smart contracts have been hacked by hackers; The capacity of each block is limited and cannot be adjusted at will, resulting in storage defects in the blockchain; there is the possibility of attacks in the accounting book recording process, such as double flower attack and solar eclipse attack in the consortium blockchain system; industrial application is difficult, user identity anonymity cannot be supervised sometimes, and the actual business is difficult to combine.

There are bottlenecks in the performance of the current blockchain system, and the expansion of the topology will lead to the reduction of efficiency and performance. How to further expand the topology structure under the premise of limited impact on performance is a problem to be discussed in the future. In addition, the expansion and integrity adjustment of education blockchain system also needs to be studied, and the ecological construction also needs the input of relevant departments. Now, there are many drafts and proposals in the bitcoin community, such as improving the block time, adjusting the block size and changing, and upgrading the consensus algorithm, which are all under discussion and research, and may be given in the future Blockchain technology brings innovation. However, the EOS of the second generation blockchain technology is still in the development stage. Although the main network has been online, the whole ecology has not yet been improved. The geometry of the future remains to be expected. Because the third generation blockchain technology fundamentally changes the blockchain system from decentralization, more and more enterprises and organizations are developing and mining the characteristics of consortium blockchain, looking for more application scenarios and trying. The future development focus of the project is to make up for the weak links, develop more functional chain codes and applications, and make more attempts in data security improvement, user privacy protection, consortium blockchain stability and persistence. At the bottom of the system, blockchain technology will be deeply integrated with new technologies in the future, forming a variety of innovative technologies such as artificial intelligence + blockchain, artificial blockchain experimental system, etc.

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