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Retraction

Retracted: A Smart Campus Implementation Architecture Based on Blockchain Technology

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] J. Lu and B. Wu, "A Smart Campus Implementation Architecture Based on Blockchain Technology," *Journal of Sensors*, vol. 2022, Article ID 2434277, 14 pages, 2022.

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Research Article

A Smart Campus Implementation Architecture Based on Blockchain Technology

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With the application of 5G technology in the field of education, the construction of smart campus has set off a wave of digital transformation. At the same time, the traditional smart campus is also facing the exponential growth of the number of Internet of Things devices, servers, and application terminals, which makes it difficult to achieve flat management. In view of the current difficulties in the construction of smart campus, this paper proposes smart campus architecture based on blockchain technology. Unlike the traditional smart campus architecture, this paper combines the characteristics of decentralization, high confidentiality, and data sharing of block chain with the Internet of Things technology, which greatly reduces the demand for data storage and physical network equipment. The new smart campus architecture plans the application of smart education based on blockchain, and provides a new solution model and research ideas.

1. Introduction

The smart education environment builds an intelligent system by using Information and Communication Technology, including the IoT, cloud computing, and data mining, aimed at improving the quality of teaching courses, scientific research, student living, and campus management [1–3]. However, this environment faces numerous challenges under 5G, such as high management cost, high energy consumption, low data security, and low credit, due to the increase in the number of IoT terminal equipment under 5G [4, 5]. Further, 5G network will transfer a huge amount of personal data and consume energy deficiency [6]. Tracking these challenges become increasingly more difficult under the centralized framework of a smart environment. By some literature research and analysis, an emerging technology called blockchain is paid attention to this paper [7]. Bitcoin is a decentralized digital currency that is transferred using the peer-to-peer bitcoin network. The transactions in bitcoin are verified using encryption in the network nodes and also recorded in the public distributed ledger known as Blockchain. As the underlying technology of Bitcoin, blockchain is considered the next revolutionary technology with the characteristics of decentralization, tractability, security, and nonavailability, which can be applied in almost every field, especially in the education [8, 9]. Due to these characteristics, applying blockchain to the IoT can be served as an effective solution to the above challenges of a smart education environment under 5G. Some inclusive researches of blockchain and smart education integration have been done, including education applications, data security, and intelligent operation.

Various studies have been done for the smart applications based on the blockchain. Jiang et al. designed a new industrial Internet of Things solution based on the smart contract-enabled blockchain technology, which can reduce data dependence on centralized systems [10]. By applying the MOSS smart contract, Zheng et al. proposed a permission blockchain trust framework for Multi-Operators Wireless Communication Networks. [11]. Sharples and Domingue proposed a distributed system for education records and integration through blockchain technology, making full use of the functions of smart contracts in blockchain to achieve distributed management of smart education credit [12]. Skiba systematically analyzed the application of blockchain technology in education, and pointed out that blockchain would cater to the decentralized learning mode and spur new learning revolutions increasingly [13]. To solve the separation of IoT devices and the learning process in traditional smart classrooms, Mohamed and Lamia proposed an integration of blockchain technology into IoT devices and course resources, which can improve the learning efficiency substantially [14]. Different from the traditional teacher-centered education strategy, Kong et al. proposed the TELD learning method to build an education platform by adopting the blockchain into the IoT to improve the learner's participation [15]. In addition, since the strategy of traditional smart education cannot adapt to the requirement of education under 5G, Wang et al. proposed a new method that applied the decentralization function of blockchain to the management of physical network data layer, which can improve the flexibility of the smart education IoT [16]. In order to achieve data tractability and improve the stability of smart education management, Liu combined the Big Data application of the IoT and blockchain in the design of smart education, and the course information can be exchanged between IoT nodes [17].

IoT data security has been widely studied in the background of blockchain. Dorri et al. proposed a scheme using blockchain technology to solve the security and privacy problems of IoT devices in smart education [18]. Referring to the application of Bitcoin, Ouaddah et al. proposed a privacy protection access control model, which can replace traditional IoT encryption with the Hash algorithm in blockchain [19]. For improving data security of education IoT device, Huneini et al. proposed applying the distributed ledger function of blockchain to education data management, and any modifications must be agreed to by more than 51 percent of the users in the chain [20]. Similar to the related work above, Alam used the basic encryption algorithm of blockchain to enhance IoT data security, and the data were encrypted in a heterogeneous environment for different types of IoT nodes to ensure data reliability [21]. In view of the security loopholes in data processing of edge computing used in IoT terminal devices, Yang et al. proposed integrating blockchain technology into secure processing of edge computing to improve the security of terminal data [22]. For the similar application in the field of confronting Big Data Education Model, Zheng et al. developed a method of data storage using distributed blockchain management, which can resolve the mobile data security problem [23]. Moreover, because identity authentication is weak during the connection of IoT nodes, Christidis and Devetsikiotis proposed for the first time to apply the blockchain public chain algorithm to identity authentication in the IoT, and then the identities of registrants will be broadcast on the entire chain [24]. By studying the impact of blockchain on the development of the IoT, Rashid and Siddique pointed out that the traceability of blockchain can solve the data security problem of the IoT effectively and designed a preliminary architecture [25]. For data security of the education IoT, Liang et al. proposed achieving the distributed management of core data by adopting the data management system using blockchain [26].

In recent years, several literatures have also been done in term of blockchain based intelligent operation. Samaniego and Deters applied blockchain as service in the IoT using the decentralized operation and the attribute of device sharing, which can effectively solve the aforementioned problems, including the wide variety of IoT devices and the high cost of centralized maintenance operations [27]. Vemuri built a TEduChain platform using the distributed ledger function of blockchain technology for school donation fund operation, and the funds were directly stored in the account books of students who received donations from [28]. In term of intelligent education operation theory research, Turcu et al. presented a literature review regarding the status of integrating the dynamic blockchain technology in the smart education [29]. Williams proposed a distributed degree evaluation system integrating blockchain, AI, and Big Data to focus on the overall development of students [30]. Chen et al. focused on discussing how to apply blockchain to solve the existing educational platform operational problems, including the innovative operation application of blockchain and education, and proposed a new framework of education operation [31]. Wang et al. provided a blockchain based solution for the operation of the IoT that has been applied in various aspects, such as medical care, education, and finance [32]. For the massive complex IoT devices in the current stage, Huh et al. developed a blockchain based unified management platform, and the device could be turned by the block nodes [33].

In addition to the above work of universities and research institutions, many companies had also carried out related research on the integration of blockchain and smart education IoT. Samsung, IBM, and other companies developed the ADEPT platform based on blockchain and the IoT, which had been initially applied to education, medicine, and other trade national IoT industries [34] The ADEPT concept is abbreviated as Autonomous Decentralized Peer-to-Peer Telemetry. It enables blockchains to act as the backbone of the system using the concept of proof-of-work and proof-of-stake for ensuring secured transactions. EduChain proposed the concept of the education chain, which combines blockchain, smart contract, and Big Data to facilitate decentralized management and integrate platform applications, which can reduce cost and information redundancy [35]. The study in [36] focused on the aspect of privacy protection using occupant behavior data and relevant methods pertaining to Blockchain implementations. The data used was of temperature records which were sent as transactions between sensors and local building management systems. The study in [37] developed a blockchain based smart and secured scheme for question sharing in smart education system (BSSQ) using a two-phase encryption technique for the encryption of question papers. At the initial stage, the question papers are encrypted using timestamp and in the second phase, the previous QSPs are further encrypted using timestamp, salt hash, and previous hashes. The encrypted QSPs are stored in a blockchain in association with smart contract which enables the users to unlock the selected QSPs.

According to the above research on the integration of blockchain in the field of smart education IoT, most method focuses on the single point technology and aims to optimize the pain points at the software level. However, there is no end-to-end analysis from the perspective of system architecture regarding bottlenecks that blockchain can solve the education IoT, included hardware management, layout of the sensing layer, data security, and top-layer design. To optimize the responses to the above questions, we analyze the core features of blockchain, such as system decentralization, distributed management, and high security, and explore the integration of blockchain and the IoT in education. Thus, we propose a smart new education environment framework that can solve the problems of system centralization and large management dimensions in the construction of the traditional smart educational IoT. The new framework is a "4 + 2" architecture, including the blockchain sensing layer, block node communication layer, data processing layer, education application layer, credit systems, and encryption systems. The research for applications based on the new framework has been carried out.

This paper has designed as the following parts. Section 1 describes the background of the smart education environment and the current research status on the application of blockchain with education. In Section 2, the composition and pain points of the smart education environment are analyzed, explaining the bottlenecks encountered in the construction of the current trendy education environment. In Section 3 we systematically introduce the smart education environment framework based on the IoT and blockchain proposed in this study. In Section 4, we discuss some relevant education applications to evaluate the new smart framework of this study. Finally, in section 5, the development of our work is discussed, and the direction of future research is provided for as well.

2. Structure and Pain Points of Smart Education Environment

The advent of the IoT improves traditional education to smart education by allowing connection of devices to the cloud via the network. There are three key technologies from the perspective of bottom level smart education environment IoT: 1) acquisition and collection of smart information, i.e., perception of external information; 2) management and integration of core data, i.e., processing acquired data in the computing model of data center; and 3) smart display of education information, i.e., application of the whole smart education system [38–40]. External education information sensing comprises the foundation and nerve endings of the smart education environment, which is composed of sensors, cameras, terminals, and other intelligent devices. Then, the network communication layer transmits data to cloud computing centers for processing, which can provide support for the application of top-level stylish education. Based on the functions described above [41], the structure diagram of the IoT-based smart schooling environment is shown in Figure 1.

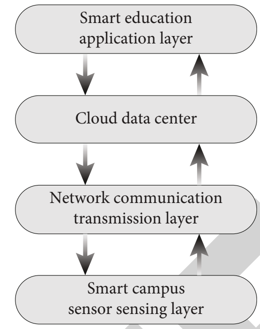

Figure 1: The campus environment detection system.

The above architecture been implemented in the field of smart education for many years. It has greatly improved the brisk level of teaching, research, and management. However, under 5G communication network, some associated problems have gradually become evident that will seriously affect its further development [42, 43]. Next, we analyze the pain points of the smart education environment, as shown in Figure 2.

Pain Point 1: The current solutions of the smart education IoT are expensive, because the infrastructure construction and maintenance of IoT devices have extremely high costs, such as IoT cloud servers and network equipment. Specifically, with the rapid increase of IoT node equipment under 5G more intermediate information must be stored, which will greatly increase the cost of construction, operation, and maintenance [44]. Even if these economic and engineering challenges are addressed, the management of cloud servers is another bottleneck. Once the cloud server of data center malfunctions, the data layer will be locked, which can eventually paralyze the entire smart education environment [45, 46].

Pain Point 2: The current smart education environment is controlled by a data center using a single centralized model based on the IoT, which makes the system architecture inflexible [47, 48]. Moreover, the smart education environment connects a large number of educational equipment through the IoT between the application layer and the acquisition layer, which could create great hidden danger in device management security [49, 50]. For example, there are a large number of LED screens for video display in the smart education environment, and its information source is transmitted to the terminal screen through the network by the remote management device. Once the remote host is attacked, the content on the screen cannot control.

Pain Point 3: Multiagent collaboration is adopted in the construction of the smart education environment through the joint construction of mobile operators and ICT enterprises in a "local area" network. Since there is no network standard, it will be difficult to achieve system integration of multiple ICT subjects when considering the establishment of the credit system in the later stage, thus will lead to several problems, such as high cost and a weak credit system [51].

Pain Point 4: Compared with the traditional digital education, the current educational IoT communication network is extremely complex under 5G. Particularly, there is not any

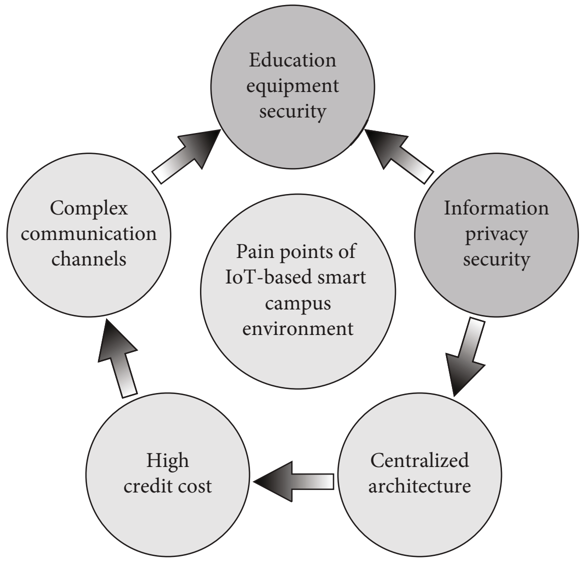

Figure 2: Pain points of existing loT-based smart education environment.

unified communication protocol, which causes obstacles in the communication of equipment. On the other hand, the existence of multiple platforms would form the isolated island of information [52, 53].

Pain Point 5: Owing to the management strategy not being strict, there are high security risks towards basic educational IoT data. In addition, the sensing layer must collect and summarize user behaviors for the application layer, which leads to the frequent leakage of private information [54–57]. At some universities, due to student information always being leaked on the Internet, hackers pose as school staff to collect fee by sending zombie mail, which has caused much economic loss.

It is obvious from the above overview that the intrinsic design and logical structure of the smart education environment is studied to explore its internal working mechanism and root problems under 5G, which can provide the reference of framework optimization.

3. Methodology

3.1. Main Blockchain Algorithms in Education. As the underlying technology of Bitcoin, blockchain is a continuously growing distributed kind of database jointly maintained by multiple nodes which has the characteristic of decentralization, strong encryption, low application costs, high credit, and easy to trace back [58]. In terms of the data structure of the algorithm, blockchain is a data chain within the unit of blocks, and each block records all the data generated during the creation time [59].

The data structure of blockchain is shown in Figure 3, which consists of a block head and some blocks. The hash value of the block head is used as the unified identification of the block, and stored in the block head field of the next block. By recording the hash value of the block head, a data chain is formed to trace from the latest block to the first block, to ensure that the blockchain system can trace the data at any time. In addition, the hash value of data in the block and the root node field of the Merkle tree in the chain will work together to assure the reliability of the system. To achieve the above function, some core algorithms will be transferred, such as the distributed ledger, asymmetric encryption algorithm, and smart contract [60] The Merkle tree is also known as hash tree in which each leaf is labelled using a cryptographic hash of a data block and nodes that are not a leaf are labelled using a cryptographic hash of labels of its child nodes. The main algorithms are introduced as following.

(i) Distributed ledger technology: distributed ledger technology uses the transaction ledger to summarize the subledgers distributed on different nodes, and each node maintains independent ledger data to ensure that it can conduct transactions under supervision [61]. The essence of the allocated ledger is a multinode database, and the access rights of the ledger are controlled by digital signature [62].

(ii) Asymmetric encryption algorithms: different from the symmetric encryption algorithms, asymmetric encryption algorithms use public and private keys to implement data encryption and decryption, respectively, and the difficulty of cracking increases exponentially according to the length of the key [63, 64].

(iii) Smart Contract: the smart contract is essentially a digital business contract which can build trust in the transaction process by matching the data structure of the blockchain. The smart contract adopts the programmable script mode, which can work automatically under the condition of meeting the rules to avoid the risks of external intervention, tampering, and malicious manipulation [65, 66]

The blockchain implements a multinode trust network through the above algorithms to achieve a decentralized trust system that cannot be achieved by traditional algorithms, and the features of blockchain include decentralization, difficulty of modification, data security, and collaborative maintenance, which makes it very suitable for multi agent management and dispersed individual collaboration scenarios, such as the smart education environment [67–69].

3.2. Integration Analysis of Blockchain and IOT Technology in Education. Based on the analysis of the smart education IoT and blockchain algorithm in the above sections, this paper intends to comprehensively optimize the pain points of the current smart education environment based on the integration IoT and blockchain, and the key technical points are shown in Table 1.

As being shown in Table 1, blockchain can solve the pain points of the smart education environment under the IoT architecture, and the details are shown below.

Autonomous backup and management of data between storage nodes can be achieved, which would improve user data safety [70, 71]. Moreover, the blockchain can ensure that the

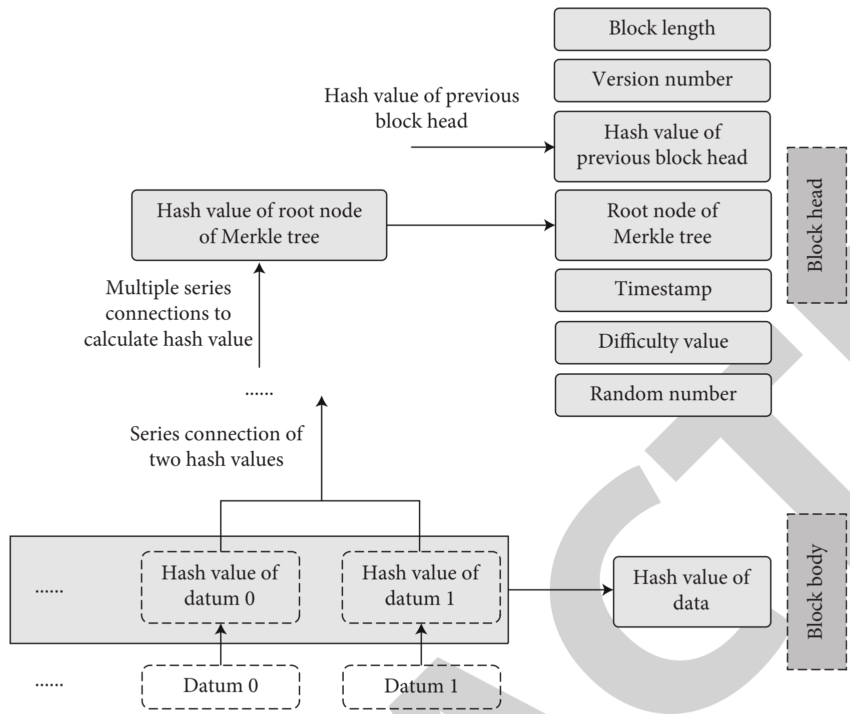

Figure 3: Data structure of blockchain.

Table 1: Integration of blockchain and loT technology.

No.	Disadvantages of educational IoT	Advantages of blockchain technology	Functional requirements of smart education
1	Adopt centralized structure, high operation, and maintenance cost	Decentralized architecture, distributed operation	Low cost, decentralized, mobile, personalized, ubiquitous education network
2	No systematic credit system	Smart contract function	Sound credit system of smart education
3	Complex communication pipeline	Use block node as the unit for communication, low complexity	Use unified interface communication for smart education terminals, humanized human-machine interface, simple, and easy to operate
4	Poor information privacy security	Asymmetric digital encryption	Protect personal privacy information and eliminate user concerns
5	Low education equipment security	Powerful identity authentication function	Enhance equipment security and save terminal Maintenance

system adds node encryption functions on the basis of traditional asylum-metric encryption algorithms, and the data decryption can work normally even if the key is lost. With the above strategy, data security can be greatly improved.

For the traditional centralized management model, all data need to be aggregated and then dispersed. More-over, in the new solution, data of the sensing layer are stored in each distributed block unit to realize the distributed pipeline processing model [72, 73]. The above mode can break the centralized architecture of block is used to classify and manage sensors. A new sensing layer of block codes is proposed, which will simplify the communication network model of layer devices. Only the block interface is required for data communication, which greatly reduces the communication complexity between the sensing layer and data management layer.

To solve the problem of low security coefficient in the current IoT equipment, the identity authentication and traceability of blockchain are applied between the data layer and the application layer, which can check the identity of users accessing the IoT equipment in real time through time-series encryption. The traceability of the block authentication information enables consistent security levels in the management unit and device, thus improving the security of the IoT equipment.

3.3. The Framework of Smart Education Environment Using Blockchain and IOT. As shown in Figure 4, we propose a new framework using blockchain and IoT to optimize the smart education environment system. It is designed to optimize the smart education environment from multiple aspects such as data security, identity authentication, node

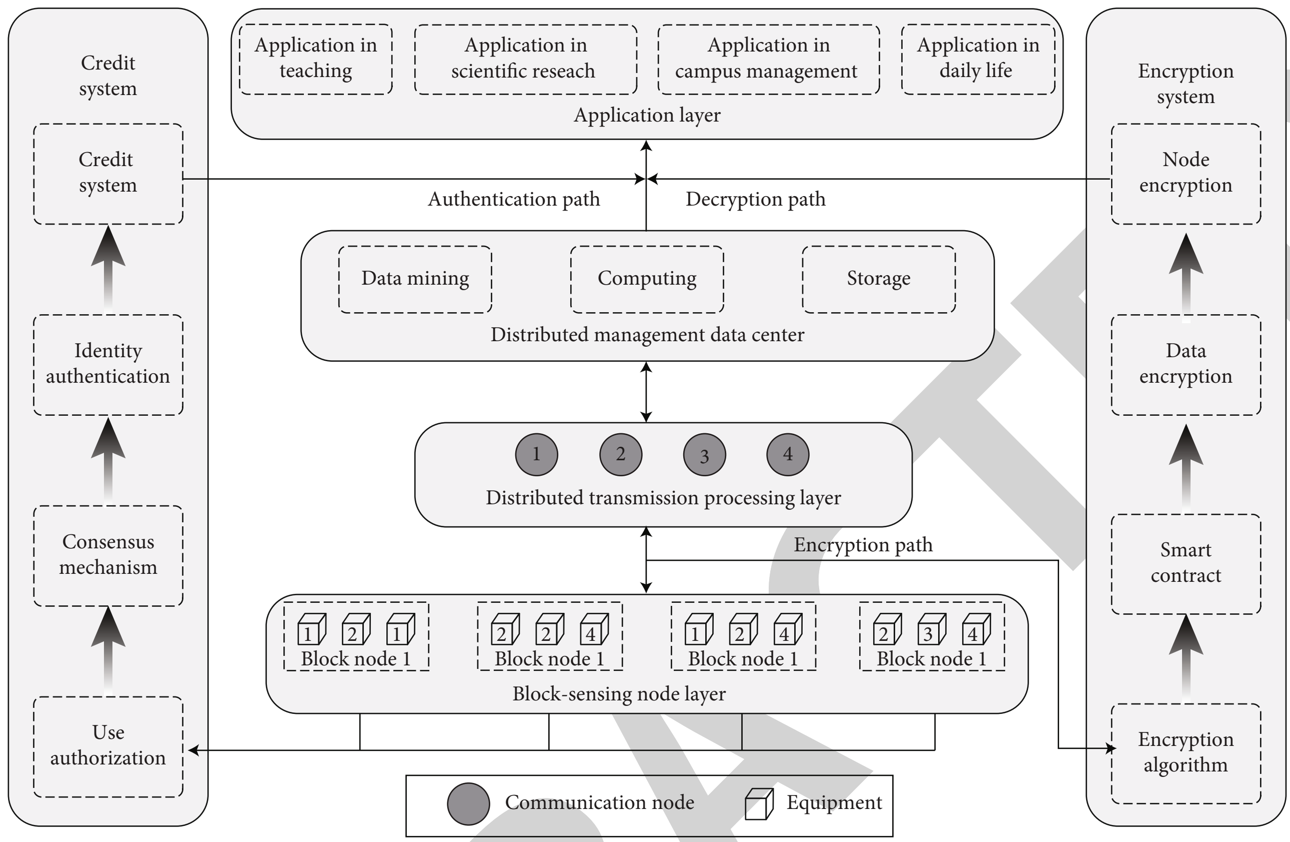

Figure 4: Smart education environment based on blockchain+loT.

reconstruction, distributed sharing, and education applications; to solve the problems included rigid system architecture, weak credit system, and difficult network management.

The new framework has a four-layer data structure in contrast to the traditional smart education IoT. Then, both authentication and encryption systems are added to realize data processing at different levels, which consists of a four-layer system model and two management systems. The functions of the four layers are as following.

3.3.1. The First Layer: Block-sensing node layer. The IoT based smart education environment perception layer remains a major challenge, in that, e.g., the system layout is scattered and the number of sensor devices is large. Compared to the traditional design, this paper proposes a novel solution to perform device management at the perception layer through block nodes, and classifies different perception nodes according to its working mode. The design is illustrated in Figure 5.

In the traditional smart education environment, a single sensor only serves one education application. However, after the block node management is adopted, the device will be time-multiplex, which can support a variety of distinct upper-layer applications and improve the utilization of sensor devices. More broadly, one kind of device may be distributed in separate nodes to build a set of block awareness layers based on time-sharing multiplexing. The specific implementation is reproduced below.

(1) The sensing layer equipment is set as nodes according to the region, and each application node is classified according to its purpose, including library, smart class-room, canteen, office building, and data center. Accounting layer node covers multiple sensing devices according to application scenarios, and can be shared according to the application.

(2) The sensing layer is composed of several nodes with different purpose. The nodes communicate in UDP mode using the broadcast channel, and application data transmission can be greatly improved in this way.

(3) The generic communication interface connects the sensing and network layers, through which all control signals and sensing data are transmitted. The blockchain API is an application programming interface that uses the Blockchain technology wherein the API provides set of guidelines to enable different applications to interact with each other seamlessly ensuring that the data is transmitted in the best possible way without any issues. The multiple applications gets connected with one another enabling them to access common information from a single source instead of acquiring data from multiple locations.

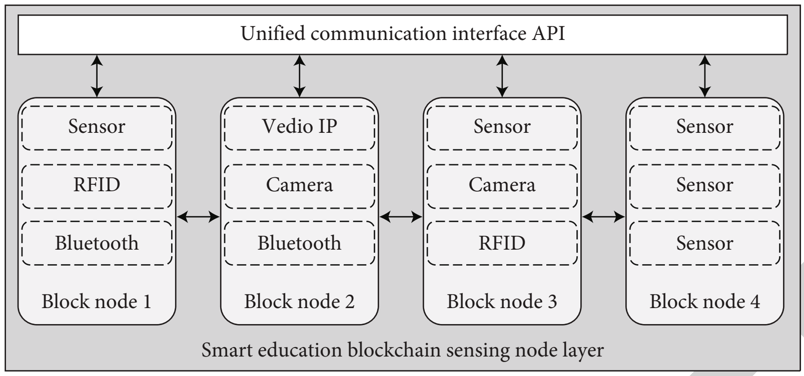

Figure 5: Sensing node layer of smart education blockchain.

(4) Distributed management is adopted for the data of nodes in the sensing layer. Data are not stored in this layer alone, but are directly uploaded to the data layer for processing after collection by the sensing layer according to the strategy adopted by the application layer.

(5) Distributed block nodes are used to realize the layout between sensing layers, and faulty equipment in a node can be maintained independently without affecting the function of other nodes, thus reducing maintenance costs.

3.3.2. The Second Layer: Block Node Communication Layer. This layer adds a data encryption processing unit on the basis of the communication transmission layer of the smart education IoT which is performed at the data source. In addition, we propose the concept of blockchain node communication, and the complexity of the communication layer is reduced by unifying wireless AP, fixed equipment, and RFID in a communication node. The structure is illustrated in Figure 6.

With the concept of blockchain node communication, different communication network devices are integrated in one communication node according to application functions, which is less complicated and easier to manage. The traditional network layer binds all IoT devices in one layer to a bus, which is the same as to a serial structure, and this mode can improve management efficiency.

When a traditional network device requires maintenance, the devices of the whole communication layer cannot function normally. However, the distributed block nodes are used between the communication layers of block nodes to realize the layout of communication equipment, and the damaged equipment can be maintained independently without affecting the normal work of other nodes.

3.3.3. The Third Layer: Decentralized Data Processing Layer. In the data processing layer, a novel distributed storage architecture is proposed that is based on the distributed decentralization of blockchain, as shown in Figure 7. This layer's distributed computing and data mining are basically the same as those in a traditional data center using the IoT, but the innovation mainly lies in distributed storage and the AI deep learning module. Decentralized data processing layer has five parts.

(1) Distributed storage: the distributed storage of blockchain is used to make data management easier, which can break the barriers on storage devices from different manufacturers. In detail, in distributed storage different storage modes are adopted for different types of data, including smart education activities, credit data, and core management data. Smart education activities are recorded through the node storage in the block, and the credit data are encrypted and stored in the node. However, core management data are directly transmitted to the system data center for processing

(2) Data Center: the Big Data Computing center provides a platform for distributed storage and data analysis, including two computing modules: CPU and GPU. The CPU mainly performs large-scale data for calculations and the GPU performs blockchain class computing, including floating-point computation and model training. Through the hybrid operation of the above two units, the data computing center can meet the function requirements, including data operation, face recognition, speech recognition, and NLP

(3) Data-mining platform: applying mainstream data-mining platforms such as Hadoop on mining data at the perception layer, especially intelligently classifying data in classrooms, libraries, bedrooms, canteens, and other places, and transforming the classified data to the Big Data analysis module

(4) Analysis Unit: the Big Data analysis unit systematically processes the multimodel education data collected for the perception layer, including classification, labeling, and analysis. These preliminary data are transferred to the top-layer education application for further processing

(5) AI Unit: in traditional solution, AI units work in the application layer. The innovation of this paper is

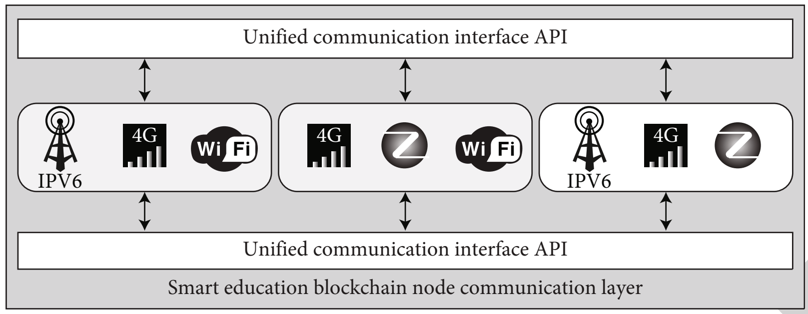

Figure 6: Node communication layer of smart education blockchain.

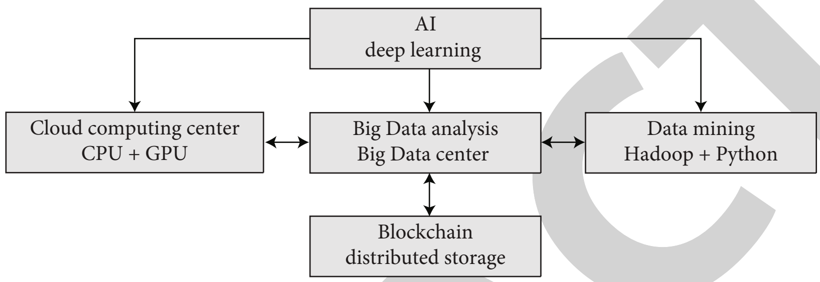

Figure 7: Data center layer of smart education blockchain.

tantamount to place. AI units in the data layer for data processing, thus avoiding secondary training of the model. In addition, cloud computing and deep learning integration can accelerate the computing operation

3.3.4. The Fourth Layer: The Education Application Layer. This paper incorporates blockchain to further expand the application of existing education platforms. The detail is explained in the next chapter.

The above four-layer structure, including blockchain sensing layer, block node communication layer, data processing layer, and education application layer, constitutes the core structure of the entire intelligent education environment, and complete the entire smart education process through cooperation. Then, the smart educational environment using blockchain and IoT includes the following two extra management systems: credit system and encryption system.

(1) Credit system: using the hierarchical identity authentication method of blockchain, a complete credit system of the sensing layer to the application layer is established for authorization, consensus mechanism establishment, and identity authentication. Through the application of the credit system in the smart education environment, it can provide identity authentication for the safe use of equipment; in addition, it can provide database resources for the later establishment of the whole society's academic degree credit authentication, record the students' information in a distributed way, and serve the wide education application. The credit system becomes the core connection throughout the sensing, transmission, data, and application layers. The whole system has four parts: use authorization, consensus mechanism, identity authentication, and the credit system, as shown in Figure 8

Use of accrediting connects the block sensing layer nodes to ensure that sensing layer devices can be used only with authorization. The consensus mechanism belongs to the interface unit between use accredit and identity authentication, which ensure that participants can perform verification through consensus. Identity authentication can authenticate a user's identity by calling the consensus mechanism module of the main process to performing full link authentication, and the main authentication method is the hash algorithm. As the core module, the credit system will serve educational applications and provide a credit database for later blockchain education trading platform and a blockchain online university.

(2) Encryption system: the encryption system addresses the data security of the basic hardware through data encryption pipeline mechanism, which has four modules: algorithm module, smart contract, data encryption, and node encryption, as shown in Figure 9

The underlying layer integrates multiple encryption algorithms which are used in different scenarios, include AES, ECC, RSA, Hash, and DES. Smart contract is a specific transaction scenario of the blockchain, and different underlying transactions on the block are implemented by calling the underlying encryption algorithm. Data encryption refers to encrypt the transaction content of the contract on the

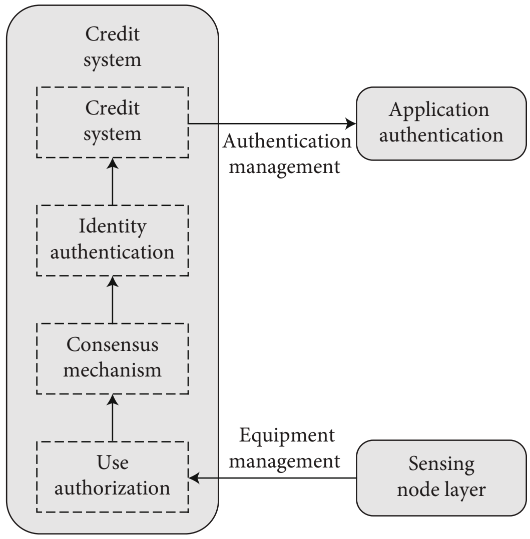

Figure 8: Credit system of smart education environment.

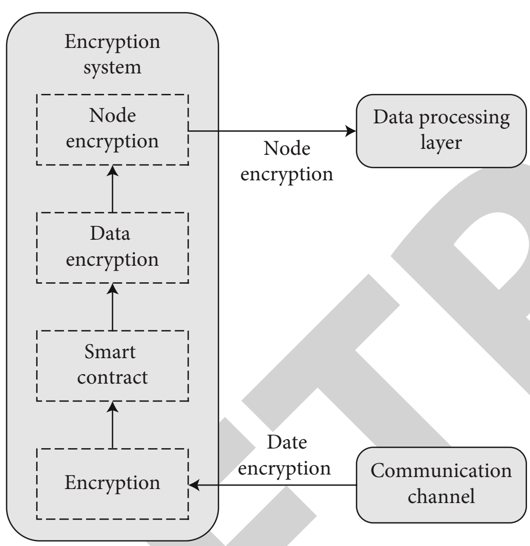

Figure 9: Encryption system of smart education environment.

basis of a smart contract, and outputting it in the form of block data, so as to facilitate the later block node encryption. As the top module of the system, node encryption is connected to the data processing layer to realize the ultimate output of the encryption system.

4. Main Application of Smart Education Environment Based on Blockchain and IOT

Four educational applications are proposed based on the new framework using blockchain and IoT in this study: blockchain education information authentication system, blockchain smart trading platform, blockchain online education platform, and blockchain smart open school. A complete smart education ecosystem based on these applications is presented in Figure 10.

4.1. Blockchain Education Information Authentication System. In recent years, education certification is increasingly attached, which can be applied in many educational fields, such as the protection of intellectual property rights of scientific research, academic degree verification, and professional title certification. The implementation architecture is illustrated in Figure 11. The whole authentication process has six steps, as the following:

(i) User generated private key and corresponding public key in the student information authentication center for later identity authentication

(ii) The authentication information of user transmitted through IoT communication unit, and transmitted data is encrypted using the public key

(iii) The user-generated data, including public and private keys, are transmitted to the management center for backup

(iv) The IoT communication unit uploads encrypted data to the smart contract module for processing

(v) Encrypted chained data are managed in distributed storage for data query and table item generation

(vi) After the third party passes the permission by the management center, application data are encrypted using the private key of the management center to complete the authentication

The blockchain education information certification system proposed in this paper is implemented through the above six steps which ensure that the relevant information of students from admission to graduation is uniformly managed. Different from the ordinary mode, the above certification system has three advantages.

(1) Utilizing the traceability and the storage of nodes, the related rights of property owners are protected by recording information on the blockchain, such as property owner, grade time, and property limit

(2) Through the application of smart property protection system, the illegal infringes will be screened in the whole network

(3) The academic performance, physical fitness test results, activity performance, and scientific research achievements since enrollment of students can be stored in the distributed database of blockchain, which can be shared with universities, enterprises, and government institutions. As an essential standard of credit judgment, the end-to-end credit system is established in the students' further study, professional title recognition, work, and employment

4.2. Blockchain Smart Resource Trading Platform. Whether online education platform or traditional offline classroom teaching, learners must pay before learning in the process of acquiring educational resources, which would make learners

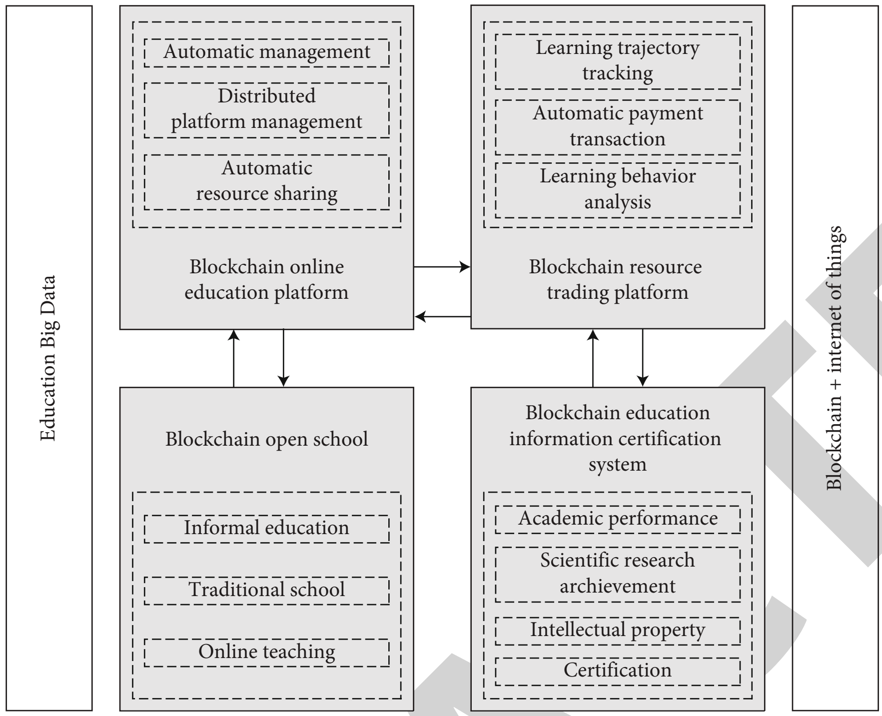

Figure 10: Smart education ecosystem based on blockchain + IoT.

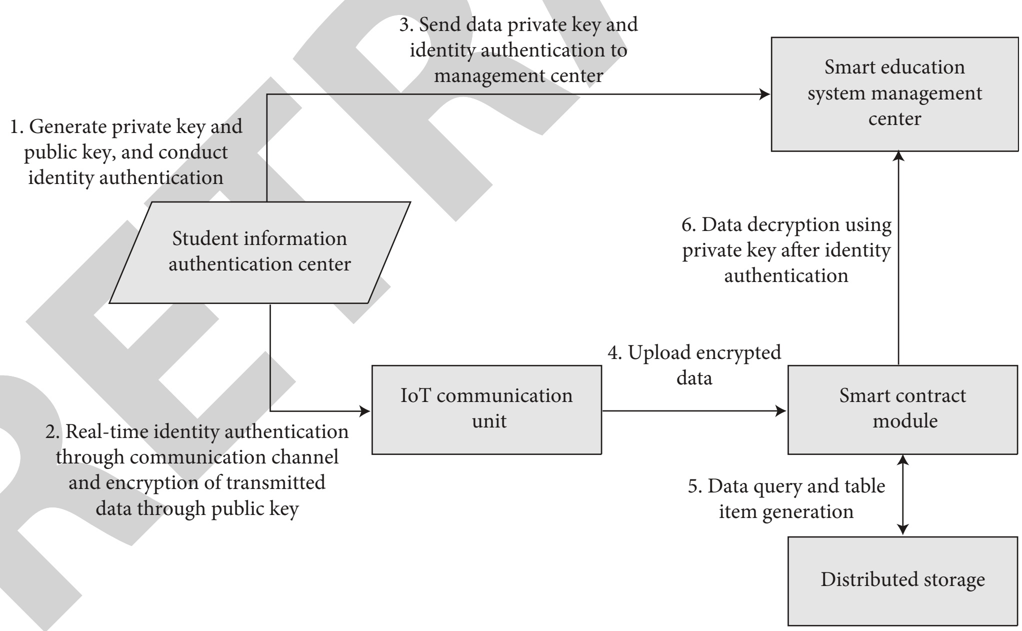

Figure 11: Blockchain education information certification system.

lose interest in course. Applying the distributed ledger and smart contract to resource trading, a modem platform is proposed. In the blockchain smart resource trading platform, people can learn first and the platform synchronously tracks learning records. When learners wish to acquire learning resources, the system can automatically pay according to previous learning records and there is no requirement for manual payment. The smart trading platform based on blockchain can break the traditional mode of paying before learning, which improves the security of payment transactions, records the process and the transaction in real time, and automatically completes the transaction. This mode can realize peer-to-peer transactions between learners and educational institutions, learners and trainers, and education institutions and educational structures, reducing the intermediary costs of education platforms.

4.3. Blockchain Online Education Platform. Smart contracts have the characteristics of automatic execution, transparent management, and resource sharing, making them widely used in financial online transactions to achieve automated management, which can greatly improve the intelligence of the entire monetary system [73]. Reference to the above applications, smart contract technology can also improve the management efficiency of online education platform and automatically complete the uploading, dissemination, certification, and sharing of educational resources. In addition, uploading the IoT cloud database, allocated education resources are stored in different blocks to realize the real time sharing. Platform users can conduct online learning and communication in real time through smart terminals. It is helpful to improve the sharing Efficiency of education resource and solve the problems of resource isolated islands on the traditional education platform. In the future, the construction of the platform lays a solid foundation for the establishment of education Big Data.

4.4. Blockchain Smart Open School. The centralization feature of traditional smart education environment is not only reflected in the centralization of data management, but in the closeness of educational places [74, 75]. In the financial field, blockchain has broken the monopoly of the bank, which can be used for reference to create a new type of smart open school [76–78]. Based on the development of blockchain and the IoT, the smart decentralized education system can break the centralized situation in which traditional educational resources are monopolized by schools or other scientific research institutions. Accompanied by the building of blockchain credit certification systems and trading platforms, an institution with smart education qualifications can get qualified by obtaining certificates, so as to realize the integration of traditional school and other types of education to build smart open schools.

5. Conclusion

In this paper, an optimized framework for smart education environment using blockchain and IoT was proposed. We analyzed the work mechanism of the IoT-based smart education environment, and pointed out the principal problems in the functional structure of the existing framework using 5G. In view of the pain points of the existing framework, the second application and development were carried out by combining the smart IoT education with the blockchain, and optimization solutions were proposed. The design is implemented from the top layer to realize a smart education environment framework using blockchain and the IoT. The new framework is a $4+2$ smart education environment mode, including blockchain sensing layer, block node communication layer, data processing layer, and education application layer, credit and encryption application systems. Blockchain optimization schemes were proposed for each module. The IoT and blockchain work together in the new framework to minimize the limitations of the traditional mode. A different way to perform device management was proposed at the perception layer through block nodes, which can improve the utilization of sensor devices. In communication layer, different communication network devices were integrated in one communication node, and the complexity of communication layer was reduced by unifying wireless device. Moreover, the decentralized data center and smart application layer were aimed at improving the energy optimization and privacy protection.

Education applications were preliminaries studied based on the framework of the smart education environment. Four application scenarios were proposed, including blockchain education information authentication system, blockchain smart trading platform, blockchain online education platform, and blockchain smart open school. With the proposed new framework that integrates the smart IoT and blockchain technology, a complete ecology for the smart education environment is established, including the hardware layout, certification system, and new educational applications. These application cases can evaluate that the performance of blockchain solution is more promising than traditional solutions under 5G.

In the future, in-depth research on the internal working mechanism of the proposed blockchain-based smart education environment will be conducted, which can improve and optimize the system framework with $5G + AI +$ blockchain, and achieve further architectural upgrades with the new education application. There will be more fields in which blockchain technology can be applied, including academic certification, skill identification, learning records, identity management, infrastructure security, campus busing, data cloud storage, energy management, prepaid cards, learning markets, record managements, product retailing, human resource management, and library management. It can be said that the above covers most of the scenarios in the current education field, which will bring more changes to the construction of a smart education environment in the future, and will be of great significance for the development of the overall concept of smart education.

Data Availability

All data, models, and code generated or used during the study appear in the submitted article.

Conflicts of Interest

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

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