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Research and Design of Online Education System Based on Blockchain Technology

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Abstract. This paper proposes a blockchain-based online education system for existing online education systems that are not transparent enough in calculating the benefits when resources are released, the centralized structure restriction, and the difficulty in confirming the rights of data resources. The system adopts ECC encryption algorithm to protect data security, uses smart contracts to control transaction operations, improves system reliability and execution efficiency through dual storage mechanism, uses blockchain's characteristics such as tamper-evident and timestamp to achieve effective confirmation of rights in information traceability, and achieves accurate matching of transactions and shortens the cycle of resources on the chain with the trust endorsement of blockchain's multiple participating subjects. It is proved by experiments that the system can effectively reduce the transaction cost of data resources, protect the rights and interests of resource publishers, and has good scalability and security.

Keywords. Online education; blockchain; ECC algorithm; smart contract

1. Introduction

Before the emergence of online education, the traditional education model widely adopted by schools was face-to-face teaching. The emergence of online education has brought many inspirations to the development of traditional education. Online education, also known as e-learning, aims to cultivate students' basic learning skills, information literacy, innovative thinking and other abilities. Online education was first proposed in the US Education Technology CEO Forum, which pointed out that "the core of online education is to organically integrate education technology, the Internet, digital content, human resources and other elements with the curriculum". From the development process, China's online education has gone through three stages: "Internet + education", "mobile Internet + education", and "new technology + new vocational education". According to the China Online Education Industry Status Survey and Development Trend Analysis Report (2023), it is predicted that by 2023, the market size of online education in China will reach 156.02 billion yuan, a year-on-year increase of 27.3%, and the number of online education users is expected to reach 160 million, a year-on-year increase of 21.5%.

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The effectiveness of online education is to some extent dependent on the quality and quantity of digital resources. Currently, online education digital resources are mainly created by teachers or experts in specialized fields. After the resources are created, they are uploaded to the platform and made available for users to download. The system pays a certain reward to the resource creators based on download volume. However, the actual download volume and profit calculation rules are not transparent enough for resource uploaders. Therefore, when the user's input and return are not proportional, it limits the creative enthusiasm of resource creators to some extent. In addition, due to the special nature of digital resources, there is a possibility that illegal elements may obtain the resources and publish them on other platforms to seek benefits, making it difficult for resource creators to protect their rights.

For resource users, the cost of using resources includes resource usage fees and platform management fees, and the learning costs are relatively high. In addition, users need to screen learning resources on different learning platforms, or use learning resources on several platforms at the same time, leading to scattered learning records. Blockchain is a distributed ledger technology with features such as traceability, decentralization, and tamper resistance. The emergence of blockchain technology provides a new solution to solve the limitations of centralized structure, opaque profit rules, and untraceable information sources in online education platforms. The model constructed in this article aims to use blockchain technology to optimize online digital resources and effectively protect copyright.

Research on Online Education System Based on Blockchain Technology includes:

(1) Implementing encryption protection for digital resources to make them difficult to steal and tamper with, and easy to protect the copyright of resource creators.

(2) Smart contract for revenue distribution to safeguard the rights and interests of resource creators, which can incentivize them to produce high-quality learning resources.

(3) Accurate matching of transactions between resource creators and users. By using blockchain technology, the demand for digital resources from users across the entire network can be collected and then matched with suitable resources.

(4) Introduce resource creators, resource users, and auditors as nodes on a consortium blockchain can shorten the resource review cycle and reduce transaction costs.

2. Research Status at Home and Abroad

2.1. Research on Online Education in Foreign Countries

Sun A uses content analysis methods to study the core elements of online teaching, including well-designed course content, active interaction between teachers and learners, support for online learning communities, and advanced technological support [1]. Johnson K R proposed that teachers play a critical role in high-quality online education. He suggested that training and development frameworks and models could support teachers in implementing effective online teaching [2]. Nduagbo K C discussed the transformation of traditional education and designed an online education framework [3]. Tarus J K discussed the challenges faced during the implementation of online education in Kenyan public universities, and recommended some solutions adopted by public universities for successful implementation of online education [4]. Wen J established a factor model based on the Theory of Planned Behavior (TPB) to investigate the factors influencing college students' acceptance of online education platforms, and proposed multiple hypotheses on the impact of various factors on the degree of acceptance [5].

Patel A affirmed that students can benefit from e-learning and analyzed the teaching methods and content of e-learning platforms such as SWAYAM, eDX, and CourseEra [6]. Libre N A conducted research on customized discussion tools to promote student interaction in online asynchronous courses and measured their impact on student learning outcomes [7]. Nian L H designed a new mobile education platform and analyzed the role of mobile online education platforms in promoting student self-directed learning [8]. Alam A proposed a decentralized online education system based on blockchain technology that can accurately monitor students' learning process and protect intellectual property rights [9]. Liu B proposed a cloud-based online learning platform that focuses on building infrastructure and fully utilizes cloud computing technology to provide a more complete, efficient, and excellent service for the system [10]. Korableva O has studied two methods for measuring MOOC online platforms and has made suggestions for developing the user interface of open education platforms [11]. Grimaldi E proposed a conceptual framework for analyzing the configuration of platforms, types of learning experiences, and the potential conditions they create for learners [12].

2.2. Research on Online Education in Foreign Countries

Yang T researched the theoretical foundation of online education, analyzed the teaching effectiveness of online education and the challenges it faces [13]. Tang H proposed to view the problems of online teaching from an ethical perspective and put forward corresponding strategies [14]. Wei W compared the advantages and disadvantages of three online teaching modes and proposed that teachers should choose the appropriate online teaching mode according to the characteristics of the course content [15]. Wu P proposed an online education knowledge dissemination model based on the theory of value co-creation, and based on the connotation of the model, put forward a value co-creation-based online education knowledge dissemination strategy [16]. Zhou X systematically analyzed the composition, characteristics, and operating mechanisms of various modes using the typical platform of Hujiang Online Education as the object, and proposed a blended teaching model [17].

Yang X proposed the deficiencies of the current digital course platform and put forward improvement suggestions and strategies [18]. Based on the data analysis of the course platform in Shandong and Fujian provinces, Hu X analyzed the impact and problems of online teaching on teachers and students. He proposed the measures that should be taken in the follow-up network teaching [19]. Gao X explores the design strategy of online education platforms from the perspective of distributed cognition, providing guidance for the experience design of online education platforms [20]. Zhang M proposed that it is feasible and reliable to conduct systematic research on influencing factors based on the theory of information ecology and empirical research paradigm [21]. Zhang J designed the evaluation index system for the teacher online learning platform from the perspective of user experience, which includes 4 primary indicators and 13 secondary indicators [22].

The above research enriches the theoretical basis of online education, analyzes the existing problems of online education platforms from different perspectives, and provides macroscopic solutions. However, a complete and implementable solution was not given. Based on the above research background, this paper proposes a decentralized online education platform model based on blockchain to address the shortcomings of centralized structures. Firstly, the ECC elliptic curve algorithm is used to encrypt digital resources. Secondly, a blockchain online education system architecture is proposed. Finally, smart contracts are designed for the generation of digital vouchers and the transaction of digital resources. The results show that the online education system constructed by the proposed solution has good scalability and security, can protect the rights of resource creators, and provide quality and affordable digital resource services for resource users.

3. Based on Blockchain Online Education System Analysis

3.1. Storage Model Analysis

An online education platform based on blockchain needs to store data such as user information, digital resource information, transaction data, and digital coupon redemption data. If all the data is stored in the blockchain, it will lead to a large amount of data on the chain, occupying too much storage space and reducing the efficiency of data queries. Therefore, the online education platform adopts a dual storage mechanism of “blockchain + relational database”. For system security, all data is stored in the relational database, and data that requires validation and traceability is also saved in the blockchain. The database is maintained by regulatory authorities on a daily basis, while the blockchain system is jointly maintained by resource creators, resource users, and auditors.

The dual storage model is shown in figure 1. The gray blocks in the figure represent the data that needs to be written into the blockchain network. There are 5 nodes in the blockchain, and each node stores the latest blockchain data. Four blocks are constructed in the figure, and each block contains a certain amount of transaction data.

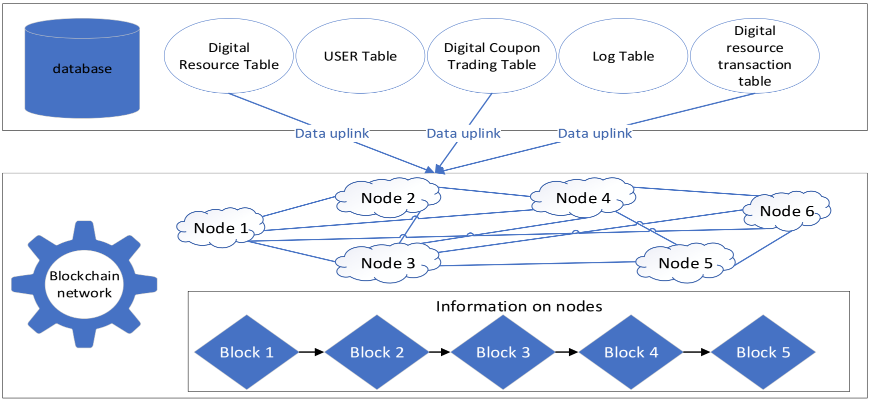

Figure 1. Dual Storage Model Diagramcracking image recognition.

3.2. Analysis of the Overall Architecture of Online Education System

The online education system is composed of digital content creators, resource users, regulatory agencies, and management agencies, etc. According to the requirements of the online education system. The system consists of four parts: data view layer, data processing layer, service interface layer, and data storage layer.

3.3. Analysis of System Functional Modules

The online education system is divided into two major business modules: front-end and back-end modules. The front-end module is an operation platform for ordinary users, which includes login, registration, digital voucher management, digital resource management, transaction inquiry, resource download income statistics, resource evaluation and other modules. The back-end module is used to manage the online education system, including digital currency casting, digital currency inquiry, transaction management, digital resource management, data statistics and analysis, user management, role management, permission management, and evaluation management. Below is a brief description of the core modules.

The digital coupon casting module completes the digital coupon casting work on the blockchain regularly according to the casting rules. Digital coupons are new digital currencies generated automatically by smart contracts when certain conditions are met by the system. Each digital coupon has a unique ID. The fees paid by users for transactions on the system are in the form of digital coupons.

The digital coupon management module provides users with services such as purchasing digital coupons, checking digital coupon balances, and viewing consumption details. Users can return unused digital coupons at any time. When purchasing, users exchange digital coupons in real-time based on the exchange rate between the currency and digital coupons. When returning, the remaining currency after consumption will be returned according to the exchange rate.

The digital resource management module can manage the digital resources uploaded by users, including searching for digital resources by time and keywords, publishing digital resources, and purchasing digital resources. The resource download income statistics complete the query of related download volume and income statistics based on the resource ID information. It can statistically analyze the income of the resources published by current users according to dimensions such as year, month, week, and day.

The transaction management module manages the process of transactions, which mainly completes the transaction operation on the blockchain. It includes transaction generation, transaction verification, transaction broadcasting, transaction packaging, transaction execution, transaction consensus, and transaction completion.

The data statistics and analysis module complete the statistics of published digital resources, transaction data, and resource access volume, and visualizes the statistical data to analyze the regularities behind the digital resources. It provides data analysis based on multiple dimensions such as transaction resource ID, transaction time, and transaction user, so as to determine the regularities behind the transactions. By utilizing these regularities, the system's resource data can be better organized and popular resources can be displayed in prominent positions, increasing the exposure of popular resources.

4. Design of an Online Education System Based on Blockchain

4.1. Design of ECC Algorithm

The system implements data protection using the discrete logarithm problem based on elliptic curve cryptography. The elliptic curve is a third-order smooth algebraic plane curve.

1. Elliptic Curve

The elliptic curve is symmetric about the x-axis and intersects a line in the plane at most three times [23].

General equation of an elliptic curve:

$$E: y^2 + a_1xy + a_3y = x^3 + a_2x^2 + a_4x + a_6 \quad (1)$$

Equation (1) can be simplified to:

$$y^2 = x^3 + ax + b \quad (2)$$

Regarding the simplified equation (2) of elliptic curve, when the parameters a and b are determined, the solution of the equation is unique. The elliptic curve equation can be represented as $E(a,b)$ or simply as E.

2.Discrete Logarithmic Solution Problem

Definition: Let $y^2 = x^3 + ax + b(\text{mod p})$ be an elliptic curve, and let P and Q be two points on the elliptic curve with an associated relationship such that point Q can be generated from point P. The discrete logarithm problem on $Q = [k]P$ is to find the value k, given the coordinates of point P and point Q on the curve E, and solving the equation.

3. Application of ECC algorithm in online education platform

1) Digital Signature

Digital signature is an unforgeable digital string generated by the information sender. The signer signs with a private key, and all nodes on the network can use the public key to verify the signature, determining that the information was signed by the private key owner. The object of the digital signature is the information code.

Operation process:

(1)To determine the elliptic curve $Ep(a,b)$. G is the generator of $E_p(a, b)$, P is a prime number. Randomly select an integer A and calculate $P_A = [A]P$. The public key is (E/F_q, P, P_A), where F_q represents the finite field, and the private key is A.

(2)Signed with the sender's private key. Randomly select an integer k such that k is coprime with g.

Calculate: $T = [k]P$

Calculate: $w = k^{-1}(m - Ax(R))(mod\ n)$,x(T) represents the x-coordinate of point T.

Sending the digital signature $s = (m, T, w)$ to the receiver.

(3) Signature verification. The recipient receives a digital signature $s = (m, T, w)$ and obtains the sender's public key (E/F_q, P, P_A). Calculate the values of V_1 and V_2. If they are valid, accept. Otherwise, reject.

$$V_1 = [x(T)]P_A + [w]R, \ V_2 = [m]P$$

2) Privacy and Security

In terms of privacy and security, the platform uses elliptic curve cryptography (ECC) to achieve private transactions. ECC is used to generate private and public keys, and the object of encryption is the plaintext code point.

(1) Mapping plaintext to elliptic curve

The plaintext message is embedded in the elliptic curve $E_p(a,b)$, using a probabilistic algorithm for encoding. The equation for the elliptic curve is (2), and the plaintext message c is encoded to the x-coordinate of a point on $E(F_p)$. However, since the probability that c is a perfect square is 50%, additional bits can be added to c. If $c' = cK + j \ (j = 0,..,K-1)$ is a complete square, then it can be mapped to a point on $E(F_p)$.

(2) Encryption

Public Key and Private Key: Select an integer S_k as the private key and $P_k = S_k G$ as the public key.

Choose a positive integer k at random and let the ciphertext be $C = (C_1, C_2)$, where $C_1 = kG$ and $C_2 = M + kP_k$ are related to P_k, so the plaintext is encrypted by the recipient's public key.

(3) Decryption

The result of E is the value of point M.

Derivation:

$$M = C_2 - S_k C_1 \qquad (3)$$

Bringing the values of C_1, C_2, and Pk in 2) into equation (3) yields: $M + kP_k - S_k kG = M + kS_k G - S_k kG = M$,it can be deduced that equation (3) holds. The plaintext can be obtained by following the operation of equation (3).

Eq. (3) is related to S_k, so the message can be decrypted by the private key of the message receiver.The ECC algorithm has a higher level of security compared to the DSA algorithm, as well as a faster processing speed.

4.2. Smart Contract Design

All valuable user actions in the system need to be recorded on the blockchain. Based on the system's business design, smart contracts include digital voucher contracts and transaction contracts.

4.2.1. Design of ECC Algorithm

To implement unified management of digital assets, all settlements in the system are completed through digital vouchers. For example, using digital vouchers can purchase platform learning resources, obtain income settled in the form of digital vouchers, and collect user consumption data to obtain the true income of resource uploaders, laying the foundation for future data statistics on the use of digital resources.

The digital voucher contract is developed based on the blockchain standard protocol ERC20. The contract implements interfaces such as digital voucher casting, digital voucher issuance, digital voucher destruction, digital voucher total amount calculation, user digital voucher quantity acquisition, digital voucher minimum unit acquisition, digital voucher abbreviation acquisition, and digital voucher description acquisition.

During digital voucher casting, it mainly completes balance increase, recording of the total amount of digital voucher tokens, transfer calls, and casting work.

4.2.2. Digital Resource Contracts

The main purpose of digital resource contracts is to complete the operation of uploading digital resources. The contract includes digital resource certification, digital resource description information, and download information acquisition interface. The contract adopts the blockchain 1155 contract specification, achieving the standardized definition of non homogeneous assets and homogeneous assets.

When digitizing digital resources, the uploader needs to provide a description of the resources, as well as information on the pricing of the resources (using digital coupons as the trading currency). If the resource price is less than zero, it will prompt that the resource cannot be purchased. The index value of the resource, MaterialIndex, represents the number of resources on the current chain. Increasing by 1 indicates an increase in resources. Record the resource information corresponding to the address of the resource creator through a two-dimensional array. Record msg. sender as the information publisher of the MaterialIndex element in the MaterialIdInStore array.

4.2.3.Digital Resource Trading Contract

Digital resource contracts enable transaction operations between resource publishers and users. The transaction contract mainly includes settings for uploader information (including uploader number and basic information of the uploader), resource information settings, uploader and resource buying and selling association settings, and transaction interfaces.

When trading, it is necessary to check whether the buyer’s account balance has sufficient digital vouchers to ensure that the transaction can proceed. Next, add a certain amount of digital vouchers to the digital creator’s account, and subtract the corresponding digital vouchers from the digital resource user’s account. The resource user needs to decrypt the data using the other party’s public key. The value of this increase or decrease is determined by the digital resource uploader.

4.3. Core Module Design

4.3.1. Statistical Module Design

Complete statistics on digital vouchers, resource sales, digital resources, etc.

1. Statistical analysis of digital vouchers

Analyze the statistics and trend analysis of the total amount of data for digital coupon casting based on dimensions such as year, month, and day, as well as the statistics and trend analysis of the total amount of data for digital coupon returns. The value of data can support the formulation and decision-making of system promotion strategies.

2. Statistical analysis of digital resources

Analysis based on year, month, and day dimensions involves ranking by quantity, download volume, and ranking of a user’s published resources. The value of data can achieve the management of resource publishers and guide users in resource download decisions.

3. Transaction Statistics and Analysis

Analyze all user revenue rankings, all digital resource transaction rankings, designated user revenue, and designated user resource upload rankings based on dimensions such as year, month, and day. Statistical data can help optimize resource transaction management and guide users' transaction decisions.

4.3.2. Transaction Module Design

Transactions can be used to record value transfers that occur on the blockchain. After the introduction of smart contracts in blockchain, transactions go beyond the original definition of value transfer and serve as digital records of transactions occurring in blockchain.

The client completes transaction creation, transaction signing, and transaction sending. Nodes on the blockchain complete transaction verification, broadcast transactions, and place transactions in the transaction pool. Consensus nodes complete transaction sorting and packaging. When a transaction is triggered, execute the transaction and add the smart contract to the chain. Multiple parties need to reach a consensus before adding the smart contract to the chain. Nodes broadcast new blocks on the blockchain, other nodes verify transactions, store transactions after verification, and the transaction is completed on the chain.

5. Operating Environment and Scheme Comparison

5.1. Operating Environment

1. Hardware configuration

MySQL database server: CPU dual core 4 GHz, RAM 16 GB, hard drive 128 GB.

Web server: CPU quadcore 16 GB, RAM: 16GB, hard drive: 128 GB.

Blockchain server: CPU: quad core 16 GB, RAM: 16 GB, hard drive: 128 GB.

2. Software Configuration

The front-end uses H5+CSS3+JS, Vue, Vant, and Axios technologies.

The server uses Java, Spring Boot, and MyBaits technologies.

Use the enterprise level financial alliance chain underlying platform FISCO BCOS. The data structure of the ledger model adopts a chain structure, with blocks connected through hash values. The accounting type is the account model, the consensus algorithm is PBFT, Raft, rPBFT, and the network protocol is JsonRPC and Channel protocol. Develop smart contracts using Solidity language, and the contract engine supports Solidity and pre compiled contracts. The contract development tool is WeBASE-IDE and ChainIDE. The contract deployment and testing tool is based on the Java SDK console.

5.2. Scheme Comparison

Compare the traditional online education model with the model proposed in this article from four aspects, as shown in table 1. Through comparison, it can be seen that the model proposed in this article can easily determine the ownership of digital resources, effectively prevent digital information from being tampered with, and effectively protect the rights of digital content creators. Transparent revenue calculation, with the ability to accurately match buyers and sellers across the entire network, and effectively protect the true identity of creators without affecting the storage data.

Table 1. Comparative analysis of the proposed model and traditional solutions in this article.

Examination points	Traditional solutions	The model used in this article
data encryption	Except for the encrypted password, all other data is not encrypted.	The uplink data is encrypted using the ECC algorithm.
income distribution	The revenue is determined by the platform, and the real resource download data cannot be obtained by the resource publisher.	After completing the transaction, automatically transfer the proceeds to the account of the resource publisher through a smart contract.
Matching range of both parties in the transaction	Matching is done on a platform by platform basis, and resources cannot be shared between different platforms.	According to the set conditions, accurately match resources within the entire blockchain network.
Resource review cycle	Resource review requires different roles to log in to the system and complete it manually.	Multiple nodes on the blockchain complete resource auditing through consensus, with fast auditing and short cycles.

6. Conclusion

Aiming at the problems of the current online education platform, such as the limitations of the centralized structure, the opacity of revenue calculation, and the difficulty of data resource confirmation, this paper proposes to use the characteristics of blockchain technology, such as Tamper resistance, decentralization, transparency, and credibility, and designs an online education system model based on blockchain. This system can achieve functions such as digital resource publishing, digital resource trading, automatic revenue calculation, and transaction statistics. Compared to traditional centralized platforms and existing blockchain online education platforms, this system can reach trusted contracts and automatically fulfill contracts between resource contributors, resource users, and resource reviewers, thereby solving the problems of digital resource ownership confirmation, long resource review cycles, and incentives, Improved the success rate of digital resource transactions, providing effective solutions for enriching digital resources on the Internet and facilitating digital resource transactions. However, the information found in the current transaction query belongs to the source code information that has not been decrypted, so the next step of work will focus on adding the decryption function of the source code.

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