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Using Blockchain Technology to Enhance the Traceability of Original Achievements

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***Abstract*—The protection of original achievements including patents and copyrights is a significant and critical issue in today's knowledge-driven economy. In this article, we propose and develop a blockchain service architecture to enhance information traceability and protection effectiveness. Our proposed service architecture is enabled by the core functionalities of blockchain technology including distributed data storage, peer-to-peer transmission, consensus mechanisms, and encryption algorithms. Through this blockchain-based traceability system, we can record, secure, validate, and track original achievements' registrations and other related transactions. The results of our simulation experiments further validate the effectiveness and robustness of the proposed traceability system design. Our experimental analysis shows that the proposed blockchain-based design can effectively enhance original achievements traceability with an embedded automatic incentive rewarding mechanism for both the creation and protection of original achievements. Moreover, our performance analysis and comparative analysis show that the proposed method has more advantages over several other methods. While our study provides an effective solution to address the existing challenges in intellectual property rights and achievements patents protection, the breadth of the blockchain concept and its applications require nuanced investigations in many different contexts. Thus, the proposed blockchain-based traceability system highlights the potential for broader applications of this disruptive technology in many other domains.**

***Index Terms*—Blockchain technology, original achievements protection, simulation, traceability.**

I. Introduction

As a concrete manifestation of intellectual property, original achievements not only reflect the hardships and efforts of creators but also infer inheritance and innovation values. In today's competitive marketplace, originality drives innovation and creates value to comprehend socioeconomic issues [1]. However, in recent years, the phenomenon and behavior of plagiarism and misappropriation of original achievements are surprisingly not uncommon. Protecting original achievements has encountered increasing challenges, such as the difficulty of right confirmation and the absence of transaction traceability. As today's global intellectual property system is undergoing substantial expansion and modernization, the implementation of policies, such as the agreement on trade-related aspects of intellectual property rights, encounters many challenges across international borders and industrial regimes [2]. How to effectively protect the original achievements remains a complex and critical issue for nations, organizations, and individuals [3]. Therefore, more effective tools need to be developed to incorporate macro, meso, and microdimensions into the architecture design for enhanced traceability.

The tracing intellectual originality usually includes querying the originality and transaction information and providing services relating to the achievements' rewards. Patents, as a common way of documenting intellectual originality, state the end outcome and not necessarily the "evolution" of a particular invention [4]. The development of an invention rarely originates from one individual, and in patent applications, the difficulty of tracing all contributors often leads to disputes and abuses. For governments across the globe, the establishment of traceability mechanisms for original achievements and further improving the science and technology incentive policies are strategically important tasks. Thus, more studies are needed to explore effective ways for improving original achievements traceability with the goal of providing managerial implications and policy guidelines.

Various disruptive technological innovations have been introduced to the domain of data management [5]–[7]. Exemplary technological innovations in the data management include mobile computing, the Internet of things, artificial intelligence, and blockchain technology. Blockchain, as the underlying technology of bitcoin [8], has recently gained significant recognition. It has been acknowledged with great application potentials beyond cryptocurrencies [9], [10]. For example, blockchain can serve as a nontamperable distributed accounting system within which information cannot be changed once the related data are interlocked on the chain [11]. Furthermore, its timestamp function can capture the real-time information storage; and chain's smart contracts can facilitate the development of various reward mechanisms. Such a nontamperable and real-time data

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management environment with reliable smart execution capabilities might help overcome the challenges in guaranteeing the original achievements' traceability.

Yet the breadth of blockchain concept and applications requires nuanced investigations in different contexts. Our article leverages blockchain technology to enhance the traceability of original achievements through a unique service architecture design. The proposed service architecture sets the stage for applying blockchain for strengthening the protection of original achievements. Unlike the traditional protection management systems, which are often constrained by different conditions, such as time and space, the integration of blockchain technology breaks significant operational boundaries. The proposed architecture represents a promising design foundation for enabling transparent data storing, and secure data filing and immutable data tracing. Our study is one of the early initiatives that incorporate the blockchain technology into the traceability architecture design. It may further open new avenues for more advanced model development and other promising applications.

The rest of this article is organized as follows. Section II provides a brief background introduction for the significance of protecting original achievements and introduces the main characteristics of the blockchain technology. Section III presents our blockchain-supported traceability service architecture with enhanced traceability virtualization for original achievements. In Section IV, the experimental simulation is utilized to illustrate the application of the architecture to improve the traceability of original achievements. Finally, Section V concludes the article with the discussions of its limitations, design boundaries, and further research opportunities.

II. Theoretical Background

Because of the characteristics of original achievements, protecting them is a complex and challenging process. The existing traceability designs have often encountered limitations in meeting the increasing demand for better protection. Blockchain, as one of the critical technologies, will be introduced to enhance the original achievements protection. This section will introduce the theoretical background of this article, focusing on three literature streams that are related to original achievements protection, traceability methods, and blockchain technology.

A. Original Achievements Protection

Intellectual property law deals with the protection of intellectual property. Intellectual property is defined as the creations of the mind, such as inventions, literary and artistic works, designs, and symbols, names, and images used in commerce [12]. Intellectual property, as intangible assets, often has a critical value to a person or a company. Intellectual property is protected by intellectual property rights. Such rights include patents, trademarks, copyrights, design rights, utility models, trade names, and confidentiality. In this article, we generalize all types of intellectual creations as original achievements, defined as scientific and technological achievements derived from creative ideas with a certain level of originality (rarity and uniqueness).

Intellectual property rights are subjected to commercial export, which transfers the ownership of the original creator through a series of processes [13], [14]. Original achievements are the commercial output of original ideas, mainly used in the field of science and technology. After the owner of an original achievement has completed its creation and obtained the license to use it, it cannot be exploited without permissions [15]. The owner of the achievement can trade or transfer its ownership. While copyrights or patents mainly focu on literary and dramatic works, original achievements include scientific works. Rapid technological development has brought tremendous changes to the production and dissemination of original achievements. We are currently witnessing a shorter cycle time and faster update rate in achievement creation. As a result, the traditional business models and existing protection processes can no longer meet the dynamic needs of original achievements protection nowadays [16].

Original achievements protection has encountered several unprecedented challenges. First, achievements' ownerships are difficult to determine. Original achievements confirmation is a complex process, including identifying the attribution of the original achievements, clarifying the original author and creator, obtaining the accurate information, and categorizing ownership type and associated rights in terms of access and time duration. The right to use an original achievement is protected by a patent. Organizations or individuals may obtain the right to use it only through obtaining the patent license [17]. Original achievements usually involve a large amount of works and sometimes appear in diversified formats. There may also be more than one subject involving in the associated rights. Because of legitimate reasons (e.g., competing R&D) or illegitimate reasons (e.g., misappropriation or plagiarism), similar original achievements may emerge at the same time. Thus, it is surprisingly common that the ownership of an achievement remains undetermined or debatably claimed. In addition, most of the current achievements registration systems are heavily centralized. Within such a system, once the copyright information is falsified, ownership confirmation may become impossible.

Second, the transaction process is difficult to trace. Original achievements' transactions refer to the achievement owners' actions of transferring complete or distributing partial ownership to others in exchange for economic gains [18]. Such transactions can rationally transform original achievements and achieve value circulation. However, most of the existing achievements' transactions follow the traditional offline model (there are no unified online transacting platforms). Very often, transaction information is scattered and the transaction history is hard to trace. When the original achievements transformation process has multiple circulation links, it is even more complex and difficult to search the transaction records to trace the original and partial owners, and to inquire about their ownership formats and rights.

Third, the current reward system is difficult to standardize. Most of the original achievements involve multiple creators. The current reward system is limited to a single creator, lacking the capability to accommodate multicreator collaborations. The challenges of protecting original achievements are primarily related to data storage and data traceability. The data storage guarantees the data traceability, and in turn, the data traceability confirms the data storage. The accuracy and security of data storage and the capability and effectiveness of data traceability are the key factors in the protection of original achievements. Therefore, it is necessary and critical to establish a set of original achievements data traceability methods, and to profoundly improve the capability to create, use, manage, and reward original achievements.

Traceability methods depend on the data management, including data acquisition, storage, and validation. Tracking and managing achievement numbers, names, applicants, and application times have been especially important. Focusing on data management to tracking capability, our proposed design enables original achievements data queries for rights protection forensics and facilitates original achievements transaction tracking (such as finding the initial owner of the work and the rewarding details).

B. *Traceability Methods*

Traceability has different definitions in different application domains [19], [20]. A common definition is the ability to trace the origin of the roots and sources of the investigated subjects. Thus, it is straightforward to see that enhancing traceability is a key to protect original achievements. The existing traceability methods are related to data traceability and information traceability. Data traceability is mainly used in the database and workflow fields for the purpose of tracking original data and reproducing historical data. The data traceability records the process of data generation and analysis from scratch [21]. It is an inverse discovery of the data based on the path of data operations.

Information traceability is a new application of data traceability in the form of chains and systems. Its core idea inherits the concept of data traceability, but it tracks specific information, such as products and copyright patents. This traceability method realizes the two-way traceability function of 100% information from the initial state to the finished goods and from the finished goods back to the initial state; resulting in the high level of information security. The information of each chain is backed up in real time. With the emergency of blockchain technology, more and more researchers have suggested the blockchain-based solutions for enhancing traceability, highlighting its role in guaranteeing information transparency and reliability [22].

C. *Blockchain Technology*

Blockchain is the underlying technology for bitcoin, a type of cryptocurrency initially proposed by Nakamoto [8]. Blockchain has received considerable attention for applications beyond cryptocurrencies [9], [23]. It has been defined as distributed digital ledgers that keep records and transactions as encrypted time-stamped chains [24]. A distinct capability of blockchain is its ability to operate independently without the need for central entities—such as banks—to confirm the credibility of transactions. Instead of central authorities and intermediaries, network participants can audit and verify transactions to be added to the ledgers.

Blockchain is a new application model composed of computer technologies, including distributed data storage, peer-to-peer transmission, consensus mechanisms, and encryption algorithms [10], [25]. The timestamp function of blockchain enables the blockchain to record the history of transactions in terms of sending and validating and the additional information and data incurred based on time sequences, ensuring that a built-in audit trail is maintained for all additions to the network [26]. Blockchain stores the transaction unit data into a structured chain in a sequential and interlocked way. Blockchain technology includes a unique system structure in which information can only be added to the ledgers. Information cannot be removed or edited without network verification. This feature, immutability, along with consensus and distributed ledgers, enhances the trustworthiness of information, greatly reducing the probability of information falsification, fraud, or corruption [27].

Smart contracts in blockchain follow digital transaction rules and run on Ethernet virtual machines. They depend on code, which is triggered by some event, and ran on a shared blockchain [28]. Smart contracts can incorporate codified business logics, rules, and terms of contracts between two or more parties. The system can automatically evaluate the embedded terms and conditions. When a term is fulfilled, a smart contract can automatically execute the associated activities and notify the involved parties in the network [29], [30]. For example, a smart contract-based financial loan management system has been established for business applications [31].

Blockchain technology has great potential of being implanted in the existing traceability mechanisms. In October 2016, a white paper on blockchain technology and application development issued by the Ministry of Industry and Information Technology of China pointed out that the application of blockchain technology has been extended to intellectual property, patent achievements, Internet of things, finance, and other fields. Blockchain technology is seen as the prototype of the next generation of cloud computing, being capable of promoting the transformation of social organizations from providing services to leading services [32]. About 20 countries around the world have begun large-scale research and development of blockchain technology. It is predicted that, by 2025, 10% of global gross domestic product (GDP) will be generated through transactions using a blockchain technology. Because technological innovation often leads to institutional innovation, the rise of blockchain technology can provide new methods to enhance the protection of original achievements. Next, we will propose a unique design of integrating blockchain technology into the traditional information traceability mechanism. Our analysis of the proposed service architecture will illustrate how this foundational technology can facilitate data management and enhance tracing effectiveness.

D. *Blockchain-Supported Traceability Mechanism and Original Achievement Protection*

While blockchain as an emergent technology has spurred extensive research in several application domains, its role in protecting original achievements is underinvestigated in the extant literature. Our study will be among the first studies that implement the blockchain-supported solutions in the context of original achievement protection. Blockchain technology's main technical features include decentralization, reliable database, and transaction anonymity. These features can effectively safeguard the data stored in blockchain by ensuring data's accuracy, security and transparency, and consistency. The data stored are public and can be easily validated by multiple participating nodes. Hence, the application of blockchain to the existing traceability methods may facilitate highly dependable digital systems for original achievement protection.

There is a growing motivation to apply blockchain technology to more fields because of its inherent capability in ensuring data and transaction integrity [33]. Current research on blockchain technology and its traceability application is mostly from supply chain management (e.g., [34]–[37]), enterprise planning (e.g., [38], [39]), and finance (e.g., [40], [41]). Outlining the challenges of conducting copyright-related transactions in the digital environment, Savelyev [42] discussed how blockchain may facilitate the transaction process. The initiatives of blockchain technology applications in this domain are limited to copyright registration, administration, and associated inquiry resolutions [43], [44]. These applications cannot fully address the challenges in the original achievement protection. Thus, an end-to-end architecture based on the blockchain has been proposed in this article. In addition, we utilize the timestamp function to record the transaction time, thereby enabling the traceability of copyright records and the related transactional information [45], [46].

Blockchain technology may transform and benefit original achievement protection because of its capabilities in promoting transparency, reliability, smart execution, and financial incentivization. With the blockchain application in our proposed traceability technological system, we can record, secure, confirm, and track both the original achievements' transactions and the rewarding information. After proposing a comprehensive blockchain-supported process architecture in the context of original achievements protection, we use simulation experiments to validate its effectiveness. The proposed traceability service architecture can meaningfully contribute to the literature on the protection of intellectual property rights and achievements' patents.

III. Method Design

This section introduces the design of our traceability service architecture. Section III-A presents the four layers, including the data layer, contract layer, logical layer, and application layer. Section III-B demonstrates the application workflow under three processes' scenarios. These three process scenarios respond to the three major current challenges of original achievements protection: achievements' registration and confirmation, transaction, and rewarding. Section III-C introduces the consensus mechanism deployed in this service architecture.

A. Blockchain-Supported Traceability Service Architecture

This article aims to establish an original achievements traceability service architecture using a blockchain technology. This architecture is divided into four layers. These layers, from bottom to top, are the data layer, contract layer, logic layer, and application layer. The data information generated by the application layer is stored in the blockchain of the data layer via the uplink. The smart contract at the contract layer can provide data traceability services for the application layer. The whole process is shown in Fig. 1.

The following four sections will explain the detailed design and functionality of each layer.

1) Data Layer: The data layer serves the foundation of the overall architecture. The data storage at the registration stage plays an important role in supporting the traceability feasibility and effectiveness at later stages. In the data layer, a single block is a collection of transaction data containing the registration information. Each block has a unique hash value. The hash value of the previous block connects the next block in a chain structure, resulting in a sequential storage of transaction information [47]. All information in each block can be traced by the following interconnected block. Each block contains the data information of the original achievements from the registration activity to all associated transactional activities. All transactional information is recorded and stored in blocks sequentially with complete transparency and high traceability.

2) Contract Layer: The contract layer serves an enabler for blockchain smart contract implementation. It is also the core aspect of the traceability service architecture. The major elements of this layer include script code design, algorithm mechanism operation, and smart contract code design. The benefit of using smart contracts in the traceability service architecture is that the smart contracts can be executed automatically when embedded with certain conditional code. That is, as long as a smart contract is scripted in the contract layer in advance, the traceability of the original achievement can be automatically enabled. In the blockchain context, automation means all contract terms are enforced in accordance with regulations and the function is valid without intermediaries [48]. In this layer, we mainly deploy smart contracts about the reward mechanism to trace and automatically reward the creators of original achievements.

3) Logical Layer: The logical layer connects blockchain technology and the original achievements mechanism through a logical embodiment. It is the middle layer between the data abstraction and data transformation. It serves as the logical structure that describes the entire service architecture [49]. The logic layer connects the business logic of the original achievements to the consensus mechanism of the blockchain and the intelligent contract requirements. It generates the feedback loop between the user interfaces and data management by receiving user instructions or data input and sending them to the data layer for processing; and finally displays the results back to the end-users. As to the original achievements traceability service architecture, the logic layer integrates the blockchain technology to the original achievements traceability mechanism, resulting in an efficient and reliable application mechanism to enhance protection effectiveness.

4) Application Layer: The application layer mainly involves the realization of original achievement protection based on the blockchain within the proposed service architecture. Major

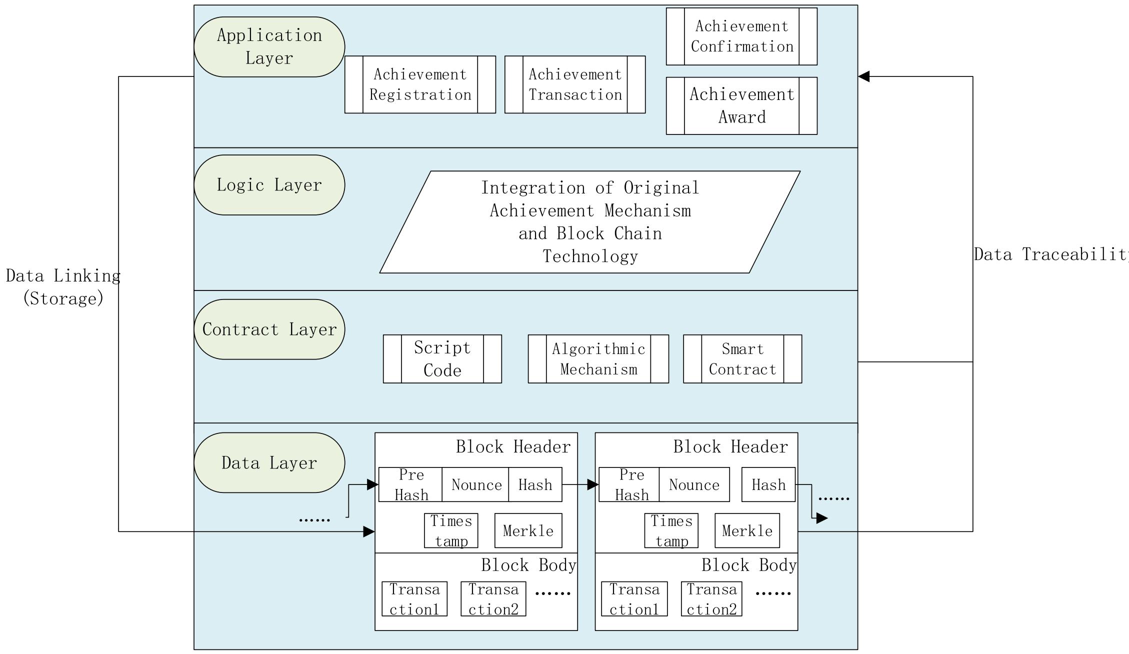


Fig. 1. Traceability service architecture.

activities at this layer include achievements registration, achievements confirmation, achievements trading, and achievements rewarding. Special customization can also be achieved in accordance with various industries, organizations, and individuals. End users can provide specific requirements through the application layer—user application interface—to this original achievement traceability service architecture.

B. Design Application

In this section, we will present the workflow of the proposed service architecture through three application scenarios. These three scenarios respond to the key original achievements' protection processes: first, registration and confirmation; second, transactions; and third, rewarding.

1) Scenario 1: Original Achievements Registration and Confirmation: Each block within the blockchain contains a block header and a block body. The block header contains block metainformation and includes a hash value pointing to the header of the previous block; and the block headers are sequentially connected to form a blockchain. All information, including transactional information, is stored in the block body, which will be presented in the form of a hash function value. A hash function is a type of function that can map information and data of any length into fixed-length values.

In the data registration and storage process, data initially will be hashed to be a fixed-length hash value, which will be stored in the blockchain. The hash value is unique. When the input information changes slightly, the resulting hash value will be completely different. Therefore, when it is necessary to verify the integrity of the data, it only needs to perform a hash operation on the data and compare the result with the hash value in the chain. If the two hash values are the same, the data are not tamper damaged, that is, confirmed. The hash function ensures that the data stored in the chain are accurate and secure.

The timestamp function further ensures such accuracy and security. The confirmed information cannot be changed or altered on a blockchain. The data within each block are interrelated and interlocked with the data of other blocks. When changing certain data at one block, essentially all the related following blocks will be modified at the same timestamp. To achieve this change, the entire blockchain needs to reach the consensus algorithm and consume massive resources/power. As more and more data blocks are added to the same chain, it is almost impossible to change the data contents of a certain block. The immutability of information ensures the accuracy of the information and prevents tampering and falsification.

Such immutability enhances the protection of the registration and confirmation of the original achievements. When a new original achievement completes its registration, the process of confirming the rights of original achievements becomes easy, accurate, and secure. The detailed steps of the registration and confirmation process are shown in Fig. 2.

Fig. 2 starts with the original achievements registration, following the certification and confirmation. When the creation of new original achievements is completed, the achievements' rights are immediately followed. After the original achievement is produced, the creator sends the work and relevant information (such as the author, creation type, and creation time) to the blockchain through the front-end application interface. The blockchain hashes the uploaded information, marks the time stamp, records the registration time, and generates the certificate. After that, relevant patent agencies can check whether the new achievement is similar to any of those registered in the blockchain system. If yes, the registration will be stopped and reported as an infringement. Otherwise, complete the copyright registration and return to the product certification stage. How to identify whether the two original achievements are similar or not requires the comparison and identification (simhash algorithm) by the third-party professional institutions and personnel, such

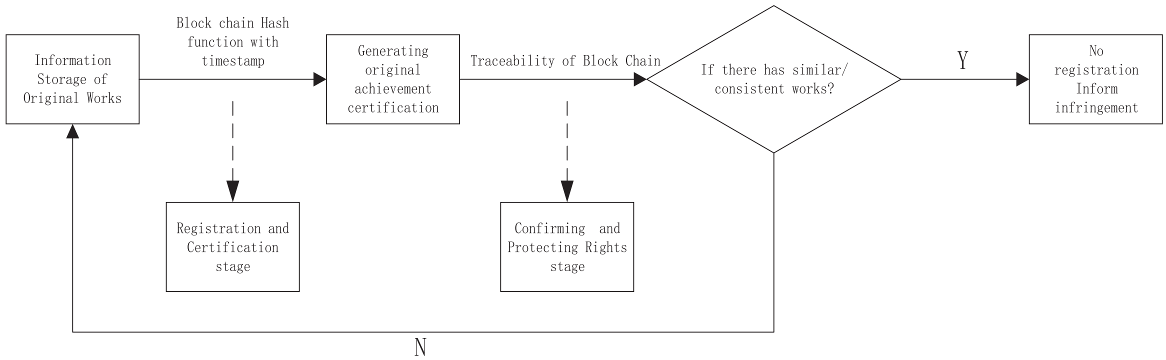


Fig. 2. Detailed steps of the registration and confirmation process.

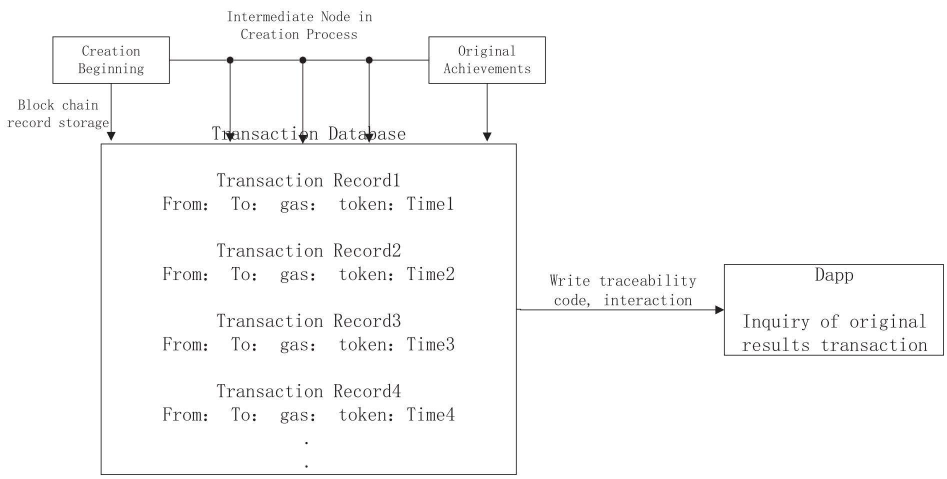


Fig. 3. Detailed steps of the transaction process.

as an Intellectual Property Office. In this article, blockchain technology is mainly used to ensure the permanent preservation of the original results information and prevent it from being tampered or changed. It also provides unique proofs, including the time of registration completion and the followed achievement ownership. At the same time, in the maintenance of original achievements, the existence of smart contracts will also supervise the implementation of the validity period of achievements. The contract code will contain terms related to the duration of the achievement, termination, or continuation of the contract, etc. The original achievement will be stamped with a timestamp from the successful registration. Based on the current time, the longest validity period of the original achievement will be set. Within this period, if there is no right to transfer, the ownership of the original achievement will always belong to the registrant. If the time limit is reached and the registrant fails to apply for continued protection or take other actions, the original achievement record mark will become invalid.

2) Scenario 2: Original Achievements Transaction Traceability: On the blockchain, every transactional activity is regarded as an attempt to change the state of a block. The block generated by each transactional activity is the confirmation of mutual agreement between two parties. Such activities include the initiation of a transaction, change of a transaction, alteration, or other status of a transaction.

Due to the decentralized nature of blockchain, the achievements' transactions on the blockchain are mostly peer-to-peer, end-to-end, or user-to-user. Each user has a unique transaction receiving address, and such address is displayed in the form of a hash value. Each transaction will result in a new block creation to record the transaction information, including the sender's and receiver's transaction addresses, transaction amount, transaction time, and other related contents.

According to the transaction address of the last exporter, the initial transaction importer can be traced on blockchain. Furthermore, blockchain can effectively record the original achievement's creators and trace all the changes of its ownership. The entire transaction database is constructed in a chronological order, starting from the creation of the original achievements. The achievements transaction traceability processes can be demonstrated through the decentralized application (DAPP) interface (see Fig. 3). DAPP is a decentralized and distributed application, which is built based on the blockchain technology. Most of it connects with blockchain and smart contracts in the form of PC web pages or clients that provide external services.

All the original achievement information, such as creation process and transaction, can be uploaded to the blockchain by the parties or the achievement owner at the front end. When it is necessary to trace and query the stored information, everyone, such as the original author, the buyer and seller of the transaction, and the patent department, can use a DAPP software to request a query from the web server. The web server sends the query request to the blockchain traceability system in the form of software development kit (SDK) or application programming interface (API). The blockchain traceability system judges the source according to the transaction confirmed by all parties and returns the query results, and finally displays the required information on the front-end visualization platform.

Therefore, we can use a blockchain to provide a safe and reliable trading and circulation environment for original achievements. Related applications include monetization pricing, digital content original achievements mall, online payment, automatic trading, transaction circulation chain tracing, etc. Users can price and transfer the copyrights of the original works that have been verified and confirmed successfully in the system, and the other users can purchase the copyrighted works of others in the mall. The whole purchase process with copyright circulation information will be recorded in the blockchain as a part of the detailed information of the copyrighted works for inspection. Once it is found that the ownership transfer is unclear or an infringement is committed, the supervision third-party organization can immediately investigate. If the infringement is found several days after the release of this trading platform, the creator can maintain the fixed function of the blockchain evidence in the confirmation phase. In the litigation process, all the copyright blockchain nodes can prove the content, which can be used as preliminary evidence to prove the infringement.

3) Scenario 3: Original Achievements Rewarding: After the registration and confirmation of the original achievements and the traceability of transactions, another key issue is the reward for the creators of achievements. When the original achievements result from the multiparty collaboration, it is not straightforward to decide when to reward the creators of the achievements, how many rewards are given, and how to distribute the benefits. If we use the traditional way of traceability, we will waste a lot of unnecessary time. The smart contract on the blockchain is a kind of computable transaction protocol, which can automatically trigger the execution of contract terms without an intermediary, and represents the cognitive consensus in a specific environment based on specific conditions and standards. The contract is based on a clause code, which is preprogrammed and deployed on the blockchain. When the specification requirements are met, the contract terms are automatically triggered and executed. Smart contract technology will ensure the efficiency and the traceability of the original achievement reward mechanism.

For example, we illustrate the code of a smart contract that sends a reward to a specified original creator's address (Appendix: Algorithm 1). In Algorithm 1, the achievement award is a transfer process of blockchain fee: set the initial reward amount, select the address of the "From" account and the address of the "To" account in the blockchain that need to allocate the reward and receive the reward, and complete the virtual transfer of the reward by using a *function transfer*. This example code can be modified and further developed based on the specifications and complexity of the desired rewarding mechanism. For example, we can complete the task of automatic transfer and payment by adding an original author address to the variable assignment.

C. Consensus Mechanism

The resources on the blockchain network are often attacked through a certain mechanism. If an attacker wants to attack, he must control more than 50% of the whole network resources, which is called a 51% attack. In order to deal with such an attack, it is necessary to reduce the value of the number of coins held [50], [51]. Sayeed and Marco-Gisbert [52] evaluated 51% attacks and revealed that these kinds of attacks are possible due to a defect of the consensus mechanism.

The consensus mechanism is designed to manage a series of rules and procedures of coherent facts among participating nodes. The consensus algorithm allows machines to connect and work normally even when some members lose their utility. This fault tolerance function is another core capability of blockchain and distributed ledger [52]. The block generated by the blockchain depends on a consensus mechanism to maintain its consistency. There are two popular consensus mechanisms in the blockchain, one is proof of X series, and the other is the consensus protocol applicable to the license chain, which is a variation of byzantine fault tolerance (BFT) and practical byzantine fault tolerance (PBFT). This article chooses proof of staked (POS) as the consensus mechanism of the traceability blockchain, trying to analyze the possibility of reducing attacks by 51%.

We can understand POS as an upgraded consensus mechanism. In each verification transaction, a certain percentage will be awarded to the verifier according to the proportion, which is determined by the number of tokens owned by the verifier. The more coins the verifier owns, the longer the holding time is, and the greater the chance to get the record transaction. Compared with the proof of work (POW) mechanism used in the past research, POS reduces the resource consumption by mathematical operations to a certain extent and improves the performance accordingly. Moreover, to a large extent, POS is more secure. If a person holding more than 51% of the equity cheats, it is equivalent to attack his own resource, which in turn punishes him. POS relies on the "stake" to select bookkeepers (lottery winners). All the "stakes" owned by the voters are recorded on the blockchain. The proportion of "stake" is the proportion of a user's "stake" to the total number of "stakes" on the blockchain. For POS to attack 51%, it needs to hold 51% stake in the chain, and the acquisition of stake can only be purchased from the existing users and cannot be invested in production outside the system. Therefore, the cost of a 51% attack on the POS system is equal to the cost of purchasing a stake from the market. And the more people who hold a stake in the legal chain, the more likely they can maintain the chain. If they transfer the stake to the attacker, the risk they face is far greater than the cost of renting. Therefore, it is difficult for the attacker to obtain enough stake through renting. Thus, as far as 51% attack is concerned, POS has more advantages than POW in resisting attacks.

IV. Simulations

In order to verify the feasibility of the traceability method proposed in this article, we use Python 3.7 to conduct the experimental simulations of blockchain in the PyCharm professional

TABLE I
INITIAL BLOCK

Attribute	Example
Prev Hash	null
Timestamp	2020-04-28 09:41:22.647910
Data	Genesis Block
Hash	89eb0ac031a63d2421cd05a2fbe41f3ea35f5c3712ca839cbf6b85c4ee07b7a3

development environment. Python has a large number of third-party libraries, such as hashlib, json, and time library, thereby providing a convenient language environment for our simulation experiments. In our future research of practical blockchain deployment, we plan to use Go language for experiments. Compared with Python, Go language is a compiled language, which runs faster and adapts better under high concurrency. In this section, we will demonstrate the following two simulations, achievement information storage simulation and achievement transaction querying and tracing simulation, respectively.

In the entire operation process, when the node needs to upload the original achievement information, the blockchain will save this information in the form of hash function value; and when the original achievement information is tampered, the subsequent blocks will judge whether the hash value is consistent, and the inconsistent blocks will be marked invalid. During traceability query, the transaction time and message that meet the conditions will be displayed, and the address of the initial output party can be traced according to the address of the terminal input party.

A. Initial Block of Blockchain

We first write a code to simulate the generation of initial blocks in the blockchain and then assign initial values. Subsequent operations, such as original achievement information storage and original achievement transaction traceability query, will trigger the generation of the next block. On the basis of the initial block, the next block records its hash value in this block, and then uses the hash value generated by the original achievement information in this block as its unique identification for the use of the subsequent block. In this way, tampering with the original achievement information in any block will lead to mismatching of the hash values generated later.

The specific processes are as follows. We use the hashlib and datetime library functions to create a new block class to represent the block. There are four attributes in the block, namely the hash value of the previous block, the uplink time, the information data, and the hash value of the current block. The hash value is generated by the sha256 algorithm. The information data are the information related to the original achievements, and the time of chain up is the current running block time. We need to create a Genesis block, the first block on the chain, where the previous hash value is empty. The code describing this process is in the Appendix (Algorithm 2), and Table I presents an example of the initial block creation.

B. Simulation 1: Achievement Information Storage

In the creation process, original achievement information will be uploaded to the blockchain. This simulation is to show the process of information storage. We use Python to generate the corresponding hash value according to the submitted information. Next, we connect the value of the founding block to form the blockchain using the time.sleep() function to generate a new block every 2 min. The code describing this process is in the Appendix (Algorithm 3). Algorithm 3 shows the process of forming a chain structure after the block generation. The genesis block generated by Algorithm 2 is taken as the first block of the blockchain, and the hash value of this block represents the prev_block.hash pointing to the next block. In this way, the blockchain is connected in sequence. The results are shown in Fig. 4.

As demonstrated by the simulated results, blockchain can use the timestamp function to record the time of the current information uplink and generate blocks at a chronological order. Each block takes its unique hash value and connects through the hash value of the previous block to ensure the sequence and integrity of the data chain. When information in a block changes, its hash value will be different, causing all subsequent blocks to be invalid. Comparing the current hash value of the block with the previous block hash, the change in value is distinguished by the valid block and the invalid block. Valid block means that the prehash value displayed in the current block corresponds to the previous block, which means that the data information of the previous block has not been tampered with, that is, the previous block is real and effective; of course, if the data of the previous block are modified, the block hash value will change, and the prehash value on the next block cannot be matched; then, it will be displayed as an invalid block, as shown in Fig. 5. This simulation attempts to modify the information data of one block (i.e., change the information in the second block to "Jack, Scientific, and Technological works, completion time: 2019/10/05"). When the data information is modified on the blockchain, the hash value of the corresponding block completely changes. The previous hash value of the subsequent block does not conform to this change, resulting the subsequent blocks to become invalid.

Through the proposed design, the storage of original achievement information is secure and cannot be tampered with, thereby providing a reliable service infrastructure for the storage of original achievement certificates. The associated information, such as certificate confirmation and user rights, can also be

```
prev Hash:
Time:2020-04-28 09:41:22.647910
Data:Genesis Block
Hash:89eb0ac031a63d2421cd05a2fbe41f3ea35f5c3712ca839cbf6b85c4ee07b7a3
----------------------------------------------------------------------------------------------------
prev Hash:89eb0ac031a63d2421cd05a2fbe41f3ea35f5c3712ca839cbf6b85c4ee07b7a3
Time:2020-04-28 09:43:22.647910
Data:Jack,Scientific and Technological works, completion time:2018/07/01
Hash:f48e19852b71ef6ca8e1bad2d7efea1f8db6516e179cab8470ed7a4e392bca8a
----------------------------------------------------------------------------------------------------
prev Hash:f48e19852b71ef6ca8e1bad2d7efea1f8db6516e179cab8470ed7a4e392bca8a
Time:2020-04-28 09:45:22.647910
Data:Lucy,Cultural works, completion time:2019/10/02
Hash:0cb5267572d529c6fcd454fa2f9fc46807d9b681320d4fa90dfa2fd252e23359
----------------------------------------------------------------------------------------------------
```

Fig. 4. Results of achievement information storage.

```
prev Hash:89eb0ac031a63d2421cd05a2fbe41f3ea35f5c3712ca839cbf6b85c4ee07b7a3
Time:2020-04-28 10:02:08.191910
Data:Jack,Scientific and Technological works, completion time:2019/10/05
Hash:b20f3d6f1206ef5abe852c568348ca3a098a33a48e2a3ced993ff771ae1cb523
----------------------------------------------------------------------------------------------------
valid block
prev Hash:f48e19852b71ef6ca8e1bad2d7efea1f8db6516e179cab8470ed7a4e392bca8a
Time:2020-04-28 10:04:08.191910
Data:Lucy,Cultural works, completion time:2019/10/02
Hash:0cb5267572d529c6fcd454fa2f9fc46807d9b681320d4fa90dfa2fd252e23359
----------------------------------------------------------------------------------------------------
invalid block

Process finished with exit code 0
```

Fig. 5. Results of the modified block information.

submitted as an electronic evidence on the blockchain. The entire process ensures the traceability, security, and immutability in the information storage of original achievements.

C. Simulation 2: Achievements Transaction Querying and Tracing

This simulation will build blockchain structure, simulate blockchain transactions, and use postman to simulate interactions. *Get operation* can view each transaction on each block. The specific steps are entailed as follows.

Step 1: Create a blockchain based on Section IV-A.

Step 2: Define the blockchain POS consensus mechanism. The core code of the POS mechanism is in the Appendix (Algorithm 4). In Algorithm 4, we use the pick_ winner function to select the bookkeeping rights. We construct a list (lottery_ pool) based on the number of tokens. Users enter their tokens into the POS mechanism, and these users become validators. In these validators, the algorithm will select a winner as bookkeeper according to the weights (determined by the number of tokens invested by validators). After selection, the POS mechanism will grant the bookkeeper to generate the next block. If the block is not generated within a certain period of time, the designed mechanism will select the second winner to continue the same process.

Step 3: Define new transaction information, which will be added to the next block to be dug. The new transaction information includes the sender's address (if the sender's address is local, the sender will be denoted as "0," indicating the newly dug transaction), the recipient's address, and the transaction amount.

Step 4: Interact with the postman server, defining *Get* functions for mine mining (transaction information) and creating new transactions (*new_transaction*). The code about obtaining new block information (including index, transactions, proof, previous_ hash, etc.) is shown in the Appendix.

Step 5: Run the code and open the postman to interact through the simulated network (http://localhost:5000/). The address suffix adds *mine*, and the method is *Get*. The information contains the block information and the current transaction information (see Fig. 6).

As shown in Fig. 6, every time we execute a Get operation, we simulate the generation process of a transaction block of the original achievement blockchain. We can use Postman to

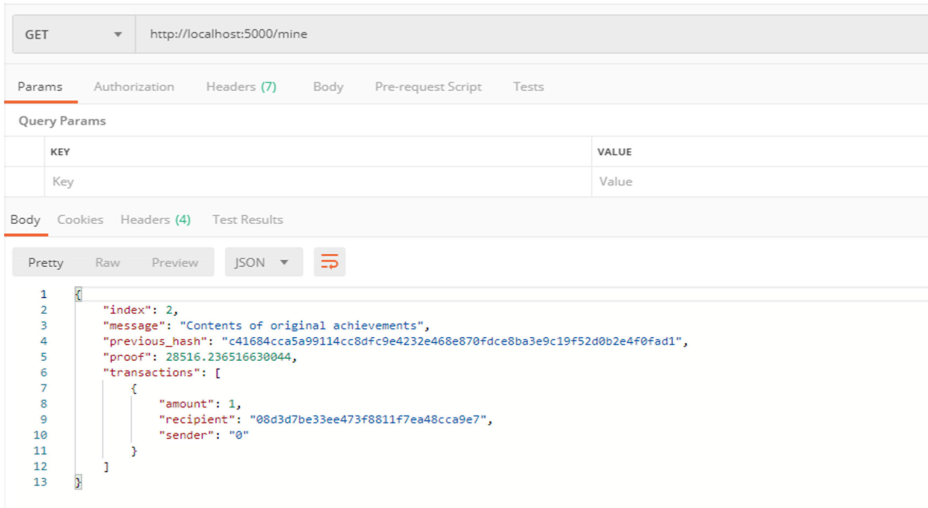


Fig. 6. Single transaction block view.

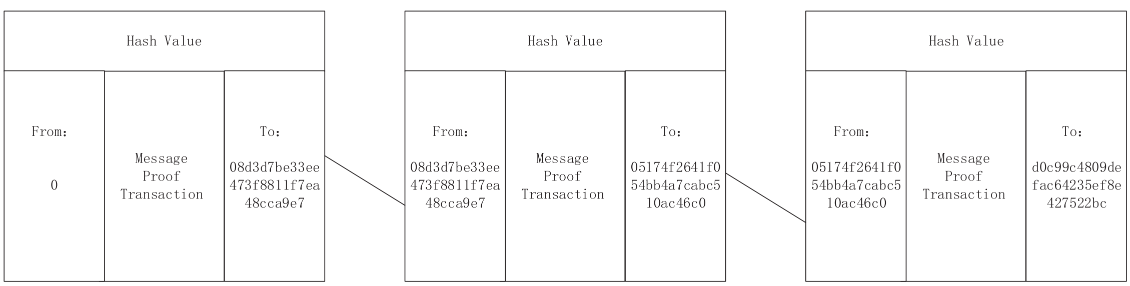


Fig. 7. Circulation process of an original achievement transaction.

visually view the information of a transaction on the currently created block. In such a transaction process, we can see the addresses of the sender (that is, the owner) and the receiver (that is, the transferor) of the original achievement, as well as the number of transactions and the content of the original achievement. Each transaction will generate a transaction block, which will be recorded on the blockchain. Consequently, the link relationship between the previous transaction block and the subsequent transaction block can be established. The whole transaction blockchain list is shown in Fig. 7. We can think of the links on the whole blockchain as a linked list structure, in which the addresses of the participating users are concatenated according to the transaction time sequence. The whole circulation process of linked list is a circulation process of original achievement transaction.

With the last input address as the traceability point, all the transaction addresses of the output party can be traced forward until the source address is found, and this address is unique, as shown in Fig. 8. This node is the founder of the original achievement. Such operations are of great help to the tracking of original authors and the query of copyright transactions.

The traditional transaction methods suffer from long processing cycle time. Such lessened design agility can easily result in circulating and mixed original achievement information, and the violation of copyright owners. Such issue becomes more complex and critical as the dramatically growing demand of original achievements' transactions and tracing capability.

```
Tracing to the flow of original results transaction:
    last author: 08d3d7be33ee473f8811f7ea48cca9e7
    third author: 05174f2641f054bb4a7cabc510ac46c0
    second author: d0c99c4809defac64235ef8e427522bc
    first author: 0


Process finished with exit code 0
```

Fig. 8. Traceability of trading address.

When applying the proposed design in practice, the traceability of the trading address is secure and unique, resolving security concerns in the original achievement trading market.

In the two illustrated experimental simulations, Python is used as the basic language to simulate the original achievements traceability using blockchain. The powerful third-party libraries of Python can facilitate the use of hash functions in these experimental simulations. Through the process of generating and constructing blockchain in our experiments, it is apparent that the blockchain technology can store information data in the form of hash function while ensuring data accuracy and security.

In the second experimental simulation, the interaction between the Python and postman software shows that the blockchain could conceal the specific names of two user nodes when trading original achievements. Only a hash value was used

TABLE II
PERFORMANCE EVALUATION OF THE PROPOSED METHOD

PERFORMANCE MATRIX	MAJOR CHALLENGES	ADVANTAGES AND SOLUTIONS OF THE PROPOSED METHOD
Security	Information has been tampered with forged data	The method in this paper can hash and encrypt the data information stored on the chain. Once the information is modified, it will invalidate all subsequent information. At the same time, the consensus algorithm of POS and 51% attack principle in the distributed system makes the forgery cost huge to resist the possibility of externally modifying data.
Efficiency	Information traceability	This paper adopts the method of digital information instant storage and front -back interactive response, which can quickly query all kinds of customers and get unified and reliable results.
Interoperability & accessibility	Difficult interaction between data	This paper uses the blockchain to realize that each original achievement participating user can access and have the right to modify the historical data of any node at any time, providing an open, consensus, and transparent transaction data platform.
Privacy	Hacking and data protection	The method of this paper will use asymmetric encryption technology (such as RSA, ECC algorithm) to encrypt data and set access control permission according to the block chain cryptography principle, which is also the key direction of future research.
Stability	Transactions stability	Under the POS mechanism, users can be rewarded for choosing the right block; support for Byzantine fault block may be punished. It ensures the stability of the system. And even if the network energy consumption is 0, POS still protects the network. If the energy consumption for POW mechanism is close to 0, this cryptocurrency is called "long-term energy efficiency".

to replace the address, and the transaction process was recorded real time, enabling transparency for the tracing purposes.

D. Discussion

This section discusses the theoretical and managerial implications of our proposed method.

1) Performance Analysis: The method proposed in this article enables all the achievement information from the beginning to the end of the original achievement to be completely and truly recorded in the blockchain system. It provides the comprehensive data information for the owners of the original achievements and the relevant transaction participants. Consequently, it becomes more convenient to understand the current creation process of the original achievements, and the transaction traceability and reward management can be more accurately implemented. In addition, compared with the existing methods of protecting original achievements, the blockchain-based method proposed in this article has several distinct advantages (as summarized in Table II).

The existing original achievement protection methods often suffer from low architecture cost efficiency, poor data structure, and security, neglected sharing and rewarding mechanisms. In practice, when uploading original achievements, owners have to face the risks of privacy leakage and security attacks. The proposed method in this article can hash and encrypt the data information stored on the chain. The embedded consensus algorithm of POS can significantly increase the forgery costs, thereby decreasing the possibility of data being externally modified. Facilitating quick queries by all types of customers, the design interfaces can generate unified and reliable registration, transaction, and related information. Overall, the proposed method helps enhance data security, efficiency, interoperability, accessibility, privacy protection, and operating stability.

2) Comparative Analysis: With the emergence of blockchain technology, several studies have investigated its application in the architecture for protecting original achievements. However, the existing designs have not fully resolved the major protection effectiveness challenges (see Table III). First, it is not difficult to see from Table III that most studies use the single-chain structure of the blockchain to complete the registration, storage, and deployment of relevant information, while the method without using the blockchain as the basic architecture has obvious weakness in privacy protection and data control. Second, the current POW consensus mechanism raises cost-effectiveness concerns. POS consensus mechanism in this article lessens the resource consumption and reduces the transaction costs. Under the POS mechanism, transaction costs are no longer paid to the mining rights' holders. As a form of transaction cost, gas* mainly depends on the steps of the calculation process and the complexity of the transaction. The method in this article generates only one transaction in a block, which minimizes the transaction volume. So, by contrast, it incurs less gas and costs. Third, the existing copyright tracing systems mainly focus on the protection of copyright identification and management. The proposed method in this article enables the automatic distribution of rewards, realizing the whole copyright application process from initial uploading to final rewarding.

In summary, as a distributed database, blockchain can ensure the authenticity of stored information with high accuracy, security, immunity, and traceability. The transaction information can be recorded in blocks, and the transaction information can be easily searched by querying the location of the block or the corresponding hash value. Therefore, blockchain technology can be incorporated into the next generation of traceability architectures designed to protect original achievements.

3) Managerial and Business Implications: With the rapid advance of today's knowledge-based economy, technological

*Gas is a form of transaction costs for Ethereum blockchain. Our article uses it to compare the transaction costs generated by POW and POS mechanisms.

TABLE III
EXISTING METHOD COMPARISON

PAPER	CONSENSUS MECHANISM	CHAIN TYPE	PRIVACY PROTECTION	DATA CONTROL	TRANSACTION FEE	FUNCTIONS
[53]	TundMink	Single chain	√	Medium	×	• Intelligent copyright review, storage; • Transaction traceability
[54]	×	Single chain	√	Medium	×	• Copyright and transaction security
[55]	POW	Single chain	×	Weak	√	• Copyright recognition and permission; • Copyright transfer search
[56]	×	Not blockchain	×	Weak	×	• Copyright protection • Transaction monitoring and management
This paper	POS	Single chain	√	Strong	√	• Identification and confirmation of original achievements • Transaction tracing • Automatic distribution of rewards

innovations have brought great changes and severe challenges to the creation, distribution, trading, and rewarding modes of original achievements. While the creation cycle of works has been shortened, the frequency of updating transactions is accelerating. The traditional business models and information management processes can no longer solve many challenges in original achievements protection. In this article, a blockchain-based service architecture is developed to provide an effective business solution with enhanced security and protection effectiveness.

Original achievements protection mainly focuses on the traceability of the creative rights ownership, the associated transaction process, and the reward distribution. According to the three scenarios and simulation experiments in the proposed method, blockchain technology can provide a secure, transparent, and immutable architecture for original achievements' right confirmation, utilization, and protection. This architecture can provide a new solution for the identification of original achievements, ownership of rights, achievement tracking, award distribution, and reward mechanism.

The introduction of blockchain technology can break the significant operational boundaries, change the traditional mode of achievement protection, and advance the traditional protection management system, which is often constrained by different conditions, such as time and space. Our scheme is designed to promote a traceable, secure, and protected intellectual property ecosystem for both original achievement creators and regulators. Such a design philosophy can be applied to many other industries and provide solutions to strategically important business issues, such as organizational resource integration and database security.

The managers and regulators of original achievements management institutions can apply the proposed blockchain-based achievements protection system as an effective solution to address several current management challenges. Blockchain technology can trace through the different life stages of the original achievements. Starting from the confirmation of the right, every authorization and transaction can be accurately recorded and tracked in a real-time manner. The design of such service architecture not only benefits the creators of original achievements and government regulators but also provides the accurate judicial evidence for all kinds of disputes over original achievements rights.

With the support of the underlying algorithms and smart contracts of blockchain, the rights of original achievements can be strictly protected, and the rewards can be distributed automatically and accurately, which will greatly stimulate the enthusiasm of applying for original achievements and intellectual property, and further enhance the overall research creativity and the vitality of both scientific and practical disciplines. The application of blockchain in the domain of original achievements, patents, and other intellectual property helps to solve the existing problems, such as uneven reward distribution.

The managers and regulators of many other industries can also apply the proposed blockchain-based service architecture to address information storage and management issues. As demonstrated by the proposed design, blockchain consensus mechanisms, hash function algorithms, and smart contracts can facilitate the establishment of a platform for integrated data registration, confirmation, and sharing. Thus, our study can provide new insights into more advanced information system designs for communication management, circulation transactions, infringement monitoring, resources allocation, product distribution, and employees' reward distribution. Multiple business stakeholders—both intraorganizational and interorganizational—can be involved in such information system designs, leveraging the capabilities of shareable yet immutable databases.

V. CONCLUSION

Blockchain technology is fundamentally a consensus mechanism of decentralized trust. Decentralization, nontamperability, time stamping, smart contract mechanism, and other characteristics of the blockchain technology have motivated its widespread adoption in many industries. In this article, we proposed a traceability service architecture to enhance the protection of original achievements. We demonstrated the detailed design of this service architecture with four key layers: data layer, contract layer, logical layer, and application layer. Three scenarios were demonstrated to show how this architecture can enhance the effectiveness of the original achievement protection. These scenarios were represented by three key protection activities: original achievement registration and confirmation, transactions, and rewarding. To better visualize the application procedure of the proposed service architecture, we used two experimental simulations to demonstrate its workflow in detail.

Our proposed service architecture can facilitate original achievements' identification, rights attribution, achievements tracking, revenue distribution, and rewarding. The traditional protection management systems were often constrained by different conditions, such as time and space. The introduction of blockchain technology broke the significant operational boundaries, such as time and storage space. The blockchain-supported traceability architecture can better promote resource integration and reliable information management, thereby opening new avenues for more advanced model development and applications in the related application domains.

Our application of blockchain technology in the traceability architecture for original achievements also had several limitations. First, the completed original achievement information was uploaded to the blockchain and time stamped. While the blockchain itself can prove the results that had been uploaded with an assigned timestamp, it cannot prove that the results were truly original before uploading. Even if there was no similarity between a newly added achievement and the original achievement in the stored chain, it did not guarantee its "ingenuity." Second, the decentralized data storage within the blockchain required high storage capacity and massive resources, which will eventually lead to serious wastes. For example, in the interaction of the transaction information, the hash algorithm consumed a lot of computing power and transaction fees [57]. Finally, all the information in the blockchain will appear in the form of fixed hash function values. Thus, there were concerns about how to properly manage information disclosure and privacy protection for blockchain-supported systems in general.

In addition, with the digitalization of the storage and the transfer of original achievements, it becomes more difficult to determine the ownership relationships. New technologies have also brought challenges to the traditional means. Therefore, the relief mechanism at the legal level has become increasingly important. While the connotation of original works is increasingly rich, the right relief has shown a new positive attitude different from the general civil relief. Right relief must embody the fundamental goals of law—fairness and efficiency. Otherwise, it will deviate from the original intention of encouraging creation and innovation.

While many companies have launched pilot programs using a blockchain technology to manage their strategic planning, supply chain coordination, and financial transactions, no detailed performance data about the technical implementation of such projects have been released. Thus, future studies can further explore the value and potential problems of using a blockchain in various contexts and conduct more comprehensive analyses for model development, validation, and interpretation. Moreover, we only simulated the states of blockchain generation and transaction (smart contract deployment was not simulated). Thus, future investigations are strongly encouraged to find more efficient ways to leverage blockchain to enhance the traceability of original achievements.

Appendix. Algorithms and Simulation Code

Algorithm 1: Reward Distribution of Original Achievements.

```
Pragma solidity ^0.4.4;
Contract EncryptedToken {
  uint start_token = 100 000; //initial fee
  mapping (address = > uint) balances;
  function EncryptedToken() {
    Balances[msg.sender] = start_token;} //Send a
     reward
  function transfer(address_to, uint_amount){
    assert(balances[msg.sender] > = _amount);
    balances[msg.sender] − = _amount;
    Balances[_to] + = _amount;} //Specify an account
     address and transfer
  function balanceof(address_from) constant returns
   (uint) {
    return balances[_from];}
  }
```

Algorithm 2: Block Generation.

```
class YCCGBlock:
  def __init__(self,data,timestamp,prev_hash):
    self.previous_hash=prev_hash
    self.data=data
    self.timestamp=timestamp
  @property
  def hash(self):
    message=hashlib.sha256()
    message.update(str(self.data).encode("utf-8"))
    return message.hexdigest()
def create_genesis_block():
  return YCCGBlock(data="Genesis
      Block",timestamp=datetime.datetime.now(),prev_hash="
      ")
```

Algorithm 3: Blockchain Generation.

```
class YCCGBlockchain:
  def __init__(self):
    self.blocks = [create_genesis_block()]
  def add_block(self,data,timestamp):
    prev_block = self.blocks[len(self.blocks) −1]
new_block = YCCG-
 Block(data,datetime.datetime.now(),prev_block.hash)
    self.blocks.append(new_block)
    return new_block
if __name__ = = '__main__':
  bc = YCCGBlockchain()
…
def change_hash(b):
…
    i f b.previous_hash and b.previous_hash! =
     bc.blocks[i−1].hash:
    …
```

Algorithm 4: POS Mechanism.

```
def pick_winner(announcements):
  time.sleep(10)
  while True:
    with My_Lock:
      temp = temp_blocks
    lottery_pool = [] #
    if temp:
      for block in temp:
        if block["Validator"] not in lottery_pool:
          set_validators = validators
          k = set_validators.get(block["Validator"])
          if k:
            for i in range(k):
              lottery_pool.append(block["Validator"])
    lottery_winner = choice(lottery_pool)
    print(lottery_winner) # add block of winner to
     blockchain and let all the other nodes
              know #
    for block in temp:
      if block["Validator"] = = lottery_winner:
        with My_Lock:
          block_chain.append(block)
        # write message and broadcast.
        msg = "\n{0} Won bookkeeping rights
         \n".format(lottery_winner)
        announcements.put(msg)
          break
    with My_Lock:
      temp_blocks.clear()
```

Algorithm 5 :Get Function.

```
@app.route('/mine', methods = ['GET'])
def mine():
  last_block = blockchain.last_block
  last_proof = last_block['proof']
  proof = blockchain.proof_of_work(last_proof)
  blockchain.new_transaction(sender = '0', recipient =
   node_identifier,
        amount = 1)
  block = blockchain.new_block(proof)
  response = {
      v 'message': "New Block Forged",
      'index': block['index'],
      'transactions': block['transactions'],
      'proof': block['proof'],
      'previous_hash': block['previous_hash'],
  }
  return jsonify(response), 200
```

References

[1] T. U. Daim *et al.*, "Exploring the communication breakdown in global virtual teams," *Int. J. Project Manage.*, vol. 30, no. 2, pp. 199–212, Feb. 2012.

[2] T. Ravichandran and S. I. Giura, "Knowledge transfers in alliances: Exploring the facilitating role of information technology," *Inf. Syst. Res.*, vol. 30, no. 3, pp. 726–744, Aug. 2019.

[3] H. Sadreazami, M. O. Ahmad, and M. N. S. Swamy, "Multiplicative watermark decoder in contourlet domain using the normal inverse Gaussian distribution," *IEEE Trans. Multimed.*, vol. 18, no. 2, pp. 196–207, Feb. 2016.

[4] Y. Cao, J. Fan, and G. Li, "A user-friendly patent search paradigm," *IEEE Trans. Knowl. Data Eng.*, vol. 25, no. 6, pp. 1439–1443, Jun. 2013.

[5] T. Ravichandran, "Exploring the relationships between IT competence, innovation capacity and organizational agility," *J. Strategic Inf. Syst.*, vol. 27, no. 1, pp. 22–42, Mar. 2018.

[6] M. I. Bellgard, "ERDMAS: An exemplar-driven institutional research data management and analysis strategy," *Int. J. Inf. Manage.*, vol. 50, pp. 337–340, Feb. 2020.

[7] T. L. Nguyen, "A framework for five big V's of big data and organizational culture in firms," in *Proc. IEEE Int. Conf. Big Data*, Dec. 2018, pp. 5411–5413.

[8] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system."Accessed on: Jun. 27, 2020. [Online]. Available: www.bitcoin.org.

[9] S. Underwood, "Blockchain beyond bitcoin," *Commun. ACM*, vol. 59, no. 11, pp. 15–17, Nov. 2016.

[10] S. N. G. Gourisetti, M. Mylrea, and H. Patangia, "Evaluation and demonstration of blockchain applicability framework," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1142–1156, Nov. 2020.

[11] R. Yuan, Y.-B. Xia, H.-B. Chen, B.-Y. Zang, and J. Xie, "ShadowEth: Private smart contract on public blockchain," *J. Comput. Sci. Technol.*, vol. 33, no. 3, pp. 542–556, May 2018.

[12] T. Bromfield and H. Barnard, "The evolution of the intellectual property management strategy of an emerging multinational: Learning the purpose of patenting and scientific publications," *IEEE Trans. Eng. Manage.*, vol. 57, no. 1, pp. 118–131, Feb. 2010.

[13] X. Quan and H. Chesbrough, "Hierarchical segmentation of R&D process and intellectual property protection: Evidence from multinational R&D laboratories in China," *IEEE Trans. Eng. Manage.*, vol. 57, no. 1, pp. 9–21, Feb. 2010.

[14] P. Zhu, F. Jia, and J. Zhang, "A copyright protection watermarking algorithm for remote sensing image based on binary image watermark," *Optik*, vol. 124, pp. 4177–4181, 2013.

[15] Z. Chen and J. Zhang, "Types of patents and driving forces behind the patent growth in China," *Econ. Model.*, vol. 80, pp. 294–302, Aug. 2019.

[16] A. C. Marco, J. D. Sarnoff, and C. A. W. deGrazia, "Patent claims and patent scope," *Res. Policy*, vol. 48, no. 9, 2019, Art. no. 103790.

[17] K. S. Jacobsen, "Patents and standardization—Part 1: A tutorial on patents," *IEEE Commun. Mag.*, vol. 54, no. 3, pp. 10–14, Mar. 2016.

[18] N. Figueroa and C. J. Serrano, "Patent trading flows of small and large firms," *Res. Policy*, vol. 48, no. 7, pp. 1601–1616, Sep. 2019.

[19] Q. Lu and X. Xu, "Adaptable blockchain-based systems: A case study for product traceability," *IEEE Softw.*, vol. 34, no. 6, pp. 21–27, Nov./Dec. 2017.

[20] P. Olsen and M. Borit, "How to define traceability," *Trends Food Sci. Technol.*, vol. 29, no. 2, pp. 142–150, Feb. 1, 2013.

[21] D. Lee, "Big data quality assurance through data traceability: A case study of the national standard reference data program of Korea," *IEEE Access*, vol. 7, pp. 36294–36299, 2019.

[22] G. Zhang, T. Li, Y. Li, P. Hui, and D. Jin, "Blockchain-based data sharing system for AI-powered network operations," *J. Commun. Inf. Netw.*, vol. 3, no. 3, pp. 1–8, Sep. 2018.

[23] M. Guerar, A. Merlo, M. Migliardi, F. Palmieri, and L. Verderame, "A fraud-resilient blockchain-based solution for invoice financing," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1086–1098, Nov. 2020.

[24] M. Swan, "Blockchain thinking : The brain as a decentralized autonomous corporation [commentary]," *IEEE Technol. Soc. Mag.*, vol. 34, no. 4, pp. 41–52, Dec. 1, 2015.

[25] P. Zhu, J. Hu, Y. Zhang, and X. Li, "A blockchain based solution for medication anti-counterfeiting and traceability," *IEEE Access*, vol. 8, pp. 184256–184272, 2020.

[26] L. Hughes, Y. K. Dwivedi, S. K. Misra, N. P. Rana, V. Raghavan, and V. Akella, "Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda," *Int. J. Inf. Manage.*, vol. 49, pp. 114–129, Dec. 2019.

[27] J. Mendling *et al.*, "Blockchains for business process management—Challenges and opportunities," *ACM Trans. Manage. Inf. Syst.*, vol. 9, no. 1, pp. 1–16, Feb. 2018.

[28] M. Giancaspro, "Is a 'smart contract' really a smart idea? Insights from a legal perspective," *Comput. Law Secur. Rev.*, vol. 33, no. 6, pp. 825–835, Dec. 2017.

[29] M. Osmanoglu, B. Tugrul, T. Dogantuna, and E. Bostanci, "An effective yield estimation system based on blockchain technology," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1157–1168, Nov. 2020.

[30] J. Pan, J. Wang, A. Hester, I. Alqerm, Y. Liu, and Y. Zhao, "EdgeChain: An edge-IoT framework and prototype based on blockchain and smart contracts," *IEEE Internet Things J.*, vol. 6, no. 3, pp. 4719–4732, Jun. 2019.

[31] Y. Wang, A. Bracciali, T. Li, F. Li, X. Cui, and M. Zhao, "Randomness invalidates criminal smart contracts," *Inf. Sci.*, vol. 477, pp. 291–301, Mar. 2019.

[32] M. Banerjee, J. Lee, and K.-K. R. Choo, "A blockchain future for internet of things security: A position paper," *Digit. Commun. Netw.*, vol. 4, no. 3, pp. 149–160, Aug. 2018.

[33] D. Bumblauskas, A. Mann, B. Dugan, and J. Rittmer, "A blockchain use case in food distribution: Do you know where your food has been?," *Int. J. Inf. Manage.*, vol. 52, 2020, Art. no. 102008.

[34] M. M. Queiroz and S. F. Wamba, "Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA," *Int. J. Inf. Manage.*, vol. 46, pp. 70–82, Jun. 2019.

[35] M. Kouhizadeh, Q. Zhu, and J. Sarkis, "Blockchain and the circular economy: Potential tensions and critical reflections from practice," *Prod. Plan. Control*, vol. 31, no. 11/12, pp. 950–966, Sep. 2020.

[36] S. J. Divey, M. H. Hekimoglu, and T. Ravichandran, "Blockchains in supply chains: Potential research directions," in *Proc. IEEE Technol. Eng. Manage. Conf.*, Atlanta, GA, USA, 2019, pp. 1–6.

[37] M. Du, Q. Chen, J. Xiao, H. Yang, and X. Ma, "Supply chain finance innovation using blockchain," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1045–1058, Nov. 2020.

[38] G. Spinedi, G. Rigotti, L. Canetta, L. G. Camoesa, and C. Redaelli, "Guideline for enterprise to a value plan through blockchain and ICO," in *Proc. IEEE Int. Conf. Eng., Technol. Innov.*, 2019, pp. 1–8.

[39] A. Karamchandani, S. K. Srivastava, and R. K. Srivastava, "Perception-based model for analyzing the impact of enterprise blockchain adoption on SCM in the Indian service industry," *Int. J. Inf. Manage.*, vol. 52, 2020, Art. no. 102019.

[40] I. Eyal, "Blockchain technology: Transforming libertarian cryptocurrency dreams to finance and banking realities," *Computer*, vol. 50, no. 9, pp. 38–49, 2017.

[41] G. Gürkaynak, İ. Yılmaz, B. Yeşilaltay, and B. Bengi, "Intellectual property law and practice in the blockchain realm," *Comput. Law Secur. Rev.*, vol. 34, no. 4, pp. 847–862, 2018.

[42] A. Savelyev, "Copyright in the blockchain era: Promises and challenges," *Comput. Law Secur. Rev.*, vol. 34, no. 3, pp. 550–561, 2018.

[43] Y. Yuan and F.-Y. Wang, "Blockchain and cryptocurrencies: Model, techniques, and applications," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 48, no. 9, pp. 1421–1428, Sep. 2018.

[44] M. Finck and V. Moscon, "Copyright law on blockchains: Between new forms of rights administration and digital rights management 2.0," *Int. Rev. Intellectual Property Competition Law*, vol. 50, no. 1, pp. 77–108, Jan. 2019.

[45] L. Xiao, W. Huang, Y. Xie, W. Xiao, and K.-C. Li, "A blockchain-based traceable IP copyright protection algorithm," *IEEE Access*, vol. 8, pp. 49532–49542, 2020.

[46] N. Jnoub and W. Klas, "Detection of tampered images using blockchain technology," in *Proc. IEEE Int. Conf. Blockchain Cryptocurrency*, May 2019, pp. 70–73.

[47] S. Ahmed and N. Broek, "Blockchain could boost food security," *Nature*, vol. 550, no. 7674, 2017, Art. no. 43.

[48] T. Hardjono, A. Lipton, and A. Pentland, "Toward an interoperability architecture for blockchain autonomous systems," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1298–1309, Nov. 2020.

[49] D. Geneiatakis, Y. Soupionis, G. Steri, I. Kounelis, R. Neisse, and I. Nai-Fovino, "Blockchain performance analysis for supporting cross-border E-government services," *IEEE Trans. Eng. Manage.*, vol. 67, no. 4, pp. 1310–1322, Nov. 2020.

[50] C. Ye, G. Li, H. Cai, Y. Gu, and A. Fukuda, "Analysis of security in blockchain: Case study in 51%-attack detecting," in *Proc. 5th Int. Conf. Dependable Syst. Appl.*, Dec. 2018, pp. 15–24.

[51] H. Watanabe, S. Fujimura, A. Nakadaira, Y. Miyazaki, A. Akutsu, and J. Kishigami, "Blockchain contract: Securing a blockchain applied to smart contracts," in *Proc. IEEE Int. Conf. Consum. Electron.*, 2016, pp. 467–468.

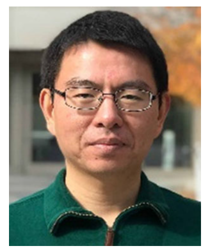
[52] S. Sayeed and H. Marco-Gisbert, "Assessing blockchain consensus and security mechanisms against the 51% attack," *Appl. Sci.*, vol. 9, no. 9, Apr. 2019, Art. no. 1788.

[53] X. Zhang and Y. Yin, "Research on digital copyright management system based on blockchain technology," in *Proc. 3rd Inf. Technol., Netw., Electron. Autom. Control Conf.*, Mar. 2019, pp. 2093–2097.

[54] J.-S. Hwang and H.-G. Kim, "Blockchain-based copyright management system to register creative ideas," *J. Internet Comput. Serv.*, vol. 20, no. 5, pp. 57–65, Oct. 2019.

[55] T. Ishida *et al.*, "Tokenizing and managing the copyrights of digital content on blockchains," in *Proc. IEEE 8th Global Conf. Consum. Electron.*, Oct. 2019, pp. 170–172.

[56] S. Kim *et al.*, "Copyright protection and distribution system for scanned books/comics," in *Proc. Int. Conf. Inf. Netw.*, 2014, pp. 352–355.



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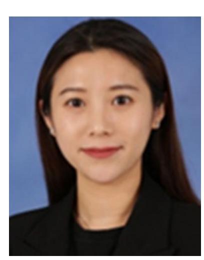

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