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Design of Intellectual Property Service System Based on Renewable Energy Blockchain Technology-Taking Guangxi, China as an Example

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Abstract. In the field of intellectual property protection research, traditional blockchain technology ignores energy efficiency issues and lacks scalability and processing speed, and the existing system cannot meet the local intelligent recommendation needs in Guangxi. This paper combines the characteristics of blockchain technology and renewable energy to design an intellectual property service system suitable for Guangxi. Blockchain technology is used to ensure the security of intellectual property data, prevent data tampering and loss, and smart contracts are used to automatically manage data access and permissions to reduce manual operations. Taking full advantage of Guangxi's abundant renewable energy resources, photovoltaic and wind power generation solutions are adopted, and energy management modules are designed to dynamically adjust energy consumption, reduce energy waste, and improve overall energy utilization efficiency, making it efficient and green. The historical data of Guangxi intellectual property applicants is analyzed, and the BERT (Bidirectional Encoder Representations from Transformers) intelligent algorithm is used to intelligently recommend relevant patent and trademark services to improve service efficiency and user experience. A seamless connection between the Guangxi intellectual property service system and the national intellectual property database is achieved, and a cross-platform data interaction interface is built to support multi-terminal and multi-system collaboration, improving the system's adaptability and expansion capabilities. Experimental results show that the energy efficiency ratio of the proposed system increases from 0.72 to 0.91 under the task volume of 1000 to 8000, showing strong energy efficiency. TPS gradually increases from 150 to 310, and the processing capacity is significantly improved; the average precision and average recall of BERT-based intelligent recommendation in all age groups were 0.80 and 0.83, respectively, which has stronger adaptability and effect in personalized recommendation tasks. The research combines blockchain, renewable energy, and intelligent recommendation systems to improve the security, efficiency, and green sustainability of Guangxi's intellectual property services. It innovatively solves the shortcomings of traditional blockchain in energy efficiency and processing speed and provides an important demonstration for the intelligent and green development of the intellectual property field. It has broad promotion potential and far-reaching impact.

Key words. Renewable Energy, Blockchain Technology, Intellectual Property Service System, Guangxi Region, Bidirectional Encoder Representations from Transformers

1. Introduction

As an important economic and cultural development region in China, Guangxi is gradually promoting the protecting and utilizting intellectual property rights. The existing intellectual property protection system has not yet fully integrated modern technological means, especially combining blockchain and renewable energy [1,2]. Blockchain technology has the characteristics of decentralization and immutability, which can effectively ensure the security and transparency of intellectual property data [3,4]. Guangxi has abundant renewable energy resources. Combining blockchain with energy optimization solutions such as photovoltaics and wind power can improve system performance and reduce energy consumption, providing sustainable support for the intelligent management of intellectual property rights in the region.

First, traditional intellectual property management methods rely on centralized data storage and manual intervention. Xie L studied the inheritance of tea-picking dance in the southeastern region of Guangxi [5], and Guo R studied the protection of digital intellectual property rights in enterprises and explored the issue of patent infringement in depth [6]. These studies have low data processing efficiency and limited ability to process massive amounts of data. In Guangxi, intellectual property protection involves a variety of fields. In emerging industries such as scientific and technological innovation and renewable energy, more efficient management and service systems are needed [7,8]. Traditional technical means have failed to fully meet this demand. When processing large amounts of application information, document storage, and authority management, problems such as information lag and authority confusion are prone to occur [9,10].

Secondly, Guangxi is rich in renewable energy resources, but the existing energy management system lacks targeted optimization solutions. Lyu Z proposed an energy management system based on microservice architecture, which significantly improved the reliability and performance of the system and reduced costs through containerization and horizontal expansion technology [11]. Zhang H optimized the energy management of hydrogen fuel power system through the equivalent hydrogen consumption minimization strategy, reduced hydrogen consumption and extended the service life of batteries and fuel cells [12]. These studies are not applicable to Guangxi's complex energy structure. Most blockchain systems have not yet considered how to effectively combine energy utilization. There is a large amount of energy waste during node operation, which affects the stability and sustainability of the system to some extent [13,14]. The energy efficiency problem of traditional blockchain systems is particularly prominent when processing complex tasks, and it fails to achieve the organic integration of green energy and efficient computing in the region [15,16].

Furthermore, the lack of an intelligent recommendation system makes Guangxi's intellectual property services less efficient in responding to user needs, and it is impossible to provide personalized services based on users' actual needs [17,18]. The existing intellectual property management system lacks a flexible intelligent analysis and recommendation mechanism. Many companies and individuals fail to obtain sufficient professional guidance and accurate recommendations when applying for, searching for, and protecting intellectual property rights [19,20], which reduces the overall service experience and work efficiency. The existence of these problems shows that the existing system is in urgent need of innovation. The combination of blockchain technology and renewable energy can provide new solutions for the efficient protection and service of intellectual property rights.

Aiming at the intelligent recommendation needs of Guangxi, this paper designs an innovative and efficient intellectual property service system, combining blockchain technology with renewable energy to improve the security of intellectual property management and optimize energy utilization efficiency. The system designs a multi-layer blockchain storage structure to ensure the security of intellectual property data and reduce the risks brought by centralized management; the automation mechanism of smart contracts is introduced to achieve automation of data permissions and calls, reducing manual intervention; given the rich renewable energy resources in Guangxi, an energy management module is designed to optimize the energy utilization efficiency of blockchain nodes based on regional energy conditions. With the help of photovoltaic and wind power supply solutions, the node calculation load and energy consumption strategy are dynamically adjusted to solve the energy waste problem of traditional blockchain systems. The design of the intelligent recommendation system is based on the actual needs of Guangxi, combined with the BERT intelligent algorithm, and conducts in-depth analysis of historical data to provide personalized and accurate service recommendations for intellectual property applicants. The system design goal is to improve user experience, use technical means to optimize service efficiency and quality, inject new vitality into Guangxi's intellectual property protection cause, and promote regional technological innovation and industrial development.

2. Related Work

Many scholars have conducted relevant research on the application of blockchain technology in intellectual property protection. Traditional blockchain systems [21,22] are mostly used for information storage and data exchange. When faced with massive intellectual property data, processing speed and data storage issues become bottlenecks restricting their application [23,24]. Regarding the issue of blockchain processing speed, some scholars have proposed an automated permission allocation mechanism combined with smart contracts to reduce manual intervention and improve data processing efficiency [25,26]. Ouyang L proposed a decentralized AI (Artificial Intelligence) collaboration framework that used blockchain and smart contracts to promote distributed AI collaboration and transactions in a trustless environment. This framework can help distributed AI participants complete learning tasks that cannot be achieved by traditional methods [27]. Blockchain technology has also been widely used in the field of energy management. Some studies have pointed out that optimizing the energy consumption of blockchain nodes can significantly improve the system's overall efficiency [28,29]. Xu Y proposed an integrated blockchain and mobile edge computing framework based on spatial structured ledgers, which improved the transaction throughput of IoT applications through collaborative mining and reputation-based proof-of-work mechanisms. The framework can effectively optimize bandwidth and computing resource allocation to achieve throughput improvement [30]. However, existing research generally ignores the combination of blockchain technology and renewable energy and focuses on a single energy optimization solution, failing to consider the diversified energy structure in the region and intelligent recommendations for user needs; existing research still has shortcomings in system efficiency, energy management, and intelligent recommendations.

Some studies have attempted to combine blockchain technology with renewable energy and proposed improved blockchain architectures and energy optimization algorithms [31,32]. Xu Yang proposed a blockchain-based trusted scheduling method to solve the problems of electric vehicle charging and prosumer loads in power systems with high renewable energy penetration. It can optimize the scheduling model and introduce an orderly charging algorithm to achieve power balance, reduce grid shocks, and use blockchain to ensure the transparency and credibility of the scheduling process [33]. These studies have made breakthroughs in the energy efficiency and smart contracts of blockchain technology, which can effectively improve the system's processin speed and scalability. However, the applicability of existing research is still insufficient in view of the characteristics of Guangxi. The energy structure in Guangxi is complex, and the advantages of renewable energy such as photovoltaic and wind power have not been fully utilized. The existing intellectual property service system has a low level of intelligence and cannot accurately and efficiently recommend appropriate intellectual property services to users. This study combines blockchain technology with renewable energy resources to design an innovative intellectual property service system for the diversified energy structure and intelligent recommendation needs in Guangxi, overcoming the bottlenecks of traditional blockchain in terms of processing speed and data storage. Unlike existing research that focuses on a single energy optimization solution, this system dynamically adjusts energy consumption and combines the BERT [34,35] intelligent algorithm for personalized recommendations, improving the applicability and efficiency of the system and fully meeting the local needs of Guangxi.

3. Design of Intellectual Property Service System

Section 3.1 introduces the blockchain-based intellectual property data storage architecture to ensure data security and efficient access. Section 3.2 proposes a renewable energy-driven energy management module to optimize energy consumption. Section 3.3 designs an intelligent recommendation system to provide personalized recommendation services using the BERT algorithm. Section 3.4 discusses the energy scheduling strategy to optimize energy consumption through load forecasting and ensure stable system operation.

A. Design of Intellectual Property Data Storage Architecture Based on Blockchain

This paper designs a multi-layer chain storage structure to store intellectual property-related data in a hierarchical manner in the blockchain to ensure the immutability and traceability of the data, which is conducive to the realization of automated authority allocation and data call by smart contracts [36,37] and reduces manual intervention.

1) Design of Multi-Layer Chain Storage Structure

Based on the intellectual property data storage architecture of blockchain, this paper constructs a multi-layer chain storage structure to realize the hierarchical storage of intellectual property related data. Each layer of blockchain is responsible for data storage and management at different levels. Data can be divided into multiple levels according to its importance and access frequency to ensure the security and traceability of data. High-frequency accessed data and low-frequency accessed data are stored in the main and side chains, respectively.

The research uses the hash chain technology to chain-store the data of each layer. The i layer data storage block is B_i , and each block contains the data of the current layer and the hash value $H\left(B_{i-1}\right)$ pointing to the block of the previous layer; this structure can ensure that data updates occur between different levels. The formula is as follows:

$$H\left(B_i\right)=H\left(\mathrm{Data}_i \| H\left(B_{i-1}\right)\right) \quad (1)$$

Data_i represents the storage data of the i layer, and H is the hash function. This formula ensures the uniqueness and immutability of data at each layer, making it easy to trace; Table 1 shows the data storage hierarchy and its characteristics.

Table 1. Data storage hierarchy and its characteristics.

Layer Number	Data Type	Storage Frequency	Hash Length	Access Permissions
1	High-frequency data	High	256-bit	Open access
2	Medium-frequency data	Medium	256-bit	Restricted access
3	Low-frequency data	Low	512-bit	Admin access

Table 1 shows the data storage layers and their characteristics. The three-layer data storage design is chosen based on a comprehensive consideration of data access frequency and security. The first layer stores high-frequency data, which has a high access frequency and open access. It is suitable for data that is frequently accessed and does not require high security, such as metadata of active patent applications, recent trademark applications, or copyright registration timestamps; the second layer stores medium-frequency data, which is suitable for detailed patent specifications, trademark images, or copyright works themselves, with a medium access frequency, and uses restricted access to ensure a certain degree of security; the third layer stores low-frequency data, which is suitable for archived intellectual property records, historical transaction logs, or rarely accessed legal documents, with low access frequency, long hash length, and strict control using administrator permissions. Different layers use different hash lengths to balance security and performance. Low-frequency data has higher security requirements, and using 512-bit hash can enhance data integrity and prevent collision attacks. High-frequency data is frequently accessed, and using 256-bit hash can increase access speed and save storage space; long hash values enhance the security of low-frequency data, and short hash values optimize the performance of high-frequency data, achieving a balance between security and performance. This three-layer structure balances access efficiency and security, avoids the situation where a single layer is too simple or a multi-layer structure is too complex, can adapt to the processing needs of different types of data, and ensure the best match between application performance and security.

The design of multi-layer chain storage also needs to pay attention to how to improve storage efficiency and access speed through layered storage and cross-chain protocols. The hash-based timestamp mechanism is used to mark the data changes of each block. The data changes at a higher frequency level, and the more stable data is regularly synchronized to the side chain to avoid the problem of excessive congestion in the main chain.

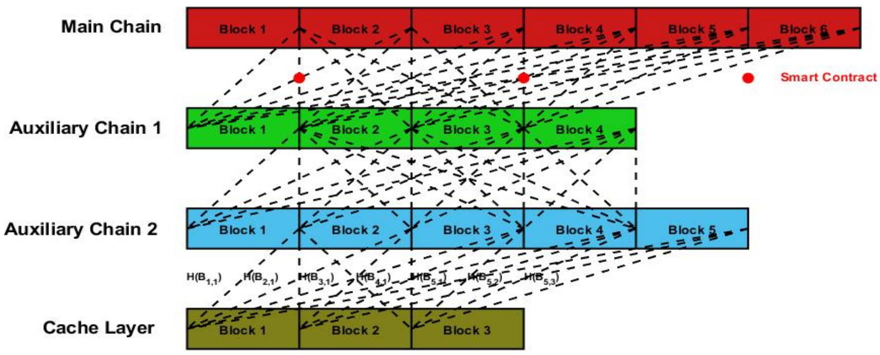

Figure 1. Blockchain storage structure.

Figure 1 shows the intellectual property data storage structure based on blockchain. Different storage layers form a structure through hash connections between blocks. Each block represents a piece of intellectual property data and is connected using hash values. Contract nodes are marked as red dots and are responsible for automatically executing data permission allocation and calls to reduce manual intervention. The storage structure and hash connection ensure the stability and integrity of intellectual property data. The introduction of smart contracts makes permission management and data operations more intelligent and automated. This structure can effectively improve the security, transparency, and efficiency of data storage and processing and meets the application requirements of blockchain technology in the field of intellectual property.

2) Automated Permission Allocation and Data Call Based on Smart Contracts

The paper introduces authority allocation and data calling mechanism to improve the efficiency and automation of intellectual property data storage in blockchain. Using different user identities and operation rights, automated data access authorization and call, reduce manual intervention.

With preset permission rules, only eligible users can access the specified IP data. Assuming that user U needs to access certain intellectual property-related data D, the following formula can be used to define user permissions:

$$P(U,D)=\begin{cases}1 & \text{if } U \text{ has access to } D \\ 0 & \text{if } U \text{ does not have access to } D\end{cases} \quad (2)$$

$P(U,D)$ represents the access rights of user U to the intellectual property data D. This permission is automatically controlled by the smart contract. When a user requests access, the smart contract can determine whether to allow access by verifying their identity and permissions.

Smart contracts use preset functions to achieve efficient calls to data. The request initiated by the user is parsed by the smart contract, which uses the decentralized nature of the blockchain to automatically allocate the corresponding resources, making the data call process seamless and highly secure. Supposing the user needs to call a certain intellectual property data D, the smart contract performs the following operations:

$$Call(U,D)=\text{Invoke}\big(Smart\_Contract, P(U,D), D\big) \quad (3)$$

$Call(U,D)$ represents the call request of user U to data D. The smart contract can check its access rights and execute the data call operation if the rights are allowed.

The introduction of smart contracts makes the storage and call of intellectual property data more efficient and reliable. Automated rights management reduces the occurrence of human errors and improves the entire system's security and operability.

Table 2. Smart contract rights allocation rules.

User Role	Data Type	Access Permission Type	Permission Description	Permission Allocation Logic
Regular User	Patent Data	Read-Only	Can only view patent data	Auto-granted based on user authentication
Advanced User	Patent Data	Edit	Can edit patent data	Dynamically granted based on user identity and historical contribution
Administrator	All Data	Full Access	Full access to all data	Static allocation based on role
Developer	All Data	Read-Only	Can view data	Auto-granted based on developer identity

Table 2 shows the data access rights allocation for different user roles in the smart contract. Each role is granted specific data access rights, and the permission allocation logic is based on different conditions, such as user identity verification, role assignment, or historical contribution. The administrator role has full access rights, while ordinary users are limited to viewing data. The permissions of advanced users and developer roles are dynamically allocated based on user contributions and identity authentication. This permission allocation method helps ensure system's security and efficiency, and avoid unnecessary manual intervention.

B. Integration of Energy Management Modules Driven by Renewable Energy

An energy management module can be constructed, and combined with the characteristics of renewable energy in Guangxi, a blockchain node energy optimization solution can be designed to reduce energy waste. Photovoltaic power generation and wind power supply solutions are introduced, and energy consumption strategies are dynamically adjusted according to node calculation loads.

1) Integration of Photovoltaic and Wind Power Supply Solutions

An energy management module that combines photovoltaic power generation and wind power supply solutions is designed by integrating renewable energy resources in Guangxi. In practical applications, the output power of photovoltaic power generation and wind power generation is time-varying and unstable, and it is necessary to coordinate the output of the two through advanced algorithms to ensure the stability and sustainability of energy supply.

In the system design, the time-varying power of photovoltaic and wind power generation is calculated through the prediction model. Assuming that the photovoltaic power generation is $P_{\mathrm{PV}}(t)$, and the wind power generation is $P_{\mathrm{Wind}}(t)$, the combined power generation of the two can be expressed as:

$$P_{\mathrm{Total}}(t) = P_{\mathrm{PV}}(t) + P_{\mathrm{Wind}}(t) \quad (4)$$

The study adopts a dispatching strategy based on load forecasting and real-time data feedback to balance the supply difference between photovoltaic and wind energy, so that the output of the two energy sources can complement each other in different time periods.

Energy scheduling methods based on prediction and real-time adjustment are used to optimize energy utilization. Combining historical data with real-time power generation data, the optimal scheduling can reduce the waste of excess power under the condition of meeting the load demand. The optimization problem can be expressed by the following formula:

$$\min_{x} \sum_{t=1}^{T} \left(\mathrm{Energy}_{\mathrm{waste}}(t) + \lambda \cdot \mathrm{Energy}_{\mathrm{cost}}(t) \right) \quad (5)$$

$\mathrm{Energy}_{\mathrm{waste}}(t)$ represents the wasted electricity generated at time t; $\mathrm{Energy}_{\mathrm{cost}}(t)$ is the cost of energy supply; λ is the weight factor used to balance the relationship between waste and cost. The proportion of photovoltaic and wind energy can be adjusted dynamically to ensure that energy utilization efficiency is maximized, and energy waste is reduced.

2) Node Load Calculation and Dynamic Adjustment of Energy Consumption Strategy

The dynamic adjustment scheme based on the load calculation of blockchain nodes is adopted to meet the energy consumption management challenge brought by the load fluctuation of each node in Guangxi.

The load of each node can be monitored in real-time, and the energy demand of each node can be dynamically adjusted. The node load calculation takes into account the power demand and the supply of photovoltaic and wind energy. The system can automatically adjust the strategy when the load is too high, giving priority to more stable energy supply sources. It is assumed that at time t, the load of node i is $L_i(t)$. If the load exceeds the threshold $L_{\mathrm{threshold}}$, the following adjustment strategy is adopted:

$$L_i(t) = \begin{cases} L_{\mathrm{threshold}} & \text{if } L_i(t) > L_{\mathrm{threshold}} \\ L_i(t) & \text{otherwise} \end{cases} \quad (6)$$

This strategy can prevent the load of each node from exceeding its maximum tolerance range, avoid excessive consumption or overload, and reduce energy waste.

The system also introduces a load prediction mechanism based on real-time calculation to optimize the energy consumption strategy of each node. This mechanism combines historical load data with the load of the current node to predict the load demand at the next moment and adjust the energy consumption in advance. It is assumed that the predicted load is $L_{\text{pred}}(t+1)$. According to the prediction results, the energy consumption adjustment formula of node i is:

$$E_{\text{adjust}}(t+1) = \eta \cdot \left(L_{\text{pred}}(t+1) - L_i(t)\right) \quad (7)$$

η is the adjustment coefficient, indicating the intensity of adjusting energy consumption according to load forecast. This formula ensures accurate adjustment of energy consumption and improves the system's energy efficiency to a certain extent.

C. Intelligent Intellectual Property Recommendation Service Design

The BERT intelligent algorithm can be used to analyze and model the historical data of intellectual property applicants in Guangxi. It can intelligently recommend relevant intellectual property services such as patents and trademarks based on user needs to improve service efficiency and user experience.

1) User Demand Modeling and Analysis Based on Historical Data

The user's historical data is analyzd to help Guangxi intellectual property applicants get intelligent recommendation services. Through deep learning technology, key information is extraced from the user's behavioral data, such as industry, technical field, and application time, to predict the user's future intellectual property needs.

Text information is converted into digital form, and the self-attention algorithm is used to better understand user needs. User historical data is converted into digital vectors, and a comprehensive demand representation is calculated:

$$X_{\text{user}} = \sum_{i=1}^{n} w_i \cdot X_i \quad (8)$$

w_i is the weight of each historical patent record, and X_i is the feature vector of the corresponding patent record. This method allows user needs to be represented by a global vector through weighted average, which better reveals the user's potential needs.

Deep learning algorithms can be used to model user historical data, which can effectively extract user demand trends and behavior patterns, and provide data support for subsequent recommendation services; this method can significantly improve the personalization of services and ensure the accuracy and efficiency of recommendations.

2) Intelligent Recommendation and Matching of Intellectual Property Services

After completing the modeling of user needs, intelligent algorithms are used to match them with corresponding intellectual property services to achieve intelligent recommendations. Patents, trademarks, copyrights, and other services in the intellectual property service database are encoded and vectorized, and the characteristics of various services are converted into corresponding vector representations, which are then matched with the vectors of user needs to ultimately achieve accurate recommendations.

Each intellectual property service is converted into its vector representation X_{service}^j to achieve accurate matching, and the similarity $\text{Sim}\left(X_{\text{user}}, X_{\text{service}}^j\right)$ between the service and the user demand vector is calculated, using cosine similarity as the metric:

$$\text{Sim}\left(X_{\text{user}}, X_{\text{service}}^j\right) = \frac{X_{\text{user}} \cdot X_{\text{service}}^j}{\left\|X_{\text{user}}\right\| \left\|X_{\text{service}}^j\right\|} \quad (9)$$

X_{user} is the user demand vector, and X_{service}^j is the vector representation of the j-th intellectual property service; the calculation of cosine similarity can effectively reflect the similarity between user demand and each service.

Based on the calculated similarity value, the system can intelligently recommend the intellectual property service that best matches the user demand. The system also introduces a feedback-based online learning mechanism to further improve the recommendation effect. When users select or evaluate recommended services, the system can update the recommendation model based on user feedback to make the recommendation results more accurate; if a recommended service is selected by a user, the system can adjust the weight of the service to give it a higher priority in future recommendations, and vice versa.

The intelligent recommendation system can significantly improve user experience through accurate service matching. The recommendation algorithm and feedback mechanism can be continuously optimized to realize adaptive recommendation services, meet the personalized needs of intellectual property applicants in Guangxi, and improve the efficiency and quality of services.

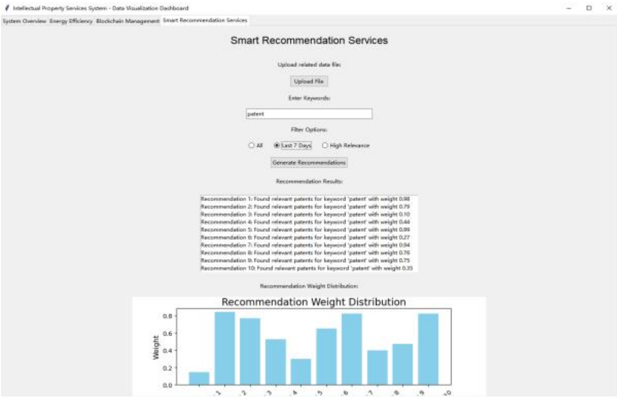

Figure 2. Intelligent Recommendation Service System Interface.

The intelligent recommendation service system in Figure 2 provides an intuitive user interaction platform for displaying and managing recommendation results related to intellectual property rights. The recommendation interface has multiple functional modules such as data upload, keyword input, filtering options, and recommendation generation button. The client can upload relevant files and enter keywords to generate personalized recommendation results. The list of recommendation results can use charts to show the weight distribution of each recommendation to help users understand the priority of the recommendation. The interface also provides an export function, allowing users to save the recommendation results as text files for subsequent viewing and use. The overall interface is simple and fully functional, improving the user's operating experience and the accuracy of recommendations.

D. Cross-Platform Interoperability Design

1) Cross-Platform Data Interaction Interface Design

The cross-platform data interaction interface is used to achieve seamless connection between the intellectual property service system in Guangxi and the national intellectual property database. This interface can support data transmission and coordination between different platforms, allowing information between different systems to be exchanged quickly and accurately.

The design adopts the interface design principle based on RESTful architecture to ensure that all platforms and terminals can communicate through a unified interface standard [38,39]. Each data field remains correct by format conversion and validation of the received request parameters. The request contains a patent application data D_{app}, and the interface can verify the legitimacy of the request and use the following function to ensure data integrity:

$$f_{\text{validate}}\left(D_{\text{app}}\right)=\begin{cases}\text{True}, & \text{if } D_{\text{app}} \text{ is valid}\\ \text{False}, & \text{otherwise}\end{cases} \quad (10)$$

The interface verification process ensures that the received data meets the requirements. The data can be encoded in the standard JSON (JavaScript Object Notation) format and sent to the target platform to achieve cross-platform data transmission.

The research introduces the dynamic data format conversion mechanism to support the collaboration between multiple terminals. For a data field used by different systems, the data format conversion is automatically transformed according to the data conversion rules, so that different terminals can analyze and understand the data content.

2) Enhanced System Collaboration and Expansion Capabilities

A unified data management framework is used here, which enables efficient collaboration between different terminals and systems, supporting real-time data synchronization and sharing between the Guangxi regional intellectual property service system and the national intellectual property database.

The system uses asynchronous communication mechanism and distributed storage technology to achieve efficient collaboration of multiple terminals and multiple systems. Asynchronous communication transmits data through the message queue system, which can ensure timely delivery of data without affecting the main process. The request data is queued and processed through a queue to avoid performance bottlenecks caused by differences in response time of different systems. The data transmission time $T_{\text{trans}}\left(N_i\right)$ can be described by the following formula:

$$T_{\text{trans}}\left(N_i\right)=T_{\text{queue}}\left(N_i\right)+T_{\text{process}}\left(N_i\right) \quad (11)$$

$T_{\text{queue}}\left(N_i\right)$ represents the waiting time of data in the message queue, and $T_{\text{process}}\left(N_i\right)$ represents the processing time of data at the receiving end. This design can effectively reduce the communication delay between nodes and improve the response speed and processing capacity of the system in cross-platform collaboration.

The modular architecture is designed to further improve the scalability of the system, and the system can flexibly integrate new data sources or platforms. The modular design allows different functional modules to be independently deployed and maintained, avoiding the problem of excessive system coupling. Each module has a certain degree of independence and upgradeability. This design allows the system to support the addition of new intellectual property platforms or the update of existing services. Figure 3 shows the distributed data storage and asynchronous communication architecture.

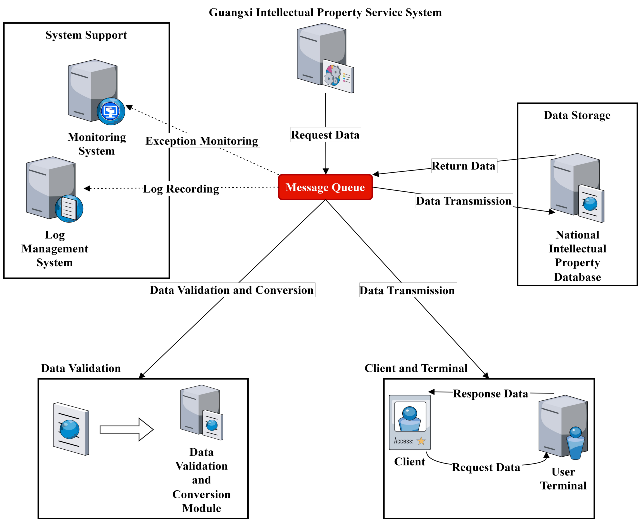

Figure 3. Distributed data storage and asynchronous communication architecture.

The improvement of system collaboration and expansion capabilities ensures the efficient operation of the intellectual property service system in Guangxi and also supports extensive connections with other intellectual property platforms across the country. Using real-time data sharing and dynamic expansion mechanisms, the system can seamlessly collaborate between multiple terminals and platforms to provide stable and reliable services.

4. System Effect Evaluation

In Section 3, the system design involves key components such as blockchain data storage architecture, energy management module, and intelligent recommendation service. Section 4 uses multiple indicators to evaluate the effects of these designs, such as energy efficiency, processing speed, security, and recommendation system accuracy. The energy efficiency evaluation is directly related to the energy optimization solutions such as photovoltaic, wind power supply, and load regulation in Section 3; the data processing speed matches the multi-layer storage architecture of the blockchain and the design of automated authority allocation of smart contracts; the accuracy of the intelligent recommendation system reflects the effect of the recommendation service design based on the BERT algorithm in Section 3. These indicators verify the efficiency, sustainability, and intelligence level of the system design.

A. Dynamic Scheduling and Load Optimization of Renewable Energy, Energy Utilization Efficiency Analysis

Figure 4 intuitively shows the energy scheduling scheme based on photovoltaic power generation and wind power generation and the load demand matching process, revealing the key links in optimizing energy utilization. The peak power of photovoltaic power generation is significant during the day and zero at night, while wind power generation shows a more stable output characteristic. The two form a complementary relationship. In the load demand curve, the peak period is mainly concentrated at noon, when the total power generation can basically meet the demand, showing the system's scheduling effect. Energy waste is mainly concentrated in the peak period of photovoltaic power generation, and the total power generation significantly exceeds the load demand; after the optimization of the dynamic scheduling strategy, the overall energy waste is controlled, indicating that the system allocates energy more accurately. The coordination of load demand and power generation shows that the combination of photovoltaic and wind power supply can achieve effective energy utilization in most time periods, reducing waste while ensuring the stability of power supply. The system has played a significant role in meeting the load demand in Guangxi, reducing energy waste, and improving the utilization rate of renewable energy.

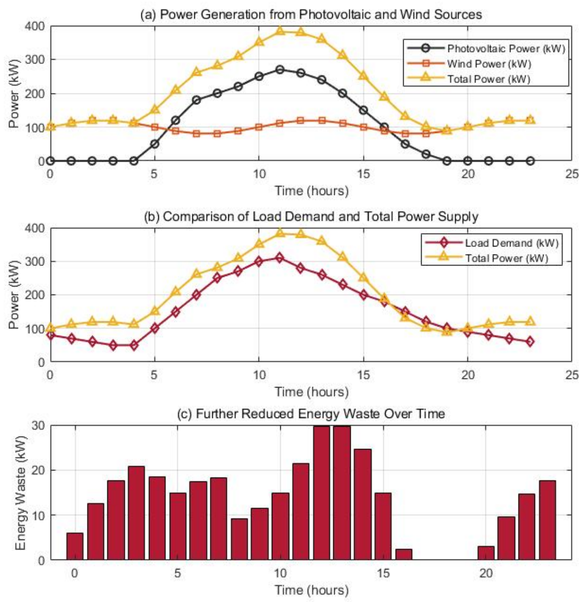

Figure 4. Schematic diagram of dynamic scheduling and load optimization based on renewable energy.

The energy efficiency of the system is evaluated by comparing the energy consumption and processing capacity of the system using the Energy Efficiency Ratio (EER) [40]. The energy consumption data of the system under different loads is recorded in the evaluation, and the ratio of the produced electricity to the total energy consumption is calculated. The results are compared with the energy efficiency of traditional Ethereum and Hyperledger blockchain technologies under the same conditions. The energy efficiency ratio is calculated based on the system's energy consumption and processing speed when performing blockchain operations, evaluating the energy consumption efficiency of each system when providing the same service. This evaluation helps determine the energy utilization advantages or disadvantages of the proposed system compared with traditional blockchain technology and further guides the formulation of energy optimization solutions.

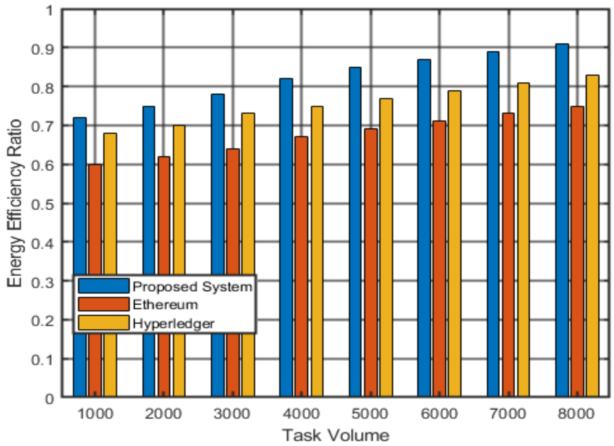

Figure 5. Energy efficiency ratio values under different systems.

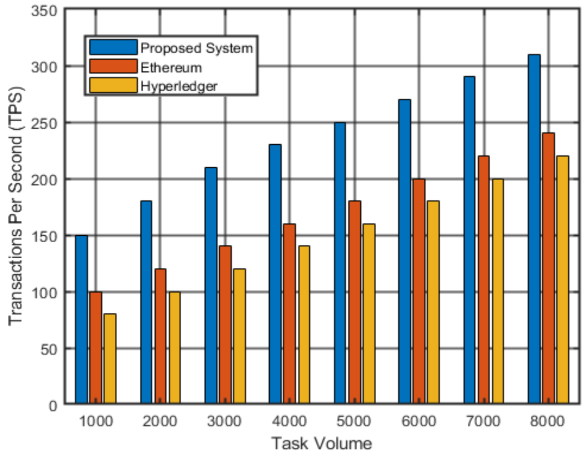

Figure 6. Comparison of TPS of different systems.

Figure 5 shows the energy efficiency ratio comparison of the proposed system, Ethereum, and Hyperledger under different task volumes. The task volume ranges from 1000 to 8000. The energy efficiency ratio shows the energy utilization efficiency of each system under different task volumes.

The energy efficiency ratios of the three systems have all increased. The energy efficiency ratio of the proposed system increases from 0.72 to 0.91, showing a strong improvement in energy efficiency and demonstrating significant advantages under high workloads. The energy efficiency ratios of Ethereum and Hyperledger show a relatively stable improvement, indicating that their energy efficiency management when processing large-load tasks has certain limitations, and the energy optimization effect under high workloads is relatively limited. These changes indicate that the proposed system has higher energy efficiency when processing large-scale tasks and can better cope with the challenges when the task volume increases. The energy efficiency improvement of Ethereum and Hyperledger under high load is relatively slow, and there is room for optimization.

B. *Data Processing Speed*

The data processing speed of the evaluation system uses transactions per second (TPS) as the key performance indicator. The evaluation simulates transaction processing under different load conditions, records the number of transactions that the system can process per unit time, and compares and analyzes the results with the TPS of the traditional intellectual property blockchain system under the same test environment. All systems are measured under the same network conditions and hardware environment, and the TPS values of different systems when executing the same number of transactions are compared to evaluate the processing performance of the system and determine its response speed and efficiency in actual applications. This process provides a quantitative basis for further optimizing the data processing process and improving the system throughput.

Figure 6 compares the TPS of three systems under different task loads. The TPS of the proposed system gradually increases from 150 to 310. As the task load increases, the system shows a more obvious improvement in processing power and performs better under high task loads. Ethereum's TPS increases from 100 to 240, a large increase, but it is still lower than the proposed system; Hyperledger's TPS increases from 80 to 220, and its overall performance is relatively low. The TPS of the three systems has all improved, and the proposed system has shown stronger performance when processing larger tasks, which is better than Ethereum and Hyperledger. Under large task volumes, the proposed system can handle transactions more efficiently and has certain advantages; these changes reflect the system's adaptability and processing efficiency under different load conditions.

C. *Accuracy of Intelligent Recommendation System*

When evaluating the accuracy of the BERT-based intelligent recommendation system, the precision and recall rate indicators are used for comprehensive evaluation. During the evaluation process, the user's historical data is first tested in the intellectual property service scenario to calculate the degree of match between the recommendations given by the recommendation system and the user's actual needs. Precision measures the proportion of correct items in the recommendation results, while recall focuses on whether the system can cover the breadth of users' potential needs. To ensure the objectivity and comprehensiveness of the evaluation, the system's performance can be compared with the traditional collaborative filtering algorithm to analyze its advantages in personalized service recommendations. By comparing the precision and recall of the two recommendation methods on the same data set, it is evaluated whether the BERT-based intelligent recommendation system can provide more accurate and targeted intellectual property services.

Figure 7 compares the precision and recall rate of BERT algorithm and collaborative filtering algorithm among users of different age groups. The horizontal axis represents six different age groups. BERT algorithm is generally better than collaborative filtering in terms of precision. The average precision of BERT is about 0.80. BERT also outperforms collaborative filtering in terms of recall, with an average of 0.83. The BERT algorithm outperforms the collaborative filtering algorithm in both precision and recall, showing that the BERT algorithm has stronger adaptability and effect in personalized recommendation tasks.

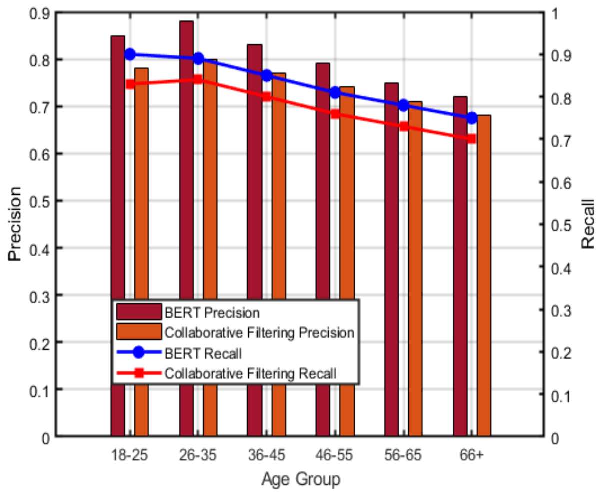

Figure 7. Comparison between BERT algorithm and collaborative filtering algorithm.

5. Conclusions

This study focuses on the innovative design of the intellectual property service system and proposes a comprehensive solution that combines blockchain technology and renewable energy. The solution performs well in improving energy efficiency and optimizing recommendation accuracy. The multi-layer chain storage structure based on blockchain ensures the immutability and traceability of intellectual property data and uses smart contracts to achieve automation of rights management and data calls, greatly reducing manual intervention. The system combines photovoltaic and wind power supply solutions in energy management, dynamically adjusts energy consumption strategies, reduces energy waste, and improves the overall system's energy efficiency. The BERT model successfully improves the accuracy and recall rate of the recommendation system in intelligent recommendation. Compared with traditional collaborative filtering algorithms, it has higher personalized recommendation capabilities and meets the diverse needs of users; the construction of a cross-platform data interaction interface has achieved seamless connection between the Guangxi region and the national intellectual property database, ensuring data sharing and collaborative work.

The system performs well in various indicators, verifying its potential in improving the efficiency of intellectual property services, ensuring data security and realizing intelligent management. In the future, the application of this system can be more extensive, and its adaptability and influence in multiple fields can be further enhanced.

Consent to Publish

The manuscript has not been published before, and it is not being reviewed by any other journal. The authors have all approved the content of the paper.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon request.

Conflicts of Interest

The authors affirm that they do not have any financial conflicts of interest.

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