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RESEARCH ARTICLE

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Data sharing mechanism of various mineral resources based on blockchain

Abstract Basins with various mineral resources coexisting and enriching often occupy an important strategic position. The exploration of various mineral resources is repetitive at present due to unshared data and imperfect management mechanism. This situation greatly increases the cost of energy exploitation in the country. Traditional data-sharing mode has several disadvantages, such as high cost, difficulty in confirming the right of data, and lack of incentive mechanism, which make achieving real data sharing difficult. In this paper, we propose a data-sharing mechanism based on blockchain and provide implementation suggestions and technical key points. Compared with traditional data-sharing methods, the proposed data-sharing mechanism can realize data sharing, ensure data quality, and protect intellectual property. Moreover, key points in the construction are stated in the case study section to verify the feasibility of the data-sharing system based on blockchain proposed in this paper.

Keywords data sharing, blockchain, various mineral resources, collaborative exploration, big data

1 Introduction

The coexistence of various mineral resources is common. Instances of mineral resources coexisting in over 30 major sedimentary basins have been found worldwide. For example, coal gas, uranium, and oil coexist in the Western Siberian Basin of Russia; uranium, oil, and gas coexist in the Fergana Basin of Kazakhstan; and coal, oil, gas, and uranium coexist in the Karakum Basin of Turkmenistan.

Basins with various mineral resources often occupy an important strategic position. In China, the Ordos Basin, with a total area of 20×10^4 km^2, contains many kinds of mineral resources. Its reserves such as coal, oil, natural gas, coal-bed methane, shale gas, uranium, and salt, all rank top in China, and it also contains bauxite, clay, limonite, geothermal and other resources. All in all, the Ordos Basin is an important energy and mineral resource enrichment area and supply base in China.

The mechanism of symbiosis and interaction among various mineral resources is very complex. Moreover, the exploration of different mineral resources is carried out by different departments. The relationship among mineral rights is complex, and exploration methods have certain similarities and repeatability. This situation has greatly affected the construction and coordinated development of the national energy base. The key to realizing collaborative exploration among different mineral resources is data sharing. Data are the bases of mineral resource exploration. Data among different mineral resources are repetitive and similar, enabling data sharing among different mineral resources. However, the traditional data sharing model has the following disadvantages:

- The right of data is difficult to confirm. In data sharing, four main bodies are involved: Data owner, data manager, data user, and data supervisor. The final solution is the “four rights” coordination of data ownership right, data management right, data use right, and data supervision right. However, in the traditional data-sharing process, clarifying the ownership is difficult.
- The value of data is difficult to estimate. In traditional data sharing, evaluating the value of data is difficult, which makes establishing an effective incentive mechanism for data sharing challenging. Moreover, data parties cannot generate the willingness and motivation to share data.
- The cost of data processing is high. In the traditional data-sharing model, complex data cleaning, standardized processing, data copy storage, and other complex processes are needed after collecting a large amount of heterogeneous data, resulting in additional costs.
- The initiative of data sharing is not strong. The fixed way of thinking and the concept of privatization still

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occupy the dominant position. In the opinion of most people, once the data are shared, the data assets will no longer be owned by themselves.

• Data validity cannot be guaranteed. Data transmission entails an additional transit, which increases the risk of data transmission and makes ensuring the effectiveness and accuracy of data difficult.

Therefore, how to overcome these problems in traditional data sharing is the key to realizing the collaborative research of multiple mineral resources. In this paper, we comb and study the data status and exploration methods of different mineral resources. On this basis, we put forward a data-sharing mechanism based on blockchain. Compared with the traditional data-sharing model, this mechanism has the advantages of low cost, clear data rights and responsibilities, high initiative of data sharing, and good data quality control. This work helps improve the efficiency of energy exploration in China. The main contributions of this paper are as follows:

• The idea of data sharing among various mineral resources is put forward, which guarantees collaborative exploration.

• A data sharing, data quality control, and intellectual property protection management mechanism based on blockchain is proposed. It can realize the separation of four rights of data by technical means and solve the core problem of trust in data sharing.

• The key points and precautions of the data-sharing mechanism based on blockchain are provided as references for the implementation in a later stage.

2 Related works

Previous studies mainly focused on the mechanism of symbiosis and enrichment of various mineral resources. Many local and international scholars believe that certain interactions and relatively close internal relations in the accumulation of various resources exist in the basins where oil, gas, and other mineral resources coexist (Dai et al., 2005; Liu et al., 2006; Shi and Zheng, 2007; Wang et al., 2017; Fabre et al., 2020). This situation enables theoretically exploring mineral resources in a unified manner.

Taking the Ordos Basin as an example, Zhao et al. (2006) analyzed the enrichment characteristics of oil, gas, coal, and uranium in the Ordos Basin, and studied their coexistence characteristics and relationship. Li et al. (2011) explained the connotation of "exploration in coordination" and expounded its concept among various mineral resources. Wang et al. (2014) discussed the accumulation system and distribution law for various energy minerals which coexist and enrich in the same basin, and tried to establish a cooperative exploration model.

Several researchers focused on different models and systems of collaborative exploration among mineral resources. Combined with the exploration practice and theoretical achievements in recent years, Zhou (2017) analyzed the spatial and temporal distribution, orderly accumulation characteristics, and collaborative exploration technology mode of energy minerals in the basin. He proposed a multi-mineral collaborative exploration system with oil and gas as the main body, and discussed its framework and meaning. Bai et al. (2016) established three kinds of collaborative models: oil–gas–coal–salt, oil–coal, and uranium–oil–gas–coal, and developed a corresponding exploration method according to the three models. Practice has proven that the collaborative exploration theory is realistic. Based on the principle of maximizing economic benefits and optimizing exploration methods, Yang et al. (2010) established a collaborative exploration model of multi-energy minerals in the Ordos Basin, which divided the basin into seven collaborative exploration areas. Based on the collaborative exploration mode, corresponding collaborative exploration methods were developed for different exploration areas, which laid a theoretical foundation for the implementation of multi-energy mineral collaborative exploration.

Some progresses have been made in the study of symbiosis mechanism and cooperative exploration mode of various mineral resources. However, few papers focused on data sharing and data quality control, which guarantee realizing the collaborative exploration among different mineral resources.

In recent years, with the continuous development of blockchain technology, it has shown unique advantages in multi-part cooperation (Dwivedi et al., 2020; Narayan and Tidstrom, 2020; Wang et al., 2020a; Wang and Su, 2020). In the medical field, Xia et al. (2017) proposed the MeDShare (Medical Data Sharing), a system that addresses the issue of medical data sharing among medical big data custodians in a trust-less environment. The blockchain-based system provides data provenance, auditing, and control for shared medical data in cloud repositories among big data entities. In intelligent transportation, Kang et al. (2019) proposed a reputation-based data-sharing scheme to ensure high-quality data sharing among vehicles and achieve secure data storage and sharing in vehicular edge networks. Furthermore, Yu et al. (2019) raised a data-sharing model for Internet of Things based on blockchain. This model can establish trust without any centralized organization to address the problem that the traditional data-sharing model is likely to cause a single point of failure and is not transparent to participants.

In conclusion, in terms of collaborative exploration of various mineral resources, the existing research mainly focuses on the symbiotic enrichment mechanism. Only a few papers elaborate the mechanism of collaborative exploration management, but they are all about the workflow of collaborative exploration of various mineral resources and do not involve the problem of data sharing. Data sharing is the basis of collaborative exploration of various mineral resources. Therefore, establishing a scientific, effective data-sharing mechanism among various mineral resources is very important.

3 Collaborative exploration and management of various mineral resources: Problems and challenges

3.1 Problems in collaborative exploration of various mineral resources

In general, several urgent problems must be solved in the coordinated development of various mineral resources in enrichment basins where various mineral resources coexist.

(1) Repeated exploration

Exploration technologies of different mineral resources have not been systematically combed due to the lack of effective communication and coordination mechanisms, unshared data, and other reasons. At present, repeated exploration is observed among different mineral resources, and collaborative exploration has not been realized. This situation greatly increases the cost of national energy exploitation.

(2) Isolated data island

Different mineral departments have carried out numerous geological surveys, general surveys, and exploration of mineral resources. They have accumulated much geophysical exploration data and geological survey data such as artificial earthquake, gravity, aeromagnetic, electrical sounding, and geoelectric current. For example, preliminary statistics show that there are over 9000 oil and gas exploration and development wells in Inner Mongolia of the Ordos Basin. These extremely valuable materials remain scattered in different departments and are kept separately due to various reasons. No data-sharing mechanism is available, and the materials are far from being well developed and utilized.

(3) Poor intelligent analysis

In recent years, the technology of big data and artificial intelligence has set off a wave. It has also emerged in mineral resource exploration (Hatampour et al., 2018; Chen et al., 2019; Li et al., 2019). Since the reform and opening-up of China, a large amount of geological exploration data has been accumulated for different mineral resources, such as coal, oil, natural gas, shale gas, and uranium, which provides a good platform for big data and artificial intelligence applications. However, limited by unshared data and other reasons, the current information levels of resource geological exploration and intelligent analysis of geological exploration data are relatively low.

(4) Imperfect cooperative research management mechanism

As an example, many departments and institutions of geological exploration, exploration of oil and gas, coal, and nonferrous metals, chemical industry, and nuclear industry have carried out numerous geological surveys, mineral resource surveys, and exploration works in the Ordos Basin since the reform and opening-up. However, researchers in different departments are not clear about the exploration technology and data types of each other due to the lack of communication and sharing mechanism among different departments, resulting in repeated investment and research.

The root cause of these problems is that the data of various mineral resources are not shared. Therefore, a mechanism for collaborative research and management must be urgently established to reduce the cost of national investment in energy exploration.

3.2 Data status analysis of various mineral resources

Different minerals have certain commonness and differences in exploration. Exploration of solid minerals such as coal, sandstone-type uranium, and salt rock mainly depend on the means of drilling and coring (Ataei et al., 2015; Zhai et al., 2018; Ni et al., 2020; Wang et al., 2020c). Mineral evaluation is carried out with the help of geophysical logging. However, oil and natural gas exist in the form of gas liquid state, and drilling (not cored or partially cored) is the main method in the exploration, which depends on geophysical logging resource evaluation (Yang et al., 2011; Chen and Linn, 2017). Table 1 summarizes the exploration methods for different types of mineral and shows that several exploration methods are common among various mineral resources.

Data of different mineral resources have commonness due to the similarity and repeatability of exploration methods. Taking oil and gas resources as an example, geological data of oil and gas mainly include first-hand data such as seismic data, logging curve, drill cuttings, core, and rock physics, as well as interpretation result data such as seismic interpretation data, logging interpretation results, and reservoir parameters.

In mining, various mineral departments have accumulated massive geological data and established a relatively complete data collection and storage system. For example, PetroChina has accumulated a large amount of exploration and development data, which are stored in the group company's unified construction system (A1, A2, and A5) and the self-built systems of each unit as well as in the hands of researchers. These data are large in volume and rich in types, which provide a basic guarantee for data sharing between different minerals.

3.3 Defects of traditional data-sharing mode

At present, no data sharing exists among various mineral resources. People gradually realize the value of data assets with the continuous accumulation of industry data, and

Table 1 Exploration methods of different mineral resources

Mineral type	Exploration methods				
	High-resolution remote sensing	Comprehensive logging	Geochemical exploration	High-resolution seismic	Magnetoelectric earthquake
Colliery				•	
Metallic mine	•		•		•
Uranium mine	•				
Saline-alkali mine		•			
Geotherm		•	•	•	
Oil gas	•	•	•	•	•
Carbon dioxide	•	•	•	•	•

almost all energy departments have proposed the development concept of "sharing". For example, PetroChina put forward the development goal of "Sharing PetroChina" and started the construction of the "E&P Cloud". However, these are all data sharing of a single mineral resource and a single energy department. No coordinated exploration of different minerals and different departments exists. Moreover, the previous data-sharing system is often dependent on the construction of a big data platform, which entails a high cost and many problems in data quality control.

Figure 1 shows that relying on the construction of the data center, the energy department collects and collates energy data (including exploration data, production data, enterprise resource planning (ERP) data, and sales data) to realize data sharing among internal units (Wang et al., 2020b; Xuan et al., 2020; Zhang et al., 2020a; 2020b). At present, many institutions or enterprises carry out data sharing business, but the data sharing industry has many problems. In summary, the traditional data-sharing process has the following disadvantages:

- Data leakage;
- Easily tampered with;
- High cost;
- Unclear data ownership;
- Lack of relevant standards and specifications.

All these problems restrict the development of data sharing. Blockchain technology must be combined with data sharing, which can effectively solve these problems, to benefit from the characteristics of blockchain, such as distributed storage and tamper prevention. Figure 2 shows that data governance focuses on solving the problem of "isolated data island", and the way is changing from centralized data-sharing modes to distributed and decentralized modes.

3.4 Application of blockchain technology in data sharing

Blockchain is a distributed shared database based on cryptography. Its essence is to maintain a reliable database collectively through decentralization and distrust. At present, the function of blockchain is mainly to solve the actual complex business scenarios through characteristics of distributed ledgers, non-tampering, and other technologies, e.g., smart contracts. Key issues of data circulation, such as authorization, certificate keeping, and data traceability, can be improved through blockchain technology, and new trading means such as smart contracts can be realized (Lin and Liao, 2017; Zheng et al., 2018).

Figure 3(a) shows that the transaction is not effectively controlled and audited, and the authenticity of authorization cannot be verified in real time in the traditional mode. Figure 3(b) shows the complete authorization in the

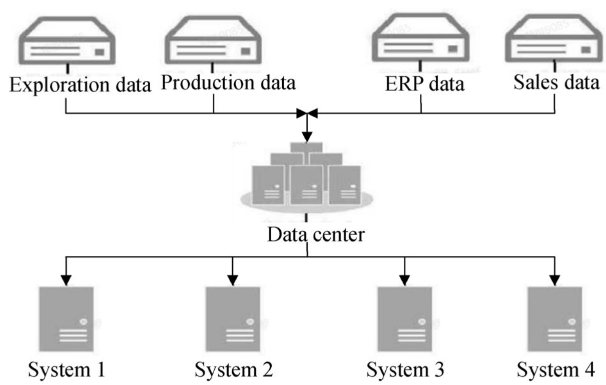


Fig. 1 Flow diagram of traditional data-sharing system.

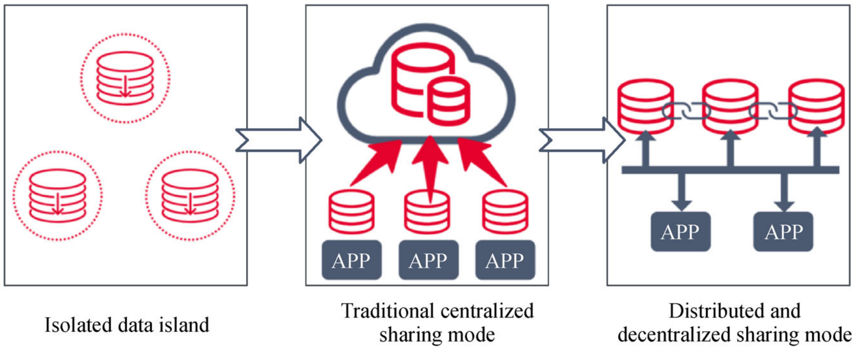


Fig. 2 Distributed and decentralized data governance becomes the future direction.

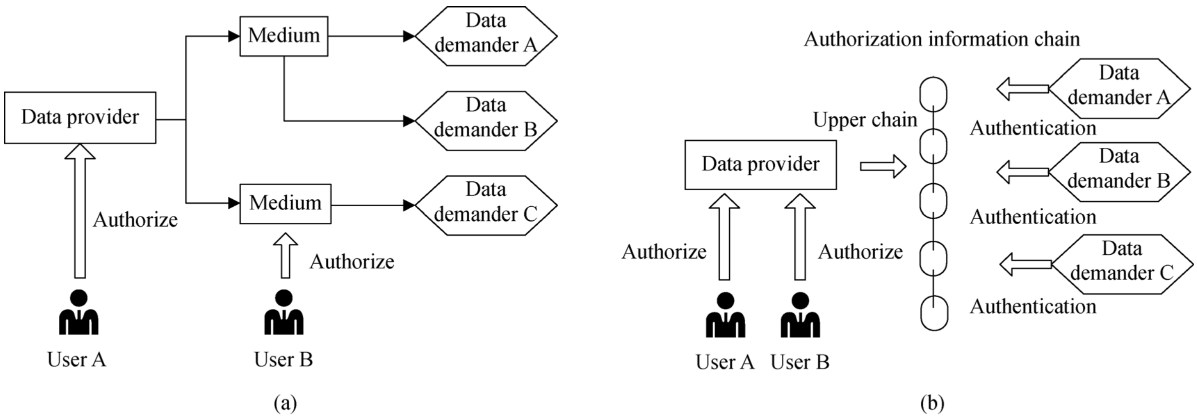


Fig. 3 Authorized storage of user data transaction in (a) traditional and (b) blockchain mode, respectively.

blockchain mode. The user signs the electronic agreement and authorizes the corresponding authority to the data provider. The data provider first stores the credentials locally through the application system and then uploads the authorization information to the authorization information chain. The application system executes the code on the chain, initiates the query on the chain, and records the authorization information to the block. When the data demander submits the data requirements, it initiates an authentication transaction on the chain to confirm whether the user is authorized. Next, the authentication node on the chain returns the authorization information and the corresponding data.

The blockchain mode avoids the defects of the traditional mode. Any node can record authorization information and cannot be changed. Multiple parties can share authorization records in real time, and the query efficiency is high. Multiple computing nodes in the blockchain network participate in data computing and recording, and verify the effectiveness of their information to provide information anti-counterfeiting and traceability path. Transaction information of each block constitutes a complete transaction detail list, which cannot be tampered with, to record the context of each transaction through the information chain. Data sharing based on blockchain shows great application potential (Dwivedi et al., 2020; Dagher et al., 2018; Zhang et al., 2019). Thus, studying how to use blockchain technology to realize data sharing and collaborative research among various mineral resources is of great significance.

4 Data-sharing mechanism based on blockchain

Big data management and application of mineral resources becomes increasingly critical with the deployment and implementation of the national big data strategy. At present, technical barriers and thinking difficulties remain in data exchange, data opening, data maintenance, and many other aspects for the collaborative exploration management and application of various mineral resources. When faced with multi-part data and business collaboration, researchers are often unable to do their best. Therefore, the establishment of a credible, transparent, and traceable data exchange and business collaboration system has become the key to the collaborative exploration management of various mineral resources.

4.1 The architecture of blockchain system

As the underlying technology architecture of digital currency, blockchain technology has been a wide concern in current scientific and industrial circles. Its core is decentralization. Decentralized point-to-point transaction, coordination, and cooperation can be realized without the trust of peer-to-peer (P2P) nodes through the use of data encryption, timestamp, distributed consensus, and other means. Thus, the problems of high cost, low efficiency, and insecure data storage of the centralized system are solved.

The data-sharing mechanism of various mineral resources based on blockchain realizes data sharing by establishing an industrial alliance chain among different mineral departments. This model can realize data traceability and anti-tampering, ensure data quality while sharing data, share research results, and protect intellectual property rights. We formulate the data-sharing mechanism by using the blockchain technology among untrusted parties for data security and protection. Figure 4 displays the architecture of the blockchain system.

We build a data-sharing mechanism of various mineral resources based on the industrial alliance blockchain. Figure 5 shows that the mechanism consists of three parties: Owner, executor, and user. The owner refers to the individual or institution with all management rights of mineral resource data. The user refers to the researcher, research institution, company, or project team who needs mineral data. The executor refers to the decentralized data-sharing platform, which can provide computers, central servers, or cloud servers for remote data access to provide trusted execution environment for data exchange between data owners and users.

In this mechanism, each subject has a clear role boundary. The data owner is the starting point of the information flow, and the data user has no right to obtain the source data. Finally, both parties share and interact with each other on the platform of the executor in a credible, transparent, and equal manner.

This mechanism maintains the normal operation of the ecosystem model and ensures the reliability of the information through the incentive mechanism such as blockchain mining. Moreover, poor and false data are exposed in the chain, which helps create a good data-sharing ecological environment. The main features of this sharing model are as follows:

- Mineral resource data on the chain are stored in a unified format, which is convenient for multi-part sharing.
- Point-to-point distributed storage can realize data sharing on different nodes. Information disclosed by a node in the chain can be viewed by other nodes (or nodes with permission).
- Consensus rules of the blockchain are jointly decided by alliance members. Data on the alliance chain are

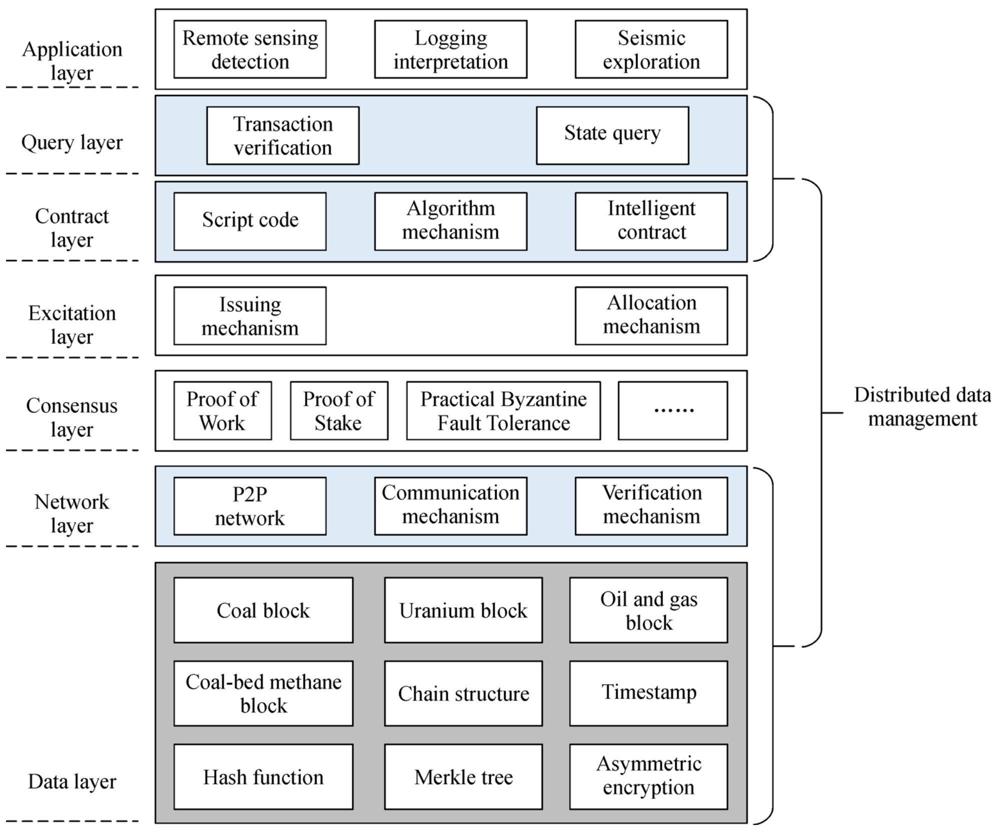


Fig. 4 Blockchain system architecture.

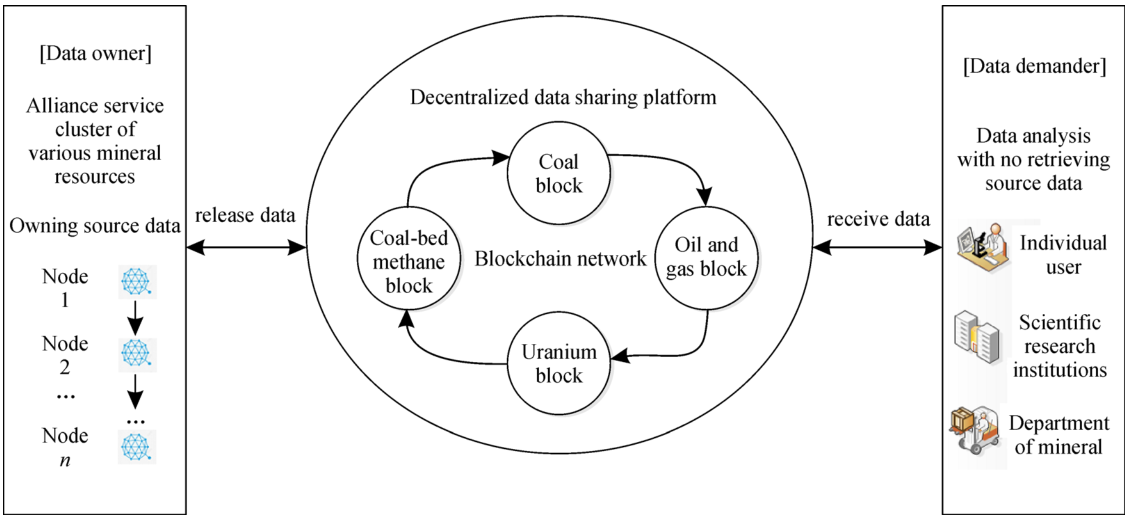


Fig. 5 Data-sharing model based on blockchain for various mineral resources.

conditionally open. One of the most substantial characteristics is that each node corresponds to an entity. Any entity node that wants to join the alliance chain needs the permission of the alliance. Nodes authorized to join the blockchain use the same structure to store data and can access the data in the nodes simultaneously.

4.2 Quality control mechanism based on blockchain

The blockchain system adopts the transaction mode based on asymmetric encryption to realize anonymous transactions in terms of security, and it mainly provides users with data tampering verification, data traceability, and encryption security mechanisms to solve the privacy security problem of shared data.

The industrial alliance blockchain organizes the mineral resource data into blocks and the blocks into a chain structure by recording the hash value. This structure makes the data storage of the blockchain difficult to tamper with, as well as traceable and verifiable.

Figure 6 shows that the data-sharing model can realize credible data exchange among different mineral departments and ensure that the data of all parties are tamper-resistant, controlled, and safe by establishing a full data index.

4.3 Intellectual property protection mechanism based on blockchain

The features of blockchain, such as decentralization, anti-tampering, and instantaneous recording, provide technical feasibility for digital copyright protection. Each data block is concatenated with a hash algorithm to ensure that the block data cannot be tampered with. The block data are arranged in timestamp order in the chain, which lays the foundation for the authentication problem in copyright disputes. Blockchain has multiple account blocks, and characteristics of consensus accounting further strengthen the credibility of blockchain, making it an important means of digital copyright protection. Figure 7 shows the intellectual property protection process.

4.4 Key points in the implementation of data sharing

Based on the application experience of digital asset management and industry characteristics of various mineral resource data, the key problems to be solved in the implementation of a data-sharing platform include confirmation and storage of data property rights, unique identification of data assets, and the smart contract in property right transaction.

(1) Confirmation and storage of data property rights

The confirmation and verification is the key link in the blockchain system and is the core step of intellectual property protection for various mineral resource data. Taking mineral resource data as an example, the data and its related information are stored in a block in a specific encoding after the data owner uploads it to the original blockchain system. The system can confirm the data right by comparing them with the data in the previous blockchain. After the right is confirmed, the block is stamped with a corresponding timestamp, encrypted according to the characteristics of data and information, and abstracted into an abbreviated version of copyright information.

The system generates the copyright certificate according to certain rules and forms the link in a chronological order according to the generation and update of information. Timestamps saved in the blockchain can be seen by all participants in the entire network. This timestamp proves that someone has access to a particular file at a particular time. The owner of the mineral data are usually the first

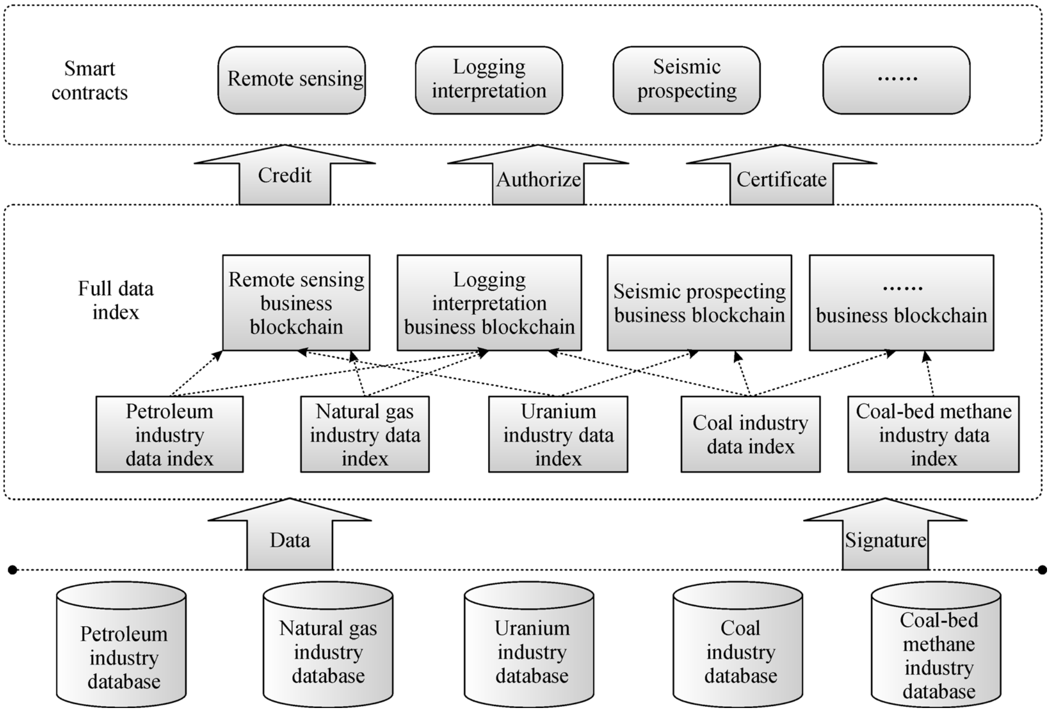


Fig. 6 Quality control mechanism based on blockchain.

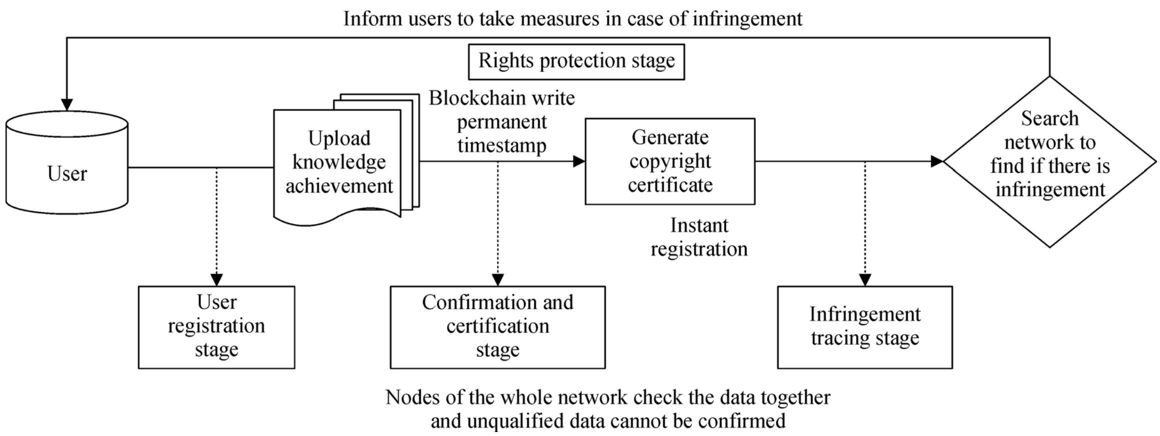


Fig. 7 Intellectual property protection mechanism based on blockchain.

person to access the file; thus, the author's identity can be proven. After authentication, the system immediately generates the authentication certificate and synchronizes the entire network. Figure 8 shows the entire process. Then, every access and modification of this data is recorded by the system and updated synchronously in each node of the network.

(2) Unique identification of data assets

Obtaining various mineral resource data is very difficult and costly, and the mixing, variability, and correlation among data vary with time, space, and basin. Data of mineral investigation results in the same area often vary due to different exploration means, exploration time, and exploration scale. Moreover, data may come from various links in the entire process, such as field exploration, internal data processing and analysis, unit business management, result collection, and archiving. The result data often have the value of deep research and mining. Therefore, compared with common digital assets, various mineral resource data have the characteristics of large quantity, complex content, numerous systems, and strong derivatives.

The blockchain system hashes and records any access, change, and other operation of the data on the chain. This approach has resulted in not only the integrity of process records but also the multiple-record versions of the same

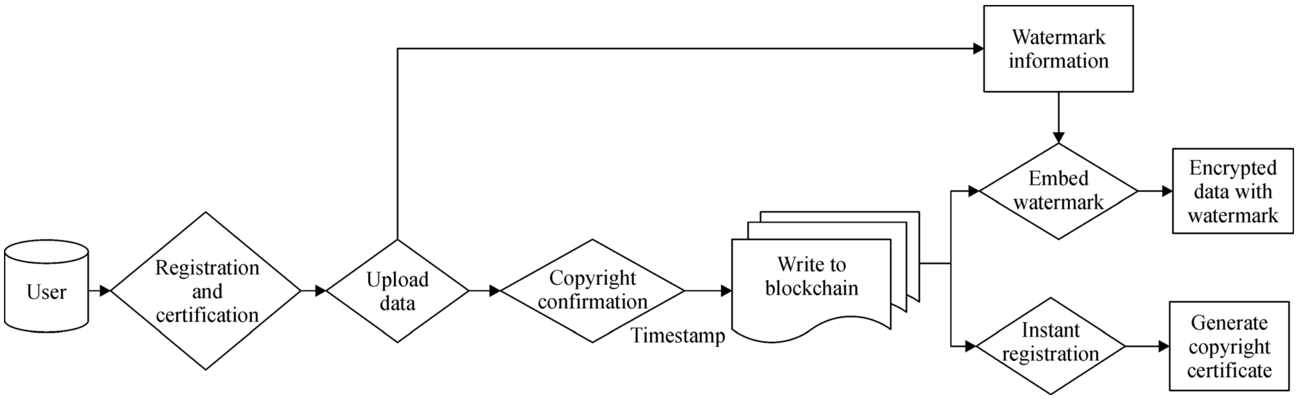


Fig. 8 Intellectual property right confirmation of various mineral resource data.

mineral data. Consequently, effective content comparison becomes complex, and management cost increases. Therefore, the unique identification of assets must be carried out after the confirmation and certification for various mineral resource data. Based on the unique identifier of a digital object commonly used in publishing industry, this paper designs a relevant coding scheme according to the information of collection area, collection means, professional category, data format, data scale, secret level, and provider of the mineral resources. In this scheme, a unique identification code is generated for the data after right confirmation and comparison. The scheme can form a copyright authentication certificate in the forms of 2D code, barcode, and character code. The copyright authentication certificate is the unique identification certification of mineral data and is convenient for the traceability and original mark of property rights in different situations such as data version updating and derivative research.

(3) Smart contract in property right transaction

Smart contract technology is the key to the application of blockchain in property right trading for various mineral resources. It is a stateless event-driven code written by developers. Smart contracts expose numerous interfaces, which respond to transactions sent by applications and interact with ledgers.

Programmable features of smart contracts provide increased freedom in mineral data protection. The data protection mechanism of mineral resources based on blockchain can make contracts consistent with the interests of data holders and users according to local conditions. The contract is automatically executed by event triggering, which reduces the cost and improves the efficiency.

4.5 Comparison between traditional and blockchain-based data-sharing methods

Existing data-sharing applications have many deficiencies, such as unclear data ownership, privacy data disclosure, and difficulty in tracing the sharing process, which seriously hinder the healthy development of data sharing. This paper proposes a data-sharing mechanism of mineral resources based on blockchain technology to solve these problems.

The data-sharing platform based on blockchain no longer needs to rebuild a large database due to the characteristics of distributed storage, point-to-point transmission, and asymmetric encryption. The platform directly uses blockchain technology to trade data stored in different departments, which greatly reduces the cost of data storage. Moreover, data quality and intellectual property rights are guaranteed in the transaction due to the tamperability of blockchain.

Compared with the traditional data-sharing system, the blockchain-based data-sharing mechanism has the following advantages. Data on the blockchain are almost tamper-resistant, and copyright and the entire process data can be traced. The right confirmation, privacy protection, and traceability of shared data can be realized. The form of shared-data report is used to ensure the security of all sources of data and prevent multiple data sharing and data leakage. The data-sharing mechanism based on blockchain is conducive to promoting the external sharing of various mineral resource data, breaking the information barriers within the industry, curbing the "isolated island" of data information, and promoting the utilization rate of data resources. In this manner, problems such as large investment, long period, and difficult data quality control caused by the construction of large database are avoided.

5 Case study

We build a data-sharing system based on blockchain for various mineral resources. In this system, we can ensure that data only flow among the nodes joined in the blockchain, and no third party is involved.

5.1 System review

The system maintains a blockchain network and a ledger, which records the details of data query operations. The flow of shared data can be captured by tracking the history of the ledger. In addition, the first mock exam mechanism provided by the blockchain implements the unified mode and application programming interface (API) of data query operation. The API validates each data query request and records its details on the smart contract if it passes the validation successfully. Data nodes of the system eliminate the situation that most nodes only maintain their own databases and are difficult to share with a third party. Also, the API can track and monitor the detailed process of shared data and record the corresponding data in the block.

For security- and privacy-related issues in sharing, the system uses the security data query model, which is also known as certificate authentication request (CAR). Data can be shared among users who pass authority authentication, and data privacy can be protected during data transmission. In summary, the system aims to connect the systems and databases of various mineral resources through blockchain technology; realize the safe, fast, and convenient sharing of mineral resource data; reduce the cost of intensive resources; and improve the utilization efficiency of mineral resource data.

5.2 Technical structure of the system

Figure 9 shows that the structure of the system is divided into three layers of distributed data, data acquisition, and application.

(1) Distributed data layer

The distributed data layer is mainly responsible for the management of databases and the processing of related data query requests. The distributed data layer is built on the blockchain network of the system and is generally maintained by the relevant organizations of the node. This layer consists of data management layer and data storage layer. The data management layer includes a smart contract mechanism and a blockchain ledger, which is responsible for managing the query operation interface of various mineral resource data. Related organizations can request the access of remote database by using this interface. Before processing the request, the data management layer judges the validity of the query request by checking whether the authority of the organization has been authenticated. The data storage layer stores historical blocks, status data, etc.

(2) Data acquisition layer

The data acquisition layer is used to collect various mineral resource data. The main core of this layer is a variety of mineral resource data aggregators. When a user initiates a specific set of query requests about data properties, the data aggregator attempts to register the request in the smart contract to obtain the access address of the database containing the required data properties. The data aggregator then obtains the requested data from the remote database by establishing a connection. After receiving the data, the layer merges the data set locally into the result data set and returns it to the application layer.

(3) Application layer

The application layer uses data mining, differential privacy protection, feature engineering, and other technologies to process the relevant users' or institutions'

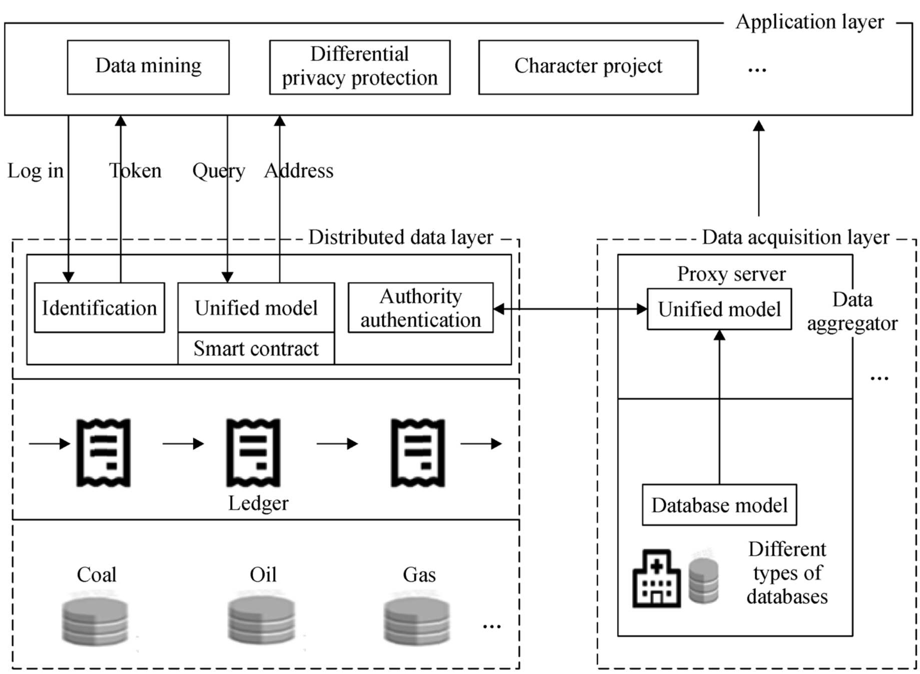


Fig. 9 Technical structure of the proposed system.

queries and requests for relevant data. Relevant organizations can share various mineral resource data safely and effectively through this layer.

5.3 Main functions and realization

(1) Data acquisition

The data-sharing model of mineral resources based on blockchain mainly realizes the following functions during data acquisition. First, only certified mineral resource managers can upload mineral data online. Second, when uploading multi-resource mineral data, 32-bit random binary system password (i.e., data key) and high-intensity symmetric encryption algorithm are used to encrypt the data. Third, multiple mineral resources are encrypted after encryption. Resource data are placed in the key envelope and sent to the blockchain along with the mineral ciphertext data. Finally, the nonce is introduced to prevent the collision attack and improve the security of the encrypted content. Data users of mineral resources can view and use the data. Data query results show the mineral ciphertext data and other blockchain public information by default.

(2) Data authorization

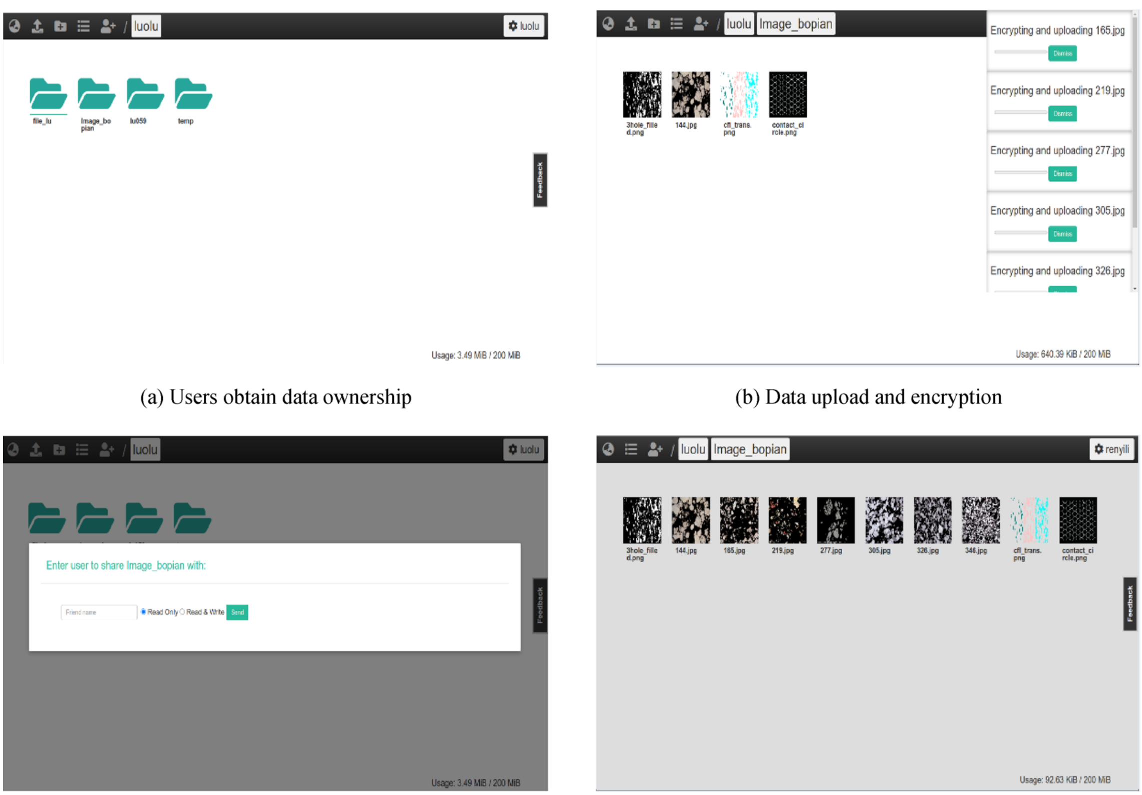
This system provides the unification model of the local database and its corresponding API to check the validity of the query request for mineral data. Based on the unification model and API, a query model called CAR is proposed to secure the shared data in the system. When accessing the mineral data, the system denies the unverified request by verifying the request permission. In the data transmission of mineral resources, the privacy of the data are protected, which ensures that only users who have access to the data can use their wallet and private key to view the plaintext data of mineral resources, without obtaining the source data.

(3) Data encryption

In this system, the private key of the blockchain account address is used as the seed to derive the corresponding business key pair. The public key is used as the primary key of the system's business. The service key pair can be regenerated according to the mnemonics of the wallet to avoid recording multiple mnemonics and prevent loss. The generation of key pair improves the security of mineral resource data.

(4) System interface

Figure 10 shows part of the system interface. Data are encrypted during upload. Only authorized organizations can view the corresponding mineral data. When viewing data, ciphertext data are displayed by default. In the process, users are informed of the information and purpose to be viewed.



(a) Users obtain data ownership

(b) Data upload and encryption

(c) Data authorization

(d) Authorized users can view data

Fig. 10 Several diagrams of the user interface.

6 Conclusions

Data sharing is the basis of realizing collaborative exploration of various mineral resources. Blockchain has shown great potential in data sharing. In this paper, we propose a data-sharing mechanism based on blockchain. This mechanism has three functions: Data sharing, data quality control, and intellectual property protection, which solves the problems of difficult quality control, high cost, and unconfirmed data right in the traditional data-sharing mechanism. We also build a demonstration platform of data sharing based on blockchain and elaborate important matters in the implementation of data-sharing technology based on blockchain. This work helps realize the breakthrough of mineral exploration to greatly reduce national investment and minimize the effect on the ecological environment.

In the future, we will explore how to combine blockchain with existing databases of various mineral departments, such as "PCEP.CLOUD". Based on existing databases, we will study how to use blockchain technology to achieve an efficient data-sharing mechanism with clear data rights and incentive mechanism.

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