Design and Implementation of Energy Internet Big Data System Based on Blockchain

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Abstract. Blockchain is a new application model that integrates distributed data storage, point-to-point transmission, consensus mechanism, encryption algorithm, and other computer technologies. These technologies make blockchain traceable, reliable, and resistant to modification, characteristics that suit the need for data storage and exchange. As a result, in this paper, we design an energy internet big data system based on energy and blockchain technology systematically. Firstly, we discuss the basics that support for energy scheduling and policymaking of the management department, including energy data coordination, enterprise monitoring, and consumption monitoring, and trading services. Secondly, we develop the Unified Energy Reporting Service. It can generate the energy demand and supply table, production and sales table, demand forecast table, energy consumption monitoring table, environmental protection monitoring data, and energy data of critical customers. Finally, we ensure the storage and collection of evidence in our system, which would guarantee the electric security of the Winter Olympic Games.

Keywords: Blockchain, Energy Internet, Big Data System, Design and Implementation (key words)

1. Introduction

Electricity is an essential material foundation necessary for modern cities. Energy consumption also correlates with the citizen's living standards, development of the national economy, as well as social progress. Typical energy sources like water, electricity, gas and heat are main driving forces for urban infrastructure and production, the use of which would generate vast amounts of energy data resources. Meanwhile, under the background of tremendous changes in both the domestic and international energy landscape, the significance of energy data's security would reach the strategic height for national development.

Blockchain uses a distributed peer-to-peer network and open ledger, and it has the features of decentralization, traceability, and resistance to modification. It has been applied in the fields of finance, energy, and public services, which all show successful results [1-2]. As a result, we decide to design an
energy big data center based on blockchain, which would integrate the energy data of water, electricity, gas, and heat. The mining of energy big data by artificial intelligence will provide decision-making supports and planning suggestions for urban construction, promoting the development of smart cities. Meanwhile, the service level of energy data will be improved, and information barriers removed because of blockchain's characteristics.

2. Block chain

2.1. The key technology of Block chain

Blockchain technology uses a chain of blocks as its data structure and data storage, distributed node consensus algorithm to generate and update its data, cryptography to ensure data security during transmission and access, and smart contracts of automated scripts to program and operate the data. The key technologies include distributed ledger, point-to-point transmission, cryptographic algorithm, consensus mechanism, and intelligent contract [3].

2.1.1. Distributed ledger. The blockchain database is a distributed ledger, which is shared by different regional network nodes, which will jointly supervise the transaction's legality. Different from the traditional distributed ledger, each participating node in the blockchain network is independent and equal. The consensus mechanism ensures the data's consistency, credibility, and security [4].

2.1.2. Point-to-Point transmission. The peer-to-peer network is a new technology that relies on the computing power and bandwidth of the participants in the network. The users in a point-to-point network are both the data provider and the data consumer. One or some of the nodes' dishonesty will not impact the whole network, so the multi-node system's reliability is highly increased. Any node in the whole network can join or exit freely, and the more nodes participate, the better the performance. The point-to-point network does not require the central index server to process data, which has been widely used in the field of point-to-point information sharing and transmission.

2.1.3. Cryptographic algorithms. Blockchain is an innovative technology that refers to computer science, mathematics, cryptography, and many other disciplines. It provides machine algorithms to solve the problem of untrust between participants. The ultimate objective of using cryptography algorithms is to ensure the authenticity of data, which realize the safe, credible and fault-tolerant decentralized distributed system [5]. Cryptography is the basis of blockchain. Numerous modern cryptographies include hash algorithms, encryption and decryption algorithms, digital certificate and signature, and zero-knowledge proof. Those are being used to build data transmission and access security mechanism.

2.1.4. Consensus mechanism. Each node on the blockchain will have a ledger that records all transactions on the chain. When a new transaction is generated on the chain, the malicious node may publish some false information. The consensus mechanism will effectively eliminate errors through the principle of "minority obeys majority" to ensure the consistency and validity of data records at each node of the blockchain. The most commonly used consensus mechanisms are Proof of Stake (POS), Proof of Work (POW), and Byzantine Consensus Algorithm (PBFT) [6].

2.1.5. Smart contract. The intelligent contract, which automatically executes the terms of the contract, is a kind of computer transaction protocol that does not need mediation or self-verification. To realize the traceability and irreversibility of a transaction, the predefined terms will be automatically executed. The smart contract is written into the blockchain in digital form, to ensure that the entire process of storage, reading and execution is transparent, traceable and untamable. Meanwhile, smart contract effectively saves social resources, reduces transaction steps and time, and ensures the credibility of transaction participants. [7-9].
2.2. **Block chain classification and selection principles**

According to different service objects, blockchain can be divided into the public chain, the private chain, and the alliance chain. The public chain is open to anyone who wants to participate in; The private chain is open to some specific groups; The alliance chain is open to specific groups of organizations.

2.2.1. **Public Chains.** Any individual or group in the world can send a transaction and obtain the valid confirmation of the blockchain, and the consensus process is open and transparent. The public blockchain is the earliest and the most widely used blockchain, which is entirely decentralized. The transaction can be effectively confirmed on the blockchain. Anyone can read and send the transaction, and anyone can participate in the consensus process. Each node of the public chain can join and exit the network freely.

2.2.2. **Private Chains.** The private chain is a blockchain system that is open to specific individuals or organizations, and the system is controlled by an organization with write and read permissions. The individual nodes within the system will have write permissions assigned by the organization, which will decide how much information and data to obtain depending on the circumstances. Besides, the query transaction progress is limited, and the private chain still has the typical architecture of multi-node operation. While the application of the public chain, such as bitcoin, has been industrialized, the private blockchain's application is still being experimented, by organizations including traditional finance.

2.2.3. **Alliance chain.** Alliance chain is a mode of an alliance between companies and organizations, and multiple centers usually control it. Its essence is a distributed managed accounting system controlled by multiple "authoritative" nodes designated by the organization, among which the whole system is managed and operated according to the consensus mechanism. The alliance chain can be viewed as "partially decentralized" because the public can view and trade it. However, the alliance's permission is required to verify the transaction or publish a smart contract. The typical characteristic of the alliance chain is that each node has a corresponding entity and can only join or exit the system with the approval of the alliance. The main groups of alliance chain are banks, insurance, securities, business associations, and group enterprises. The relevant institutions and organizations work closely together on the blockchain to maintain the system's health and stability [10].

3. **Characteristics of energy Internet**

3.1. **Characteristics of energy Internet structure**

According to the differences in the data subjects' functions, the energy information interaction between the source-network-load subjects can be divided into the followings:

- **The interaction between the source and the network:** The energy is transferred from the source end through the transmission network to the user side. The energy load transmission and distribution path are negotiated between the source-network.
- **The interaction between the source and the load:** industrial users can purchase energy directly from the source.
- **The interaction between the net and load:** the energy enterprises distribute energy to various users, while the micro-grid users can sell the surplus energy to the enterprises to complement each other, and the enterprises can provide other extended services to the users.
- **The interaction between the load and load:** during the peak period of energy demand, the system can supplement users' demand for electricity via the development of micro nets. The users of microgrids can sell surplus energy directly to surrounding users to reduce long-distance transmission and distribution of microgrid resources [11].
3.2. Application method of energy internet base on block chain

Energy transaction has characteristics of multiple business types with its long implementation cycle and complex transaction information. The integrated energy terminal system is composed of different energy equipment, energy conversion, and storage units. The energy service based on blockchain covers all links, which can realize the credible endorsement of energy production information, energy network distribution information, energy consumption data, energy storage information, which together optimize the business process.

The application of blockchain technology can overcome the problem of data and information sharing in the energy industry and the problem of trust between muti-subjects, which will promote data exchange, mutual recognition and sharing. Meanwhile, the intelligent contract mechanism can control data access rights to ease privacy data protection concerns. The process of energy blockchain application is shown in figure 1.

4. Function and design of system based on block chain

Based on the existing software, hardware, and data system, the public service platform of energy based on the blockchain serves the upstream and downstream of multiple urban energy members in the industry supply chain. This will provide valuable energy big data for urban to build into an international metropolis and energy data support for the integrated construction planning for the smart city. It can also optimize and adjust the city’s energy industry structure.

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Figure 1. The process of energy block chain application

Figure 2. The energy public service platform basing on block chain
Based on the integration of blockchain, big data, and artificial intelligence, the overall architecture of the energy blockchain platform is designed to build a common service capacity for the energy industry and provide technical support for the healthy and high-speed development of the energy industry. The energy public service platform basing on the blockchain is shown in figure 2.

Energy alliance chain is based on the blockchain technology. It includes energy enterprises and relevant government institutions. The energy alliance chain will regard electric power enterprises as the central nodes, energy industries or government institutions as nodes, which supports for blockchain service.

4.1. Basic layer
The Basic layer is mainly the hardware facilities of the energy blockchain public service platform, which include the servers, storage media, transmission network, the provision of physical resources, and computing drivers for the upper layer.

4.2. Platform layer
The platform layer mainly includes the supports for energy public service platform application and blockchain components. The supportive services mainly utilize privacy protection, multi-chain, contract engine, network service, security audit, state secrets algorithm, block management, and consensus mechanism. The essential components of blockchain technology include channel management and node management. Other convergence technologies of service platform include artificial intelligence, big data, edge computing, cloud computing, Internet of Things, and 5G. The platform layer will provide the environment and technical foundation for the upper layer.

4.3. Data layer
The data layer realizes the generalized access to the data of the energy industry, which will integrate the data of the energy industry from the energy big data center and realize the complete convergence of all energy big data including power, water, oil, coal, gas, and heat.

4.4. Service layer
The service layer is the primary service provided by the energy public service platform. Identity authentication will achieve user login, operation authentication, and user rights configuration. Data storage uses the blockchain to achieve the information transaction, data content, and other information storage services. Data traceability service is mainly used to retrieve, trace, and monitor full flow trajectory of the stored data. Data confirmation right refers to the critical technology to solve the separation of data ownership and use right. The service layer could realize the essential service functions of the energy public service platform, and the application layer develops new application scenarios.

4.5. Application layer
The application layer is the core of the energy blockchain public service platform, which mainly realizes these functions, including comprehensive energy perspective, energy enterprise monitoring, comprehensive energy consumption monitoring and energy trading services. It will provide data support for urban municipal government in energy dispatching and policy formulation. Secondly, energy demand and supply table, energy production and sales table, energy demand forecast table, comprehensive energy consumption monitoring table and energy data of key customers (environmental protection monitoring data) can be realized by the Unified Energy Reporting Service for core-district and sub-district. Winter Olympic security power supply will realize the secure storage, evidence collection and other functions of Winter Olympic. With the promotion and application of the energy public service platform, the content of the application layer will be continuously expanded as required.
4.6. Two sizes

"Two sides" refers to the security protection and maintenance management functions of the energy public service platform. The operation of system security management is called security protection, which should include the operation audit, authentication management, authorization management and the operation and maintenance security protection of application, data, host, network and physical.

5. Application scenarios

The energy public service platform and the energy big data center share data interactively, which will realize functions such as data right confirmation and data value-added services and promote data aggregation and sharing in various industries.

Based on the features of resistance to modification and traceability of blockchain, the system can trace the entire lifecycle of the data, including its generation, transmission, use and transaction. Reliable tracing can be used to realize business functions such as comprehensive perspective on energy and Unified Energy Reporting Service. These will ensure the accuracy of the comprehensive energy supply information and the credibility of statements and data. During the period of the Winter Olympic Games, multiple agencies (energy enterprises, regulatory authorities, organizers, government departments, public security bureau, fire bureau, urban management, law enforcement bureau, meteorological bureau, emergency command center, etc.) would share data reliably. It will promote efficient coordination among all parties in the organization of energy security work, programs, facilities, exercises and implementation. This would ensure the safe and stable of the energy system, ensure the safety of the energy supply and prevent the occurrence of events that cause severe social impacts [12]. The application scenario basing on the blockchain is shown in figure 3.

Figure 3. The application scenario basing on blockchain

5.1. Technology Advantages of Energy Internet Basing on Blockchain

The energy big data center is the embodiment of the data advantage of the energy ecosystem, a necessary component to support the city's energy ecosystem and an important platform to promote the digital transformation of energy.

The method would include data mining to form data assets and apply blockchain technology to solve problems such as multi-party data trusted sharing. As a result, the system can provide the government
and advisory services with industrial economic development monitoring and assessment, comprehensive energy development assessment, and commercial property utilization. Energy big data involves data sharing in many fields including water, electricity, gas, heat, energy storage and photovoltaic.

Firstly, blockchain technology can realize data authentic, decentralization and tamper-resistant. Data management and sharing platform basing on the blockchain could be developed. Basing on the underlying technology of blockchain, the level of data storage, data sharing, data monitoring and management can be improved, which will realize data credibility, traceability, and non-tampering. These will meet the diversified service needs of big energy data and realize the realization of data value.

Secondly, the key data related to the business will be blockchain anchors to the chain. Meanwhile, the access rights of different users to electronic data will be controlled, which effectively settle the security problem of electronic data storage on the chain [13].

Finally, the trust problem of complex systems involving multiple parties could be resolve through the block chain technology, which can link information islands between different subjects of data sharing, information communication and others.

5.2. Some Other Suggestions

Big data, cloud computing, Internet of things, artificial intelligence, 5G, and other technologies could be integrated into this system. Blockchain technology is applied to build an energy data alliance chain based on power data covering water, gas, heat, coal, oil and other energy sources. In this way, we can realize an objective and untameable trusted energy data alliance chain. We can also fully utilize the data of energy production and transmission, which will provide support for enterprises, energy industries, and government departments.

We suggest that energy data, including water, electricity, gas, and heat, should be extensively accessed in the construction of energy big data center and energy public service platform. Also, the integrated energy data of source, network, load, and storage should be widely used. Energy services including industrial planning, energy planning, emission reduction and pollution control, energy efficiency diagnosis and equipment monitoring will be provided based on the public management service platform, which will promote the construction of smart cities and effectively support the digital transformation of urban energy.

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