Research of Energy Consumption Monitoring System Based on IoT and Blockchain Technology

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Abstract. As the underlying platform for security applications of the Internet of Things, blockchain can provide reliable storage, data encryption, access control, identity authentication, and other service support for the security of the Internet of Things. Its immutability can ensure the authenticity of the information on the chain and the construction of shared accounts. The foundation of trust is to ensure business transparency and traceability. Asymmetric encryption can ensure the information security of the Internet of Things. Smart contracts support automatic transactions of IoT devices to improve the operating efficiency of the system, thereby promoting the flow of IoT data and enabling timely warning and carry out effective control. The application research and industrial application of blockchain in the energy field will bring innovative application models to the Energy Internet and realize the flow of data value. This article focuses on the energy consumption monitoring of the Energy Internet consumption, applies blockchain technology to the construction of an energy consumption monitoring system for key energy-consuming units, analyzes the fit between business needs and blockchain technology, designs a blockchain platform architecture, and discussed the issues of energy consumption monitoring blockchain terminal equipment authentication and collection of trusted data.

Keywords: Internet of Things, Blockchain, Energy Consumption Monitoring, Trusted Data

1. Introduction
Blockchain is a distributed shared ledger and database, multi-party participation, multi-party maintenance, through cryptography, P2P network, consensus algorithm to ensure that data can be reliably stored, transmitted, and accessed technical system, laying the foundation for the blockchain to create trust. In essence, the core technology of blockchain is mainly to solve the trust and security issues of the information transaction process on the internet of value. The rich application scenarios of the blockchain are basically based on the ability of the blockchain to solve the problem of information asymmetry and realize the cooperative trust and concerted action between multiple subjects. Using blockchain technology, the stakeholders in the production, transmission and distribution, transaction, consumption and other links of the energy internet are used as the nodes of the blockchain. The
information of each link is collected and then linked to the chain, which is linked in an orderly manner into block storage and cannot be stored. Changes can provide an autonomous, efficient and decentralized credit environment for energy transactions[1] Energy consumption data comes from on-site energy metering equipment. The security of these data is directly related to the security of the equipment and online monitoring system. Once non-cognitive collection equipment accesses, data is accessed in violation of regulations, malicious tampering, illegal theft, etc., Will have a serious impact on the upper-level energy consumption monitoring and data analysis applications, so the safety of energy consumption data has been paid more and more attention. The integration of blockchain and IoT technology can realize trusted collection of energy consumption data, distributed storage and collaborative governance.

2. Current situation and pain points of energy consumption monitoring system
The energy consumption monitoring system for energy-consuming units in China adopts a multi-level structure of "national platform + provincial and municipal platform + enterprise energy consumption system", and is designed for various ministries and commissions, national statistical departments, competent departments at all levels, and key energy-consuming units to provide different levels of service. The system mainly uses smart devices to automatically collect energy consumption data such as electricity, water, gas, and heat, and assists in manual data entry. The system architecture is shown in the following figure.

![Fig.1 Architecture of energy consumption online monitoring system based on IoT and blockchain](image)

At present, the system adopts a centralized architecture, and the data is stored in the provincial and national government cloud servers. This mode is convenient for data collection and unified management. During the operation of the energy consumption monitoring system, a large amount of accumulated data is formed through data collection and storage. There are still pain points in data verification, system security, node trust, value flow, etc., mainly including data collection end equipment authentication problems, multi-data credibility problems of participating nodes, etc. There are security problems such as data tampering and single node failure. This is also a common flaw in the centralized architecture. At the same time, due to the poor flow of information between energy-consuming units and the existence of data, the management party often lacks in-depth analysis and decision-making refinement of the collected data, unable to explore the internal laws hidden in the data, and the value of the data cannot be fully utilized.

3. Architecture of energy consumption online monitoring system based on IoT and blockchain
Blockchain technology has the characteristics of decentralization, openness, tamper-proof modification, account anonymity, traceability, built-in contracts, etc., which can provide new means to solve the above pain points. Therefore, starting from the need to solve the pain points in data sources, data transmission, data fusion, data storage, data sharing, data security, and data privacy in the energy consumption monitoring system, a solution based on blockchain technology is proposed, as shown in the following figure.

![Fig.2 Architecture of energy consumption monitoring system based on IoT and blockchain](image)

The consensus mechanism is the core technology of the blockchain. As blockchain technology is increasingly used in reality, the consensus mechanism is constantly improving. DPOS (Delegated Proof of Stake) is developed on the basis of POW[2] and POS. It solves the high energy consumption of POW and avoids possible trust balance bias under the distribution of POS rights. DPOS has greater advantages over POW and POS in terms of transaction speed. Simply speaking, it maximizes benefits and minimizes costs, so DPOS-based consensus mechanism is selected. At the same time, the whole structure adopts the consortium chain. The advantage of the consortium chain is that the number and identities of the nodes are determined[3], so a relatively loose consensus mechanism can be used, and the data processing speed will be much higher than that of the public chain.

The existing energy consumption monitoring system is organically combined with blockchain technology, and the enterprise energy consumption data is collected and uploaded to the existing platforms. At the same time, through the construction of dual-chain structure, including provincial
energy consumption monitoring blockchain and national energy consumption monitoring blockchain, participants at all levels are separately connected to the provincial and national energy consumption monitoring blockchain, through which their energy consumption data is uploaded to the blockchain network via a trusted blockchain terminal. The energy consumption data is stored as a uniform format in a distributed storage cloud within the multi-center government cloud, so that it can be tamper-proof, traceable, and transparent to the account. The energy consumption monitoring enterprise-side system should adopt redundant measures to prevent the occurrence of single points of failure, and the data should be non-repudiation, that is, have the function of providing evidence of the original data to the originator or receiver of the data upon request.

Combined with blockchain technology, the trust management of the energy consumption monitoring system is submerged to the "end devices", which is responsible for collecting real-time energy consumption data of on-site energy consumption measurement equipment and sending it to the enterprise "end system". Thus the “end devices” plays a comprehensive role of data collector, gateway and isolation gatekeeper. We need to embed data collection smart contracts in existing enterprise "end devices", as well as security policies such as identity authentication, node authorization, and access control. Therefore, the blockchain terminal has multiple functions such as energy consumption data collector, IoT gateway, security isolation gatekeeper, and embedded blockchain mechanism. An enterprise "end system" is an information system that integrates "end devices", existing systems, and provides manual reporting. It acts as a "fog node", which is both an aggregation node and an edge computing node, responsible for receiving, summarizing, uploading, and analyzing energy consumption data, And provide localized energy consumption monitoring and alarm, energy efficiency analysis, power prediction and other functions.

4. Trusted data collection

Blockchain can help devices in the Internet of Things communicate with each other and realize distributed control of the Internet of Things. Its decentralized nature provides a way for the self-governance of the Internet of Things. Energy-consuming units configure and manage energy metering instruments. Enterprises and equipment need to be registered. After passing the platform identity authentication, they can become trusted equipment before they access the blockchain. This realizes that the subject and data are included in the blockchain system authentication management. Enterprise "end devices" is equipment verified by the metrology department and authorized by the supervisory authority. It has functions such as local data collection, processing, aggregation, and reporting. At the same time, information security isolation is required to ensure the safety of energy consumption monitoring end devices and enterprise information security. Provable and traceable data refers to a consensus algorithm based on the blockchain, and energy consumption data cannot be tampered with after being written into the blockchain. Identity authentication refers to the use of blockchain verification and consensus mechanisms to prevent illegal or malicious “end devices” from accessing the Internet of Things, thereby tampering or stealing data from smart energy metering instruments.

The original centralized mode uses a centralized server to issue certificates and authenticate registered devices, but there are problems with trustworthiness, monopoly, and user privacy, and there is a risk of tampering with authentication information. The node authentication mechanism of the blockchain system uses digital signature technology, which can be processed at the edge, and has the characteristics of autonomy, transparency, and node anonymity. The authentication information is stored on the chain to prevent artificial tampering. The node authentication mechanism of the blockchain is adopted, so that only registered "end devices" can access the system, preventing illegal device access and unverified devices from continuing to use. Through the smart contract embedded in the blockchain terminal to verify the digital signature of the device, the node authentication can be marginalized, automated, and efficient, and the identity of the real user can be verified through the device to ensure that the device is used with a legal identity.

Through the implementation of the "end devices" embedded smart contract, the data collection is guaranteed to be automatic and credible, hierarchically classified collection and authorized distribution.
The energy consumption data to be shared is encoded in a unified format through the block chain public-private key and digital signature technology, and it is packaged on the chain after it is associated with the device attribute and status information, and transmitted via the blockchain network. Establish a trustworthy binding relationship between the energy consumption data in the blockchain and the metering equipment outside the blockchain, so that a trusted mapping can be established between the equipment off the chain and the data on the chain to achieve data storage and traceability. The transfer of control authority for data controlled by smart contracts can also optimize the flow of trusted data.

Regulatory authorities have stipulated rules and constraints on the scope of collection of enterprise energy consumption data, selection of collection items, upload frequency, industry data items, and combined data item codes[4]. Adopting a trusted data collection solution that integrates blockchain and the Internet of Things, energy metering instruments use digital signatures for their data to be fidelity. The data collection smart contract is embedded in the blockchain terminal device, the contract is generated and released on the blockchain to take effect, and the authorized recipient obtains the data through the transaction. Energy consumption data is classified and provided for different users, different businesses, and different data types. Data providers can also obtain token revenue based on data sharing smart contracts. Through enterprise "end devices" embedded with smart contracts, functions such as identity authentication of collection equipment, collection of energy consumption data on demand, classification of data, and automatic routing and distribution are realized.

5. Conclusion
Blockchain, as a new generation of information technology, is being accelerated research and breakthrough applications. The combination of blockchain and the IoT is an important trusted infrastructure for the energy internet, and the combination of blockchain and artificial intelligence is an important future direction[5]. With the gradual improvement of edge intelligence, the trend of autonomy of smart devices will continue to evolve. Each agent has a certain degree of autonomy. There will be no aggregation node in the entire energy consumption monitoring cluster system. According to the preset smart contract, data is sent and received autonomously, and different devices and subjects interact and collaborate with each other. Blockchain and IoT technology will accelerate the development and industrialization driven by multi-link and multi-scenario applications, promote the progress of social governance, and create an open, autonomous and credible social form.

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