A Blockchain-Based Intelligent Data Management Platform for Power Grid Applications

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Abstract. With the access of a large number of renewable energy sources in the power system, the increasingly complex power system operations bring considerable safety concerns for data management. While measurement data analytics in the power grid play an important role in different control and alarming applications, smart and reliable data management is required. Blockchain technology is a decentralized database based on cryptography and distributed storage, which is immutable and traceable. This paper analyzes the matching degree between the characteristics of blockchain technology and the demand for measurement data management, showing the advantages of blockchain for power grid data management. In this paper, a data intelligent management platform based on blockchain technology is designed. A standardized interface design of data service is elaborated, and the application scenarios of intelligent data are listed, providing new possibilities for developing advanced applications based on the measurement data.

Keywords: Intelligent data; Blockchain; Power system measurement; Data platform .

1. Introduction

Power metering plays an important role in the electric power trade and is a fundamental unit in power grids. With the construction of smart grids, applications of power metering data, i.e. power meter data analytics have become a hot research spot in power systems[1-3]. Intelligent data systems for electric energy metering can not only improve the operation efficiency of a power system, but also can effectively reduce the labor workload. At present, the electric energy metering data are managed in a centralized mode, suffering from the issues, such as isolated information and data security risk[4-5]. In order to solve these problems, this paper proposes a unified intelligent management platform based on blockchain technology, with the advantages of privacy protection, data security, data sharing and security transmission.Organization of the Text

2. The matching degree of blockchain technology and power measurement data management

There is a high degree of matching between the management of power measurement data and the characteristics of blockchain technology[6-9]. On the one hand, energy enterprises have a strong demand for metering business, and accurate and reliable metering results can be used as a guarantee for enterprises to obtain profits. The blockchain has the characteristics of immutable and distributed storage[10-14], which ensures the reliability and authority of data in this field. On the other hand, it is an international convention that the measurement data of electric power enterprises is supervised by the local legal system of the country. The immutability of blockchain technology has a high degree of matching with the requirements of legal metrology[15]. Hence, the blockchain technology can be employed in power management systems, for example, applied in power metering data management[16-18]. The establishment of an intelligent management platform based on blockchain and the proposition of a unified standard system can effectively facilitate the legal supervision in the energy metering field. Due to the decentralized characteristics of blockchain technology, data

stored on the blockchain can be easily and securely shared by potential users, which facilitates the development of intelligent data application scenarios. Overall, the combination of blockchain technology with power metering data management is feasible in this field.

3. Architecture design of intelligent management platform

3.1 The Data Architecture

In this paper, power measurement data is divided into two parts: measuring instrument verification data and metrological tracing data. Measuring instrument verification data is the basis of power transactions, while metrological tracing data usually contains quantity transmission and traceability chain information. Power measurement data can be stored by blockchain technology so that the power service data will have the characteristics of distributed storage and not be tampered. Through the solidification of national standards, enterprise standards, measurement instrument verification information and verification certificate information with blockchain technology, electric power measurement services with legal qualification, effective recognition, metrological traceability, and accurate verification are provided to legal measurement regulatory agencies and power users.

3.2 The Platform Architecture

The overall architecture of the platform consists of a blockchain interface module, management and configuration module, metering business supervision module, public information service module, supplier collaboration and data service module, visualization module and source-end interface module.

The source interface module provides functions such as interface management and operation maintenance monitoring of the metering service system through the IT infrastructure.

The blockchain interface module is used to realize the following three functions:(1)the data interaction on the blockchain, including transactions, data queries, events, contracts, CA certificates, logs;(2)the implementation of the blockchain platform operating parameters settings, including configuration, node configuration, user configuration, etc;(3)achieving the acquisition and analysis of the operating status information of the blockchain platform, including block height, trading volume and other information.

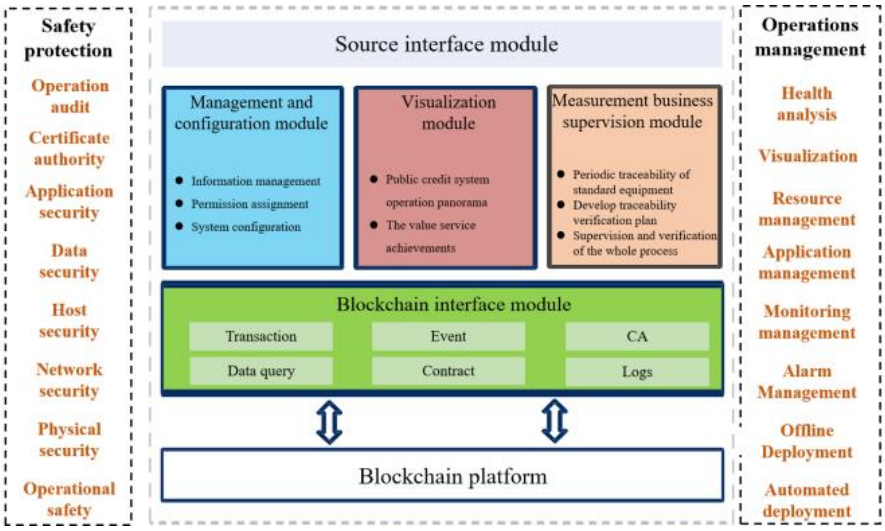

Fig. 1 Power measurement data intelligent management platform architecture

The management and configuration module is built to realize the functions such as the union information, unit members, user information and the node configuration function, which can

support configuration examination and approval of member information. At the same time, this module is also built to realize the assignment of user authority, the configuration of the user secret key, CA certificate, the corresponding relationship between the sub-ledger and data, and the attributes and validity of the node.

The measurement business supervision module is responsible for supporting the supervision and management of the verification institutions. Therefore, this module ensures that the institutions could complete the periodic traceability of measurement equipment and the traceability verification plan according to the legal regulations. Furthermore, the whole process of data credible supervision, traceability query and verification can be realized.

The visualization module is built to display the public credit system of electric energy measurement verification, the overview of the blockchain system, and the achievements of the blockchain platform.

3.3 The Technical Architecture

The technical architecture of the platform mainly includes basic layer, adaptation layer, service layer, interface layer and display layer. The basic layer includes blockchain and micro-service architecture to support the overall construction of the intelligent management platform. The adaptation layer includes blockchain interface, blockchain smart contract, data encryption service, data integration service and other basic support services. The service layer is the main function of the system, including data service, blockchain service and universal services. The data service is designed for data synchronization and data analysis, supporting the data processing of the system. Blockchain service achieves blockchain docking and state monitoring. Universal services such as scheduling service, queue service, message service, and log service, serve as a service buffer to support platform service decoupling. The interface layer contains various interfaces related to external applications, such as sessions, authentication, authorization, and requests. This layer implements data communication, protects the data security of the information system, and prevents illegal operations. The display layer adopts B/S architecture to form multi-terminal access, such as PC browser and mobile APP.

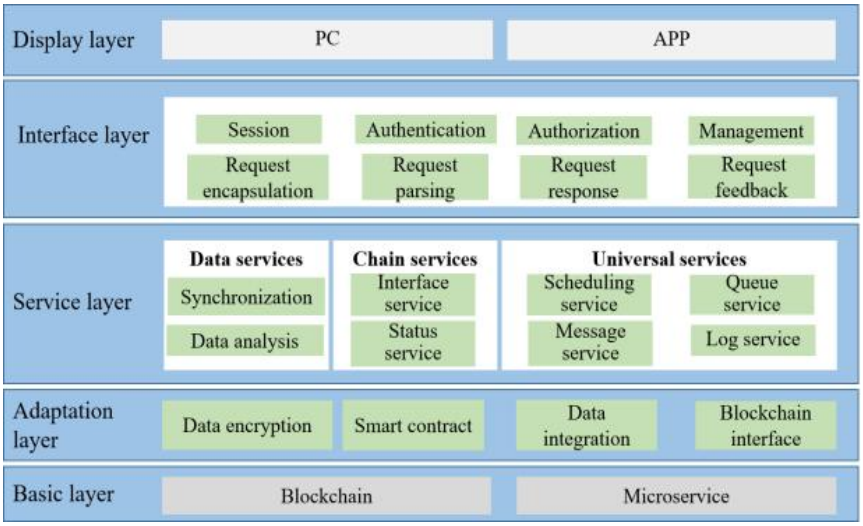

Fig. 2 The technical architecture

4. Standardized Interface Design of Data Services

In order to unify the interaction mode of electric metering intelligent data and standardize the data usage environment, Spring Cloud micro-services is adopted as the framework to design a standardized interface service for metering intelligent data. The standardized electrical metering

data interface can be accessed through DLL (dynamic link library) and HTTP. The specific design content includes data type division, interface data structure definition and interface access control strategy.

4.1 The Data Type

The types of data that can be obtained through the standardized electric power metering data interface include: (1) The life-cycle verification data of measuring instruments: including the factory qualification verification certificate, type test certificate and returned identification test certificate of measuring instruments such as electricity meters, transformers; (2)Metrological verification equipment traceability information: including equipment accuracy grade, equipment number, measurement range, calibration certificate; (3)Qualification information of metrological verification institutions: including government authorization certificate, laboratory certification information, information of certificate holders.

The power metering data can be divided into three types according to the security level. The data of class I can be fully disclosed and shared. Such data can be stored directly on the blockchain after being encrypted by public keys. Class II data is selectively disclosed, only to users with access permission. Such data is encrypted by a private key and stored in a chain. Users with permission can access the data through dynamic tokens. Class III is refer to unstructured data, which usually represents the certificate of testing institutions, the government authorized certificate. These data often occupy large storage space in a computer, so only the MD5 hash code of these data will be stored on the blockchain. Users can access class III data through standardized interfaces with the verification of a digital signature from the chain.

4.2 The Structure of Returned Data

In order to standardize the data format returned by the platform, improve the applicability of power metering intelligent data, and reduce the development difficulty of data application connected to the platform, the structure of data object returned from the interface is defined as TableJson, ImageJson and SignJson. This division method is based on the data interface design principle of Spring Cloud micro-service architecture. TableJson is mainly aimed at structured data such as measurement data and measurement equipment information. Such data is usually stored in the form of two-dimensional tables, which need to be converted into standard Json format strings through TableJson. ImageJson is mainly applicable to unstructured data such as the government authorization certificate and the qualification certificate of testing institution. Such data usually occupies a large storage space. Spring Security mechanism is invoked to hash the data and generate a unique MD5 hash code, which will be used for verification with source files. The SignJson object is used to convert the encryption information generated by the electronic signature server into a standard Json string.

Take the TableJson object as an example. This object contains four attributes: Type, Property, Structure and Cell. Type refers to the type description of the data body, Property refers to the metadata attribute information of the data body (including data description and timestamp), Structure refers to the table structure description, and Cell refers to the measurement data object entity (including data type identifier, element field, and data encoding mode).

4.3 Interface Access Permission Control

Standardized data service interfaces must have well-designed permission control policies to prevent unauthorized access. Spring Boot integrated with JWT (Json Web Token) is used to implement token authentication for the verification of access authority of user identity, routers, service and data resources. JWT is a Json-based open standard (RFC 7519) for delivering claims over the network. Jwt encoded data is digitally signed to ensure that the sent message cannot be forged. JWT is a lightweight Internet authentication management system with the properties of

decentralization and user-oriented. JWT usually adopts HMAC algorithm or RSA algorithm as the data sign method.

The JWT consists of Header, Payload, and Signature. The Header includes the Token type and encryption algorithm. Payload Stores valid information, including registration statements, public statements, and private statements. Signature is generated after Header and Payload are encrypted by Base64. The JWT request flow is as follows:

1)User with account and password issues a POST request;

2)Server creates the JWT with a secret;

3)Server returns the JWT to the browser;

4)Browser sends the JWT on the Authorization Header;

Server checks JWT signature and sends the response.

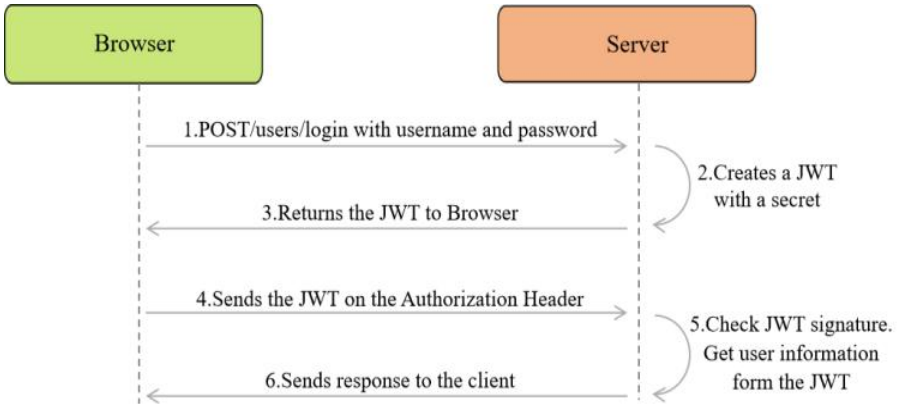

Fig. 3 JWT request flow

Compared with traditional Token authentication, JWT has the following advantages:

1)Compact: Send data through URL, POST parameter and HTTP header, with a smaller amount of data and faster transmission speed.

2)Self-contained: Payload contains complete information required by users, which effectively reduces the frequency of database access.

3)Compatibility: Token is stored in the client in the form of Json encryption. JWT has good cross-language and cross-platform features.

Microservice applicability: Because there is no need to save the session on the server.

5. Application of Power Metering Intelligent Data

5.1 Power Market Transactions Invoke Blockchain Power Metering Data

With the deepening and maturity of blockchain technology applied in power market transactions, the decentralized distributed characteristics of blockchain effectively solve the problems of information security, openness and transparency existing in the traditional centralized transaction architecture. The benchmark for measuring electric energy in electricity trading is the electric energy meter. The accuracy of the electric energy meter is related to the fairness of electric power transactions. In addition, according to the international legal metrological management convention, the electrical measurement data used for trade settlement is subject to the supervision of the government, and the electrical measurement information related to the power market transaction should also be included in the supervision. The standardized interface design of the Intelligent data management platform makes power metering data easily accessible, while blockchain technology ensures data immutability and reliability. The application of intelligent management platform ensures the fairness and authority of electricity market transaction information.

5.2 Residential Power Users Query Electrical Measurement Data

In recent years, with the popularization of intelligent power equipment, the coverage rate of smart electricity meters has a rapid growth. Meanwhile, some residential electricity users doubt the measurement accuracy of their electricity meters. The platform provides power users with the power measurement information query interface, in which power users can only query the measurement data of their own electrical assets. E-certificate information exists in each node of the blockchain network, and users access the data of their electricity meters through various client programs connected to the platform. This application scenario meets the residential electrical power users' requirements of measurement data querying, and realizes the innovative application of measurement intelligent data based on blockchain.

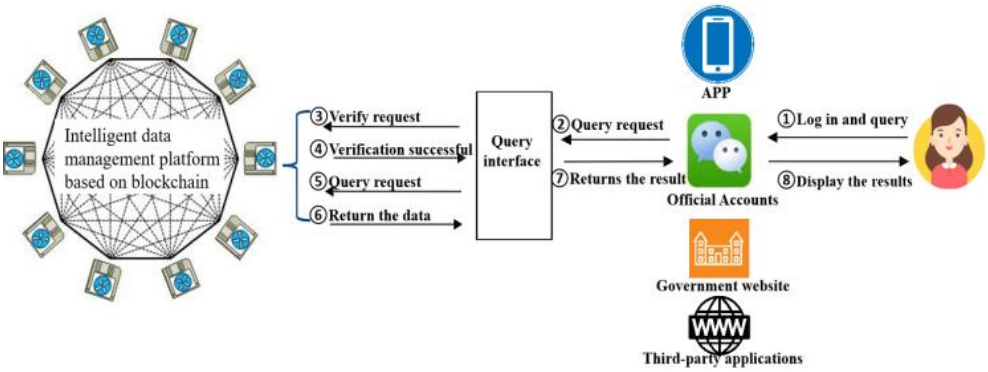

Fig. 4 Process of residential users obtain power metering information

5.3 Data Synchronization with Power Equipment Suppliers

The intelligent management platform discloses the power measurement data, which can facilitate information synchronization between power enterprises and power equipment suppliers. By storing the internal testing data of power equipment suppliers on blockchain, the power enterprises can fully control the production quality of power equipment, thereby reducing the testing processes after the power equipment leaves the factory. By storing the demand data of power equipment of electric power enterprises on blockchain and synchronizing with the power equipment suppliers, it can help suppliers arrange production plans accurately and reduce operation costs appropriately.

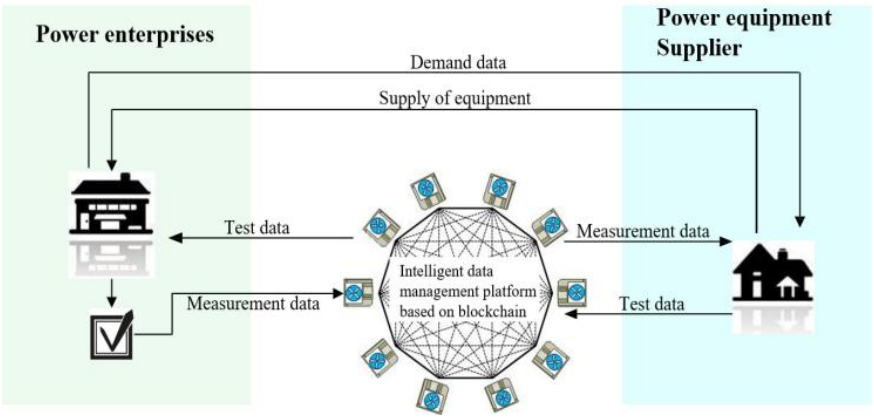

Fig. 5 Vendor collaboration business process

6. Summary

Electric power measurement data management is the base of energy management and also an indispensable part in the development of energy science and energy saving. This paper studies the advantages of power measurement data Management Based on Blockchain. This paper discusses

the matching degree between blockchain technology and power metering data management needs. The intelligent platform architecture and the standardized interface of metering data are described in detail, and the application scenarios are illustrated with examples. The measurement data intelligent management platform can effectively solve the problems existing in the data management of traditional electrical measurement, and the standardized design of the data interface provides a technical basis for the application of power system intelligent data.

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