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Trusted Data Exchange and Blockchain Smart Contracts in the "the Belt and Road" Digital Economy Cooperation

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Abstract: With the acceleration of global integration and the rapid development of technology, economic cooperation and regional integration have become an undeniable force in today's world development. Especially with the implementation of the "the Belt and Road" strategy, this development trend is more obvious. This plan was launched by China in 2013 with the aim of promoting infrastructure construction, trade cooperation, cultural exchanges, common development, and regional cooperation in Asia, Europe, Africa, and other regions. With the rapid development of Internet, big data, artificial intelligence and other technologies, the digital economy has become an important driving force for the development of the world economy. It has not only changed the operation mode of traditional industries, but also spawned new industrial forms. However, in a network environment lacking trust, trustworthy communication of data is an important prerequisite for promoting active data sharing among network entities. Information security technology based on encryption technology can effectively solve problems such as data untrustworthiness and privacy leakage in information exchange. This paper focused on the trusted exchange of data in the "the Belt and Road" digital economic cooperation, and discussed how to solve the trust problem in data exchange with the help of blockchain smart contract technology. First, the background of the "the Belt and Road" initiative and the significance of digital economy development were briefly introduced. Subsequently, the challenges faced by trusted data exchange in a network environment lacking trust were analyzed, and a solution based on blockchain smart contracts was introduced. The experimental results showed that when the data block size was 1GB, the data trusted exchange system based on blockchain technology took 10 seconds, and the data transmission rate still reached 891Mbps.

1. Introduction

With the development of emerging technologies such as blockchain, Internet of Things, artificial intelligence, 5G, and cloud computing, there is an increasing demand for supply chain management. In order to gain a first mover advantage in future global competition, the supply chain and logistics industries must improve their traditional models and engage in digital transformation and industrial innovation. With the development of Internet of Things technology, including advanced technologies such as artificial intelligence, 5G, and edge computing, these technologies have become an indispensable infrastructure of the entire industry chain. Innovation and transformation of supply chain process management have become a national strategy, and blockchain technology naturally adapts to the upgrading of supply chain process management, which can improve the operational efficiency of the entire supply chain at the computational and automation levels. Blockchain is a reliable distributed database based on distributed ledgers, which can collaborate with multiple parties in multiple fields, ensuring that important information can be transmitted in a trustworthy network.

In the research methodology section, this article delves into the core concepts and advantages of blockchain technology. As a decentralized distributed database, it achieves secure storage and immutability of data through hash pointers, thereby constructing a highly trusted and secure digital transaction environment. At the same time, this article also introduces the close integration of blockchain and smart contracts, as well as the credit mechanism of its technical endorsement for smart contracts, thereby ensuring the automatic performance and reliability of contracts. Subsequently, through experimental results and discussions, this article demonstrates the richness of experimental data, including trade data, payment information, cooperation agreements, and highlights the important applications of blockchain smart contracts in data sharing, cross-border payments, logistics management, and product security traceability.

2. Related Works

Experts have long conducted specialized research on trusted data exchange and blockchain smart contracts. To enhance vehicle safety and ensure the sharing and communication security of vehicle networking information, Das D designed a blockchain-enabled vehicle-to-vehicle communication system (BVCS) based on blockchain technology, which can achieve identity recognition for users and vehicles [1]. Jyoti A proposed a blockchain and smart contract-based data provenance (BSCDP) architecture to address data security and privacy issues in cloud environments. Compared with existing methods, the BSCDP method has significant advantages in terms of security and performance [2].

Liu Y investigated a single-domain and multi-domain semi-centralized trust management architecture based on blockchain technology. Experiments showed that the method can effectively localize malicious terminals and can effectively inhibit the impact of malicious terminals [3]. Peng Z introduced BlockShare, a verifiable data sharing system based on blockchain. He verified the feasibility of the method through experiments [4]. Wan Z, based on the existing research results, generalized the traditional zk-SNARK (Zero-Knowledge Succinct Non-Interactive Argument of Knowledge) mechanism to zk-DASNARK (Zero-Knowledge Distributed Autonomous Succinct Non-Interactive Argument of Knowledge) mechanism and applied it to the existing research. He designed zk-AuthFeed (Zero-Knowledge Authentication Feed) zero-knowledge authentication off-chain data distribution mechanism under the zk-DASNARK framework to solve the privacy protection and authentication problems of distributed applications. Experiments showed that zk-AuthFeed was highly efficient: keys were generated in 10 seconds; proofs were generated in 4 seconds; authentication was completed in 40 milliseconds [5]. Yuan M introduced TRUCON, a trusted data sharing mechanism based on the blockchain and featuring IoT congestion control. It has been proved to be feasible and effective [6]. Wang E integrated a crowdsourced evidence data exchange system with an intelligent blockchain and incorporated a smart contract called CDToken. CDToken is a trusted third party that is used to record the requester's payment as well as the worker's ability to upload data, thus preventing targeted fraud. He implemented CDToken on Ethernet to verify its efficiency and usefulness [7].

The TCB (trusted consortium blockchain) framework proposed by Juma M combined trusted consortium blockchain and secure super ledger structure modules to address the integrity challenges of industrial IoT big data faced by intelligent manufacturing. The trustworthiness of endpoint peers was managed through heterogeneous networks to achieve strong integrity of big data, and support high transaction throughput and low latency. The experiment verified the evidence of big data signature in real-time management. The experimental results showed that TCB outperformed similar consortium blockchain frameworks in terms of throughput and latency [8]. Gai K proposed a blockchain-based cross organizational data access control scheme to address data security issues in a zero trust environment. A trusted environment was established through consortium blockchain, and a role-based access control model was implemented using multiple signature protocols and smart contracts. An evaluation was conducted on the HyperLedger Fabric to validate the practicality of the scheme [9]. Khan A U proposed a blockchain-based wireless sensor Internet of Things solution, which achieved registration, authentication, data sharing, and non repudiation. The simulation results showed a reduction of approximately 81.82% in transaction latency, with a data request and supply cost of $0.10 [10]. Lin S Y reviewed the working principle, deployment, and application status of blockchain smart contracts, and explored the advantages and challenges of smart contracts in fields such as finance, Internet of Things, healthcare, supply chain, and manufacturing [11].

Naresh V S proposed using BDACGKA (Blockchain-based Dynamic Authenticated Contributory Group Key Agreement) for contemporary Group Key Agreement (GKA). Blockchain technology was adopted to integrate lightweight computing, decentralized authentication, privacy protection and other functions, and generate group keys through privacy protection smart contracts [12]. Wang H proposed a privacy protection scheme for smart contract data feeding based on zero knowledge proof and Hawk technology, which was applied in medical insurance scenarios. The experimental results showed that this scheme was secure and efficient on Ethereum, achieving complete privacy protection [13]. Dwivedi S K proposed a fully decentralized Industrial Internet of Things (IIoT) system based on Ethereum smart contracts and Interplanetary File System (IPFS), abandoning Trusted Third Party (TTP). Research has shown that these solutions are safe and meet key standards [14]. Li T proposed the blockchain-based privacy-preserving and rewarding private data-sharing scheme (BPRPDS), which solved privacy, security, and access control issues when individuals share private data. BPRPDS has proven safety and has demonstrated high efficiency and practicality in performance analysis and experiments [15]. Zhang Y proposed a system framework for managing construction site information using blockchain and smart contracts to address fraudulent behaviors such as engineering data forgery and modification. The security and stability of the management system were verified by verifying common data types such as text, time series, and images [16]. Albalwy F implemented smart contracts on the blockchain-based framework pharmacogenetics (PGx) Chain to address the privacy issues of genomic data sharing in PGx. The performance testing results indicated that blockchain technology had the potential to promote PGx data sharing, especially in terms of security, accessibility, interoperability, and legal compliance [17]. There are performance issues, privacy protection challenges, standardization and interoperability requirements, security requirements, cost and scalability considerations, as well as insufficient verification in practical application scenarios in the existing research on trusted data exchange and blockchain smart contracts. Interdisciplinary cooperation and continuous research efforts are needed to address these issues and bottlenecks.

3. Methods

3.1 Blockchain Technology

Blockchain is a peer-to-peer distributed ledger composed of individual blocks forming a linked list. The difference from a regular linked list is the use of hash pointers instead of regular pointers. The first block of the data structure of blockchain is called the Genesis block, while the last block is the recently generated block. Each block contains a hash pointer to the previous block, combining all the contents and hashes of the previous block to calculate the hash. Any tampering with blocks result in mismatched hash values, making it easy to locate data tampering.

3.2 Providing Credit Mechanism with Technical Endorsement for Smart Contracts Based on Blockchain Technology

Blockchain provides a technology supported credit mechanism for smart contracts. The reason why blockchain technology is so closely linked to smart contracts is due to its technical support, which makes automatic execution of smart contracts possible. Taking vending machines as an example, blockchain technology allows consumers not to worry that after setting up the program, merchants maliciously modify it, causing consumers to suffer losses after payment. In traditional circumstances, consumer trust in a company is built on honesty and credibility, reputation maintenance, third-party authoritative agency guarantees, and legal protection, rather than the company itself. The credit mechanism of blockchain is based on algorithms and mathematics, and is a disruptive change. A trusted digital trading platform without third-party participation is constructed based on the integration of multiple fields such as P2P transmission, distributed data storage, consensus mechanism, and cryptographic algorithms. The blockchain based credit generation method breaks the dependence on third-party platforms and realizes the decentralized function of blockchain technology. After being on the chain, this distributed ledger structure can enable other members in the network to timely understand the changes in data, achieving transparency, tamper resistance, and ensuring the authenticity and reliability of transactions.

4. Results and Discussion

4.1 Experimental Preparation

Table 1: Data sources and quantity

Number	Data type	Data sources	Data volume	Blockchain smart contract application
1	Trade data	Company in country A	1,000	Yes
2	Transportation records	Logistics companies in country B	800	Yes
3	Payment information	Financial institutions in country C	600	Yes
4	Cooperation agreement	Multinational companies in country D	10	Yes

By collecting data from various countries and industries, including trade data, payment information, cooperation agreements, etc., the experiment successfully achieves the sharing and trustworthy exchange of these data. The application of blockchain smart contracts ensures the security and tamper resistance of data, thus providing a reliable data foundation for the "the Belt and Road" digital economic cooperation. In terms of cross-border payments and contract execution, blockchain smart contracts achieve automated execution and recording of transactions, ensuring transparency and traceability, reducing transaction costs and disputes, and accelerating capital flow and business execution speed. In terms of logistics and supply chain management, blockchain technology enables full traceability and data sharing of products from the production country to the destination, improving the transparency and efficiency of the supply chain, and reducing logistics costs and risks. In terms of security traceability and data authenticity verification, blockchain smart contracts establish a trust mechanism between products and manufacturers, ensuring the authenticity and credibility of product information, providing consumers with transparency and verifiability, helping them make wiser purchasing decisions, and improving product market competitiveness. The sample data of the experiment is shown in Table 1.

4.2 Experimental Results

Table 2: Cross-border payments and contract execution

Number	Transaction type	Counterparty	Amount ($)	Blockchain smart contract application
1	Import trade payment	Enterprises in country A	500,000	Yes
2	Export trade payment	Enterprises in country B	300,000	Yes
3	Service contract payment	Service provider in country C	150,000	Yes
4	Logistics service settlement	Logistics company in country D	80,000	Yes

Table 2 covers the scenarios of cross-border payments and contract execution, including import trade payments, export trade receipts, service contract payments, and logistics service settlements. Through blockchain smart contracts, automated execution and recording of these transactions are achieved, ensuring transparency and traceability of transactions. This automated payment and contract execution process reduces transaction costs, reduces disputes, speeds up capital flow and business execution, and facilitates cross-border trade and cooperation in the "the Belt and Road".

Table 3: Logistics and supply chain management

Number	Product name	Producer country	Transportation starting point	Transportation terminals	Blockchain smart contract application
1	Electronic products	Country A	Port A	Port B	Yes
2	Textiles	Country B	Port B	Port C	Yes
3	Mechanical equipment	Country C	Port C	Port D	Yes
4	Chemical products	Country D	Port D	Port E	Yes

In the experiment in Table 3, applications in the fields of logistics and supply chain management are focused on. Through blockchain smart contracts, the full traceability and data sharing of products from the production country to the destination are achieved. This traceability ensures the safety and quality of the product, while improving the transparency and efficiency of the supply chain. All parties involved can view the transportation status and historical records of products in real-time, thereby better coordinating logistics and inventory management, reducing logistics costs and risks.

Table 4: Security traceability and data authenticity verification

Number	Product name	Producer country	Manufacturer	Blockchain smart contract application
1	Electronic products	Country A	Company X	Yes
2	Textiles	Country B	Company Y	Yes
3	Mechanical equipment	Country C	Company Z	Yes
4	Chemical products	Country D	Company W	Yes

In this Table 4 experiment, the safety traceability and data authenticity verification of the product are given special attention. Through blockchain smart contracts, a trust mechanism is established between products and manufacturers, ensuring the authenticity and credibility of product information. Consumers can view the production process and supply chain information of products through blockchain platforms, thereby better understanding the source and quality of products. This transparency and verifiability help consumers make wiser purchasing decisions and improve the market competitiveness of products.

The accuracy of the data is checked and the data transmission time is recorded. The data exchange transmission performance is tested. The specific test data and results are shown in Figure 1. The system requires the completion of MySQL (My Structured Query Language) database data exchange and FTP (File Transfer Protocol) file transfer. The test quantity for MySQL database data exchange is 100000 data. The number of tests for FTP file transfer is 50000, 100, and 1. The test results are shown in Figures 1 and 2.

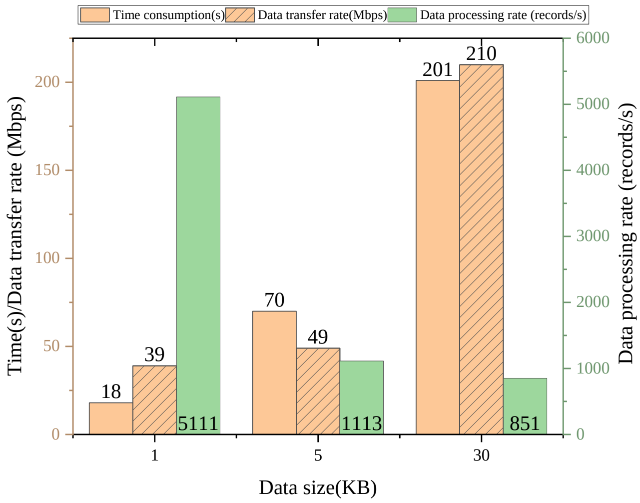

Figure 1: Performance of MySQL database data exchange task

From Figure 1, it can be seen that the data exchange rate is relatively excellent and sufficient for use. Even if the data size is 30KB and the number of tests is 100000, the speed can still reach 851 entries/s.

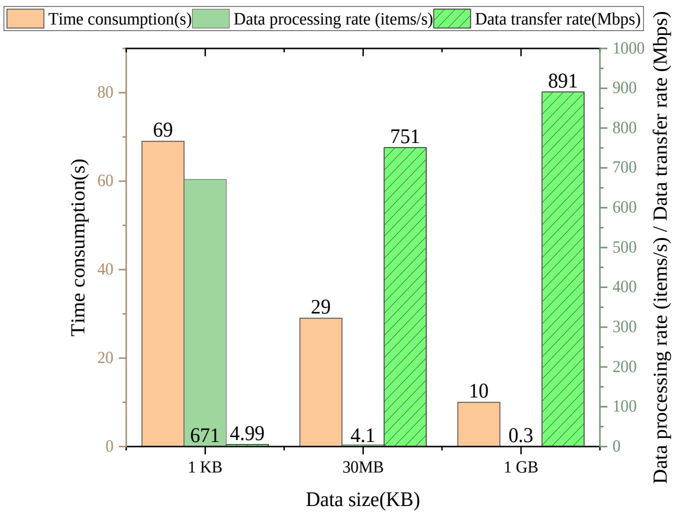

Figure 2: Performance of FTP file transfer data exchange task

Figure 2 shows the performance data of the system completing FTP file transfer. From Figure 2, it can be seen that when the data block size is 1GB, it takes 10 seconds and the data transfer rate still reaches 891Mbps. Due to the testing quantity of 50000 when the data block size is 1KB, the data transfer rate is relatively slow.

5. Conclusion

With the rapid development of the digital economy, the "the Belt and Road" initiative has become one of the important platforms for international cooperation, promoting economic exchanges and digital transformation between countries. However, in cross-border data exchange, the security and credibility of data have always been a challenge. This paper studied the feasibility and advantages of using blockchain technology and smart contracts to achieve reliable data exchange in the "the Belt and Road" digital economy cooperation. By analyzing the characteristics of blockchain technology and the application scenarios of smart contracts in data exchange, the following conclusions were drawn: blockchain technology and smart contracts provided reliable technical support for reliable data exchange in the "the Belt and Road" digital economic cooperation. The decentralized nature, immutability, and automated execution mechanism of smart contracts of blockchain effectively ensure the security, transparency, and traceability of data exchange. The experimental results indicate that blockchain technology and smart contracts have played an important role in cross-border payments, contract execution, logistics management, and product traceability, reducing transaction costs, improving cooperation efficiency, and promoting the development of digital economy cooperation. This provides a feasible technical solution for international cooperation and an important reference for promoting the development of digital economy under the "the Belt and Road" initiative.

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