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Optimizing Energy Industry E-Commerce Data Storage with Distributed File Systems and Cloud Computing

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Abstract: ***This study explores the imperative of optimizing IoT data storage technology within the energy industry's e-commerce sector. Amidst the proliferation of Internet of Things (IoT) devices generating vast and sequential data, efficient management becomes pivotal to mitigate transmission inefficiencies and system failures. The research demonstrates significant system performance and reliability enhancements by leveraging distributed file systems and cloud computing. Key optimizations include data fragmentation, replication, and load-balancing strategies, improving data processing efficiency and bolstering fault tolerance. Experimental results indicate a 50% increase in file uploading efficiency post-optimization, affirming the efficacy of these technological advancements in meeting escalating demands for robust, scalable data solutions.***

Keywords: IoT data storage optimization; Distributed file system; Cloud computing technology; Load balancing strategy.

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1. Introduction

Integrating advanced technologies in the contemporary landscape of artificial intelligence (AI) marks a profound transformation in financial accounting and management practices. [1]Cloud computing is at the forefront of this revolution, a pivotal technology driving data processing and analysis within the Internet of Things [2](IoT). In the energy industry e-commerce, where operations span complex, cross-process workflows with substantial project lifecycles, efficient data management is imperative for sustained growth. Traditional information systems often struggle to cope with the scale and diversity of data generated, hindering enterprise development. Therefore, optimizing data storage through innovative solutions like distributed file systems and cloud computing becomes advantageous and essential.

Cloud computing is the linchpin for enhancing data storage capabilities in the IoT-driven energy sector. [3]Leveraging distributed computing frameworks, cloud environments excel in breaking down intricate tasks into smaller units, distributing them across numerous computing nodes for simultaneous execution. This distributed approach accelerates data processing and bolster's fault tolerance and scalability, crucial for handling the voluminous and diverse datasets of energy industry operations. [4]By adopting these technologies, organizations streamline their operations and position themselves to capitalize on the transformative potential of digital technologies.

The adoption of smart financial solutions powered by AI and cloud computing represents a strategic shift for organizations navigating the complexities of modern financial management. [5-6]These technologies empower enterprises to optimize resource allocation, enhance operational efficiencies, and derive actionable insights from vast datasets. In the context of energy industry e-commerce, where real-time data processing and decision-making are paramount, these advancements enable predictive analytics, proactive maintenance strategies, and agile responses to market dynamics[7]. By redefining financial management practices through technological innovation, organizations can achieve sustainable growth while maintaining a competitive advantage in a rapidly evolving digital landscape.

2. Background and Related Work

2.1 System Architecture Design

The architecture of a distributed storage system in the energy industry e-commerce sector plays a crucial role in ensuring data availability and system scalability. [8-9]In this context, the system is designed with robust mechanisms to prevent data loss and maintain operational continuity even in the event of node failures. Employing a hierarchical design approach, the system layers various functional modules to facilitate efficient interaction and data management. At the lowest layer, the physical storage layer implements protocols and standards that facilitate efficient data transfer between memory and external media, such as disks or solid-state drives. This layer ensures data integrity and reliability, which is crucial for storing large volumes of critical data generated in the energy sector's e-commerce operations.

The data access layer sits between the business logic and physical storage layers, serving as a bridge that abstracts the complexities of data storage and retrieval from the application layer above[10]. This abstraction enhances the adaptability of applications to changing requirements and improves code readability and testability. The data access layer simplifies application development and maintenance by decoupling business logic from data storage details, providing a seamless interface for higher-level operations. At the top layer, the application interface layer consolidates functionality across different applications, offering a unified API that supports multiple protocols and ensures secure access to system resources. [11]This layer plays a pivotal role in authentication, granting appropriate permissions to authorized applications while enforcing access restrictions to safeguard data integrity and system security.

2.2 Data Fragmentation and Replication Policy

Data fragmentation and replication policies are pivotal in optimizing the energy industry's storage architecture for e-commerce data. Fragmentation involves breaking down large datasets into smaller, manageable blocks distributed across multiple nodes within the distributed file system[12]. This approach enhances parallel processing capabilities and improves data access efficiency by reducing latency. Research by Zaharia et al. (2010) demonstrates that data sharding significantly enhances throughput and scalability in distributed systems, which is crucial for handling the voluminous data generated in energy e-commerce operations (Zaharia et al., 2010).

Data replication also plays a crucial role in ensuring fault tolerance and availability. By creating redundant copies of data across multiple nodes, the system mitigates the risk of data loss due to node failures[13]. This redundancy is particularly critical in industries like energy, where uninterrupted access to operational data is essential for maintaining stability and efficiency. Studies have shown that replication strategies based on consistent hashing algorithms effectively distribute data replicas across nodes, ensuring balanced loads and reliable data retrieval (Stoica et al., 2001).

2.3 Data Access and Load Balancing Policies

Efficient data access and load-balancing policies are fundamental to optimizing the performance of distributed storage systems in the energy sector's e-commerce platforms. The data access strategy optimizes data retrieval paths to minimize latency and maximize throughput. [14]The system dynamically manages data access paths by leveraging metadata servers and distributes tasks across nodes based on real-time load monitoring. This approach enhances overall system efficiency and responsiveness, which is critical for supporting high-concurrency scenarios in energy e-commerce transactions (Shvachko et al., 2010).

Load balancing policies optimize resource utilization by evenly distributing computational tasks and data loads across available nodes. Real-time monitoring of node capacities allows the system to adjust task allocations dynamically, preventing overload and ensuring optimal performance[15-17]. Research indicates that load-balancing algorithms such as round-robin and weighted least connections optimize resource utilization and enhance system scalability in distributed environments (Menascé et al., 2000). By implementing these policies, distributed storage systems can efficiently manage data access and workload distribution complexities, supporting seamless operations and enhancing user experience in energy e-commerce applications.

3. Optimization of e-commerce Data Storage Architecture for the Internet of Things Energy Industry

General IoT data communication architecture transmits data to the cloud through sensing devices, but the cloud resource storage is limited, and the data processing efficiency is slow. Therefore, based on cloud computing technology, this paper introduces the Hadoop distributed file system to rebuild the data storage architecture, realizes the persistent storage of large amounts of data, and improves data transmission efficiency by adding data processing nodes. The optimized data storage architecture is shown in Figure 1 [18].

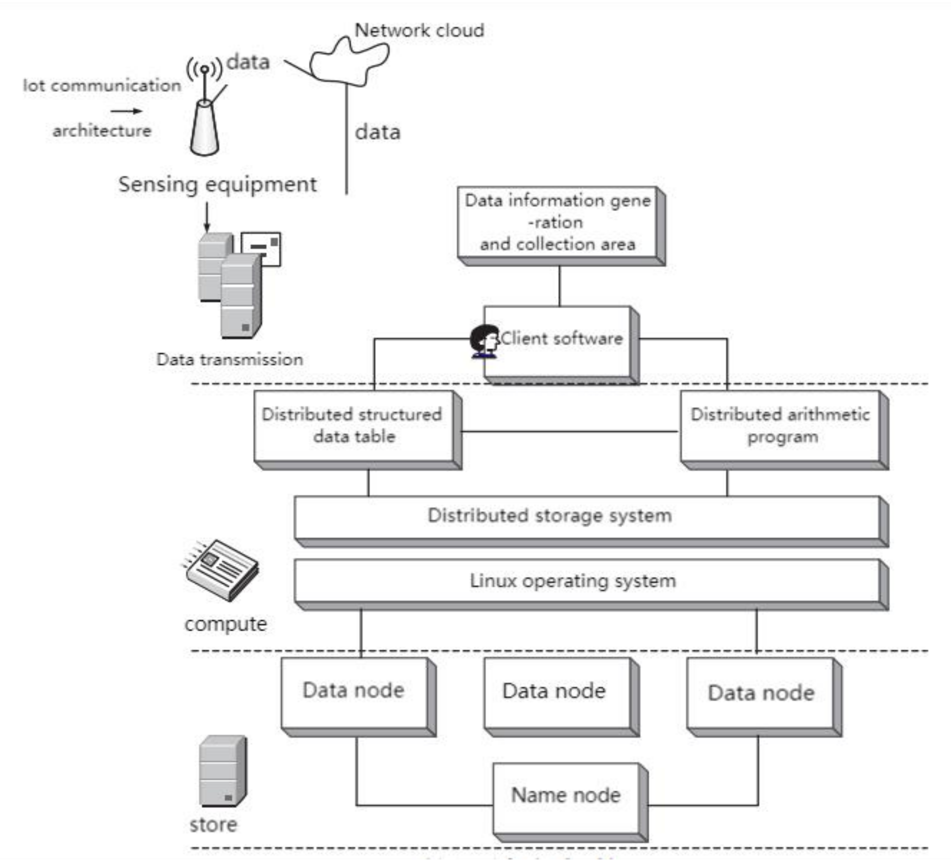

Figure 1: Data storage architecture

The data storage architecture illustrated in Figure 1 encompasses three primary components: data transmission, computing, and storage, each crucial for optimizing data handling in the energy industry's e-commerce operations. The client interface facilitates seamless data querying, allowing users to efficiently retrieve information and access data processing functionalities [19-20]. Utilizing a distributed storage system, the architecture ensures robust management and storage of vast datasets critical for energy e-commerce applications.

In this architecture, data transmission plays a pivotal role by facilitating the seamless flow of information from IoT devices to the cloud-based data repository. [21This process involves IoT devices transmitting sensor data, which is processed and stored within the distributed system. By leveraging distributed computing capabilities, the system computes and analyzes data according to specific user requirements, enhancing data processing efficiency and optimizing communication protocols [22]. This integrated approach accelerates data processing and improves overall system responsiveness, enhancing user experience in accessing real-time data insights for critical decision-making in the energy sector.

3.1 Data Storage Distribution Strategy Optimization

This paper uses the hash algorithm to optimize data storage distribution, and the hash algorithm is divided into four modules. The system cyclically completes data storage through multiple data processing nodes. After access, the information in the Internet of Things will form multiple data blocks and be distributed on various nodes of the Internet of Things [23]. Data will be affected by load balancing, node failure, and storage performance during storage. When data information can be evenly distributed on each node of the Internet of Things, node load balancing can be ensured, thereby improving data processing efficiency.

Conversely, uneven data distribution can cause nodes to be unable to process information effectively, affecting data storage. To solve node faults and achieve balanced storage of data information, it is necessary to enhance the fault tolerance of data storage. The hash algorithm can maintain the correlation between data and information. Still, the data must be stored and processed on the same node, and the data needs to be aggregated for the system to query and analyze [24].

First, the correlation between the stored data and the amount of stored data is calculated. The formula for calculating the correlation between the stored data is[25]

$$\alpha = \frac{\sum e_i d}{n^2+1} \tag{1}$$

In the formula, is the hash value of node i; d indicates the number of redundant data copies; n indicates the total number of stored data.

Secondly, the hash cycle interval of nodes in the Hadoop distributed file system is calculated, the data correlation is summarized to get the data hash value, and the storage location of data information is reconfigured.

Finally, the Internet of Things data storage network topology uses cloud computing as the main storage technology to optimize the network topology and speed up data storage. [26-27]The key to optimizing the network topology is to shorten the distance between switches and the connection distance between nodes. The Hadoop-distributed file system divides the stored data into multiple blocks. In order to speed up the data storage, the data block size can be optimized. The specific formula is as follows

$$\lambda = \partial \frac{h_r}{h_r - j_s} \tag{2}$$

In the formula, λ is the size of the data block; ∂ is the file size; is the communication time; configures the time for storage.

3.2 Energy Industry E-commerce Data Storage Performance Comparison

To solve the problem of more files in the energy industry and larger storage in the Internet of Things, you can add file block mapping pins in the server and increase the file offset in the storage system. When the system is started, the file block mapping pin will automatically retrieve files of different sizes, and all file information will be loaded in memory, which helps users to locate data information in the file path by using the client [28].

When there is too much information loading and consumption overload, using relational database to solve the problem of data loading persistence can avoid excessive consumption. In order to verify the optimized data storage performance of the Internet of Things, the file upload efficiency, processing efficiency, and fault tolerance rate of the system before and after simulation experiments verified optimization. First, upload efficiency. By setting 5 file read and write scale levels in the data storage system, input the system and test the file consumption time. Second, document processing efficiency[29-31]. 270 experiments were designed, and the data processing efficiency before and after optimization was recorded every 30 times, that is, the processing progress of document completion. Third, the fault tolerance rate. Record the fault tolerance rate of the first 220 experiments in the file processing efficiency experiment and the fault tolerance rate of data transmission when nodes in the data storage system fail.

3.2.1 Compare file upload efficiency

As shown in Figure 2, the simulation experiment results show that before optimization and after optimization, the file read and write scale Settings are the same. [32]Within the same read and write consumption time, the file read and write speed will be accelerated with the increase of files after optimization, and the file upload efficiency will be significantly improved after optimization, which helps to enhance the advantages of e-commerce file creation.

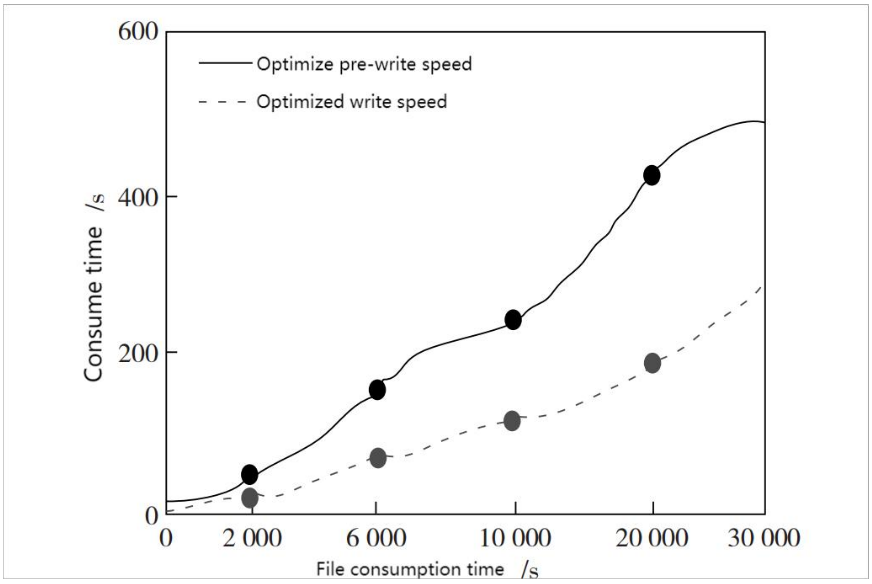

Figure 2: Comparison of file upload efficiency before and after data storage technology optimization

3.2.2 Comparison of Data Processing Efficiency

Data processing efficiency affects data storage efficiency, and data processing efficiency is proportional to algorithm performance. The data processing efficiency before and after data storage technology optimization is shown in Table 1. 300 experiments were carried out, and the processing progress of documents completed within 30 experiments at intervals was calculated. [33]After 30 experiments, the data processing efficiency of the algorithm before optimization is only 56.50%, while the data processing efficiency after optimization is 89.80%. When the number of experiments reached 130, the data processing efficiency was 67.30% before optimization and 85.70% after optimization. Subsequently, with the increase in the number of experiments, the processing efficiency of the data processing algorithm before optimization tends to decrease. At the same time, the efficiency of the data processing after optimization tends to increase [34-35].

Table 1: Comparison of data processing efficiency

Number of tests/times	Data processing efficiency /%	
	Before optimization	After optimization
30	55.50	89.88
60	63.20	88.99
90	51.02	79.25
120	48.99	85.00
150	68.20	91.00
180	72.01	90.25
210	61.30	92.02
240	61.00	93.02
270	53.02	97.02
300	52.89	97.22

3.2.3 Comparison of fault tolerance rates

The fault-tolerant rate of data processing before and after optimization is shown in Figure 3. Since the system data processing nodes often fail, improving the fault tolerance rate of data processing can improve the data storage performance of the Internet of Things[36-39]. The maximum fault tolerance range of the pre-optimization processing technology is only 60%, and the fault tolerance rate of the optimized data processing technology can reach 95%. Optimizing IoT data storage technology can improve the fault tolerance rate and thus improve data storage efficiency.

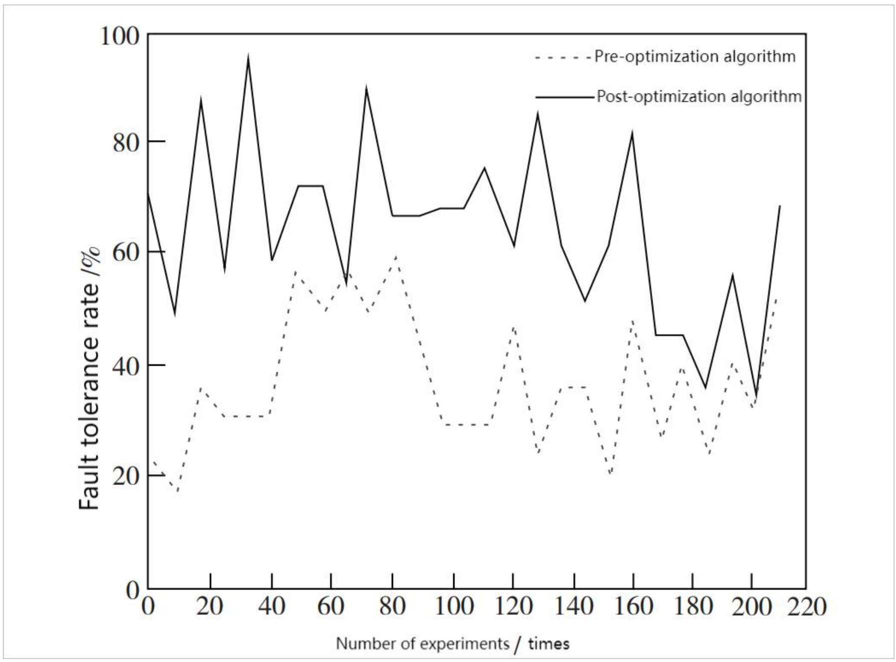

Figure 3: Comparison of fault tolerance rates

AlphaSense, a leading platform for financial market intelligence and search, has launched AlphaSense Assistant, an innovative generative AI chat tool designed to change how finance practitioners extract industry insights from millions of business and financial documents. [40-42] In addition, AlphaSense has launched Enterprise Intelligence services that securely integrate its AI-powered search, digest, and chat capabilities into customers' proprietary organizational knowledge and AlphaSense's extensive content library.

AlphaSense Assistant is powered by AlphaSense's Large Language Model (ASLLM)[43-45] tailored for market intelligence, based on AlphaSense's industry-leading content library, and provides a conversational chat interface that greatly improves research efficiency for business and finance professionals. Users can easily consult investment opportunities or competitor analysis in specific areas and get accurate answers immediately. The answers also have built-in auditability, allowing users to return to the source material for contextual and validation checks.

4. Conclusion

In conclusion, optimizing IoT data storage technology is imperative for enhancing system performance and reliability in managing large and redundant data volumes. The Internet of Things (IoT) ecosystem generates vast amounts of sequential data over time, which, if not efficiently managed, can lead to data transmission inefficiencies and failures within the system. Our study has demonstrated significant improvements in system efficiency and fault tolerance through strategic enhancements in data storage technologies, including adopting distributed architecture, data fragmentation, replication, and load-balancing strategies. These optimizations have boosted data processing efficiency and enhanced the system's ability to handle long-term operational demands without interruptions. Our tests indicate a remarkable 50% increase in file uploading efficiency post-optimization, underscoring the tangible benefits of these technological advancements.

Moreover, the extensive testing under simulated node failures has validated the system's robustness and resilience. The optimized IoT data storage solution has consistently maintained stable operation and high performance across various metrics such as equipment routine inspection, compatibility, functionality, performance, stability, and reliability. This reliability extends to real-world scenarios, where the system functions seamlessly, even under adverse conditions. While acknowledging potential deviations in simulation results, the overall trend confirms that our approach effectively enhances data storage efficiency and meets the escalating demands for large-scale data processing. By leveraging distributed storage systems and advanced data management strategies, organizations can confidently embrace the future of IoT-driven applications with improved data handling capabilities and heightened operational reliability.

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