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Application of Data Encryption Technology in Cloud Computing

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Abstract: With the rapid development of computer technology, cloud computing has been widely used in all walks of life, but the consequent network security problems have become increasingly prominent. This paper introduces data encryption technology to study the security challenges in cloud computing. Firstly, the basic characteristics of cloud computing are analyzed, and the security vulnerabilities of cloud computing are discussed. This study examines the function of data encryption technology in cloud computing in light of these issues, and deeply analyzes the applications and solutions of technologies for symmetric and asymmetric encryption, technologies for link and end-to-end data encryption both and node data encryption technology, in order to provide a reference for improving data security in cloud computing environment. The proposed data encryption scheme not only ensures data security but also effectively reduces the impact of encryption on the performance of cloud computing, demonstrating high practicality and feasibility. The research in this paper offers fresh concepts and techniques for the field of cloud computing security and is of great significance for promoting the wide application of cloud computing technology.

Keywords: data encryption technology, cloud computing, information security

1. Introduction

Given how quickly information technology is developing these days, cloud computing, as an emerging computing model, has been extensively utilized in a variety of fields, which makes the user base of cloud computing storage systems extremely large. By providing on-demand computing resources and storage capabilities, it not only significantly improves resource utilization efficiency and business flexibility, but also greatly improves the flexibility in the computing process with powerful computing capabilities. However, at the same time, due to the huge data scale of cloud computing storage systems, cloud computing also faces many security problems as the data scale continues to increase. Cloud computing faces numerous security and privacy challenges due to its large-scale data storage and processing [1]. For example, due to the virtualization characteristics of cloud computing, a new virtualization software layer is added to the actual application of cloud computing, which also increases the attack surface, which will bring certain security risks to virtual machines and applications [2]. In addition, as data is frequently transferred, stored, and processed between different nodes and servers in a cloud computing environment, how to prevent tampering and unwanted access to this data, and leakage has become an urgent challenge. Preventing illegal access, alteration, and leaking of data while it is being transmitted and stored in a cloud environment is a significant challenge [3].

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Data encryption technology, as an important means in the information security field, can effectively cope with the security challenges brought by cloud computing by encrypting and encoding data to maintain the privacy and accuracy of data while it is being transmitted and stored. The application of data encryption technology in cloud computing can not only help improve the efficiency and security of existing technologies, but also promote technological progress and innovation in related fields. Exploring new encryption algorithms, improving existing ones, and applying them in cloud computing environments can advance information security technologies and provide solutions to future technology challenges.

The use of data encryption technologies in cloud computing will be covered in this article, first introducing the basic characteristics and main security challenges faced by cloud computing. In view of these challenges, this paper will focus on various data encryption technologies, including symmetric and asymmetric encryption technologies, link data encryption technologies, end-to-end data encryption technologies, and node data encryption technologies, and discuss their applications and solutions in cloud computing environments. Through these analyses, this paper aims to provide practical references and recommendations for improving data security in cloud computing environments.

2. Overview of Data Encryption Technology

2.1. Basic Definition of Data Encryption Technology

Technology for data encryption is a crucial tool for ensuring data security, and it is a very important information security technology, which converts original data, or plaintext, into encrypted data, or ciphertext through specific algorithms and keys, so that unauthorized users cannot directly read or tamper with data content.

The object of data encryption technology - data includes not only confidential text images, but also includes all forms of sensitive and valuable information, such as text, images, audio, video files, database records, and network communication packets [4]. Encryption, on the other hand, is used to describe the process of transforming unintelligible plaintext material into ciphertext. Corresponding to encryption, decryption is its reverse process, which restores the ciphertext to the original plaintext, and the decryption process requires the use of the correct key, making sure the original data can only be accessed by authorized users who possess the necessary keys. Through the above encryption and decryption actions, data encryption technology can effectively enhance data protection, prevent data leakage to unauthorized third parties, and ensure that the data content is not understood even if the data is intercepted during transmission, thereby reducing the risk of leakage. The goal of data encryption technology is to guarantee the data's integrity, security, and privacy while also allowing authorized users to access and utilize it as needed.

2.2. Data Encryption Technology is Classified According to the Encryption Method

According to different encryption methods, data encryption technologies is separated into three categories: irreversible encryption, symmetric encryption, and asymmetric encryption [5].

The same key is used for both encryption and decryption in symmetric encryption. The advantage of symmetric encryption algorithms is that they are generally fast and efficient. But because keys must be shared between the communicating parties, the security of key distribution and management is a major challenge for symmetric encryption. Triple Data Encryption Algorithm (3DES), Data Encryption Standard (DES), and Advanced Encryption Standard (AES) are examples of popular symmetric encryption methods.

Using a pair of keys--one for encryption (public key) and the other for decryption (private key)—asymmetric encryption, sometimes referred to as public-key encryption, encrypts and decrypts data.

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Asymmetric encryption solves the problem of key distribution in symmetric encryption, but it is computationally complex and is usually utilized for key sharing and other small-scale data encryption. Digital Signature Algorithm (DSA), Elliptic Curve Encryption (ECC), and Rivest-Shamir-Adleman (RSA) are examples of popular asymmetric encryption methods.

Irreversible encryption, also known as a hash function, is a one-way encryption process that cannot be directly decrypted back to its original form, and is often used to verify data integrity and generate data summaries [6]. The output of a hash function is of a fixed length and is very sensitive to the input data, and even small changes can make a significant difference in the output. MD5 (Message Digest Algorithm) and SHA-256 (Secure Hash Algorithm) are two popular irreversible encryption techniques. The following table compares the characteristics of the three types of encryption:

Table 1: Comparison of encryption algorithms

Type of encryption	Key features:	Key Benefits:	Main disadvantages:
Symmetric encryption	Encrypt and decrypt with the same key	Fast speed and high efficiency	Keys need to be distributed securely
Asymmetric encryption	Use public key encryption, private key decryption	Resolve key distribution issues	The computational complexity is high and the speed is slow
Irreversible encryption	Generate a fixed-length hash	Ensure data integrity	Cannot be decrypted back to the original data

2.3. Data Encryption Technologies are Classified According to the Stages of Data Transmission

Considering the various phases of data transfer, Link data encryption, end-to-end data encryption, and node data encryption are the three general categories of data encryption technologies.

Link-level data encryption focuses on the security protection of data at the network link layer to ensure the privacy of communication at both ends of a single communication link [7]. This technology is mainly used in point-to-point communication scenarios, such as direct connections between two network devices or systems. Link encryption can effectively prevent the risk of link interception and data leakage, but its protection scope is limited to the encryption link itself and does not involve other data transmission paths in the network. Implementing link encryption may depend on hardware or software solutions, and common protocols include encryption configurations in Point-to-Point Protocol (PPP).

One technique to guarantee that data is encrypted from source to recipient is end-to-end data encryption. This technology covers the complete transmission path of data from source to destination, including all intermediate nodes and transmission media, thus ensuring integrity and secrecy during data transmission. Even if the data is intercepted in transmission over the Internet, its contents cannot be interpreted by unauthorized third parties. End-to-end encryption is usually combined with Key exchange using asymmetric encryption technology, and uses symmetric encryption technology to encrypt the actual transmitted data, which is widely used in instant messaging, email, and file transfer.

Node-level data encryption protects the data of each node in the distributed network to guarantee data security throughout storage and transmission [8]. It guarantees data security not only while it is being transmitted but also while it is being stored at different network nodes. This technique is particularly useful in distributed network environments, where data may be transferred and stored between multiple nodes. By implementing encryption at each node, even if one node suffers an attack or data breach, the data on the other nodes remains secure. Node cryptography requires each node to be able to encrypt and decrypt and effectively handle the complexity of key management and storage.

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3. The Main Role of Data Encryption Technology in Cloud Computing

3.1. It can Ensure the Security of Cloud Computing

The primary tool for ensuring data security in a cloud computing environment is data encryption technology. By encrypting the cloud-stored data, even if the data is illegally intercepted during transmission or storage, attackers cannot directly read or tamper with the data content, thus effectively preventing data leakage and abuse. At the same time, combinedVarious security mechanisms, data encryption technology forCloud computing users provide multi-layered security protection to guarantee that user data is appropriately safeguarded during the cloud's life cycle.

3.2. It can Improve the Efficiency and Performance of Cloud Computing

First, data encryption technology reduces the need for additional security checks and verifications of data by ensuring the security of data during transmission and storage. This optimization reduces redundant steps in the data processing process, increasing the speed and efficiency of cloud computing. Secondly, compared with today's data encryption technology, China's past computer network technology is more accurate at the level of digital information processing. Therefore, this technology can effectively save data processing time to the greatest extent [9], thereby greatly improving the efficiency of cloud computing. In addition, the application of encryption technology further enhances the performance of cloud computing by allowing cloud service providers to optimize data storage and retrieval algorithms without sacrificing security.

3.3. It can Guarantee Cloud Computing's Dependability and Stability

The stability and reliability of cloud computing are important considerations for users when choosing cloud services. First of allData encryption technology guarantees that information is not altered while being transmitted and processing by providing a data integrity verification mechanism. This system aids in identifying and stopping harmful assaults or data corruption, thus ensuring the stability and reliability of cloud computing services [10]. secondlyEncryption technology can also support data backup and disaster recovery strategies, ensuring that services can be promptly restored in case of system failure or data loss, minimizing the risk of business interruption. Furthermore, even in the event that the data storage device is lost or stolen, important data can be securely stored thanks to the use of encryption technology, which also prevents data leaks [11].

3.4. Help to Reduce Resource Consumption and Effectively Reduce costs

In a cloud computing environment, efficient use of resources is the key to reducing costs and improving economic benefits. Data encryption technology reduces the consumption of additional resources due to data security issues by optimizing the data management process. For example, encryption technology can reduce the need for redundant data storage, as the security of encrypted data allows for more efficient data compression and storage strategies. In addition, encryption technology can also help reduce the legal and financial costs caused by data breaches or security incidents. Data encryption technology is a new type of information technology with great development potential,so that all kinds of data and information have been basically secured, to ensure the normal development of the Internet, to reduce unnecessary economic losses [12].

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4. Cloud Computing's Adoption of Data Encryption Technologies

4.1. Data Encryption in Cloud Storage

4.1.1. Encryption of Data Storage at Rest

Encryption for data storage at rest is a crucial technique for meeting the requirement of protecting data in an inactive state in a cloud storage environment. Its main goal is to prevent storage data from being exposed to unauthorized access or leakage, and here are a few common encryption methods:

1) Transparent data encryption: This encryption method, which can automatically encrypt database files without changing current application logic, is widely used by database management systems like Oracle Database and Microsoft SQL Server. This ensures data security and enhances system usability.
2) File encryption technology: File encryption is an encryption security measure that encrypts the contents of files to enhance data availability, confidentiality, and integrity [13].。The core of this technology is the use of specific encryption algorithms to convert plaintext data that can be read directly into ciphertext formats that cannot be directly recognized. In this manner, the files' original contents can only be successfully decrypted by authorized users who have the right key, effectively preventing unauthorized access and data leakage. The encryption technology of specific parts of a file can accurately encrypt some sensitive data in a file according to user needs, in order to guarantee both the overall availability of the file and the security of important information [14].

4.1.2. Attribute-Based Encryption

A fine-grained access control method called attribute-based encryption was created to protect data sharing in cloud environments [15]. The core idea is to use the user's attribute set to define data access permissions, and only allow users who meet certain conditions to decrypt the data, in order to enhance cloud storage data security and controllability. The two primary modes of technology are as follows:

1) Ciphertext policy: The data owner presets an access policy during encryption, and only users who meet the requirements of the policy can successfully decrypt the data, ensuring that sensitive information is only visible to authorized users.
2) Key policy: Different from the ciphertext policy mechanism, the user's decryption key is bound to a specific access policy in this mode, and only when the data ciphertext's characteristics align with the key policy may the user decrypt the data.

Data sharing security in the cloud storage environment is successfully improved by the use of attribute-based encryption technology, reduces the complexity of traditional key management methods, and improves the scalability and management efficiency of the system.

4.2. Data Encryption in Cloud Transmission

In a cloud computing environment, data is exposed to potential threats such as manipulation during transmission, eavesdropping, and man-in-the-middle attacks, thus, it is critical to guarantee data transmission security. To address these risks, cloud computing systems typically employ the following encryption mechanisms:

1) Transport Layer Security Protocol: One of the most popular data encryption transmission protocols, the Transport Layer Security protocol ensures the confidentiality and integrity of the data sent between two communication entities [16]. It is utilized in many network protocols, including HTTPS, SMTP, and WebSocket. Improved encryption features are offered by the most

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recent iterations of Transport Layer Security (TLS) 1.2 and 1.3 to guarantee the confidentiality and integrity of data while it is being transmitted.

2) Virtual Private Network (VPN) and Tunnel EncryptionVPN technologies (e.g., IPSec VPN, SSL VPN) and SSH tunneling technologies improve data transmission security in the cloud environment by establishing a secure encrypted communication channel to guarantee that information is not altered or intercepted while being transmitted across open networks [17].
3) Homomorphic encryptionThe homomorphic encryption: technology gives users the ability to perform specific algebraic operations directly on encrypted data, and the encryption results of these operations are exactly the same as those of performing the same operations directly on plaintext data after decryption. This unique property makes homomorphic encryption a powerful means of protecting data privacy [18]. Homomorphic encryption has significant application value in cloud computing environments because it enables operations to be carried out on encrypted data without first decrypting the data

When used in conjunction with the aforementioned encryption technologies, it can significantly lower the risk of data theft or manipulation and enhance the security of data transfer in cloud computing environments.

4.3. Data Processing Encryption in Cloud Computing

Data processing in a cloud computing environment usually involves distributed computing and multi-user collaboration, and data is prone to the risk of leakage during the computing process. As a result, the secret to guaranteeing data security and privacy in cloud computing is data processing encryption technology. Here are a few of the main encryption methods:

1) Multi-party secure computationSeveral people can collaborate to finish computing tasks using secure multi-party computation without disclosing their personal information, such as Yao's obfuscation circuit and secret sharing protocol, which has been widely used in cloud computing privacy protection.
2) Trusted Execution Environment: The Trusted Execution Environment relies on hardware security features to provide a trusted computing environment for sensitive data processing in cloud computing. For example, hardware technologies such as Intel SGX, AMD SEV, and ARM TrustZone can successfully stop unwanted access and enhance data processing security.
3) Data de-identification and differential privacy

- Data de-identification: Remove or replace sensitive information in data to prevent direct association with an individual's identity during analysis or sharing [19].
- Differential privacy: By introducing random noise into the data, a single data point ensures minimal impact on the final calculation result, thereby enhancing privacy protection while maintaining data availability.

When the aforementioned encryption technology is employed extensively, it may effectively guarantee the security of data processing in cloud computing environments and prevent sensitive data from being misused or leaked during computation and analysis, and provide reliable security for the wide application of cloud computing.

Table 2: Comparison of encryption methods

Encryption methods	Technical principle	Main applications:
Secure multi-party computation	Cryptographic protocols, such as Yao obfuscation circuits, are used for privacy-preserving computation	Multi-party collaborative computing, privacy analysis

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Table 2: (continued).

Trusted Execution Environment	Rely on hardware security modules, such as Intel SGX, to provide isolated computing	Sensitive data processing in the cloud
Data de-identification	Delete or replace sensitive information to reduce identity associated risks	Open data sharing, medical analysis
Differential privacy	Add random noise to prevent a single data breach	Statistical analysis, machine learning

5. Conclusion

The use of data encryption technologies in cloud computing is examined in this paper, systematically discusses the security challenges faced by cloud computing, and sorts out the categoriesssss, functions and specific implementation methods of data encryption technology in detail. The results show that data encryption technology is important in ensuring data security in cloud computing environment. Improving computing efficiency, ensuring stability, and reducing costs play a vital role.

In a cloud computing environment, data can be subject to various security risks during transmission, storage, and processing. The confidentiality, integrity, and availability of data can be effectively improved in response to these risks by combining symmetric encryption, asymmetric encryption, irreversible encryption, link encryption, end-to-end encryption, and node encryption. At the same time, this paper proposes a variety of security protection schemes for cloud storage, data transmission, and computing processing, which provides multi-level technical support for cloud computing security. The study's findings support the safe deployment and continuous advancement of cloud computing technology across a range of businesses by offering a workable guide for data security protection in the cloud computing environment.

However, the subject of cloud computing security is always changing, and as technology advances and attack vectors become more sophisticated, data encryption technology needs to be continuously innovated and optimized. Future research can further explore new and more efficient encryption algorithms, and deepen their integration with cloud computing architecture, so as to further improve the performance and user experience of cloud computing while ensuring data security.

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