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Artificial Intelligence Techniques for Secure Cloud Data Storage and Retrieval Using Giant Trevally Optimizer with Quantum Convolutional Neural Network-Based Encryption Algorithm: Trends and Challenges

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Abstract

Cloud computing has become a fundamental infrastructure for modern digital services due to its scalability, cost efficiency, and accessibility. However, the rapid growth of cloud environments has also raised significant concerns regarding data confidentiality, integrity, and secure access mechanisms. Traditional encryption methods and security protocols often struggle to cope with evolving cyber threats, large-scale data processing requirements, and the distributed architecture of cloud systems. To address these challenges, researchers are increasingly integrating artificial intelligence and advanced optimization techniques into cloud security frameworks. Artificial Intelligence (AI)–driven approaches such as deep learning, metaheuristic optimization algorithms, and quantum-inspired computing models have demonstrated strong potential for enhancing data protection in cloud environments. In particular, the Giant Trevally Optimizer (GTO**)**, a nature-inspired metaheuristic algorithm designed for complex optimization problems, has been widely explored for resource allocation, intrusion detection, and security optimization in distributed systems. The algorithm imitates the hunting behaviour of giant trevally fish and is capable of efficiently exploring large solution spaces to identify optimal configurations in cloud infrastructure. Alongside optimization algorithms, Quantum Convolutional Neural Networks (QCNNs) and deep learning-based encryption techniques have emerged as promising solutions for secure data transmission and storage. QCNN-based encryption mechanisms combine the feature extraction capability of convolutional neural networks with quantum cryptographic principles to generate complex encryption keys and secure communication channels. Such hybrid techniques offer stronger resistance to cryptographic attacks and improve the randomness of encryption keys compared with traditional methods.

Introduction

Cloud computing has revolutionized the way organizations store, process, and manage digital information. With the rapid expansion of data-driven technologies such as Internet of Things (IoT), artificial intelligence, and big data analytics, cloud platforms have become essential for handling massive volumes of data and computational workloads. Cloud infrastructure allows users to access computing resources,

storage, and services through the internet without the need for maintaining physical hardware, thereby reducing operational costs and improving scalability. However, as organizations increasingly rely on cloud systems, concerns related to data security, privacy protection, and secure information retrieval have become critical research topics.

One of the major challenges in cloud computing is ensuring the confidentiality and integrity of sensitive data stored on remote servers. Cloud service providers manage large amounts of data belonging to multiple users, which creates potential vulnerabilities such as unauthorized access, insider attacks, data leakage, and cyber-attacks. Traditional security approaches, including symmetric and asymmetric encryption algorithms, are widely used to protect data. However, these methods often face limitations when dealing with large-scale distributed environments and advanced cyber threats. As a result, researchers have started exploring intelligent security mechanisms that incorporate artificial intelligence and optimization algorithms to improve cloud security frameworks.

Artificial intelligence has shown significant potential in enhancing cybersecurity solutions. Machine learning and deep learning techniques can analyse complex patterns in network traffic, detect anomalies, and identify potential security threats in real time. Convolutional Neural Networks (CNNs), in particular, have been widely applied in pattern recognition and data transformation tasks, making them suitable for encryption and secure communication systems. CNN-based encryption models can generate complex transformations of input data, making it difficult for attackers to decode encrypted information without the appropriate neural network model.

Another emerging research direction is the use of quantum computing and quantum cryptography for secure communication. Quantum cryptographic systems utilize principles such as quantum superposition and quantum key distribution to create highly secure encryption mechanisms. These techniques significantly reduce the risk of interception and eavesdropping during data transmission. Integrating quantum computing concepts with neural networks has led to the development of Quantum Convolutional Neural Networks (QCNNs), which combine classical deep learning with quantum circuits to enhance security and computational performance.

In addition to encryption methods, optimization algorithms play an important role in improving the efficiency and performance of cloud systems. Metaheuristic optimization algorithms are particularly useful for solving complex problems involving resource allocation, task scheduling, and parameter optimization. The Giant Trevally Optimizer (GTO) is a recently developed nature-inspired optimization algorithm that mimics the hunting strategy of giant trevally fish. The algorithm uses exploration and exploitation mechanisms to efficiently search large solution spaces and identify optimal solutions. Due to its high convergence speed and global search capability, GTO has been successfully applied in various engineering optimization problems, including cloud resource management and cybersecurity systems.

Artificial Intelligence (AI)–driven approaches such as deep learning, metaheuristic optimization algorithms, and quantum-inspired computing models have demonstrated strong potential for enhancing data protection in cloud environments. In particular, the Giant Trevally Optimizer (GTO), a nature-inspired metaheuristic algorithm designed for complex optimization problems, has been widely explored for resource allocation, intrusion detection, and security optimization in distributed systems. The algorithm imitates the hunting behaviour of giant trevally fish and is capable of efficiently exploring large solution spaces to identify optimal configurations in cloud infrastructure. Alongside optimization algorithms, Quantum Convolutional Neural Networks (QCNNs) and deep learning-based encryption techniques have emerged as promising solutions for secure data transmission and storage. QCNN-based encryption mechanisms combine the feature extraction capability of convolutional neural networks with quantum cryptographic principles to generate complex encryption keys and secure communication channels. Such hybrid techniques offer stronger resistance to cryptographic attacks and improve the randomness of encryption keys compared with traditional methods.

Literature Review

Sadeeq and Abdulazeez (2022) introduced the Giant Trevally Optimizer (GTO), a novel metaheuristic optimization algorithm inspired by the hunting strategy of giant trevally fish. The algorithm employs exploration and exploitation mechanisms to efficiently search the solution space for optimal results. Their study demonstrated that GTO performs better than many traditional optimization techniques in solving complex engineering and computational problems. The researchers highlighted the potential of GTO for cloud computing applications such as resource allocation,

workload scheduling, and security optimization. The algorithm's ability to balance exploration and exploitation enables it to efficiently manage large-scale computational environments.

Li and Huang (2020) investigated the role of quantum cryptography and neural network-based encryption for secure communication systems. Their work explored how convolutional neural networks can enhance quantum cryptographic frameworks by generating complex encryption patterns and improving key distribution mechanisms. The researchers showed that integrating quantum cryptography with neural network models significantly improves data security and reduces the risk of interception in distributed communication networks.

Man (2023) proposed a neural network-based encryption scheme designed to enhance the security of cloud-stored data. The study introduced a bidirectional activation neural network model to generate dynamic encryption keys and improve randomness within the cryptographic system. The results showed that the proposed model effectively protects sensitive information in cloud environments by increasing key complexity and reducing vulnerability to brute-force attacks.

Yang et al. (2020) developed a decentralized framework based on Quantum Convolutional Neural Networks (QCNN) to improve data privacy in distributed computing environments. The system utilized quantum circuit encoders to extract features and protect sensitive information during data processing. Experimental results demonstrated that QCNN-based systems can achieve high accuracy while maintaining strong privacy protection, making them suitable for secure cloud computing applications.

Zhang, Wang, and Liu (2021) investigated the application of deep learning-based encryption mechanisms for secure cloud data storage systems. Their study proposed a hybrid framework combining convolutional neural networks with symmetric encryption algorithms to improve data confidentiality and integrity in cloud environments. The CNN model was used to generate complex encryption keys and enhance key randomness during secure data transmission. Experimental results demonstrated that the proposed approach significantly improved resistance against brute-force attacks and cryptanalysis. The researchers concluded that AI-based encryption frameworks can provide stronger security compared with traditional cryptographic techniques while maintaining computational efficiency.

Kumar and Kumar (2022) presented a machine learning-based cloud security framework for intrusion detection in distributed computing environments. The proposed model utilized deep neural networks for analyzing network traffic patterns and identifying malicious activities in cloud infrastructures. Their framework incorporated feature extraction techniques to detect abnormal behaviour and improve threat detection accuracy. The study showed that AI-driven security systems are capable of detecting complex attack patterns such as Distributed Denial of Service (DDoS) attacks, insider threats, and data tampering. The results demonstrated improved detection accuracy compared with conventional rule-based security systems.

Sharma, Gupta, and Singh (2023) proposed a metaheuristic optimization-based cloud security model using nature-inspired algorithms. Their research explored the use of optimization techniques such as particle swarm optimization and genetic algorithms to optimize encryption parameters and improve system performance. The authors emphasized that optimization algorithms play a crucial role in managing resource allocation and enhancing cryptographic strength in cloud environments. Their experimental evaluation indicated that optimized encryption mechanisms can significantly reduce computational overhead while maintaining high levels of data protection.

Chen and Zhao (2021) developed a quantum machine learning framework for secure cloud computing applications. Their research introduced a hybrid architecture integrating quantum neural networks with classical encryption algorithms to improve cloud data security. The proposed system utilized quantum circuits to generate secure cryptographic keys and protect data during transmission. The study demonstrated that quantum-based encryption techniques provide stronger resistance against cyber-attacks compared with classical encryption approaches. Furthermore, the researchers highlighted that quantum computing can play a critical role in future cloud security architectures.

Alqahtani et al. (2022) explored artificial intelligence-driven cybersecurity systems for protecting cloud computing infrastructures. Their study focused on the use of machine learning algorithms for detecting security vulnerabilities and predicting potential cyber-attacks in cloud environments. The authors proposed a predictive security framework that continuously monitors system behaviour and identifies anomalies in real time. The results showed that AI-based security models can significantly improve threat detection rates

while reducing false positives. The researchers concluded that integrating AI with cloud security mechanisms can enhance system resilience against emerging cyber threats.

Alazar et al. (2021) investigated the role of deep learning techniques for cloud cybersecurity and data protection. Their research proposed an intelligent intrusion detection system based on convolutional neural networks and recurrent neural networks to analyse network traffic patterns within cloud infrastructures. The system was trained on large-scale datasets to detect malicious behaviour and unauthorized access attempts. Experimental results indicated that the proposed AI-driven approach significantly improved attack detection rates while minimizing false alarms. The study concluded that deep learning-based cybersecurity frameworks provide an effective solution for securing cloud environments against evolving cyber threats.

Khan, Alqahtani, and Alsubhi (2022) proposed a secure cloud data storage framework using machine learning and cryptographic techniques. The researchers developed a hybrid security architecture where machine learning algorithms were used to monitor data access patterns and identify suspicious activities. The system also implemented advanced encryption mechanisms to protect sensitive information during storage and retrieval processes. Their findings showed that integrating machine learning with encryption systems enhances the overall security and efficiency of cloud computing infrastructures.

Zhou et al. (2023) explored the use of quantum cryptography for secure cloud communication systems. Their research highlighted how quantum key distribution (QKD) can be applied to cloud networks to provide secure data transmission channels. The study demonstrated that QKD-based encryption systems offer extremely high levels of security due to the fundamental principles of quantum mechanics, which make eavesdropping detectable. The authors emphasized that combining quantum cryptographic systems with artificial intelligence can significantly strengthen cloud security frameworks.

Patel and Patel (2021) conducted a comprehensive study on metaheuristic optimization algorithms for cloud resource allocation and security enhancement. Their research analysed several nature-inspired algorithms including genetic algorithms, particle swarm optimization, and ant colony optimization for optimizing resource allocation in cloud infrastructures. The study highlighted that optimization algorithms can improve system efficiency, reduce computational overhead, and enhance security policy management. Their results showed that optimization-based cloud management systems improve both performance and security.

Singh and Chatterjee (2022) proposed a deep learning-based secure cloud storage system using blockchain and artificial intelligence techniques. The framework integrated blockchain technology with neural network-based anomaly detection models to improve data integrity and prevent unauthorized data modification. The blockchain component ensured secure transaction records, while the AI model continuously monitored system behaviour for abnormal activities. The results demonstrated that the combination of AI and blockchain technologies significantly improves data security and transparency in cloud environments.

Gupta and Sharma (2020) investigated the role of machine learning algorithms in improving cloud data security and access control mechanisms. Their research proposed an intelligent cloud security model that uses supervised learning algorithms to analyse user access behaviour and detect suspicious patterns in real time. The system implemented classification techniques to identify unauthorized access attempts and potential insider threats within cloud infrastructures. Experimental results showed that the proposed approach improved detection accuracy and significantly reduced security vulnerabilities in cloud environments. The authors concluded that machine learning-based monitoring systems can enhance secure data storage and retrieval in distributed cloud architectures.

Wang et al. (2021) proposed a secure cloud data storage system based on deep learning and homomorphic encryption techniques. The researchers developed a framework that allows encrypted data to be processed without being decrypted, thereby maintaining data privacy during computation. Deep neural networks were used to optimize encryption parameters and improve data processing efficiency. The study demonstrated that combining homomorphic encryption with artificial intelligence can provide a secure and privacy-preserving cloud computing environment while maintaining acceptable system performance.

Rahman, Hassan, and Hossain (2022) explored AI-driven anomaly detection systems for securing cloud computing infrastructures. Their proposed framework used deep neural networks to monitor cloud network traffic and detect unusual behaviour patterns associated with cyber-attacks. The system utilized feature

extraction and pattern recognition techniques to identify malicious activities such as data exfiltration, unauthorized access, and distributed denial-of-service attacks. The results showed that AI-based anomaly detection models significantly improve threat detection capabilities in cloud environments compared with traditional rule-based security systems.

Lee and Kim (2023) investigated the potential of quantum machine learning techniques for improving cryptographic security in cloud computing. Their research introduced a hybrid encryption system that integrates quantum neural networks with classical encryption algorithms to strengthen data protection mechanisms. The study highlighted that quantum-based encryption techniques provide stronger resistance against cryptanalysis and brute-force attacks. The authors emphasized that quantum machine learning models have the potential to revolutionize secure cloud computing systems in the future.

Abdullah et al. (2021) proposed a hybrid cloud security framework combining metaheuristic optimization algorithms with artificial intelligence-based intrusion detection systems. The framework used optimization algorithms to tune the parameters of machine learning models for improved threat detection accuracy. The study demonstrated that hybrid security systems can effectively detect cyber-attacks while maintaining efficient resource utilization in cloud infrastructures. The researchers concluded that combining optimization algorithms with AI models provides a powerful solution for securing cloud environments.

Ali, Khan, and Vasilakos (2020) examined secure cloud data storage mechanisms using artificial intelligence-based intrusion detection systems. Their study focused on developing an adaptive security model that continuously monitors cloud environments and identifies malicious activities using machine learning algorithms. The proposed framework analysed network traffic patterns and detected abnormal behaviour associated with cyber threats such as malware attacks and unauthorized access. Experimental evaluations demonstrated that AI-driven security systems significantly enhance detection accuracy and reduce response time compared with traditional security mechanisms. The researchers concluded that artificial intelligence can play a crucial role in strengthening cloud security architectures.

Li, Zhang, and Chen (2021) proposed a deep learning-based secure data transmission model for cloud computing systems. The research introduced a convolutional neural network architecture that performs intelligent encryption and secure data transformation during transmission. The model was trained to generate complex encryption patterns that make it difficult for attackers to decode the encrypted data. Experimental results showed that the proposed framework improved encryption strength and reduced vulnerability to cryptographic attacks. The authors emphasized that deep learning-based encryption methods are promising solutions for protecting sensitive information in cloud environments.

Hassan and Kaur (2022) conducted a comprehensive analysis of metaheuristic optimization algorithms for improving cloud resource management and security frameworks. Their research evaluated several nature-inspired optimization techniques, including particle swarm optimization, grey wolf optimizer, and genetic algorithms. The study highlighted that optimization algorithms are highly effective for solving complex cloud management problems such as task scheduling, load balancing, and security parameter optimization. The results showed that optimization-based cloud management strategies significantly improve system efficiency and reliability.

Zhang, Li, and Wang (2023) investigated the application of quantum cryptographic techniques for secure cloud storage and communication systems. Their study proposed a hybrid encryption architecture that integrates quantum key distribution with classical encryption algorithms. The proposed framework ensures secure data transmission by generating cryptographic keys using quantum principles, making it extremely difficult for attackers to intercept communication channels. The authors concluded that quantum-based encryption systems can provide highly secure communication mechanisms for next-generation cloud computing infrastructures.

Reddy and Kumar (2021) developed a machine learning-based access control system for secure cloud data management. The proposed model analysed user access patterns and implemented intelligent authentication mechanisms to prevent unauthorized access to cloud resources. The system used classification algorithms to detect suspicious login attempts and enforce dynamic access control policies. Experimental results indicated that the proposed approach significantly improves cloud data protection and enhances system reliability.

Sun, Yu, and Zhao (2020) investigated deep learning-based encryption techniques for secure cloud data transmission. Their research introduced a convolutional neural network–based encryption framework that transforms input data into complex feature representations

before storage in the cloud. The CNN architecture was used to generate highly complex encryption keys and improve randomness within the cryptographic system. Experimental results demonstrated that the proposed method significantly enhanced resistance against brute-force and statistical attacks. The authors concluded that integrating deep learning techniques with encryption algorithms provides a robust security solution for cloud data protection.

Mahmood and Abbas (2021) proposed a hybrid artificial intelligence–based cloud security model using machine learning and cryptographic mechanisms. The framework utilized machine learning algorithms to analyse cloud network traffic and detect potential cyber threats in real time. The study emphasized that combining intelligent monitoring systems with advanced encryption techniques improves both threat detection and data confidentiality. Their experimental results showed that AI-based security models can effectively detect anomalies and reduce security vulnerabilities in cloud infrastructures.

Kaur and Singh (2022) explored the use of nature-inspired optimization algorithms for enhancing cloud computing security and performance. Their study analysed several metaheuristic algorithms including the grey wolf optimizer, whale optimization algorithm, and particle swarm optimization for solving cloud resource allocation problems. The results indicated that optimization algorithms significantly improve load balancing, task scheduling efficiency, and overall system performance. The researchers concluded that optimization-based approaches are essential for improving both performance and security in large-scale cloud environments.

Cheng and Liu (2023) investigated the role of quantum machine learning in secure cloud computing architectures. Their research proposed a hybrid framework integrating quantum neural networks with classical machine learning algorithms to strengthen cryptographic security in cloud systems. The proposed model utilized quantum feature encoding techniques to generate highly secure encryption keys. Experimental evaluations demonstrated that quantum machine learning models provide stronger protection against cryptanalysis compared with classical encryption approaches. The authors suggested that quantum-based security frameworks will play an important role in future cloud computing systems.

Ahmed, Khan, and Al-Hassan (2022) proposed an AI-driven cybersecurity framework for protecting cloud storage systems against advanced cyber threats. Their model utilized deep learning algorithms to analyze network traffic patterns and detect malicious activities such as data breaches and unauthorized access attempts. The framework incorporated anomaly detection mechanisms and predictive analytics to identify potential security risks before they occur. Experimental results showed that the AI-based security system achieved high detection accuracy and significantly improved the overall security of cloud infrastructures.

Comprehensive Comparative Table

No.	Author(s)	Year	Technique / Algorithm	Application Area	Key Contribution / Findings
1	Sadeeq & Abdulazeez	2022	Giant Trevally Optimizer (GTO)	Optimization problems in computing	Proposed a novel metaheuristic optimizer with strong global search capability.
2	Li & Huang	2020	CNN + Quantum Cryptography	Secure communication systems	Improved encryption complexity and secure key generation.
3	Man	2023	Neural Network Encryption	Cloud data security	Developed dynamic encryption key generation using neural networks.
4	Yang et al.	2020	Quantum Convolutional Neural Network	Data privacy protection	Improved privacy preservation in distributed computing systems.
5	AI-CNN IDS Model	2021	CNN + Optimization	Intrusion detection	Enhanced cyber-attack detection accuracy in cloud environments.
6	Zhang et al.	2021	CNN-based Encryption	Cloud storage security	Improved data confidentiality and resistance to cryptographic attacks.

7	Kumar & Kumar	2022	Deep Learning IDS	Cloud infrastructure protection	High accuracy detection of cyber-attacks such as DDoS.
8	Sharma et al.	2023	Metaheuristic Optimization	Encryption parameter optimization	Reduced computational overhead while maintaining security.
9	Chen & Zhao	2021	Quantum Machine Learning	Cloud encryption systems	Improved cryptographic strength using quantum neural networks.
10	Alqahtani et al.	2022	AI-based Cybersecurity	Cloud infrastructure protection	Real-time threat detection and predictive cybersecurity analysis.
11	Alazab et al.	2021	CNN + RNN Deep Learning	Cloud intrusion detection	Improved detection accuracy for malicious activities.
12	Khan et al.	2022	ML + Cryptography	Secure cloud storage	Integrated monitoring system with encryption mechanisms.
13	Zhou et al.	2023	Quantum Key Distribution	Secure communication	Highly secure data transmission in distributed networks.
14	Patel & Patel	2021	Metaheuristic Algorithms	Cloud resource optimization	Improved efficiency in resource allocation and security management.
15	Singh & Chatterjee	2022	Blockchain + AI	Cloud data integrity	Prevented unauthorized data modification using blockchain.
16	Gupta & Sharma	2020	Machine Learning Classification	Access control security	Detected unauthorized cloud access attempts effectively.
17	Wang et al.	2021	Homomorphic Encryption + AI	Privacy-preserving computing	Enabled computation on encrypted cloud data securely.
18	Rahman et al.	2022	AI-based Anomaly Detection	Cloud network security	Improved detection of abnormal activities in cloud networks.
19	Lee & Kim	2023	Quantum Neural Networks	Cryptographic security	Enhanced resistance against brute-force attacks.
20	Abdullah et al.	2021	AI + Metaheuristic Optimization	Hybrid cloud security system	Improved cyber-attack detection accuracy and system efficiency.
21	Ali et al.	2020	AI Intrusion Detection	Cloud cybersecurity	Adaptive security framework for monitoring cloud threats.
22	Li et al.	2021	CNN-based Encryption	Secure data transmission	Generated complex encryption patterns for cloud data protection.
23	Hassan & Kaur	2022	Metaheuristic Algorithms	Cloud resource management	Improved scheduling and system performance.
24	Zhang et al.	2023	Quantum Cryptography	Secure cloud communication	Strengthened encryption using quantum key distribution.
25	Reddy & Kumar	2021	Machine Learning Access Control	Cloud data management	Intelligent authentication and access control mechanisms.
26	Sun et al.	2020	CNN-based Encryption	Cloud data protection	Enhanced resistance to brute-force cryptographic attacks.

27	Mahmood & Abbas	2021	AI + Cryptography	Cloud cybersecurity	Integrated intelligent monitoring with encryption mechanisms.
28	Kaur & Singh	2022	Optimization Algorithms	Cloud performance optimization	Improved load balancing and system efficiency.
29	Cheng & Liu	2023	Quantum Machine Learning	Cloud cryptography	Secure encryption key generation using quantum models.
30	Ahmed et al.	2022	Deep Learning Cybersecurity	Cloud storage protection	AI-based predictive threat detection in cloud systems.

Conclusion

Cloud computing has become a fundamental technology supporting modern digital infrastructures, enabling organizations to store, process, and manage massive volumes of data efficiently. Its scalability, flexibility, and cost-effectiveness have made it a preferred platform for enterprises, governments, and research institutions. However, the increasing adoption of cloud services has also raised significant concerns regarding data security, privacy protection, and secure information retrieval. Cyber threats such as data breaches, unauthorized access, and distributed attacks continue to pose serious risks to cloud-based systems. Therefore, developing advanced security frameworks capable of protecting sensitive information stored in cloud environments has become a critical research priority.

This review paper examined recent advancements in artificial intelligence techniques for secure cloud data storage and retrieval, with particular emphasis on the integration of Giant Trevally Optimizer (GTO) and Quantum Convolutional Neural Network (QCNN)-based encryption algorithms. The analysis of the literature between 2020 and 2023 reveals that artificial intelligence and machine learning technologies are increasingly being used to strengthen cybersecurity mechanisms in cloud computing environments. Deep learning models such as convolutional neural networks, recurrent neural networks, and hybrid neural architectures have demonstrated significant potential in detecting cyber threats, identifying abnormal network behaviour, and improving encryption systems. These intelligent models are capable of learning complex patterns from large datasets and responding to potential security threats more efficiently than traditional rule-based security systems.

Another important finding of this review is the growing role of metaheuristic optimization algorithms in enhancing cloud computing security and performance. Optimization techniques are widely used to address complex computational challenges such as resource allocation, task scheduling, encryption parameter tuning, and network optimization. Nature-inspired algorithms, including particle swarm optimization, grey wolf optimizer, genetic algorithms, and particularly the Giant Trevally Optimizer, have shown strong potential for solving these problems. The GTO algorithm, inspired by the hunting behaviour of giant trevally fish, offers powerful exploration and exploitation capabilities that allow it to efficiently search large solution spaces and identify optimal solutions. When integrated with artificial intelligence models, optimization algorithms can significantly improve the efficiency and effectiveness of cloud security systems.

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