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Combining Data Owner side and Server Side Control for Encrypted Cloud Storage

[1]Ramesh Mocharla, [2]L Prasanna Lakshmi, [3]Lenkapally Mahesh
[1,2,3]Assistance professor, Department Of CSE, Sree dattha institute of engineering and science

ABSTRACT

People endorse the great power of cloud computing but cannot fully trust the cloud providers to host privacy-sensitive data, due to the absence of user-to-cloud controllability. To ensure confidentiality, data owners outsource encrypted data instead of plaintexts. To share the encrypted files with other users, Ciphertext-Policy Attribute-based Encryption (CP-ABE) can be utilized to conduct fine-grained and owner-centric access control. But this does not sufficiently become secure against other attacks. Many previous schemes did not grant the cloud provides the capability to verify whether a downloader can decrypt. Therefore, these files should be available to everyone accessible to the cloud storage. A malicious attacker can download thousands of files to launch Economic Denial of Sustainability (EDoS) attacks, which will largely consume the cloud resource. The payer of the cloud service bears the expense. Besides, the cloud provider serves both as the accountant and the payee of resource consumption fee, lacking the transparency to data owners. These concerns should be resolved in real-world public cloud storage. In this work, we propose a solution to secure encrypted cloud storages from EDoS attacks and provide resource consumption accountability. It uses CP-ABE schemes in a black-box manner and complies with arbitrary access policy of CP-ABE. We present two protocols for different settings, followed by performance and security analysis.

Keywords: Cloud Storage, Combined Compression, Data Access Control

1. INTRODUCTION

Cloud storage has many benefits, such as always-online, pay-as-you-go, and cheap. During these years, more data are outsourced to public cloud for persistent storage, including personal and business documents. It brings a security concern to data owners: the public cloud is not trusted, and the outsourced data should not be leaked to the cloud provider without the permission from data owners. Many storage systems use server-dominated access control, like password-based and certificate-based authentication. They overly trust the cloud provider to protect their sensitive data. The cloud providers and their employees can read any document regardless of data owners' access policy. Besides, the cloud provider can exaggerate the resource consumption of the file storage and charge the payers more without providing verifiable records, since we lack a system for verifiable computation of the resource usage.

Relying on the existing server-dominated access control is not secure. Data owners who store files on cloud servers still want to control the access on their own hands and keep the data confidential against the cloud provider and malicious users.

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Encryption is not sufficient. To add the confidentiality guarantee, data owners can encrypt the files and set an access policy so that only qualified users can decrypt the document. With Ciphertext-Policy Attribute-based Encryption (CP-ABE), we can have both fine-grained access control and strong confidentiality. However, this access control is only available for data owners, which turns out to be insufficient. If the cloud provider cannot authenticate users before downloading, like in many existing CP-ABE cloud storage systems, the cloud has to allow everyone to download to ensure availability. This makes the storage system vulnerable to the resource-exhaustion attacks. If we resolve this problem by having data owners authenticate the downloaders before allowing them to download, we lose the flexibility of access control from CP-ABE. Here lists the two problems should be addressed in our work:

Problem I: resource-exhaustion attack. If the cloud cannot do cloud-side access control, it has to allow anyone, including malicious attackers, to freely download, although only some users can decrypt. The server is vulnerable to resource-exhaustion attacks. When malicious users launch the DoS/DDoS attacks to the cloud storage, the resource consumption will increase. Payers (in pay-as-you-go model) have to pay for the increased consumption contributed by those attacks, which is a considerable and unreasonable financial burden. The attack has been introduced as Economic Denial of Sustainability (EDoS), which means payers are financially attacked eventually. In addition, even files are encrypted, unauthorized downloads can reduce security by bringing convenience to to offline analysis and leaking information like file length or update frequency.

Problem II: resource consumption accountability. In the pay-as-you-go model, users pay money to the cloud provider for storage services. The fee is decided by resource usage. However, CP-ABE based schemes for cloud storage access control does not make online confirmations to the data owner before downloads. It is needed for the cloud service provider to prove to the payers about the actual resource usage. Otherwise, the cloud provider can charge more without being discovered.

Summary of Challenges and Approaches

Challenge I: modelling the cloud provider.

Many existing CP-ABE based schemes, model the cloud providers (like Google, Amazon, Microsoft Azure) as semi-honest adversaries or passive attackers. However, such a definition is restricted, and it excludes some possible attacks in the real world, such as exaggerated resource usage. To model such attacks, we consider a less restricted security model, covert adversary, for the cloud provider.

In practice, the cloud services are usually provided by some big IT enterprises like Google, Amazon, Microsoft. They need to maintain good reputation and promise secure cloud storage services to their customers. If any attempt the cloud provider deviates from the protocol is supposed to be caught with a possibility (e.g., $p = 0.001$), the cloud provider dares not to cheat. Because being caught will not only violate the service contracts, but also lead to media exposure and destroys the reputation. Aware of the aftermath, the cloud provider has to refrain from attacking, as the cheating can be detected. This model, covert security, has been used in many secure systems.

Note that the covert security model is different with the semi-honest model. The semi-honest model, which is widely used in proxies and cloud providers, is a model that resides between "malicious" and "trusted". It models a party that observes all data, but it never executes the wrong program. Such a party will not cheat by definition, even if no other parties can detect its cheating. The covert model, which resides between "malicious" and "semi-honest", models this party differently. It will not execute the wrong program only if there is a mechanism to detect its cheating. If no detection exists in the system, the party may even compromise the data, for example. Therefore, it is more practical for public cloud storage.

Approach: model cloud providers as covert adversaries, and design protocols resilient to a covert adversary.

Challenge II: compatible with existing systems.

There are many constructions and variants for CP-ABE. We don't design a new variant of CP-ABE to resolve the first challenge, as it is hard to achieve all the functionalities in these systems and also, it's not necessary. Besides the functionalities, some variants provide additional security and privacy guarantee. For example, the literatures hide the access policy. If the cloud-side access control makes the cloud provider knowing the access policy, it is not considered secure and compatible. It requires the cloud-side access control to be zero-knowledge for arbitrary CP-ABE schemes.

Approach: use CP-ABE in a syntactical and black-box way and ensure the construction not leaking policy and attributes. The system only learns whether the user is legitimate or not, and nothing else.

Challenge III: minimal performance overhead.

To protect the cloud storage effectively against the resource-exhaustion attack, the cloud-side access control needs to be efficient and lightweight, otherwise if the cloud server spends, for example 20ms, executing the cloud-side access control, it will become a computational resource exhaustion attack, which can be used by malicious attackers for DDoS and EDoS. The performance overhead being small also benefits the data users who download the files from the cloud storage, making the computation not approachable to resource-limited devices.

Approach: design an efficient access control for the cloud provider which should not add too much overhead.

Our work and Contribution

In this work, we combine the cloud-side access control and the existing data owner-side CP-ABE based access control, to resolve the aforementioned security problems in privacy-preserving cloud storage. Our method can prevent the EDoS attacks by providing the cloud server with the ability to check whether the user is authorized in CP-ABE based scheme, without leaking other information.

For our cloud-side access control, we use CP-ABE encryption/decryption game as challenge-response. While upload an encrypted file, the data owner firstly generates some random

challenge plaintexts and the corresponding ciphertexts. The ciphertexts are related to the same access policy with the specific file. For an incoming data user, the cloud server asks him/her to decrypt randomly selected challenge ciphertext. If the user shows a correct result, which means he/she is authorized in CP-ABE, the cloud-side access control allows the file download.

To make our solution secure and efficient in real world applications, we provide two protocols of cloud-side and data owner-side combined access control. The main contribution of this work can be summarized as follows.

1) We propose a general solution to secure encrypted cloud storage to prevent the EDoS attacks, as well as have fine-grained access control and resource consumption accountability. To the best of our knowledge, this is the first work to claim that insufficient cloud-side access control in encrypted cloud storage will lead to EDoS attacks and provides a practical solution. The solution can be compatible with many CP-ABE schemes.

2) For different data owner online patterns and performance concern, we provide two protocols for authentication and resource consumption accounting. We also introduce the bloom filter and the probabilistic check to improve the efficiency but still guarantee the security.

3) Compared with many state-of-arts constructions of encrypted cloud storage that assume the existence of a semi-honest cloud provider, we use a more practical threat model where we assume the cloud provider to be a covert adversary, which provides higher security guarantee.

2. LITERATURE SURVEY

To conduct a fine-grained data owner-side access control in public cloud storage, which is semi-honest, Attribute-based Encryption (ABE) [1-3] is introduced [4]. Among ABE schemes, CP-ABE [1], [5] is practical in public cloud storage, in which the ciphertext is encrypted under an access policy and only users whose attributes satisfy the access policy can decrypt the ciphertext. Subsequently, many variants and relevant protocols [6-9] have been proposed to make CP-ABE more suitable for real scenarios with rich functionalities and security properties in public cloud storage.

The cryptography-driven access control does not protect the cloud provider against many other attacks. Since the cloud provider does not conduct the access control, it cannot stop those unauthorized users. One attack that is originated from this limitation is Distributed Denial of Services (DDoS). The power of DDoS attacks has been showed to incur significant resource consumption in CPU, memory, I/O, and network [10]. The attacks can exist in public clouds [11-14]. In [12], the limitation of cloud-side static resource allocation model is analyzed, including the risk of Economic Denial of Sustainability (EDoS) attacks, which is the case of DDoS attacks in the cloud setting in [14], or the Fraudulent Resource Consumption (FRC) attack in [11]. These attacks are intended to break the budget of public cloud customers.

Some existing works try to mitigate EDoS attacks [15, 16]. In [15], the authors proposed a mitigation technique by verifying whether a request comes from a cloud user or is generated

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by bots. In [16], the authors proposed an attribute-based way to identify malicious clients. They treat the underlying application in a black box and do not fully immunize the attack in the algorithmic and protocol level. Some existing works discuss the necessary of accounting resource consumption in the public cloud arouses some concerns. In the literature [17], the authors discussed key issues and challenges about how to achieve accountability in cloud computing.

In the literature [18], the authors surveyed existing accounting and accountability in content distribution architectures. In the literatures [19] and [20], the authors respectively proposed a systematic approach for verifiable resource accounting in cloud computing. However, the accounting approach involves changes to the system model, and requires the anonymous verification of users, which is not supported in previous systems. Compared with relevant schemes, our approach works on the protocol level to provide the resource verifiability that relies on authorized users who satisfy the CP-ABE policy and achieves the covert security which is more practical and secure.

3. PROPOSED SYSTEM

Overview of our scheme

To achieve the security requirements, the scheme consists of two components: 1) A cloud-side access control to block users whose attribute set $\mathcal{A}_i$ does not satisfy the access policy A; 2) A proof-collecting subsystem where the cloud provider can collect the proofs of resource consumption from users, and present to the data owners later.

In real-world scenarios, it is reasonable to specify an expected maximal download time, and data owners can remain offline unless it wants to increase this value. This leads to our first protocol: Partially Outsourced Protocol (POP) (V-B). In some other cases where the data owner cannot set an expectations of download times or would be offline for a long time, the data owner can delegate to the cloud. This leads to our second protocol: Fully Outsourced Protocol (FOP) (V-C).

Partially Outsourced Protocol (POP)

In this protocol, the data owner encrypts an ephemeral key in CP-ABE, which is then used for message encryption/decryption and cloud-side access control. The data owner provides the cloud provider with N challenge ciphertexts $\{enchal_i\}_{i\in[N]}$ and the hashed challenges $\{hash_i\}_{i\in[N]}$. The user proves the legitimacy to the cloud provider by showing the decryption result $chal_j$ of the randomly selected unused challenge ciphertext $enchal_j$ is a preimage of $hash_j$. If the user response is valid, the cloud provider stores the user response for further resource consumption accounting.

Furthermore, to boost the efficiency and together reduce the storage space, we introduce the bloom filter for data owners to store their challenge plaintexts. This bloom filter can be stored locally or remotely on the cloud server. As the process of challenge update should be implemented on demand or periodically by the data owner, which cannot be outsourced to the cloud, we call the scheme as Partially Outsourced Protocol (POP).

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The procedure of POP is described in detail as follows:

1) Encrypt and Upload (POP-EU): This operation is implemented by an individual data owner independently

2) Cloud-side Access Control: POP-CR.

3) Challenge update (POP-SU): If the specified upper bound of download times (N) has not yet reached, there is no need to update. But if the data owner wants to provide additional challenges, either on-demand or periodically, both only needs to be online for a short period, it is also supported. The update process is the same as that in the phase of POP-EU-2 under the same key k. We assume the data owner keeps a record of session keys either in local storage or outsourced to cloud in an encrypted form. As the plaintext space for challenges is sufficiently large, we assume no duplicated challenge plaintexts are generated. The bloom filter (and its encryption form) introduced in POP-EU-3 will be reconstructed.

4) Resource Accounting (POP-RA): data owners and the cloud interactively implement this operation.

Fully Outsourced Protocol (FOP)

If we cannot expect the file download times, we can outsource the challenge update to the cloud. In this section, we give a protocol based on signature algorithm, which has both the outsourced challenges generation/update and resource accounting without an external PKI, therefore we name it as Fully Outsourced Protocol (FOP).

Compared with POP, we have two main differences: 1) Instead of having the data owners generate the challenges $\{enchal_i\}_{i\in[N]}$, the challenges are generated by the cloud; 2) The data owners generate a pair of signature keys (vk,sk) for every file, with which legitimate users sign a confirmation to prove the resource consumption. The main procedure of FOP is described as follows:

1) Encrypt and Upload (FOP-EU)

2) Outsourced Challenge Generation (FOP-CG): In FOP, the cloud provider generates the challenges, which is different from POP. The generation can be done in advance or on demand.

3) Challenge-Response (FOP-CR). Data owners and the cloud run this operation

4) Resource Accounting (FOP-RA). This operation is interactively implemented by the data owner and the cloud.

SYSTEM MODEL AND SECURITY MODEL

In this section, we first describe the three-party model for cloud storage. Furthermore, the security against malicious data users and a covert cloud provider is also defined.

System Model

As shown in Fig. 1, the cloud storage system consists of three entities: data owners, data users, and the cloud provider.

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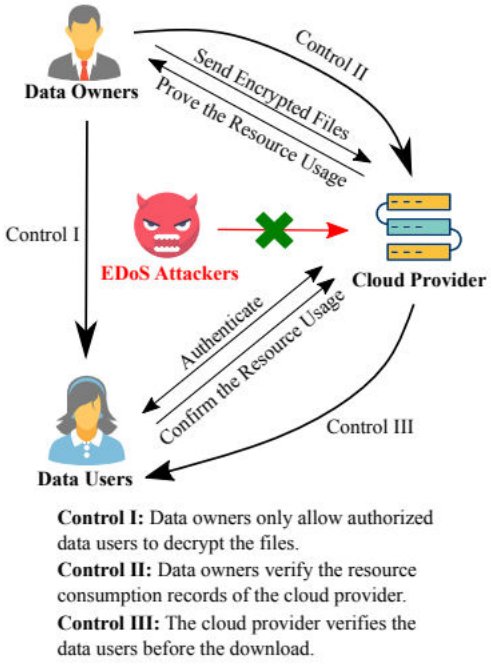

Fig. 1. System model of the encrypted cloud storage with mitigation of EDoS attacks and transparency of resource consumption accounting

- Data owners are the owner and publisher of files and pay for the resource consumption on file sharing. As the payers for cloud services, the data owners want the transparency of resource consumption to ensure fair billing. The data owners require the cloud provider to justify the resource usage. In our system, the data owner is not always online.
- Data users want to obtain some files from the cloud provider stored on the cloud storage. They need to be authenticated by the cloud provider before the download (to thwart EDoS attacks). The authorized users then confirm (and sign for) the resource consumption for this download to the cloud provider.
- Cloud provider hosts the encrypted storage and is always online. It records the resource consumption and charges data owners based on that record. The cloud is not public-accessible in our system as it has an authentication-based access control. Only data users satisfying the access policy can download the corresponding files. The cloud provider also collects the proof of the resource consumption to justify the billing.

As shown in Fig. 1, we have three controls among three entities in our system:

- Control I. Data owners assign an access policy in the document, which controls the set of data users who have the privileges to decrypt the contents.
- Control II. Data owners verifies the resource consumption from the cloud provider, which controls the cloud provider not to exaggerate the resource usage.
- Control III. The cloud provider verifies whether the user can decrypt before the download, which controls the ability of a malicious user who launches DDoS/EDoS attacks.

Moreover, our system differs from previous cloud storage constructions, as we take into account the resource consumption. In practice, the cloud services are usually charged

according to the resource consumption, which includes the resource spent on attackers. The DDoS/EDoS attacks will invariably succeed and raise the overhead, which is controlled in our system due to the introduction of the cloud-side access control.

Security Assumptions and Requirements

Data owners are trusted and data users can be considered as malicious adversaries. Users may try to cheat for files and launch the EDoS attacks. But authorized users are assumed not to collude with unauthorized users which is impossible to thwart and beyond the scope of this paper.

Different from previous constructions that assume the cloud provider to be a passive attacker (i.e., semi-honest or honest-but-curious), we consider a stronger notation called covert adversary. In the real-world cloud service platforms, the cloud providers are usually some big IT enterprises that usually treasure the reputation and try to avoid lawsuits. If any attempt to violate the protocol can be detected by any honest parties (e.g., data owners or data users) with a significant possibility like p = 0.001, they dare not to cheat. However, honest parties must keep verifying to keep the deterrence.

Definition 3. (Security against Covert Adversaries)

Consider a protocol π, the covert security with a parameter ϵ for this protocol π means the following for every covert adversary $\mathcal{A}$:

- $\mathcal{A}$ is caught with a probability of ϵ if $\mathcal{A}$ cheats.
- $\mathcal{A}$ learns nothing in addition compared with honest executions when $\mathcal{A}$ is caught.

To achieve the covert security, the protocol needs some verification steps to catch a misbehaving cloud. This verification steps can be probabilistic (e.g., 50% true positive) as this still satisfies the covert security.

We define the two security requirements of our system: 1) Unauthorized data users that do not satisfy the access policy of the file cannot download any files; 2) The cloud provider cannot forge a significant proportion of the proofs for resource consumption without being discovered with a sufficient possibility; 3) The protocol can be compatible with some CP-ABE variants with additional privacy guarantee such that the policy and attribute set indistinguishability is not broken.

4. RESULTS AND DISCUSSION

This work consists of 3 users

Data Owner: data owner will upload file and then using CP-ABE define access control and then encrypt data and then outsource encrypted data with secret key data for user verification. Sometime cloud may cheat customers by saying customer has consume this many resources and the author is saying big companies may not do that but still to prevent cloud from fraud usage cost author has provided customer an option to verify resource consumption. By using this option data owner can request cloud to provide details about his data usage or download.

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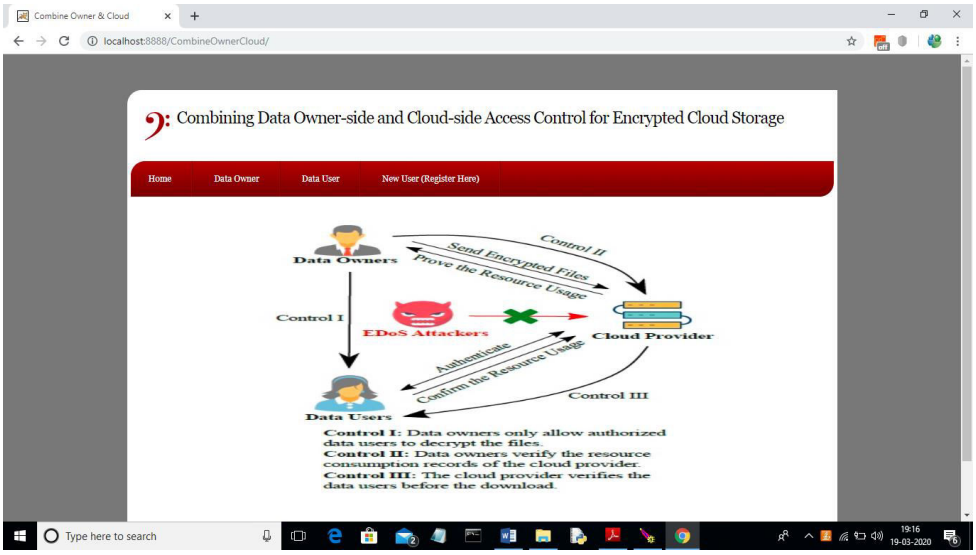
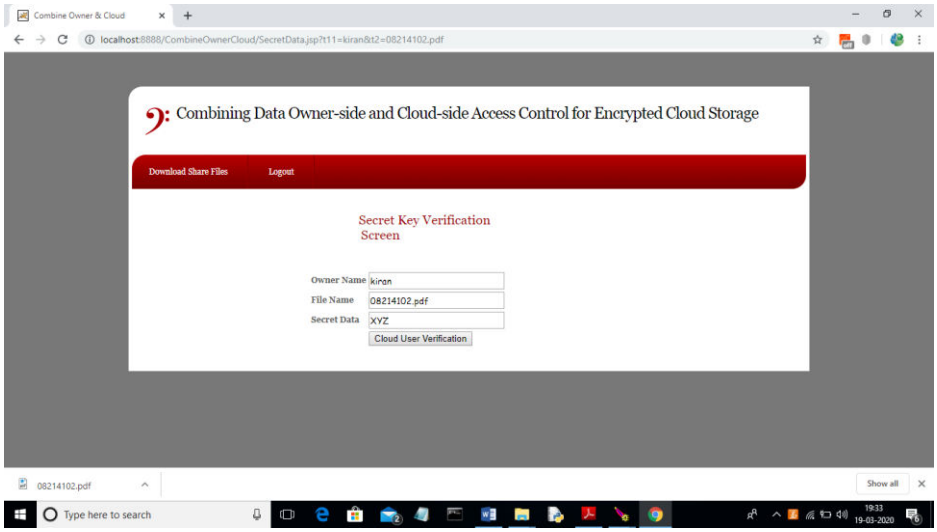
Data User: this is the user of data which request cloud for file download and before download cloud will ask user for verification by entering secret data obtained from data owner. All data owners share their secret data with their data users.

Cloud Provider: This is a cloud server which store user data and perform user verification and provide resource consumption details to data owners.



In above screen click on 'New User' link to add data owner or user



After giving wrong secret challenge will get below screen

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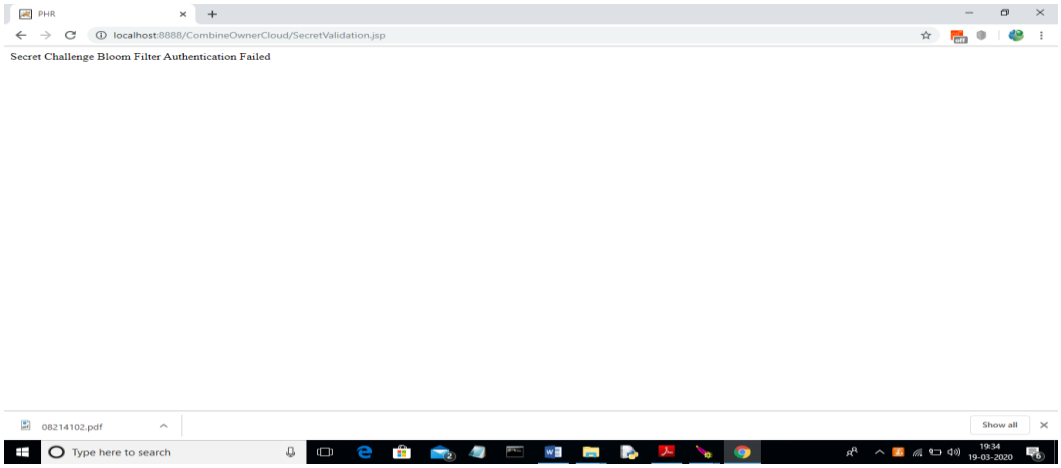

In above screen we can see secret data verification failed at cloud side and cloud will not allow user to download file

5. CONCLUSION AND FUTURE SCOPE

This work proposed a combined the cloud-side and data owner-side access control in encrypted cloud storage, which is resistant to DDoS/EDoS attacks and provides resource consumption accounting. Our system supports arbitrary CP-ABE constructions. The construction is secure against malicious data users and a covert cloud provider. We relax the security requirement of the cloud provider to covert adversaries, which is a more practical and relaxed notion than that with semi-honest adversaries. To make use of the covert security, we use bloom filter and probabilistic check in the resource consumption accounting to reduce the overhead. Performance analysis shows that the overhead of our construction is small over existing systems.

Future Scope:

Enhanced Access Control Policies: Further research can focus on refining and extending the capabilities of access control policies in cloud storage. This includes the development of more complex and expressive access policies that cater to diverse user scenarios and data sharing requirements.

Integration with Multi-Cloud Environments: Exploring the integration of the proposed data access control solution with multi-cloud environments. This can enhance the resilience and availability of data by distributing it across multiple cloud providers while maintaining the same level of security and control.

Quantum-Safe Cryptography: Considering the adoption of quantum-safe cryptographic techniques to future-proof the security of the data access control system. As quantum computing advances, it poses potential threats to existing cryptographic methods, and transitioning to quantum-safe algorithms is essential for long-term security.

Scalability and Performance Optimization: Optimizing the performance and scalability of the proposed solution, especially in large-scale cloud storage deployments. This involves addressing challenges related to processing efficiency, response times, and resource utilization to ensure the system can handle increasing volumes of data and users.

User-Friendly Interfaces and Adoption: Designing user-friendly interfaces and educational materials to facilitate the adoption of the proposed solution by data owners and cloud service users. Improving the accessibility and usability of the system can contribute to its widespread acceptance and implementation.

Real-Time Monitoring and Alerting: Implementing real-time monitoring and alerting mechanisms to notify data owners of any suspicious or unauthorized access attempts. This proactive approach enhances the security posture of the system by enabling prompt responses to potential threats.

Compliance with Regulatory Standards: Ensuring that the proposed solution aligns with evolving regulatory standards and data protection laws. Staying abreast of changes in compliance requirements and adapting the system accordingly is crucial, especially in the context of data privacy and security.

Blockchain Integration for Transparency: Exploring the integration of blockchain technology to enhance transparency and accountability in resource consumption fee tracking. Blockchain can provide a tamper-proof and transparent ledger, ensuring that data owners have clear visibility into the usage of cloud resources.

Dynamic Adaptation to Emerging Threats: Developing mechanisms for dynamic adaptation to emerging cyber threats and attack vectors. This involves continuous monitoring of the threat landscape and updating the system's security protocols and defenses to stay ahead of potential risks.

Community Collaboration and Open Source Development: Encouraging community collaboration and considering the open-source development of the proposed solution. Open-source initiatives can foster innovation, community contributions, and peer-reviewed enhancements, leading to a more robust and widely adopted data access control framework.

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