

# Amending Protection and Efficiency in Information Sharing

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**Abstract-**With the high data sharing options there have been increasing demands and concerns for distributed data security; enforcement of access policies is one of the challenging issues. Cipher text policy attribute-based encryption is becoming a promising cryptographic solution to this issue. It enables data owners to define their own policies over user attributes distributed. The advantage comes with a major drawback which is known as a key escrow problem. This is not suitable for data sharing scenarios where the data owner would like to make their private data only accessible to designated users. Applying CP-ABE in the data sharing system introduces another challenge with regard to the user revocation since the access policies are defined only over the attribute universe. In this approach we propose a novel CP-ABE scheme for a data sharing system by exploiting the Characteristic of the system architecture. (1) Escrow-free key issuing protocol solves the key escrow problem. (2) Fine-grained user revocation per each attribute could be done by proxy encryption which takes advantage of the selective attribute group key distribution on top of the ABE. The performance and security analyses indicate that the proposed scheme is efficient to securely manage the data distributed in the data sharing system.

**Keywords:** Software Security, Efficiency, Info sharing, Attribute Encryption, Cryptography.

## 1. INTRODUCTION

Recent development of the network and computing technology enables many people to easily share their data with others using online external storages. People can share their lives with friends by uploading their private photos or messages into the online social networks such as Facebook and MySpace; or upload highly sensitive personal health records (PHRs) into online data servers such as Microsoft HealthVault, Google Health for ease of sharing with their primary doctors or for cost saving. As people enjoy the advantages of these new technologies and services, their concerns about data security and access control also arise. Improper use of the data by the storage server or unauthorized access by outside users could be potential threats to their data.

### 1.1 Related Work

ABE comes in two flavors called key-policy ABE (KP-ABE) and ciphertext-policy ABE (CP-ABE). In KP-ABE, attributes are used to describe the encrypted data and policies are built into users' keys; while in CP-ABE, the attributes are used to describe users'

credentials, and an encrypt or determines a policy on who can decrypt the data. Between the two approaches, CP-ABE is more appropriate to the data sharing system because it puts the access policy decisions in the hands of the data owners.

### 1.1.1 Removing Escrow

Most of the existing ABE schemes are constructed on the architecture where a single trusted authority, or KGC has the power to generate the whole private keys of users with its master secret information. Thus, the key escrow problem is inherent such that the KGC can decrypt every ciphertext addressed to users in the system by generating their secret keys at any time.

### 1.2 Contribution

In this paper, we propose a novel CP-ABE scheme for a secure data sharing system, which features the following achievements. First, the key escrow problem is resolved by a key issuing protocol that exploits the characteristic of the data sharing system architecture. The key issuing protocol generates and issues user secret keys by performing a secure two-party computation (2PC) protocol between the KGC and the data storing center with their own master secrets.

Fine-grained user access control can be possible. Even if a user is revoked from some attribute groups, he would still be able to decrypt the shared data as long as the other attributes that he holds satisfy the access policy of the ciphertext. Data owners need not be concerned about defining any access policy for users, but just need to define only the access policy for attributes as in the previous ABE schemes. The proposed scheme delegates most laborious tasks of membership management and user revocation to the data storing center while the KGC is responsible for the attribute key management as in the previous CP-ABE schemes without leaking any confidential information to the other parties. Therefore, the proposed scheme is the most suitable for the data sharing scenarios where users encrypt the data only once and upload it to the data storing centers.

## 2. DATA SHARING ARCHITECTURE

In this section, we describe the data sharing architecture and define the security model.

**2.1 System Description and Key Management**

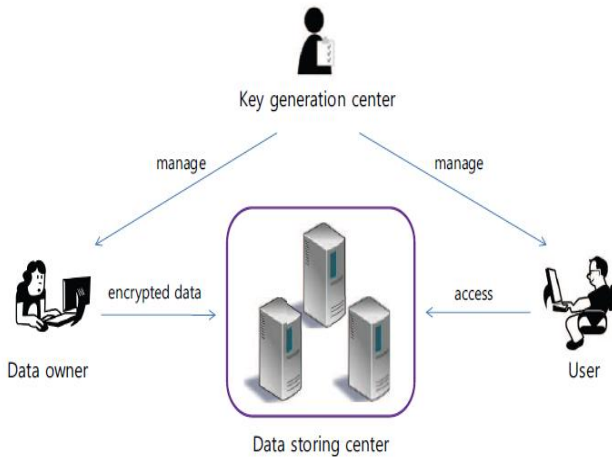


Fig1. Architecture of data sharing system

Fig. 1 shows the architecture of the data sharing system, which consists of the following system entities:

1. Key generation center: It is a key authority that generates public and secret parameters for CP- ABE. It is in charge of issuing, revoking, and updating attribute keys for users.
2. Data storing center: It is an entity that provides a data sharing service. It is in charge of controlling the accesses from outside users to the storing data and providing corresponding contents services. The data storing center is another key authority that generates personalized user key with the KGC.
3. Data owner: It is a client who owns data, and wishes to upload it into the external data storing center for ease of sharing or for cost saving. A data owner is responsible for defining (attribute- based) access policy, and enforcing it on its own data by encrypting the data under the policy before distributing it.
4. User: It is an entity who wants to access the data. If a user possesses a set of attributes satisfying the access policy of the encrypted data, and is not revoked in any of the valid data.

**2.2 Threat Model and Security Requirements**

- 1) Data confidentiality: Unauthorized users who do not have enough attribute satisfying the access policy should be prevented from accessing the plaintext of the data. Additionally, the KGC is no longer fully trusted in the data sharing system.
- 2) Collusion-resistance: Collusion-resistance is one of the most important security property required in ABE systems. If multiple users collude, they may be able to decrypt a ciphertext by combining their attributes even if each of the users cannot decrypt the ciphertext alone. We do not want these colluders to be able to decrypt the private data in the server by combining their attributes.
- 3) Backward and forward Secrecy: In the context of attribute-based encryption, backward secrecy means that any user who comes to hold an attribute (that satisfies the access policy) should

be prevented from accessing the plaintext of the previous data distributed before he holds the attribute.

**3. PRELIMINARIES AND DEFINITION**

**3.1 Cryptographic Background**

We first provide a formal definition for access structure by recapitulating the definitions in [4], [5]. Then we will briefly review the cryptographic background about the bilinear map and its security assumption.

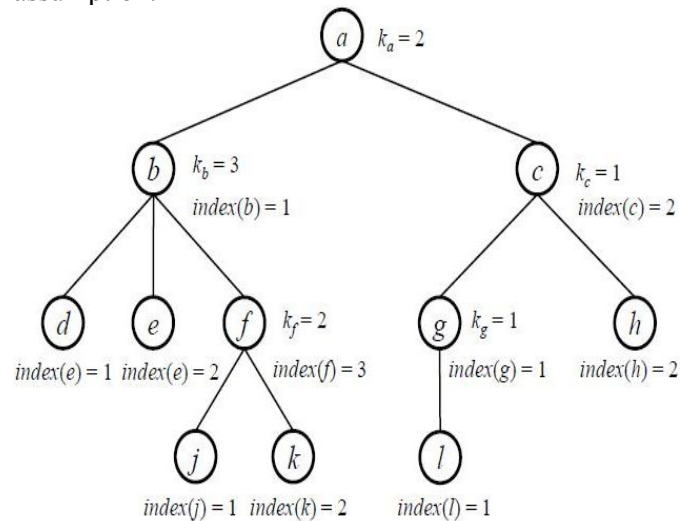


Fig.2. An example of access tree

**4. PROPOSED CP-ABE SCHEME**

The first step of the key issuing protocol is to generate the user secret keys using secure 2PC protocol between the KGC and the data storing center.

**4.1.1 Description**

Let T be a tree representing an access structure. Each non-leaf node of the tree represents a threshold gate.

**4.1.2 Satisfying an Access Tree**

Let  $T_x$  be the sub tree of T rooted at the node x. If a set of attributes  $\gamma$  satisfies the access tree  $T_x$ , we denote it as  $T_x(\gamma) = 1$ .

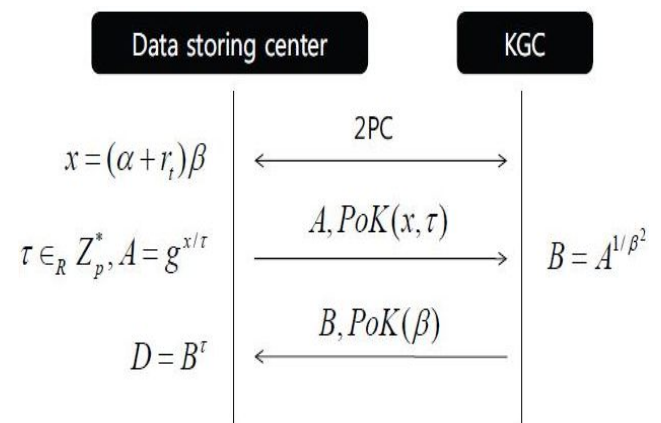


Fig.3. Key generation protocol

We compute  $T_x(\gamma)$  recursively as follows. If  $x$  is a non-leaf node, evaluate  $T_x(\gamma)$  for all children  $x'$  of node  $x$ .  $T_x(\gamma)$  returns 1 iff at least  $k_x$  children return 1. If  $x$  is a leaf node, then  $T_x(\gamma)$  returns 1 iff  $\lambda_x \in \gamma$ .

**4.2 Scheme Construction**

Let  $G_0$  be a bilinear group of prime order  $p$ , and let  $g$  be a generator of  $G_0$ . Let  $e: G_0 \times G_0 \rightarrow G_1$  denote the bilinear map. A security parameter,  $\kappa$ , will determine the size of the groups. We will also make use of Lagrange coefficients  $\Delta_i, \Lambda_i$  for any  $i \in Z^q$  and a set.

**4.3 Key Update**

The key update procedure is launched by the KGC when it receives a join or leave request for some attribute groups from a user. On receipt of the request, the KGC notifies the data storing center of the event and sends the updated membership list of the attribute group to it. When the data storing center receives the notification, it rekeys the corresponding Attribute group key. Without loss of generality, suppose there is any membership change in  $G_i$  (e.g., a user comes to hold or drop an attribute  $\lambda_i$  at some time instance).

**5. SCHEME ANALYSIS**

In this section, we analyze and compare the efficiency of the proposed scheme with the previous CP-ABE schemes (that is, Bethencourt et al.'s scheme (BSW) Attrapadung's scheme (BCP-ABE2), and Yu et al.'s scheme (YWRL)) in theoretical and practical aspects. Then, the efficiency of the proposed scheme is demonstrated in the network simulation in terms of the communication cost. We also discuss its efficiency when implemented with specific parameters and compare these results with those obtained by the other schemes.

**5.1 Key escrow and Revocation**

Table 1 shows the revocation granularity and key escrow problem of each scheme. The rekeying in the proposed scheme can be done in an immediate way as opposed to BSW. Therefore, a user can be revoked at any time even before the expiration time which might be set to the attribute. This enhances security of the shared data in terms of the backward/forward secrecy by reducing the windows of vulnerability. In addition, the proposed scheme realizes more fine-grained user revocation for each attribute rather than for the whole system. Thus, even if a user drops some attributes during the service in the proposed scheme, he can still access the data with other attributes that

he is holding as long as they satisfy the access policy. The proposed scheme also resolves the key escrow problem due to the escrow-free key issuing protocol exploiting secure 2PC protocol as opposed to the other schemes.

TABLE 1: Key escrow and revocation comparison

Scheme	Revocation granularity	Key escrow
BSW	timed attribute revocation	yes
BCP-ABE2	immediate user revocation	yes
YWRL	immediate user revocation	yes
Proposed	immediate user revocation	no

**5.2 Efficiency**

- $C_0$  bit size of an element in  $G_0$
- $C_1$  bit size of an element in  $G_1$
- $C_p$  bit size of an element in  $Z^q$
- $CT$  bit size of an access tree  $T$  in the ciphertext
- $C_k$  bit size of a set of attributes associated with private key of a user
- $t$  the number of attributes appeared in  $T$
- $T$  the maximum size allowed for  $t$  (in [9])
- $m$  the number of users in an attribute group
- $r$  the number of revoked users
- $k$  the number of attributes associated with private key of a user
- $K$  the maximum size allowed for  $k$  (in [9])
- $u$  the size of the attribute universe

In the comparison result, each scheme is compared in terms of ciphertext size, rekeying message size, private and public key size. Ciphertext size implies the communication cost that the data owner needs to send to data storing center its data, or that the data storing center needs to send to users ( $CT$  in the proposed scheme). Rekeying message size represents the communication cost that the KGC or the data storing center needs to send so as to update non-revoked users' keys (Hdr in the proposed scheme) in an attribute group or to revoke an attribute. Private key size represents the storage cost required for each user to store secret keys. Public key size represents the size of the authorities' public keys in the system.

As shown in Table 2, the proposed scheme requires ciphertext size of  $(2t + 1)C_0 + C_1 + CT$ , which is the same as that of BSW. The proposed scheme requires rekeying message (Hdr) size of  $(m + 2)C_0$  to realize the user revocation for each attribute in the system. In the proposed scheme, each user stores one more private KEK for decrypting the rekeying messages and obtaining attribute group keys than the basic BSW scheme.

TABLE 2-Efficiency comparison

System	Ciphertext size	Rekeying message	Private key size	Public key size
BSW	$(2t + 1)C_0 + C_1 + CT$	$mC_0$	$(2k + 1)C_0$	$C_0 + C_1$
BCP-ABE2	$(t + 2r + 1)C_0 + C_1 + CT$	0	$(k + 4)C_0$	$(K + T + 7)C_0 + C_1$
YWRL	$(u + 1)C_0 + C_1 + CT$	$2umC_0 + 2uC_p$	$C_k + (2u + 1)C_0$	$(3u + 1)C_0 + C_1$
Proposed	$(2t + 1)C_0 + C_1 + CT$	$(m + 2)C_0$	$(2k + 2)C_0$	$C_0 + C_1$

YWRL incurs high communication and storage overhead compared to the other schemes in all aspects, of which size are linear to the number of the whole attributes in the system. In YWRL, the KGC should send  $2u$  proxy keys to the data server, and  $2u$  key components to  $m$  users on every revocation in order to re-encrypt the ciphertext and prevent any revoked users from decrypting it. Although BCPABE2 does not need to send additional rekeying message for user revocations as opposed to the other schemes, it requires ciphertext of which size increases in proportion to the number of revoked users in the system. The proposed scheme is as efficient as BSW in terms of the ciphertext and public key size, while guaranteeing immediate rekeying.

**5.3 Simulation.**

Now we measure the communication cost of the schemes. In this simulation, we consider the online data sharing system connected into the Internet. Almeroth et al. demonstrated the group behavior in the Internet’s multicast backbone network (Mbone). They showed that the number of users joining a multicast group follows a Poisson distribution with rate  $\lambda$ , and the membership duration time follows an exponential distribution with a mean duration  $1/\mu$ . Since each attribute group can be seen as an independent network multicast group where the members of the group share a common attribute, we show the simulation result following this probabilistic behavior distribution.

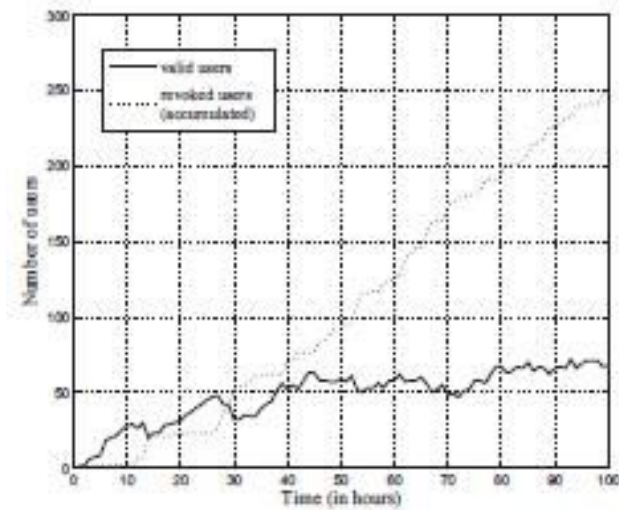


Fig.4. The number of users in an attribute group

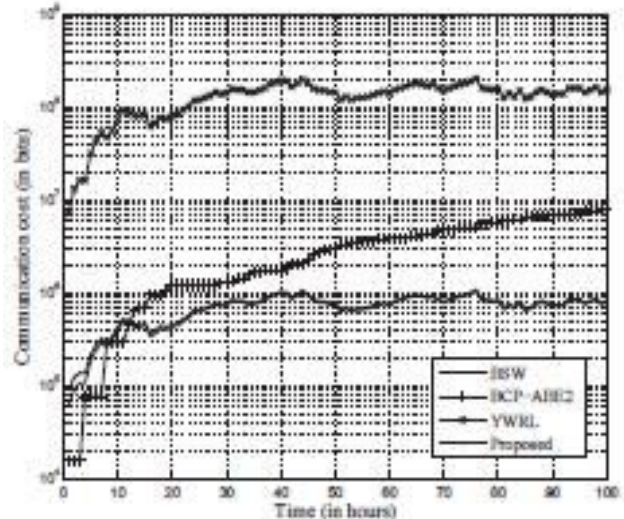


Fig.5. Communication cost in the system

We suppose that user join and leave events are independently and identically distributed in each attribute group in  $G$  following Poisson distribution. The membership duration time for an attribute is assumed to follow an exponential distribution. We set the inter arrival time between users as 20 minutes ( $\lambda = 3$ ) and the average membership duration time as 20 hours ( $1/\mu = 20$ ). Fig. 4 represents the number of users in a single attribute group during 100 hours. The solid line and dotted line represent the number of current valid users and accumulated revoked users in an attribute group, respectively. Fig. 5 shows the total communication costs in log scale that the data owner or the data storing center needs to send on a membership change in the network system. It includes the ciphertext and rekeying messages for non-revoked users. It is measured in bits. For a fair comparison with regard to the security perspective, we set the rekeying periods in BSW as  $1/\lambda$  minutes. In this simulation, the total number of users in the network is 9150 and the number of attributes to be updated in the system is  $30(= t)$ . We set  $u = 100$ . To achieve an 80-bit security level, we set  $C_0 = 512$ ,  $C_p = 160$ .  $C_1$  and  $C_T$  are not added to the simulation result because they are common in all of the schemes. As it is shown in Fig. 5, YWRL requires the largest amount of communication cost because the rekeying message increases linear to the size of the attribute universe in the whole system. The communication cost in BCP-ABE2 is the lowest in the beginning of the simulation time. However, as the time elapses, it increases conspicuously because the number of revoked users also increases accumulatively. The communication costs in BSW and proposed scheme are almost the same through the time.

TABLE 3-Comparison of computation cost

Operation	Time (ms)	BSW		BCP-ABE2		YWRL		Proposed scheme	
		owner	user	owner	user	owner	user	owner	user
Pairing	2.9		$2k + 1$		$2t + 2r + 1$		$u + 1$		$2k + 2$
Exp. in $G_0$	1.0	$2t + 1$		$(K + T + 2)t + 3r + 1$		$u + 1$	$k$	$2t + 1$	$mk$
Exp. in $G_1$	0.2	1	$\log t$	1	$t + r$	1		1	$\log t$
Computation (ms)		$2t + 1.2$	$\frac{5.8k}{2.9+0.2\log t}$	$(K + T + 2)t + 3r + 1.2$	$6t + 6r + 2.9$	$u + 1.2$	$2.9u + k + 2.9$	$2t + 1.2$	$\frac{(5.8 + m)k}{0.2\log t + 5.8}$

## 6. SECURITY

In this section, we prove the security of the proposed scheme with regard to the security requirements discussed in Section below.

### 6.1 Collusion Resistance

In the ciphertext-policy attribute based encryption; the secret sharing must be embedded into the ciphertext instead to the private keys of users. Like the previous ABE schemes the private keys ( $SK$ ) .

### 6.2 Data Confidentiality

In our trust model, the KGC is no longer fully trusted as well as the data storing center even if they are honest. Therefore, the plain data to be shared should be kept secret from them as well as from unauthorized users.

Data confidentiality on the shared data against outside users who have not enough attributes can be trivially guaranteed. If the set of attributes of a user cannot satisfy the access tree in the ciphertext, he cannot recover the desired value  $e(g, g)^{r^S}$  during the decryption process, where  $r$  is a random value uniquely assigned to him. On the other hand, when a user is revoked from some attribute groups that satisfy the access policy, he cannot decrypt the ciphertext either unless the rest of the attributes of him satisfy the access policy.

### 6.3 Backward and Forward Secrecy

When a user comes to hold a set of attributes that satisfy the access policy in the ciphertext at some time instance, the corresponding attribute group keys are updated and delivered to the valid attribute group members securely (including the user).

## CONCLUSION

The enforcement of access policies and the support of policy updates are important challenging issues in the data sharing systems. In this study, we proposed a attribute-based data sharing scheme to enforce a fine-grained data access control by exploiting the characteristic of the data sharing system. The proposed scheme features a key issuing mechanism that removes key escrow during the key generation. The user secret keys are generated through a secure two-party computation such that any curious key generation center or data storing center cannot derive the private keys individually. Thus, the proposed scheme enhances data privacy and confidentiality in the data sharing system against any system managers as well as adversarial outsiders without corresponding (enough) credentials. We demonstrated that the proposed scheme is efficient and scalable to securely manage user data in the data

sharing system.

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