

An Overview of Multi-Authority Attribute Based Encryption Techniques

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Abstract: Attribute based encryption (ABE) is a powerful encryption technique used in cloud computing, IoT, social networks and other technological fields where security and privacy are essential requirements of the system. There are different types of ABE schemes and this article highlights the features of multi-authority attribute based encryption (MA-ABE) schemes. A multi-authority ABE system consists of any number attribute authorities and any number of users. A set of global public parameters is defined in the system. A user can select an attribute authority and obtain the corresponding decryption keys. The authority executes the corresponding attribute key generation algorithm and the result is returned to the user. The encryption process uses the global public parameters and an attribute set to produce the ciphertext. Decryption is performed using the decryption keys for the attribute set.

Keywords: Attribute based encryption, MA-ABE, Multi-authority key policy attribute based encryption, Multi-authority ciphertext policy attribute based encryption, DABE

I. INTRODUCTION

Attribute-based encryption (ABE) systems use attributes for encryption and decryption of the data. Sahai and Waters proposed an attribute based encryption scheme [28] in 2005. The proposed scheme depends on a single authority for maintaining attributes. A single authority system has the following drawbacks.

- All attributes of the system are managed by the single authority; Failure or corruption of the authority affects the whole system.
- Another drawback of a single authority system is the “Key Escrow” problem.
- Private keys are distributed by the single authority so that the single authority can decrypt any ciphertext in the system

Chase [14] proposed a multi-authority attribute-based encryption system to overcome the drawbacks of a single authority attribute-based system. The proposed system uses a central authority (CA) and multiple attribute authorities (AAs). The problem with the Chase multi-authority attribute-based encryption system is that the CA can decrypt every ciphertext which reduces the user privacy and confidentiality of user data.

Chase and Chow [15] proposed a multi-authority attribute-based encryption scheme without the central authority.

The proposed system uses techniques for distributed pseudo random functions (PRF).

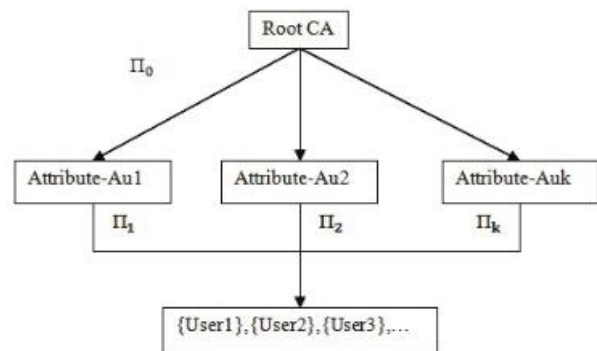


Figure 1: Multi-authority ABE system [26]

Sascha Müller, Stefan Katzenbeisser, and Claudia Eckert[22,23] proposed a multi-authority ciphertext policy attribute-based encryption scheme with one central authority and multiple attribute authorities. The drawback of the scheme is that the central authority can decrypt any ciphertext in the system.

Lewko and Waters [25] proposed an expressive, adaptively secure multi-authority ciphertext policy attribute-based encryption system for monotone access structures. The system removes the trusted central authority.

The aim of this article is to give an overview of recent developments in the field of multi-authority attribute based encryption for cloud computing, IoT and social networks. Major features of various multi-authority attribute based encryption schemes are studied in detail and the comparison results are given in a tabular format.

II. LITERATURE SURVEY

Multi-authority attribute based encryption schemes are either multi-authority key policy attribute based encryption schemes(MA-KPABE) or multi-authority ciphertext policy attribute based encryption schemes(MA-CPABE).

A. Multi-authority Key Policy Attribute-Based Encryption (MA-KPABE) Systems

1) Multi-authority attribute based encryption:

The notion of Multiple authority attribute based encryption scheme was first proposed by Chase[13]. The system uses the principles of trusted central authority (CA) and global identifiers (GID). The system also contains K attribute authorities. Each attribute authority is assigned a value dk. The system consists of the following five algorithms.

Setup:The algorithm generates a public key, secret key pair for each of the attribute authorities, and also outputs a system public key and master secret key.

Attribute Key Generation:The algorithm generates a private key for the user.

Central Key Generation:The algorithm generates a central secret key for the user.

Encryption:The sender encrypts the message and outputs the ciphertext.

Decryption:The user executes the decryption algorithm and decrypts the ciphertext.

The scheme can provide collusion resistance against any number of colluding users. With this feature, multi-authority attribute based encryption as proposed by Chase[14] becomes one of the powerful attribute-based encryption schemes used in cloud computing.

However, each authority's attribute set must be disjoint. To overcome this problem, we can create a separate copy of each attribute for each clause.

The CA can decrypt every ciphertext so that the user privacy and confidentiality of the data is less in this system.

II) CA-less multi-authority anonymous ABE:

Chase M. and Chow S.S.M. proposed a multi-authority attribute based scheme with user privacy [15].

Features

1. No trusted central authority
2. User privacy
3. Distributed pseudorandom functions are used in the system
4. Collusion resistance for any number of

colluding users

The scheme also defines an anonymous key issuing protocol. This protocol provides improved user privacy. Users are able to communicate with AAs via pseudonyms

- AAs are prevented from pooling their data.

The techniques from anonymous credentials are used that permits the users to get the decryption keys from the authorities.

The system uses the following four algorithms.

Setup:The authorities execute the setup algorithm by taking a security parameter and a public random string as inputs and generates an admissible bilinear group parameter. The authorities also generate a collision resistant hash function (CRHF).

Key Issuing:The key is generated for the user by executing the algorithm with each authority. The user invokes anonymous key issuing protocol. The authority issues secret key for each eligible attribute i for the user.

Encryption:The message is encrypted and the ciphertext is produced.

Decryption:The input is the ciphertext and the output is the message.

The advantages of the proposed system

- Trusted central authority is removed
- User privacy is protected

The disadvantage of the proposed system

- The system does not support a tree access structure

B. Multi-authority Ciphertext Policy Attribute-Based Encryption (MA-CPABE) Systems

1) Distributed attribute based encryption (DABE)

The notion of multi-authority ciphertext policy attribute-based encryption was first proposed by Müller et al. [22,23]. The system is built up of a Central Authority (CA) and multiple attribute authorities(AAs). These attribute authorities separately maintain attributes. The major components of the scheme are master, attribute authorities and users. The duty of the master is to distribute private user keys. Attribute Authority certifies the user and distributes private attribute key to the user that can be used for decrypting the ciphertext. User produces ciphertext by the method of encryption technique. Whenever needed user decrypts the ciphertext and retrieves the original message. A DABE scheme must be collusion resistant.

The following seven algorithms are defined in a DABE scheme.

Setup: The algorithm generates the public key of the system PK and the master key MK.

CreateUser: The outputs of the algorithm are a public user key PK_u and a secret user key SK_u .

Create_Authority: The algorithm generates a private authority key SK_a .

Request_AttributePK: The algorithm generates the public attribute key of attribute A

Request_AttributeSK: The algorithm generates a secret attribute key $SK_{A,u}$ for user u.

Encrypt: The inputs of the *Encrypt* algorithm are public key, message, an access policy and the public keys associated with the attributes in the access policy. The output of the *Encrypt* algorithm is the ciphertext.

Decrypt: The inputs of the *Decrypt* algorithm are the ciphertext produced by the *Encrypt* algorithm, an access policy and a key ring. Decryption is performed based on certain conditions and if the conditions are satisfied, the algorithm outputs the plaintext.

The advantage of the DABE scheme is that only two pairing operations are required in the decryption algorithm. Pairing operations are the most expensive operations in cryptography. The efficiency of the scheme can be improved by reducing the number of pairing operations. Only the decryption algorithm requires pairing operations. The pairing operations are not used anywhere else.

The major drawback of DABE scheme is that the overhead involved in managing the distributed authorities.

II) Decentralized attribute based encryption

The notion of decentralized attribute-based encryption was proposed by Lewko and Waters [25]. The proposed system is a multi-authority attribute based encryption system.

Features

1. Any party can be appointed as an authority.
2. Global coordination of the authorities is required only for creating an initial set of common reference parameters.
3. To become an ABE authority, the party creates a public key and distributes private keys to users.
4. The encryption of the data is performed by the user with the help of a Boolean formula.
5. No central authority is required in the proposed system.

The Chase [14] concept of global identifiers is used in the system so that private keys issued to the same user by different authorities can be linked together.

Scalability, Security and Efficiency

The overhead of relying on a central authority is eliminated from the system. This ensures more scalability for the system. Without a central authority, the security and the efficiency of the system much more compares to other systems.

Robustness

The authorities are working independently of each other. Therefore, the failure or malfunctioning of one authority will not affect the working of other authorities. This improves the robustness of the system.

Autonomous key generation and Collusion resistance

The system uses a hash function on the user's global identifier so that collusion resistance is ensured for multiple keys generated by different authorities.

The system uses the following five algorithms.

Global Setup: The global setup algorithm chooses a bilinear group G of order N . This N acts as a component of the global public parameter. The output of the algorithm is a description of a hash function.

Authority Setup: Each authority chooses two random exponents for the attribute i . The output of the algorithm is a public key and a secret key.

Encrypt: The inputs of the *Encrypt* algorithm are a message, an access matrix, the global parameters and the public keys of the pertinent authorities. The output of the algorithm is the ciphertext.

KeyGen: A key is created for the (identity, attribute) pair.

Decrypt: A hash function is applied on the identity for attribute i . The output of the decrypt algorithm is the message.

The advantage of the system is that the system provides collusion resistance; the system is more efficient, more robust and provides scalability.

III. COMPARISONS

The multi-authority ciphertext policy attribute based encryption schemes [22,23,25] are more expressive than the multi-authority key policy attribute based encryption schemes [13,15]. However, the implementation complexity of multi-authority ciphertext policy attribute based schemes are higher than the multi-authority key policy attribute based schemes.

Small Universe MA-ABE schemes: MA-ABE schemes use polynomial size attribute universe in the security parameter.

Large Universe MA-ABE schemes: MA-ABE schemes use exponential size attribute universe in the security parameter.

Unbounded MA-ABE schemes: These schemes are independent of the size of attribute universe.

Expressiveness of the MA-ABE schemes can be increased by the method of large universe construction and vice versa.

Efficiency of the MA-ABE schemes decreases considerably with the use of large universe construction and vice versa.

Large universe MA-ABE schemes can be constructed from small universe ones with the use of a hash function.

Table I
Comparison of Multi-authority ABE Systems

	<i>MA-ABE Techniques/ Parameters</i>	<i>Adaptively Secure</i>	<i>Standard Model</i>	<i>Prevent Decryption by Individual Authorities</i>	<i>Support Large Attribute Universe</i>	<i>Expressiveness</i>
Key policy attribute based encryption schemes	Multi-authority Attribute Based Encryption	No	Yes	No	Yes	Limited
	CA-less multi-authority anonymous ABE	No	Yes	Yes	Yes	Limited
Ciphertext policy attribute based encryption schemes	Distributed Attribute Based Encryption	No	Yes	No	Yes	Expressive
	Decentralized Attribute Based Encryption	Yes	No	Partially	No	Expressive

III. CONCLUSION

In this paper, we review the features, advantages and disadvantages of different multi-authority attribute based encryption schemes. The ultimate goal of designing a MA-ABE scheme is to develop a secure, robust, expressive and efficient multi-authority attribute based encryption system. The field of MA-ABE scheme is a vast and ever-evolving one with its wings stretched to the areas of IoT and Social Networks.

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