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University of Pittsburgh
School of Information Sciences

Insider Threat Mitigation in Attribute based Encryption

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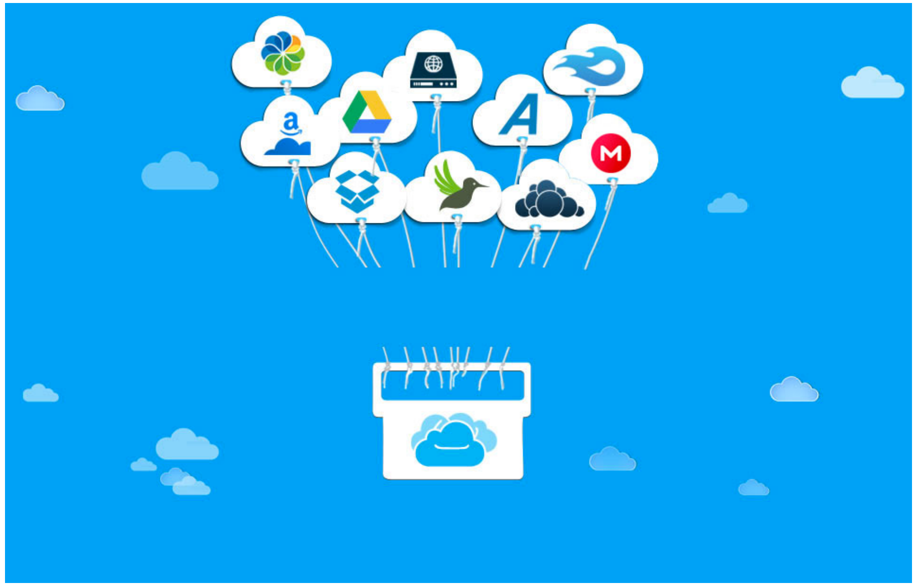
The **L**aboratory for **E**ducation and **R**esearch on **S**ecurity **A**ssured **I**nformation **S**ystems (**LERSAIS**)

Cloud Computing/Storage Service

❖It has been gaining significant success
- *potential "infinite" storage size*
- *convenience of synchronization*
- *ease of access (at anytime, from anywhere)*



❖Users/Organizations
- *increasingly utilize/rely on the cloud storage services*

Security & Privacy Concerns

Cloud Storage Providers

Honest-but-Curious

-- run the programs and algorithms correctly,

-- but gather information related to the stored data.

A Solution

- *Confidentiality for data*
- *Fine-grained access control for data*

Initial Requirement

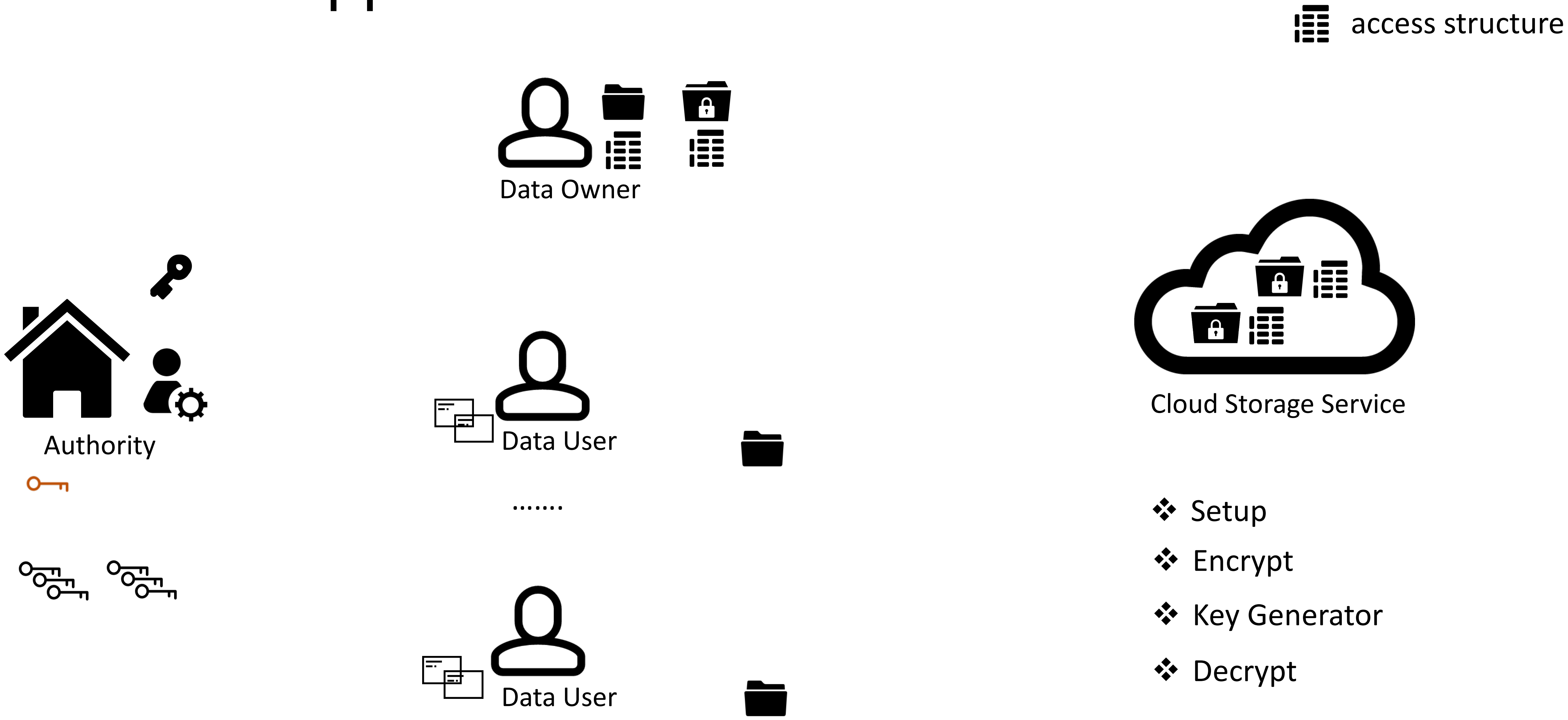
Ciphertext Policy Attribute Based Encryption

- *Combination of encryption and access control*
- *Useful for access scenario in cloud storage*

Data → self-protection feature / abilitity

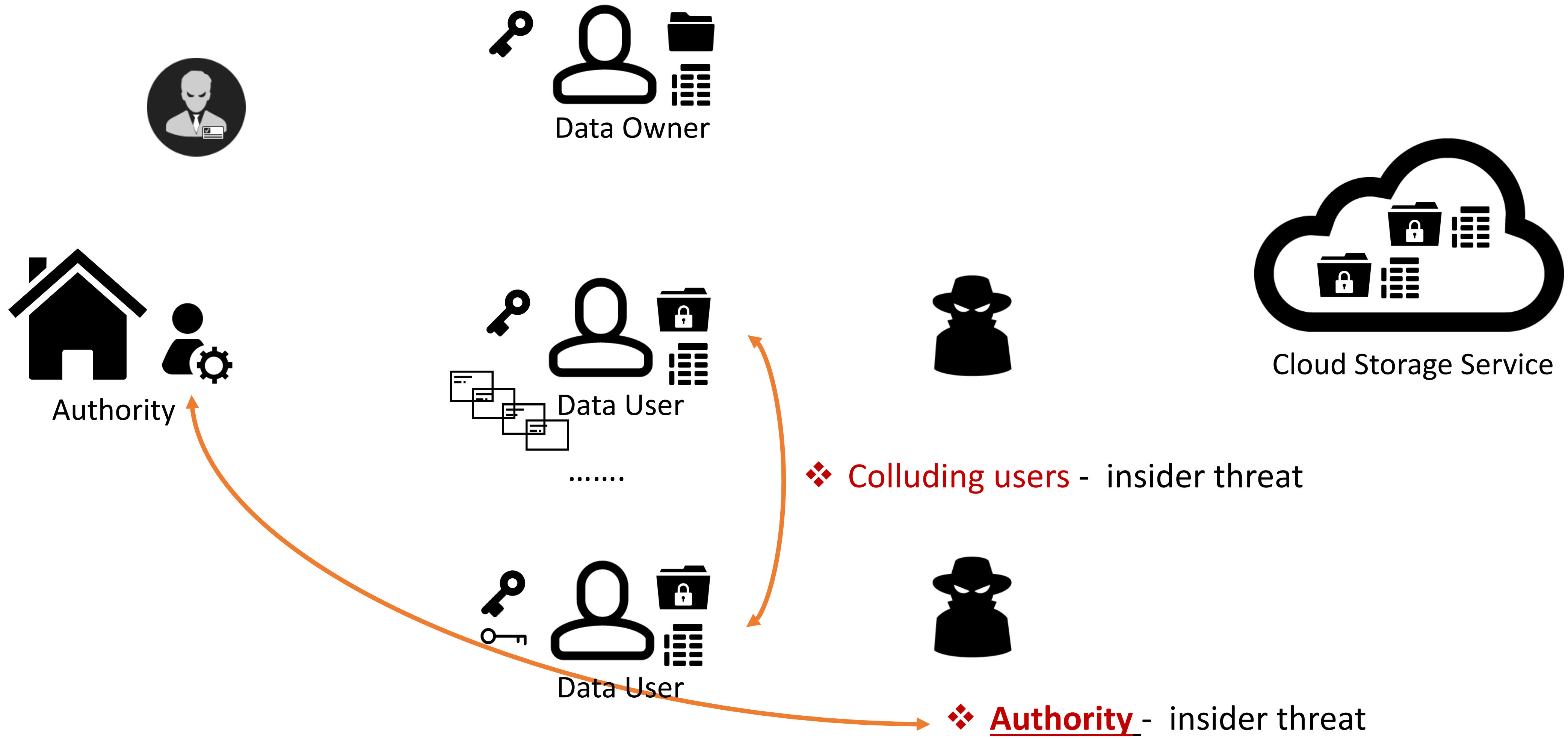
*Bethencourt John, Amit Sahai, and Brent Waters. "Ciphertext-policy attribute-based encryption." *2007 IEEE symposium on security and privacy (S&P'07)*. IEEE, 2007.

Overview of application



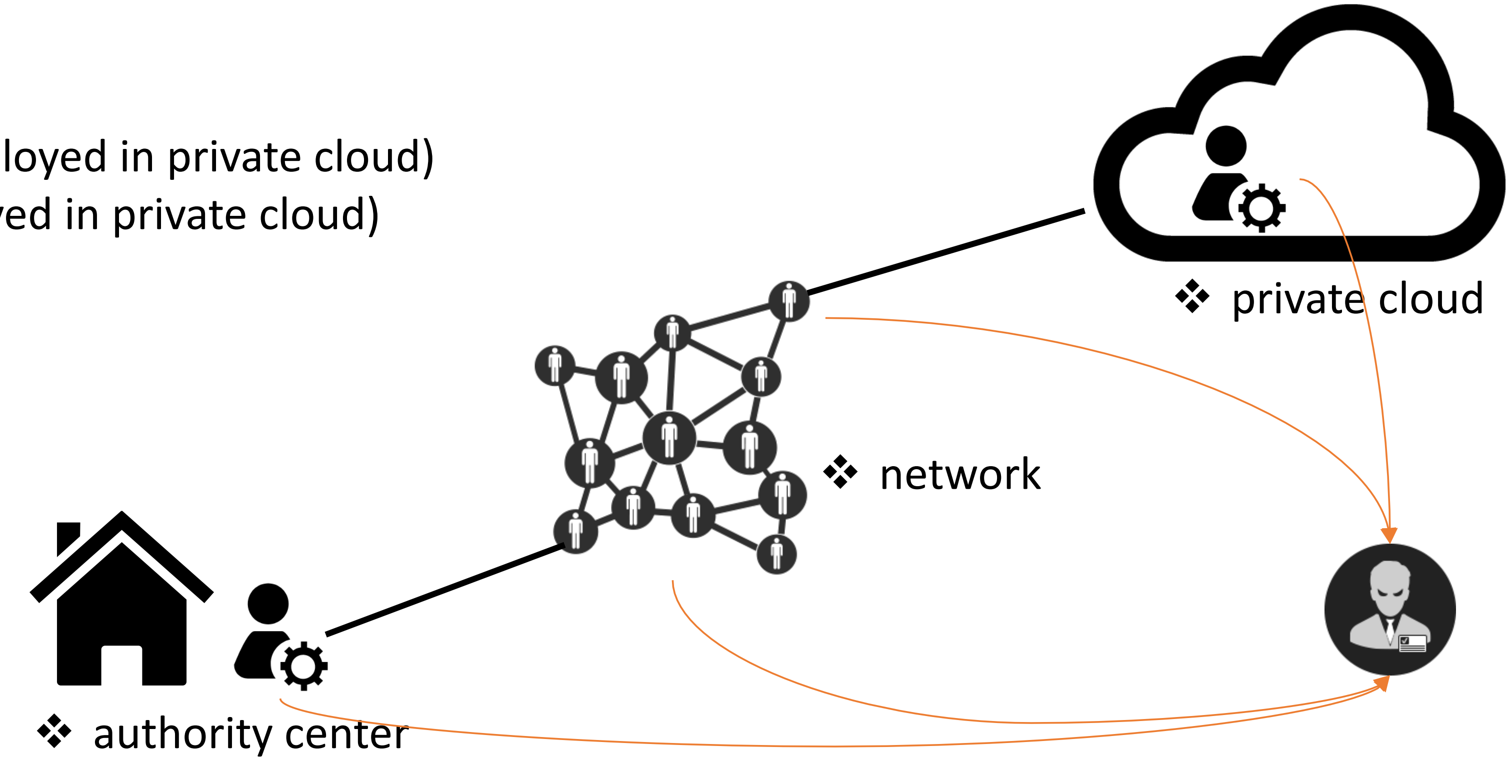
- Setup
- Encrypt
- Key Generator
- Decrypt

Two Types of Insider in ABE

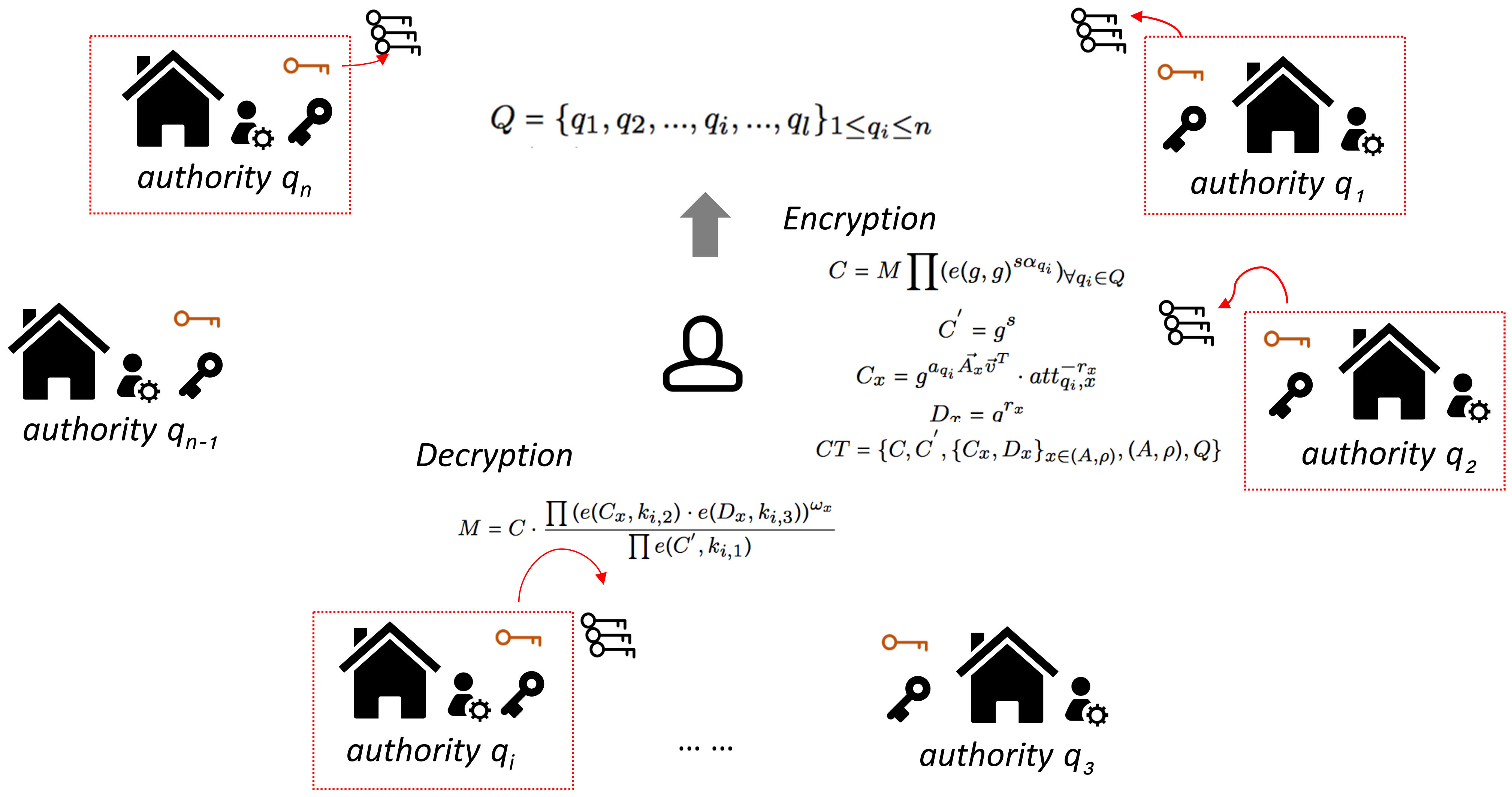


Authority as Insider threat

- Potential Insiders
  - system administrator
  - attribute authenticator
  - other employees
  - network administrator (if deployed in private cloud)
  - cloud administrator (if deployed in private cloud)



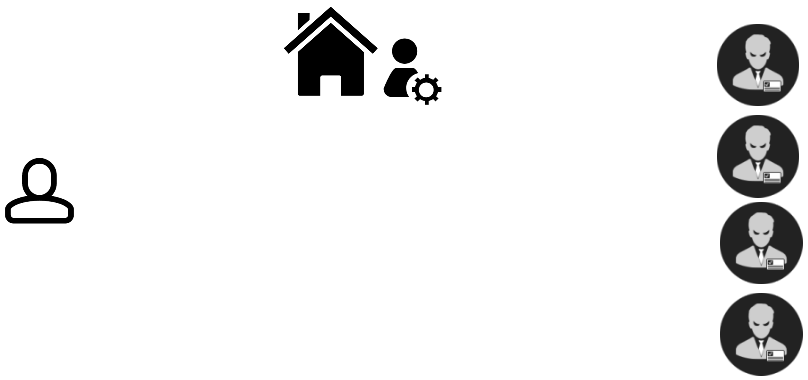
Multi-Authority CP-ABE



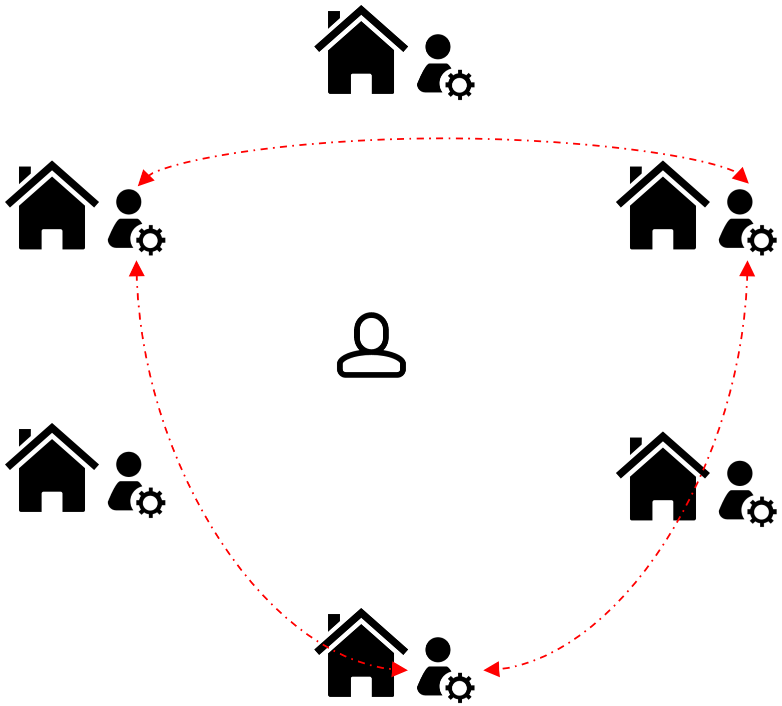
Insider Threat Mitigation Solutions

Two specific insider threat issues in Authority

- ❖ single authority as a threat
  - ❖ MA-CP-ABE removes that



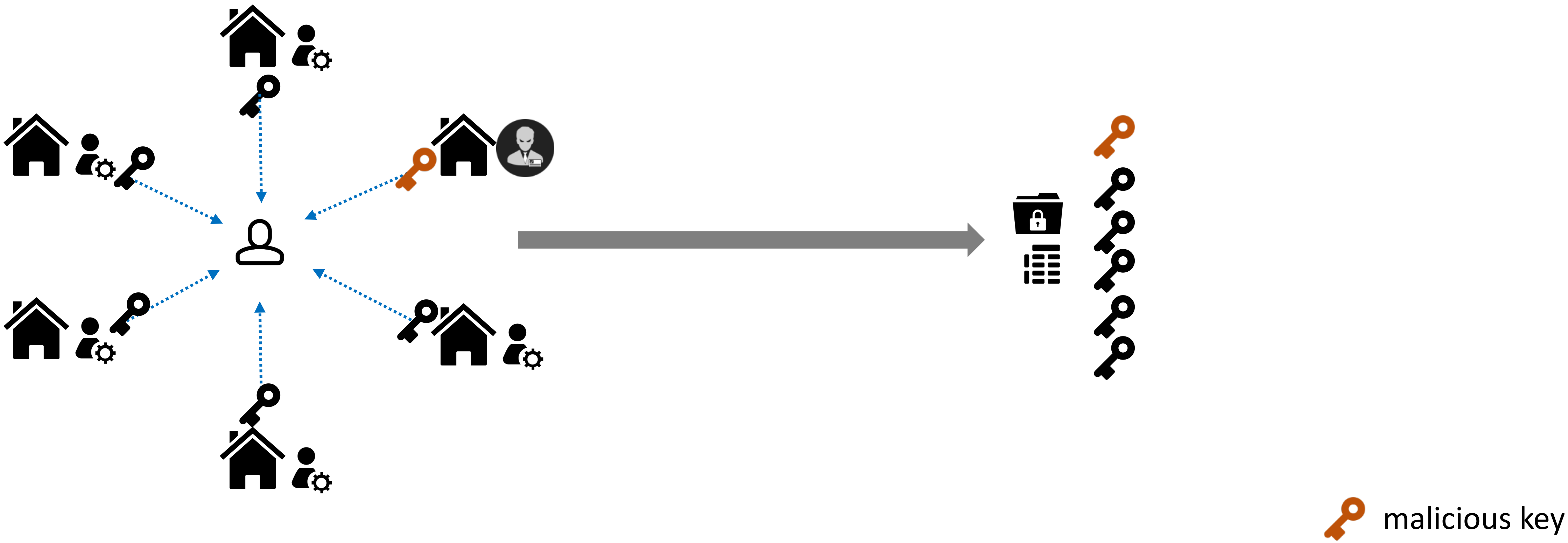
- ❖ with insiders' collusion: different authorities



Insider Threat Mitigation Solutions

single authority as insider

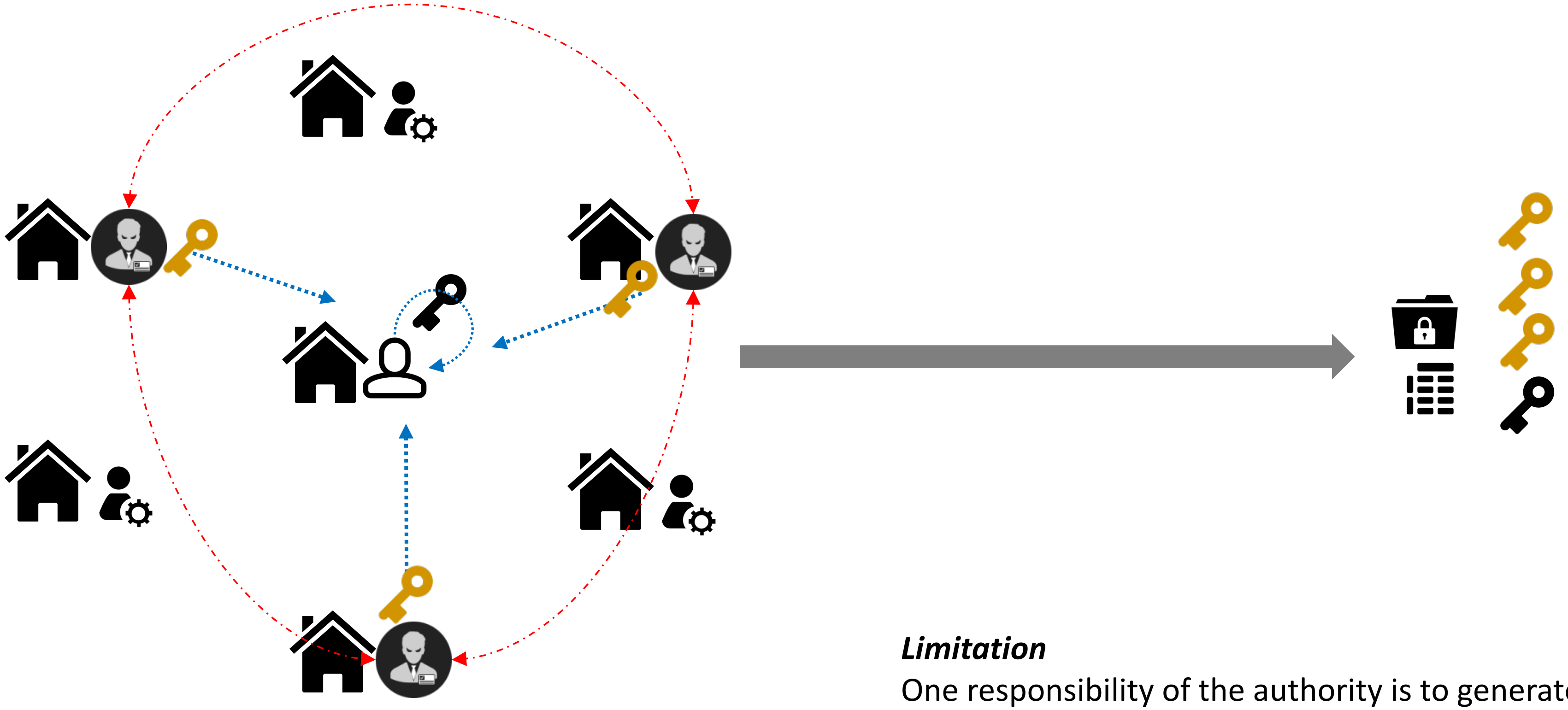
❖ multi-authority scheme can directly prevent the insider's attack from a single authority.



Insider Threat Mitigation Solutions

Collusion among different authorities

***I_N tolerance**: self-authority, the data owner can play as an ABE authority itself*



Limitation

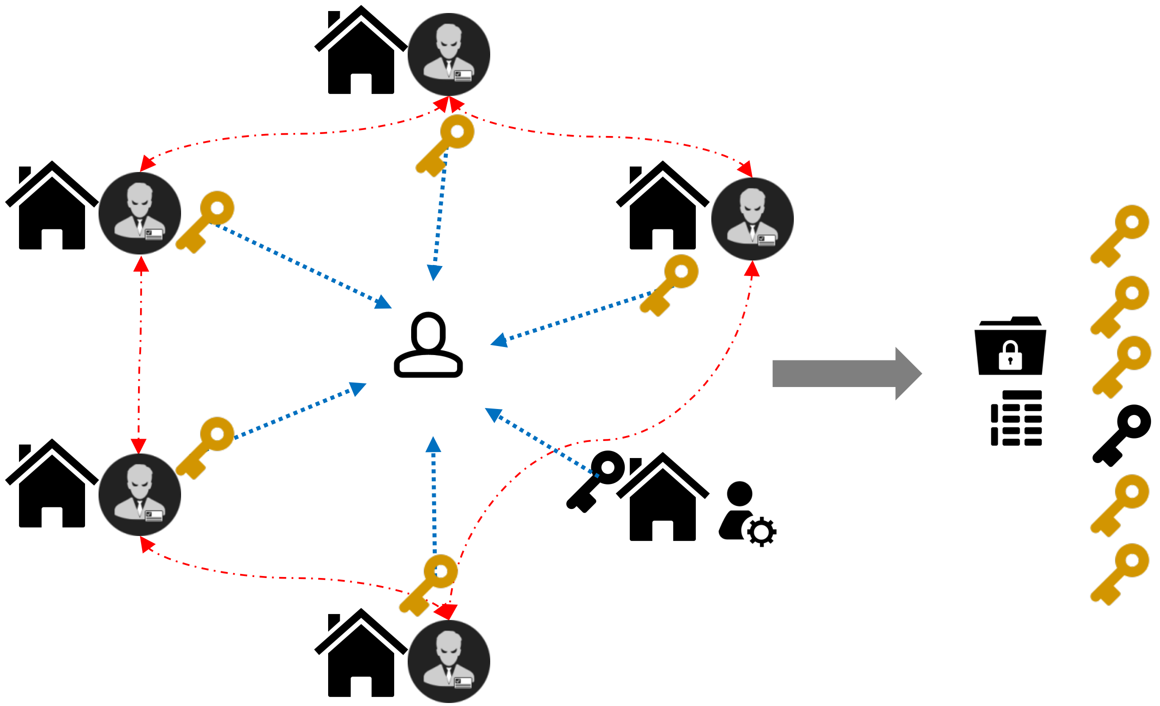
One responsibility of the authority is to generate the users' private keys

→the self-authority should be available when the data user needs the key services.

Insider Threat Mitigation Solutions

ollusion among different authorities posing insider threat

I_{N-1}* tolerance: resist at most N – 1 insiders among the N authorities*



$$Q = \{q_1, q_2, \ldots, q_i, \ldots, q_l\}_{1 \le q_i \le n}$$

Algorithm 1 The sequence Q generating algorithm.

Input: the number of attributes in the access structure l; the number of authorities N; the identity set of authorities $S_{\mathcal{A}}$.

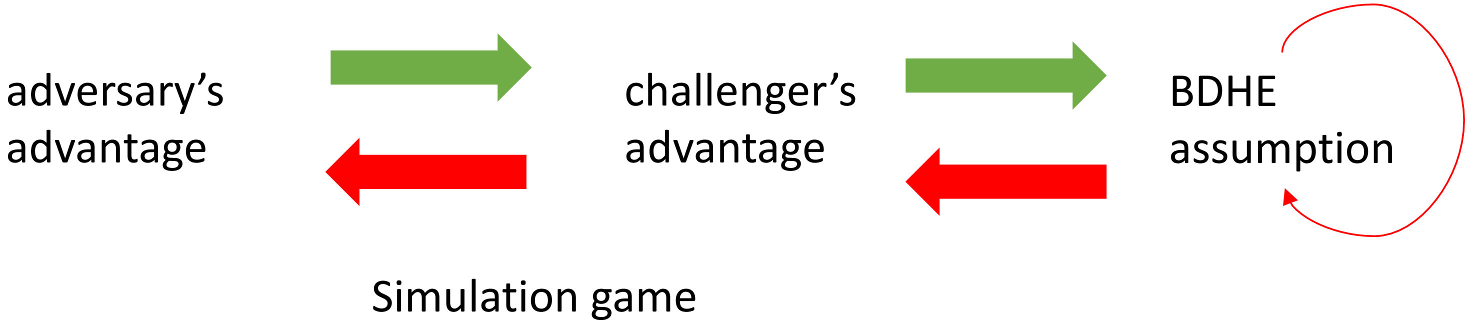
Output: the generated sequence Q.

```
if l ≥ N then
    Q_A ← select all identities from S_A.
    Q_rest ← randomly select l − N identities from S_A.
    Q ← Q_A ∪ Q_rest
    Shuffle the Q.
else
    Q ← randomly select l identities from S_A.
    Shuffle the Q
end if
return Q
```

Security Analysis

Security of MA-CP-ABE

- Simulation game [4,12]
  - Setup
  - Secret Key Queries
  - Challenge
  - More Secret Key Queries
  - Guess



- The adversary tries to break the scheme

- Insider Tolerance Analysis

- Complexity Analysis

Table 1: Comparison of efficiency

schemes	Our scheme	[8]
Encryption	$(4l+1)\mathcal{C}_{exp}$	$(4\|i\|+1)\mathcal{C}_{exp} + \|l\|\mathcal{C}_{map}$
Decryption	$3\|S\|\mathcal{C}_{map} + \|S\|\mathcal{C}_{exp}$	$3\|S\|\mathcal{C}_{map} + 3\|S\|\mathcal{C}_{exp}$

[1] Let $|\mathcal{C}_{exp}|$, $|\mathcal{C}_{map}$ be the calculation of exponent and bilinear map over $\mathcal{G}$, respectively.
[2] l is the attribute number in the access structure, and $|S|$ is the minimum set of users' attributes.

[8] Allison Lewko and Brent Waters. 2011. Decentralizing attribute-based encryption. In *Annual International Conference on the Theory and Applications of Cryptographic Techniques*. Springer, 568–588.

Conclusion

- Cloud computing/storage services are increasingly used
- Data confidentiality and Access control are among primary issues
- CP-ABE is useful in addressing both Data confidentiality and access control issues
- Authority needs to be trusted – hence can pose as insider threat
- MA-CP-ABE scheme proposed addresses the Authority as insider threat agent
    - Two schemes
    - Complexity of the scheme is better than that of another existing scheme

Acknowledgement:
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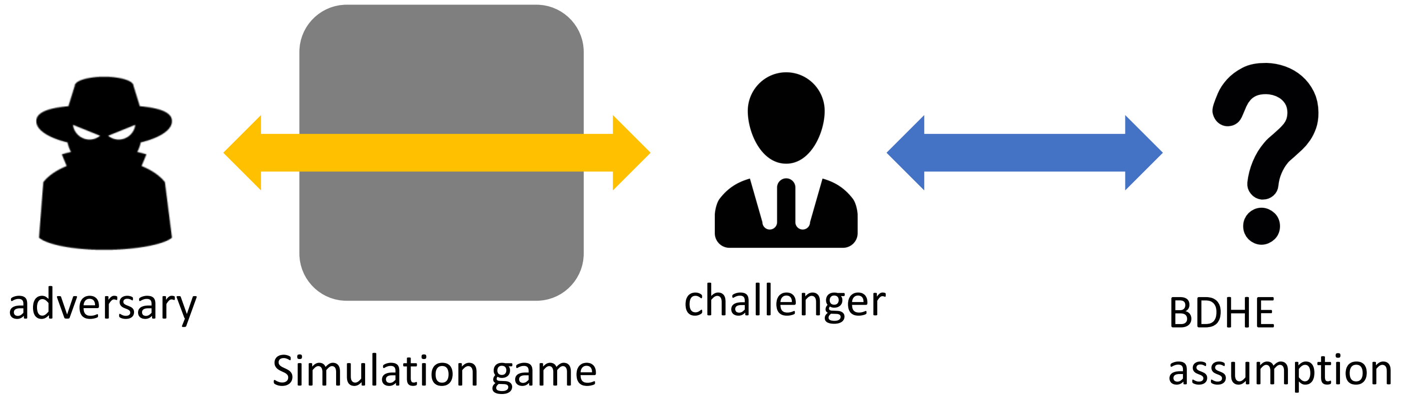
Thanks!
Questions?

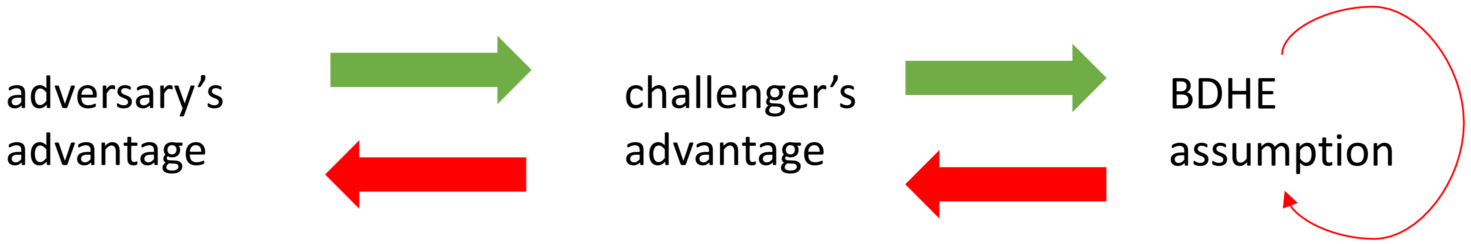
Security Analysis

Security of MA-CP-ABE

❖ Simulation game [4,12]
  - ❖ Setup
  - ❖ Secret Key Queries
  - ❖ Challenge
  - ❖ More Secret Key Queries
  - ❖ Guess



- The adversary tries to break the scheme
- The challenger tries to solve the mathematical hard problem by taking the advantage of the adversary



Complexity Analysis and Correctness

The complexity of our proposed MA-CP-ABE scheme

Table 1: Comparison of efficiency

schemes	Our scheme	[8]
Encryption	$(4l+1)\mathcal{C}_{exp}$	$(4\lvert i\rvert+1)\mathcal{C}_{exp}+\lvert l\rvert\mathcal{C}_{map}$
Decryption	$3\lvert S\rvert\mathcal{C}_{map}+\lvert S\rvert\mathcal{C}_{exp}$	$3\lvert S\rvert\mathcal{C}_{map}+3\lvert S\rvert\mathcal{C}_{exp}$

[1] Let $|\mathcal{C}_{exp}|$, $|\mathcal{C}_{map}$ be the calculation of exponent and bilinear map over $\mathcal{G}$, respectively.

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Correctness inference

$$T = \frac{\prod_{i\in Q} e(C', k_{i,1})}{\prod_{i\in Q, x\in I}(e(C_x,k_{i,2})e(D_x,k_{i,3}))^{\omega_x}}$$

$$= \frac{\prod_{i\in Q} e(g^s, g^{\alpha_i}\cdot g^{a_i t_i})}{\prod_{i\in Q,x\in I}(e(g^{a_i \vec{A}_x \vec{v}^T}\cdot att_{i,x}^{-r_x}, g^{t_i})e(g^{r_x}, att_{i,j}^{t_i})))^{\omega_x}}$$

$$= \frac{e(g,g)^{\sum_{i\in Q} s(\alpha_i+a_i t_i)}}{e(g,g)^{\sum_{i\in Q}(a_i t_i \sum_{x\in I}\vec{A}_x\vec{v}^T\omega_x)}}$$

$$= \frac{e(g,g)^{\sum_{i\in Q} s(\alpha_i+a_i t_i)}}{e(g,g)^{\sum_{i\in Q} a_i t_i s}}$$

$$= e(g,g)^{\sum_{i\in Q} s\alpha_i}$$

Then the message M could be recovered as follows:

$$\frac{C}{T} = \frac{M\prod(e(g,g)^{s\alpha_{q_i}})_{q_i\in Q}}{e(g,g)^{\sum_{i\in Q} s\alpha_i}} = \frac{Me(g,g)^{\sum_{q_i\in Q} s\alpha_i}}{e(g,g)^{\sum_{i\in Q} s\alpha_i}} = M$$