Integrating OpenID with proxy re-encryption to enhance privacy in cloud-based identity services

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Introduction

- Identity Management is a ubiquitous service
- Costly $\Rightarrow$ specific applications and personnel
- **Identity Management as a Service (IDaaS)**
  - Cloud computing solution to this problem
  - Organizations can outsource their IdM services to the cloud
  - Cloud providers specialized in Identity Management
  - New business opportunities to cloud providers

Motivation

- Classic problem of cloud computing
  $\Rightarrow$ The user loses the control of his data
- Now we are talking about **identity** data...
  $\Rightarrow$ Data protection laws and regulations
- Current solution: Service Level Agreements (SLAs)
  $\Rightarrow$ It is just an agreement not a **technical safeguard**
- Trust problem $\Rightarrow$ Users are obliged to trust the provider
- **Goal:** To define technical safeguards that allow an IdM service without compromising users' data

Proposal: Privacy-preserving IDaaS

- Privacy-preserving IDaaS system
- Based in OpenID Attribute Exchange and Proxy Re-Encryption
- Identity attributes are encrypted by the user and decrypted by the requester
- The Identity Provider (IdP) stores encrypted attributes
  $\Rightarrow$ Still capable of offering an identity service
- First proposal that tackles this problem

OpenID: Overview

- Decentralized model for identity management
- User's identity is represented by an *OpenID identifier*
- Current version is OpenID 2.0
- Defines an extension for attribute exchange
  $\Rightarrow$ OpenID Attribute Exchange 1.0

OpenID

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OpenID Authentication protocol

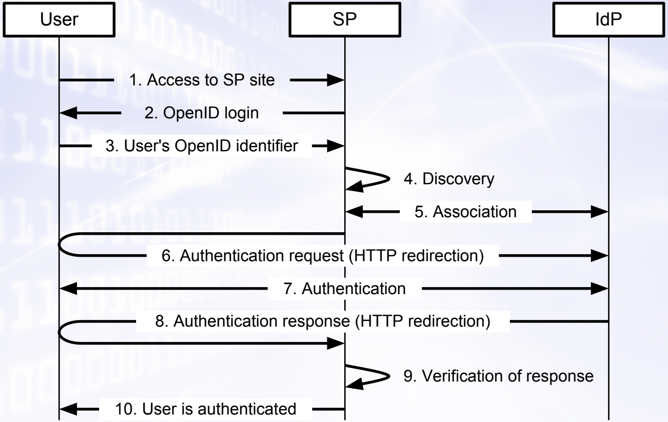


Figure : OpenID Authentication sequence diagram

OpenID: Problems

- Identity information assurance
- Lack of trust framework
- Privacy

Proxy Re-Encryption: Overview

A PRE scheme is a public-key encryption scheme that permits a proxy to transform ciphertexts under Alice's public key into ciphertexts under Bob's public key.

The proxy needs a re-encryption key $r_{A \to B}$ to make this transformation possible.

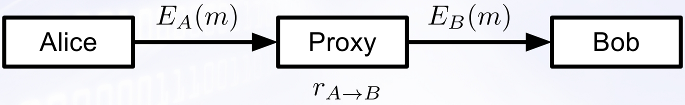


Figure : Proxy Re-Encryption flow

Proxy Re-Encryption: AFGH scheme

Global parameters:

- $\mathbb{G}_1, \mathbb{G}_2$ are groups of prime order q
- $e : \mathbb{G}_1 \times \mathbb{G}_1 \rightarrow \mathbb{G}_2$ is a bilinear pairing
- $g \in \mathbb{G}_1, Z = e(g, g) \in \mathbb{G}_2$

Primitives:

- Key Generation: $KG() = (s_A, p_A)$
- Re-Encryption Key Generation: $RKG(s_A, p_B) = r_{A \rightarrow B}$
- First-level Encryption: $E_1(m, p_A) = c_1$
- Second-level Encryption: $E_2(m, p_A) = c_2$
- Re-Encryption: $R(c_2, r_{A \rightarrow B}) = c_1$
- First-level Decryption: $D_1(c_1, s_A) = m$
- Second-level Decryption: $D_2(c_2, s_A) = m$

Proxy Re-Encryption: AFGH scheme

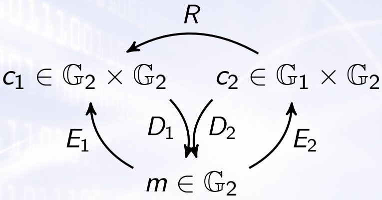
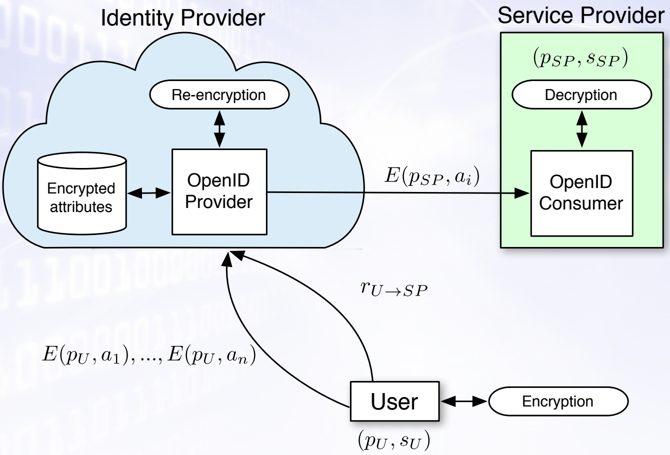


Figure : Transformations between plaintext and ciphertext spaces

Properties:

- Unidirectional
- Unihop
- Collusion-resistant

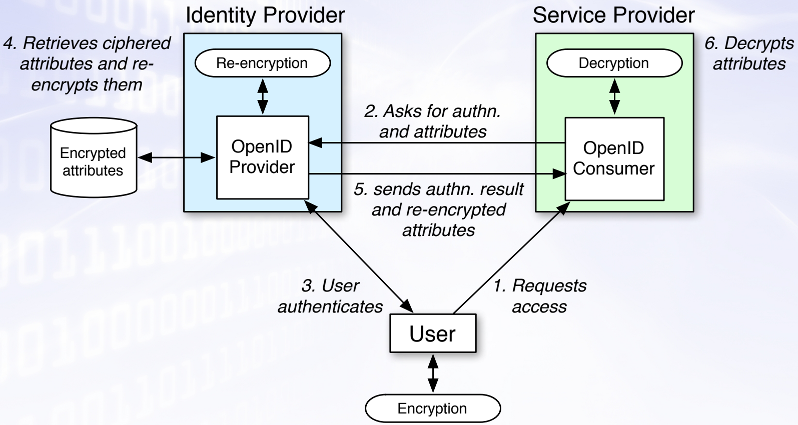
Privacy-preserving IDaaS system: overview



Privacy-preserving IDaaS system: assumptions

- **Honest-but-curious** provider: The cloud provider will respect protocol fulfillment, but will try to read users' data
- Existing trust relationship between users and requesters

Privacy-preserving IDaaS system: main interactions



Instantiation with OpenID AX

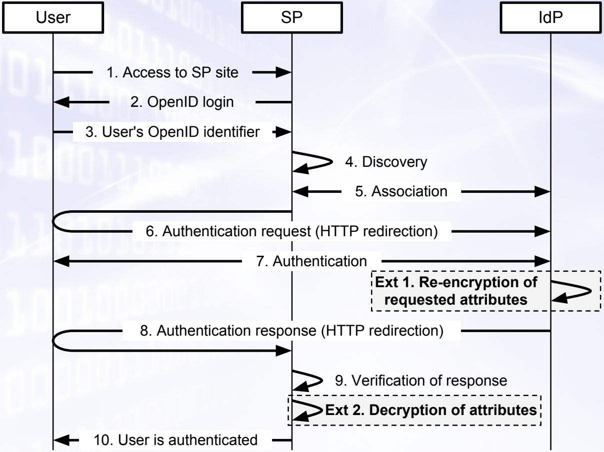


Figure : Modified OpenID sequence

Implementation details

We have implemented:

- OpenID Provider and Consumer using the OpenID4Java library[1]
- AFGH Proxy Re-Encryption scheme using Java Pairing-Based Cryptography library (jPBC)[2]

[1] http://code.google.com/p/openid4java

[2] A. D. Caro, http://gas.dia.unisa.it/projects/jpbc

Economic analysis

- Most of proposals do not analyze their economic impact
- Cryptographic operations have an economic cost due to computation, communication, etc.
  $\Rightarrow$ Cloud provider incurs in expenses due to energy consumption, personnel, ...
- Our estimations are based on a research from Chen & Sion[3]
  $\Rightarrow$ They give estimations for computation, storage and communication costs, expressed in *picocents* (1 picocent $= 10E^{-12}$ USD cent)
- We estimate the number of CPU cycles to give an approximation of the costs

[3] Y. Chen and R. Sion, "On securing untrusted clouds with cryptography" in Proc. 9th annual ACM workshop on Privacy in the electronic society

Economic analysis: time measurements

Table : Performance results for the main operations

Operation	Time (ms)	Cycles
Generation of global parameters	7279.98	1.94E+10
Generation of a secret key	0.01	1.86E+04
Generation of a public key	20.05	5.33E+07
Generation of re-encryption key	139.66	3.72E+08
Encryption	23.31	6.20E+07
Re-encryption	90.09	2.40E+08
Decryption	14.28	3.80E+07

Economic analysis: costs

Table : Costs in picocents for the main operations

Operation	Cost per operation	Operations per cent
Encryption	4.34E+08	2304
Re-encryption	4.79E+08	2087
Decryption	5.70E+08	1755

Economic analysis: example scenario

- IDaaS provider that handles 1 million attribute requests per day $\Rightarrow$ 1 million re-encryptions per day
- Approx. 2000 USD per year
- Reasonable cost for an average-sized company, considering that their information is encrypted at the cloud provider

Conclusions

- IDaaS is a promising paradigm for organizations
- Cloud providers are in a privileged position to gain information about their users
- We need technical safeguards, such as those based in cryptography, to ensure users' privacy

Conclusions

- In this work, we describe an IDaaS system that handles encrypted attributes and still provides an identity service
- Our system is based in OpenID Attribute Exchange and Proxy Re-Encryption
- The cloud identity provider transforms encrypted attributes from the original users to ciphertexts for the requesters using re-encryption
- Implementation and economic analysis is provided

Future work

- More secure and efficient proxy re-encryption schemes
- Improve trust and assurance
- Other identity management protocols (e.g., SAML)
- Evaluation in a real cloud setting

Thank you!