F3ildCrypt: End-to-End Protection of Sensitive Information in Web Services

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ISC 2009

Motivation

- Identity-related information is valuable
- You must provide such information when using an online merchant
- This information is vulnerable to disclosure at the endpoints and in transit
- Can we protect this information end-to-end without revealing details of the logical corporate architecture?

Outline

Introduction

Merchant trust

Users have to trust online merchants:

- Merchant is not malicious
- Merchant will protect sensitive information for its lifetime
- Merchant site is maintained by diligent sysadmins

Service-oriented architecture

In this work, we focus on SOAs:

- Requests to a network have a single entry point
- A parent SOA may make requests on multiple child SOAs
- SOAs may operate under differing legal and corporate policies toward private data

SOA trust

In Service Oriented Architectures, users have to trust:

- Merchant *and peer SOAs* are not malicious
- Merchant *and peer SOAs* will protect sensitive information for its lifetime
- Merchant *and peer SOAs* are maintained by diligent sysadmins

Data in transit

We consider only data in transit across the SOA pipeline

- We protect the data between the web browser and the back-end database
- Our approach does not protect against nodes with legitimate access to the data

Design alternative #1

Pair-wise key distribution

- Generate a public key for each potential destination host in the SOA pipeline
- Deliver public keys to each web browser
- Browser encrypts each field direct to its destination host

Design alternative #1 (cont.)

Issues with pair-wise key distribution

- Public keys for all hosts in any partner SOAs must also be delivered
- Public keys must be updated each time the architecture of the SOA or its partners varies
- Reveals the logical architecture of the SOA and its SOA partners

Design alternative #2

Point-to-point SSL

- SSL connection from browser to SOA gateway
- From the gateway, distribute fields to internal hosts via SSL

Design alternative #2 (cont.)

Issues with point-to-point SSL

- User has no insight into backend field protection
- Plaintext fields are revealed at the gateway

Related work

W3bCrypt

Introduced end-to-end encryption in web pipelines

- *"Encryption as a stylesheet"*
- Firefox plugin for application-level crypto
- Requires disclosure of corporate network details
- [Stavrou et al., 2006]

Proxy re-encryption

- Given plaintext P, Alice $\langle pk_A, sk_A \rangle$, and Bob $\langle pk_B, sk_B \rangle$
- There exists some $rk_{A \to B} = F(sk_A, pk_B)$ such that:

$$pk_B(P) = rk_{A \to B}(pk_A(P))$$

- [Blaze et al., 1998]

Architecture

Design goals

- End-to-end protection of fields – even across SOA boundaries
- Confidentiality of logical architecture of each SOA must be respected

This work does not focus on providing protection against compromise or failure of entities with legitimate access to sensitive information.

F3ieldCrypt architecture

- Each SOA s publishes a public key pk_{E_s}
- Browser b generates plaintext P
- b sends $C = pk_{E_s}(P)$ to s
- Gateway at s re-encrypts C to internal hosts and partner SOAs $I_0 ... I_n$

Key generation

- Key pair $\langle pk_{E_s}, sk_{E_s}\rangle$ generated at the **external-key holder**
- sk_{E_s} used in conjunction with internal application keys $pk_{I_0}...pk_{I_n}$ to generate $rk_{E\rightarrow I_0}...rk_{E\rightarrow I_n}$

External-key holder

External-key holder has sk_{E_s} and $pk_{I_0} \ldots pk_{I_n}$ — its compromise could be dangerous. However:

- Very low bandwidth requirements
- Only needed at setup and when adding new internal hosts
- Can be kept offline!

Key distribution

- pk_{E_s} is publicized
- $rk_{E \to I_0} \ldots rk_{E \to I_n}$ transmitted to **proxy re-encryption engine**
- By proxy re-encryption:

$$pk_{I_j}(P) = rk_{E \to I_j}(pk_E(P))$$

Proxy re-encryption engine

- Fields arrive at proxy re-encryption engine encrypted under pk_{E_s}
- Each field f is re-encrypted to pk_{I_j}
- The mapping $f \rightarrow j$ is determined by an admin-defined policy

Browser engine

- **Browser** generates plaintext P containing a set of fields $f_0 ... f_n$
- $f_0 ... f_n$ are encrypted under pk_{E_s} and delivered to s

Architecture summary

browser $\longrightarrow$ proxy re-encryption engine:	$pk_{E_s}(f_i)$
proxy re-encryption engine:	$pk_{I_j}(f_i) = rk_{E \rightarrow I_j}(pk_{E_s}(f_i))$
proxy re-encryption engine $\longrightarrow$ app j:	$pk_{I_j}(f_i)$

Evaluation

Implementation

- Java-based re-crypto engine uses JHU-MIT Proxy Re-cryptography Library for each browser
- XML gateway at the SOA stores the re-encryption engine
- Python-based XML proxy for each internal application to store keys and unwrap XML

Testbed servers

Dell PowerEdge 2650 Servers

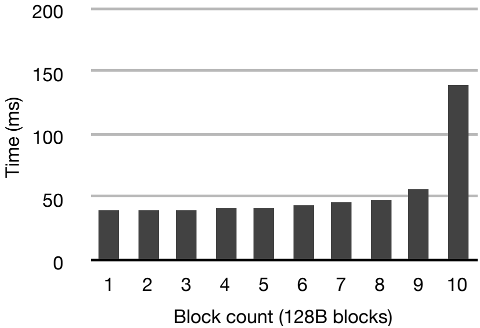
- 2.0GHz Intel Zeon processor, 1GB RAM, Gigabit Ethernet
- OpenBSD 4.2
- OpenBSD PF firewall, Apache 1.3.29, PHP 4.4.1, MySQL 5.0.45

Testbed client

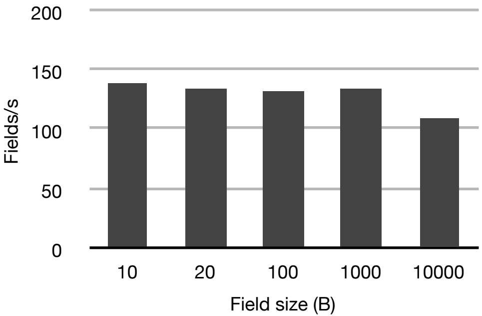
Macbook Pro

- 2.4 GHz Intel Core 2 Duo, 2GB RAM, Gigabit Ethernet
- OS X 10.5.2, Darwin kernel 9.2.2, Mozilla Firefox 2.0.0.13

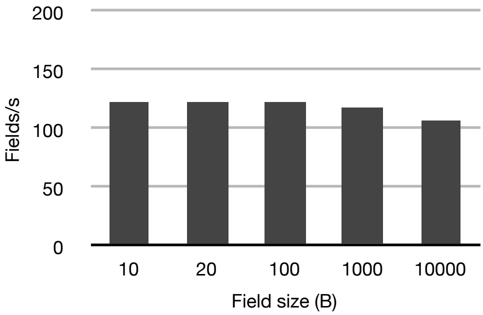
Block encryption on the client



Re-encryption rate at an XML gateway



Decryption rate at an XML proxy



Summary

- SOA logical architecture is protected
- Field contents exposed only at the endpoints

Questions?

References

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