Building web applications on top of encrypted data using Mylar

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Problem

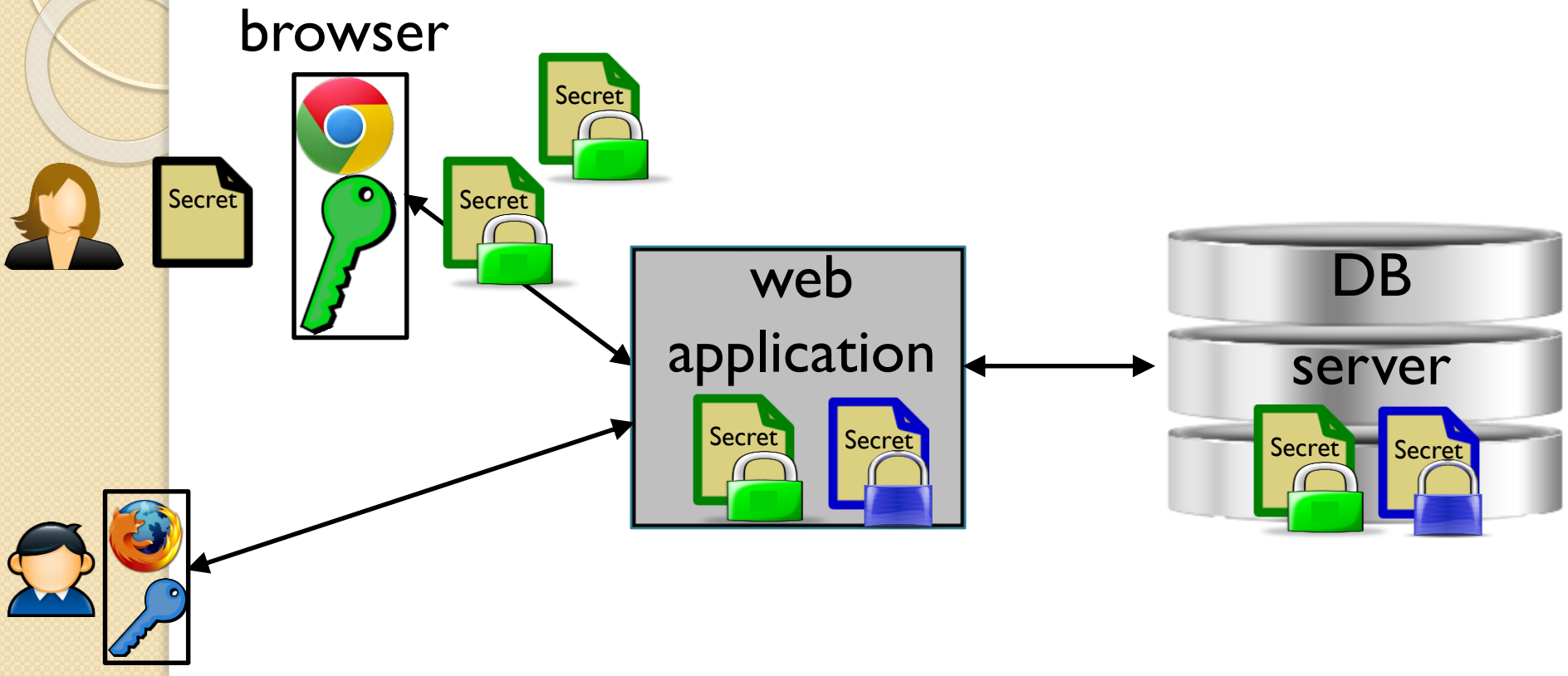
- How can I build a web application that securely stores my data without losing functionality or efficiency?
- Is there something out there that can keep these three principles in mind?

MYLAR

What is Mylar?

- Mylar is used to protect confidential data from adversaries
- Assumes attackers have *full access* to servers
- Mylar encrypts/decrypts in the user's browser (client)
- Since it is built on Meteor, its static html code and data are separate

Mylar: browser-side encryption



Decrypted data exists only in users' browsers

Why use Mylar?

- Mylar allows for different keys to be used, which enables multiple parties access to encrypted data i.e. Chat service

- Mylar allows for computation over encrypted data with multiple keys i.e. Encrypted keyword search

Simple Overview of Mylar

- Verifies the application code running on the client
- Uses Identity Provider Service (IDP) to ensure identity of user
- The client side code then is able to encrypt/decrypt relevant data

Simple Overview

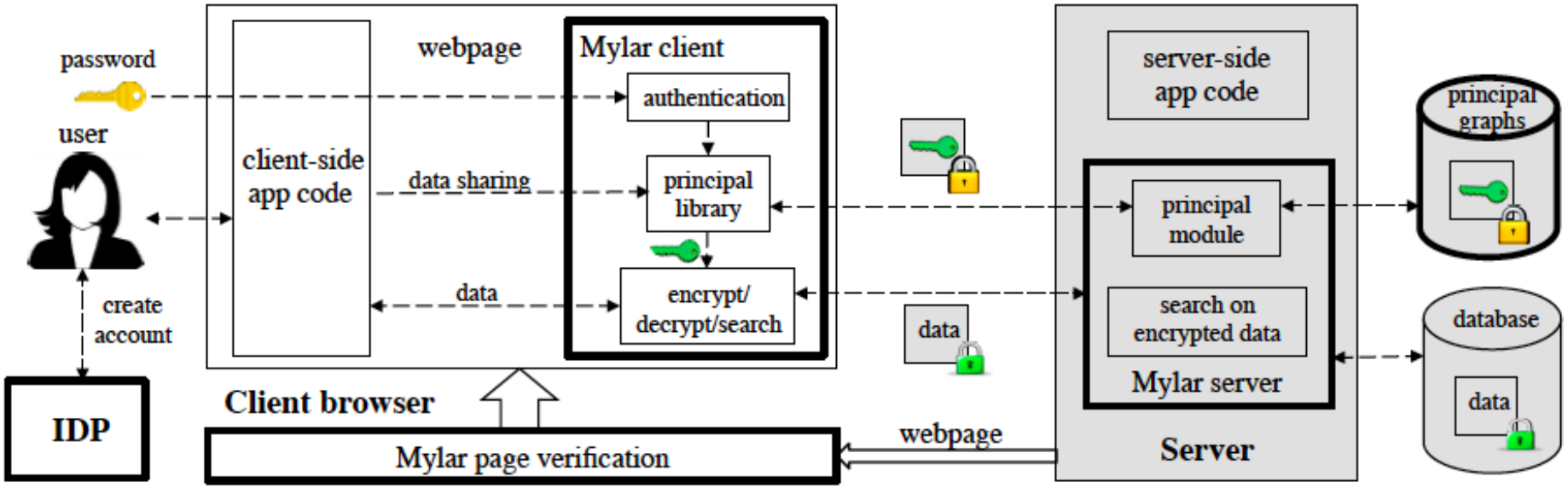


Figure 1: System overview. Shaded components have access only to encrypted data. Thick borders indicate components introduced by Mylar.

Client side Verification

```
procedure PROCESSRESPONSE(url, cert, response)
                                    ▷ url is the requested URL
                                ▷ cert is server's X.509 certificate
    if cert contains attribute mylar_pubkey then
        pk ← cert.mylar_pubkey
        sig ← response.header["Mylar-Signature"]
        if not VERIFYSIG(pk, response, sig) then
            return ABORT
    if url contains parameter "mylar_hash=h" then
        if hash(response) ≠ h then return ABORT
    return PASS
```

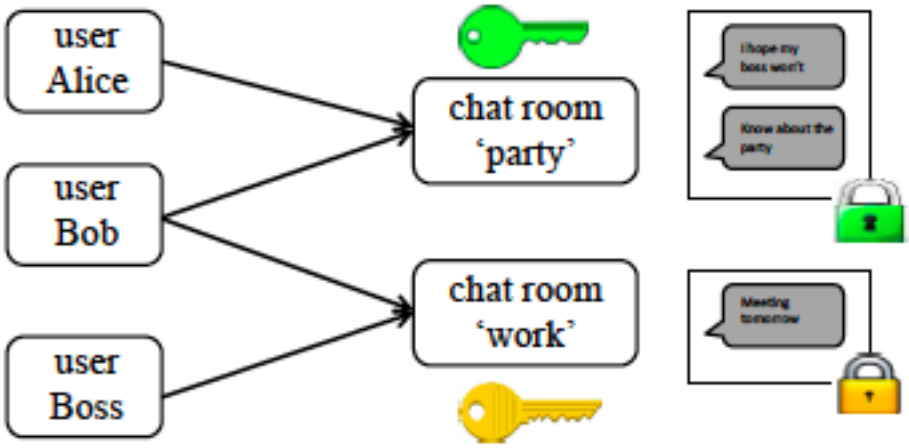
Figure 5: Pseudo-code for Mylar's code verification extension.

Sharing Data

- Access graph- uses key chains to distribute private keys of shared principals to users (principal is a public/private key pair) for application level access control entity

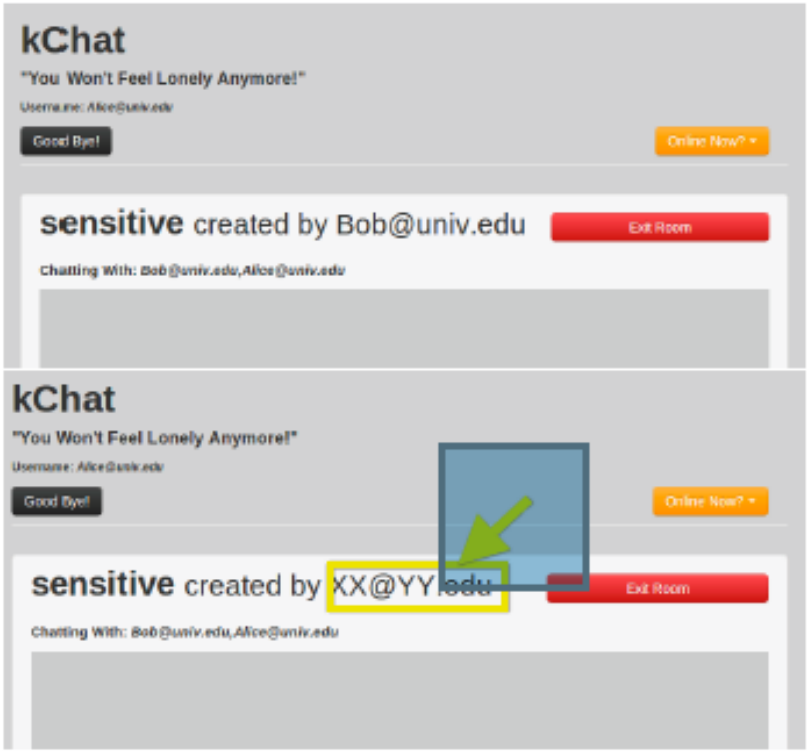
- Certification graph- uses certificate chains to attest the mapping between principal name and public key

Access graph example



- Key Chaining- Like CryptDB, Mylar stores *wrapped keys* on the server

Certificate graph example



- Adds another field like user name to ensure that the user is giving the key to the correct principal

Computing over Encrypted Data

- Must search through every word of the document if multiple
- There is a index version, that removes randomness without comprising security
  - needed to hide whether two words encrypted under the same key are equal

Multi Key Searching Algorithm

Client-side operations:

procedure KEYGEN() ▷ Generate a fresh key
  $key \leftarrow$ random value from $\mathbb{Z}_p$
  return *key*

procedure ENC(*key*, *word*)
  $r \leftarrow$ random value from $\mathbb{G}_T$
  $c \leftarrow \langle r, H_2(r, e(H(word), g)^{key}) \rangle$
  return *c*

procedure TOKEN(*key*, *word*)
  ▷ Generate search token for matching *word*
  $tk \leftarrow H(word)^{key}$ in $\mathbb{G}_1$
  return *tk*

procedure DELTA(key_1, key_2)
  ▷ Allow adjusting search token from key_1 to key_2
  $\Delta_{key_1 \to key_2} \leftarrow g^{key_2/key_1}$ in $\mathbb{G}_2$
  return $\Delta_{key_1 \to key_2}$

Server-side operations:

procedure ADJUST(tk, $\Delta_{k_1 \to k_2}$)
  ▷ Adjust search token *tk* from k_1 to k_2
  $atk \leftarrow e(tk, \Delta_{k_1 \to k_2})$ in $\mathbb{G}_T$
  return *atk*

procedure MATCH(atk, $c = \langle r, h \rangle$)
  ▷ Return whether *c* and *atk* refer to same word
  $h' \leftarrow H_2(r, atk)$
  return $h' \stackrel{?}{=} h$