Design and development of a distributed, secure and resilient vault management system

Mathonet G.

University of Liège, Belgium

June 2017

Introduction (1)

This thesis aims at solving two practical issues:

- Ease the storage of personal private data
- Ease the sharing and update of such data

When reviewing existing software, it either:

- Makes commercial use of the acquired data without consent
- Does not allow for sharing

Introduction (2)

Obviously, we want to provide some strong guarantees to the end users:

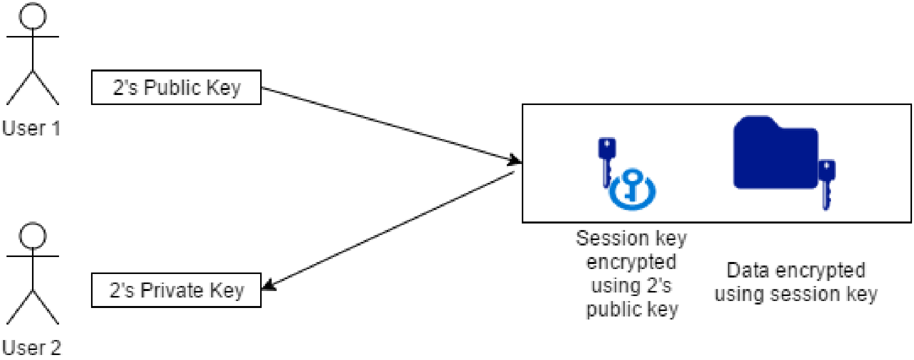
- An end to end privacy between sender and receiver
- A decentralized system for availability and resilience
- Create a simple, extensible and if possible open-source stack which allows for interconnection

Introduction (3)

Functionally, we want to provide the following services:

- Allow anyone to store *data* pieces which the server cannot access
- Share those *data* pieces to other users, which is called receiving a *vault*
- Provide an API, and a client side API for obtaining SSO and *vaults* on the fly

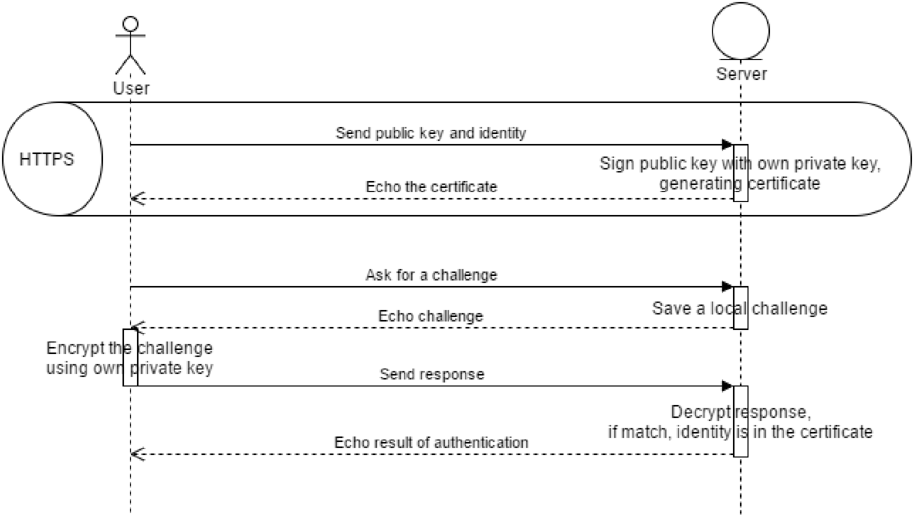
A secure mail exchange model (1)



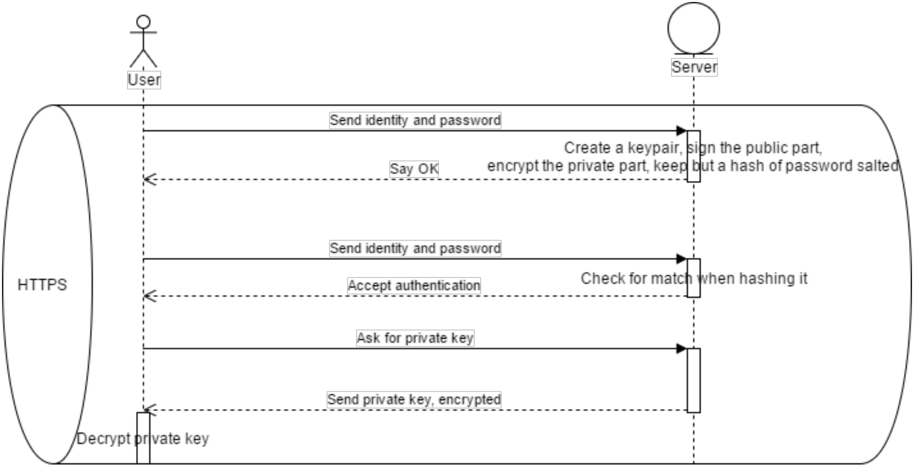
A secure mail exchange model (2)

- Based on this, we want to allow updates
- We can encrypt the session key one more time with 1's public key, we call this creating *bound vaults*
- If we want the update not to be propagated to 2, we have to duplicate the whole data, creating *unbound vaults*

Key setup (1)


User
Server
HTTPS
Send public key and identity
Sign public key with own private key,
generating certificate
Echo the certificate
Ask for a challenge
Save a local challenge
Echo challenge
Encrypt the challenge
using own private key
Send response
Decrypt response,
if match, identity is in the certificate
Echo result of authentication

Key setup (2)


User
Server
HTTPS
Send identity and password
Create a keypair, sign the public part,
encrypt the private part, keep but a hash of password salted
Say OK
Send identity and password
Check for match when hashing it
Accept authentication
Ask for private key
Send private key, encrypted
Decrypt private key

Key setup (3)

- The first model is obviously better, security-wise
- However, it is harder to use for humans so both models will co-exist
- We still need a PKI infrastructure for users who delete their account, etc.

- For the ciphers themselves, their choice is mainly driven by the small-end devices capabilities
- We might even allow for temporary key sharing for faster encryption or decryption

Other security concerns

- We do not support perfect forward secrecy as getting the private key of a user would allow for reading all of his data
- Protection against DDOS, mainly by token bucket
- Tarpitting
- Client side puzzle

API usage

- We expect two types of users: humans and (large) companies
- When using client side certificate, the SSL connection itself is trusted
- Otherwise, a token or the credentials must be echoed with each request

- The API itself cannot be behind a CDN
- However it can delegate the SSL handshake to a reverse proxy
- We will use the most used nowadays JSON format

Database (1)

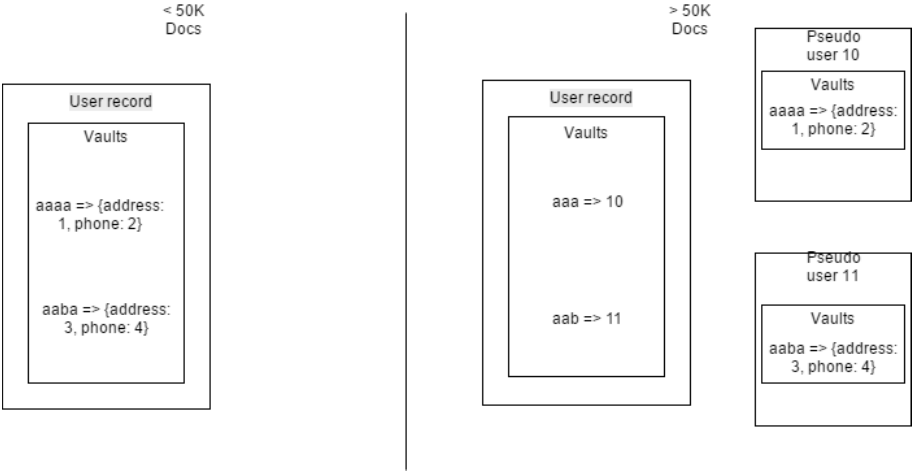
- We do not require SQL: everything is encrypted!
- We can only query the database using an ID

- HBase is probably the fastest at storing key-value mappings
- MongoDB stores documents in JSON formats already
- MongoDB replication better suits our model (replication at TCP layer)

Database (2)

- To allow for each user to maintain his documents and update them, we will create virtual filesystem
- But the document maximum size (16MB) will have us split users over several documents
- We are using *bigrams* or *trigrams* which provide a recursive level
- Trigrams are slower, but should allow for never needing two levels of recursion

Database (3)

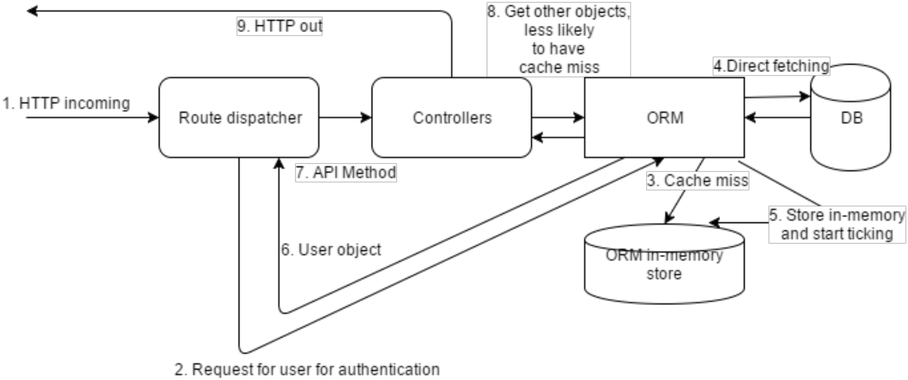


< 50K Docs
User record
Vaults
aaaa => {address: 1, phone: 2}
aaba => {address: 3, phone: 4}
> 50K Docs
User record
Vaults
aaa => 10
aab => 11
Pseudo user 10
Vaults
aaaa => {address: 1, phone: 2}
Pseudo user 11
Vaults
aaba => {address: 3, phone: 4}

Database (4)

- To allow for each user to maintain his documents and update them, we will create virtual filesystem
- But the document maximum size (16MB) will have us split users over several documents
- We are using *bigrams* or *trigrams* which provide a recursive level
- Trigrams are slower, but should allow for never needing two levels of recursion

Database (5)



9. HTTP out
8. Get other objects, less likely to have cache miss
4.Direct fetching
1. HTTP incoming
Route dispatcher
Controllers
ORM
DB
7. API Method
3. Cache miss
5. Store in-memory and start ticking
6. User object
ORM in-memory store
2. Request for user for authentication

Replication algorithms (1)

- The server obviously needs to be replicated, and so must be the database
- It is already provided between some local nodes by the database engine itself (MongoDB shards)
- We want to study the speed of convergence of the knowledge of a new use inside the system

Replication algorithms (2)

- Resource Location Indexes (RLI) is a peer-to-peer model
- Servers propagate the rows they locally have with partial or full updates at different intervals
- Servers query peers for existence, and the fetching is done recursively

- Captain Cook (CC) is a tree hierarchy
- Servers propagate the rows they locally have to their local root, which themselves propagate what they know
- Servers query roots for existence, and the fetching is done by themselves once existence resolved

Performance

- Messages are sent authenticated as a master user, and serialized using Google Protobuf
- When investigating the time required to bootstrap a new user, the variables are the length of messages exchanged, the number of active users, and the interval between messages
- As the processing time of the messages is shorter than the interval between messages, it makes sense to study the results in terms of number of cycles required for the process

Frontend session (1)

- The servers are RESTFUL, but the clients side will emulate a stateful server, for convenience
- By storing the user's keys, and a token if using a password

Frontend session (2)

- The client must also be made secure, as long as the device is not compromised
- Against CSRF by using local storage rather than cookies
- Against XSS by using libraries known for their good protection against it (Angular 2)

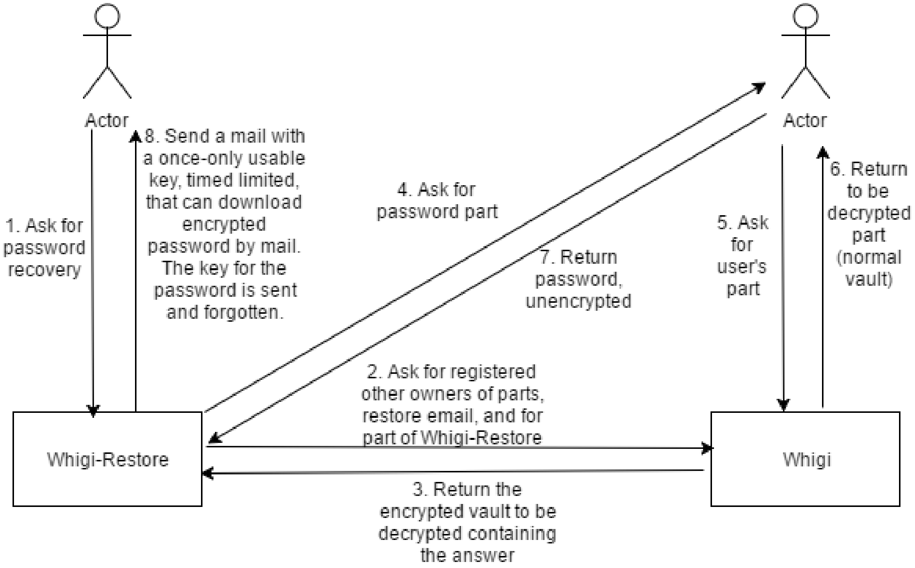
Standardized inputs

- The goal of the program is to help people share data between each other
- Defining a known format for this data is a valuable feature
- The whole definition of the fields, their contents and validation methods are defined within JSON and evaluated dynamically to be easily modified
- The client side supports transition schema's to re-encode data to a new definition if it were to change.

Latest features (1)

- Symbolic links for sharing the same data at several locations towards the same user
- Detachable *vaults* which can be claimed by the granted user
- Merging of accounts, which imply to make the decryption of session keys verifiable to know which private key to use for a user which has several
- Password recovery

Latest features (2)

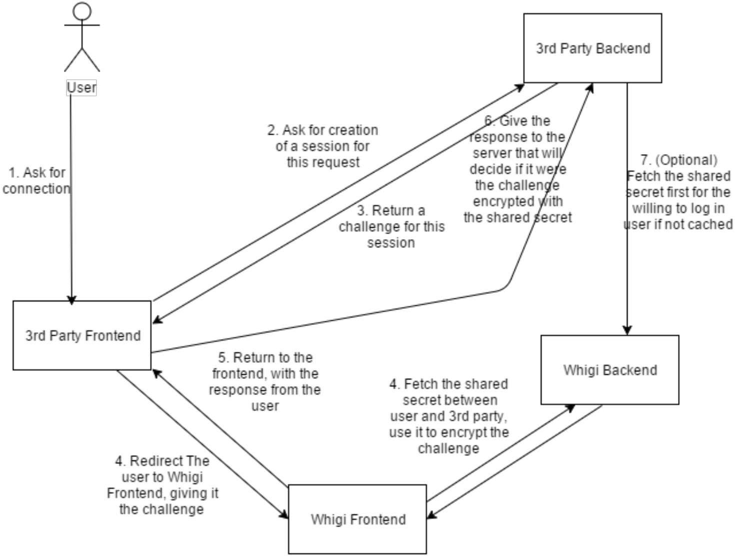


Latest features (3)

Our project, WiSSL, can be used using the API, and there exists an API for:

- Use it as identity provider
- Request for authorization (OAuth)
- Request for a grant on the fly

Latest features (4)



Conclusion

- We have created a platform in which, by its design, users can trust
- Remaining work: test replication at a larger scale and study transition schema's for ciphers
- We have projects which use the platform: WiSSL-Contacts, WiSSL-Advert or WiSSL-Voting.

LIÈGE université