Design and Implementation of a Secure Web-Based File Exchange Server
Specification Design Document

CIISE Security Investigation Initiative

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Chapter 1

Introduction

Building Trust is the basis of all communication, especially electronic one, as the identity of the other entity remains concealed. To address problems of trust, authentication and security over the network, electronic communications and transactions need a framework that provides security policies, encryption mechanisms and procedures to generate manage and store keys and certificates.

The Public Key Infrastructure (PKI) is a security architecture that has been introduced to provide an increased level of confidence for exchanging information over increasingly insecure networks, such as the Internet. A PKI infrastructure is expected to offer its users a secure and trustworthy electronic transaction.

1.1 Purpose

The intent of implementation and deployment of PKI facilities is to meet its basic purpose of providing Trust. Presently, PKI needs to perform the following security functions:

- *Mutual authentication of entities taking part in the communication:* Only authenticated principals can access files to which they have privileges.

- *Ensure data integrity:* By issuing digital certificates which guarantee the integrity of the public key. Only the public key for a certificate that has been authenticated by a certifying authority should work with the private key possessed by an entity. This eliminates impersonation and key modification.

- *Enforce security:* Communications are more secure by using SSL to transmit information.
1.2 Scope

PKI is implemented to secure sensitive resources of the organization and avoid security breaches. The PKI environment allows trustworthy communication between the different principals. These principals must be authenticated and the access to the resources (files) should be secured and regulated. Any principal wants to access to the database needs to perform the following steps:

- **Mutual authentication:** The Web Server via which the database is contacted authenticates the principal using its digital certificate and username to ensure that it is who it claims to be. The principal authenticates also the server using its certificate information.

- **Principal validation:** To validate the principal, the server looks up information from an LDAP server which contains the hierarchy of all principals along with certificates and credentials. The LDAP service is compliant with the X.500 database structure.

- **Enforcing security:** The security is enforced by using SSL to communicate between the Web Server and the LDAP server, the Web Server and the database and between the principal and Web Server.

- **Principal authentication:** Upon successful authentication, the Web Server will allow the principal to perform actions on the database according to a pre specified Access Control List.

- **Kinds of users:** We distinguish between a normal and an administrator. While a normal user can upload, download, delete and view files; the administrator has the ability to: upload, download, delete and view files; add, delete and modify users; generate user’s certificate, with all required information; generate ACL to users; manage groups, perform maintenance.

Finally, this infrastructure allows additional features such as the ability to assign users to groups in order to provide users with the access to files prepared by other group members.

1.3 Definitions and Acronyms

- **PKI:** Public Key Infrastructure

- **OpenLDAP:** is a free, open source implementation of the Lightweight Directory Access Protocol (LDAP).

- **OpenSSL:** an open source SSL library and certificate authority

- **Apache Tomcat:** A Java based Web Application container that was created to run Servlets and JavaServer Pages (JSP) in Web applications
• PostgreSQL: An open source object-relational database server
• SSL: Secure Socket Layer
• JSP: Java Server Pages
• JCE: Java Cryptography Extension
• API: Application Programming Interface
• JDBC: Java Database Connectivity
• JNDI: Java Naming and Directory Interface
• LDAP: Lightweight Directory Access Protocol
• X.509: A standard for defining a Digital Certificate used by SSL
• SRS: Specification request Document
• SDD: Specification Design document
• DER: Distinguished Encoding Rules
• Mutual Authentication: The process of two principals proving their identities to each other
• SFS: Secure File Exchange Server, this product
• COTS: Commercial Off The Shelf, common commercially or freely available software
Chapter 2

System Architecture

This chapter is intended to provide an overview of the whole system as proposed in the previous requirements and specification document. It describes the product’s perspective, interfaces and design constraints as we have assumed. We will first describe the architectural guidelines for this product, followed by software interface design design, and hardware environment.

2.1 Architectural Philosophy

The SFS technology hereby implemented is running on architecture that provides a high level of secrecy and integrity for exchanging information. The system is externally visible only through a web application for normal users, and is also entirely visible and accessible for administrators in the scope of normal operations. In addition, the system assumes an internal certificate authority which is explicitly trusted by all principals using SFS.

For the proposed architecture, it requires mutual authentication between the user and the web server, an LDAP validation of the user by using digital certificates, the use of the SSL protocol to enforce the security over the communication between modules and the preservation of files in a database.

This architecture must respect the following properties:

- **Security**: The confidentiality, integrity and availability of information. This is to be implemented by supporting the data encryption and certificates mechanisms for secured communication, as well as specifying an access control mechanism for the files stored

- **Trustworthiness**: The use of electronic certificates internally generated, and of specific use for the application, allow an high trust to be given to the user.

- **Scalability**: SFS can be expanded easily to cope with large loads. Methods such as load balancing and replication can be easily integrated.
• **Openness:** The proposed architecture can be implemented and deployed using Java Technologies and open source tools that are well-used and rely on standards. The SFS itself is an open source product developed to achieve security objectives.

• **Component-Based Software Engineering:** The SFS framework may be treated as components (modules). We have already mentioned the relevant technologies that can better fit for each of these modules.

• **Usability:** The SFS service must be designed for high usability. All the required information for a single operation should be grouped in a single screen, with a minimum number of screens needed for all the application.

This architecture aims at maximizing software reuse by the integration of COTS applications, portability and interoperability by the use of standards, security and scalability by the user of a single access point.

### 2.2 Components

The Figure 2.1 describes the overall architecture of the SFS system. We see four major interacting components: the user interface, the web server, the database and the LDAP server. Two components are not displayed on this figure, which are the certificate authority and the logging engine.

#### 2.2.1 User Interface

The user interface constitutes of HTML web pages that the user uses through a web browser. Those web pages are generated by the web server and interact exclusively with the SFS web server.

#### 2.2.2 Web Server

The web server is the single access point of the system. It handles authentication responsibilities, database access and user interaction. This is to be handled by the Apache Tomcat 5.0 server and custom J2SE 5.0 code.

#### 2.2.3 Database Server

This database server contains all the information about the files and their access control rights. It contains also a subset of the user information. This is to be handled by PostgreSQL.
Figure 2.1: Main system architecture
2.2.4 LDAP Server

This specialized server holds the user credentials (notably user name and password). It could be extended to include user certificates. This module will be realized by OpenLDAP.

2.2.5 Certificate Authority

This responsibility is manually managed by administrators. Using software tools, they are able to generate the user and server certificates. In our case, we use OpenSSL to perform those functions.

2.2.6 Logging Engine

This component is responsible for collecting the audit trails and debug information from other components and store it locally. We wanted to use log4j, but we finally opted for the logging mechanisms available in the tools we are using, notably by using Tomcat’s logging.

2.3 Interactions

We will now describe the inter-module interactions by the use of a system scenario.

The user, with a web browser, connects to the web server using SSL. The web server, being configured as to require client authentication, both parties exchange their certificates and validate their peer’s identity. The web server then prompts the user for a user name and password, thereby enforcing 2-factor authentication.

Upon receiving this information, the web server queries the LDAP directory based on the user name and retrieves the user’s password hash and certificate (if any is defined). The web server then proceeds to hash the plaintext password (using SHA1) received from the user and compare with the one from the LDAP server. If that information (as well as the certificates, if any) matches, the user is logged in the system.

The web server will then query the database server for the access rights of the user (administrator or normal user) and the list of files the user has access to. Based on this information, it will display the appropriate user interface functions and the file list.

On user requests to upload, delete or download files, the web server will request the database server to perform the needed transactions.
2.4 Software Interface Design

This section describes the software interfaces (commonly referred to as APIs) to be used to communicate between each component.

2.4.1 Web Server

The web server is reached by the client through an HTTPS connection to the single point of access for the web application, the login screen.

2.4.2 Database Server

The database server is reached using the JDBC API with the official PostgreSQL JDBC driver.

2.4.3 LDAP Server

The LDAP server is reached using the default Sun LDAP JNDI driver. The LDAP protocol is used for the queries and is encapsulated by JNDI.

2.4.4 Certificate Authority

This component is not integrated with others and, as such, does not have a software interface to document.

2.4.5 Logging Engine

On the Web server, this component is called automatically by the use of the default output and default error streams, which will write the information to a log instead of a console.

2.5 Hardware Environment

The SFS system is expected to work in a networked environment, possibly a LAN, but not necessarily. We assume that the principals have a network connection allowing to communicate with each other. Only typical low-end workstation hardware (such as a Pentium III system with 256+ MB of RAM, 2GB hard drive with a 10BaseT Ethernet connection) is required to operate all the components of the system, which may be distributed or centralized as needed. Ordinary P III with 256+ MB of Ram and 2GB HDD are the minimum requirements needed to deploy the system.
2.6 Code View

We decided to structure our software in a few main packages, as illustrated in Figure 2.2.

Those packages hold as follows:

1. securefileserver: root of our custom code
2. base64: Library for encoding and decoding Base64-encoded data
3. apps: Various applications
4. webapps: The web application code
5. conn: Connection abstraction code, such as SSL connections, LDAP connections and database connections
6. cert: Certificate authority code
7. util: Utility classes, such as the configuration file loader

Since we had to deal with a large set of non-code artifacts, we structured our repository as illustrated in Figure 2.3.

Those directories hold as follows:
1. root directory: contains the Ant makefile and all the other subdirectories

2. *cert*: certificates generated manually using OpenSSL

3. *conf*: configuration files

4. *CVS*: repository management code, handled automatically by CVS

5. *images*: documentation-related images

6. *lib*: libraries in JAR format

7. *sql*: database initialization script

8. *src*: Java source code

9. *tex*: documentation in \LaTeX\2e format

10. *txt*: various notes in text format

11. *design*: Rational Rose model of the system
Chapter 3

Detailed System Design

In this section of the specification document we elaborate the detailed description of the main modules and subprograms of the SFS system. We provide the important class diagrams for the different packages of the design phase as mentioned above.

Please consult Figure 3.1 for a high-level view of the class diagram of our application. Please note that the servlets login and User also have a fair amount of business logic integrated in them. This situation is due to the evolutionary nature of the development method used in this project which, combined with tight deadlines, did not allow for a proper refactoring of the classes.

We can also take note the presence of test classes in our class diagram, which are JUnit test cases that allowed to perform some unit testing. The smallness of the class diagram is mostly explained by the fact that most of the functionality was implemented in COTS programs that needed only some configuration.

3.1 Class Diagrams

The following diagrams show some of the important user interfaces of the SFS software system.

3.2 User Interface

The following diagrams show some of the important user interfaces of the SFS software system. On figure 3.6 we see the interface allowing clients to log in.

Once the client mutual authentication is achieved and user allowed to use the system he will get the following screen (3.7).
Figure 3.1: SFS main class diagram
Figure 3.2: Conn Package Diagram

Figure 3.3: Application Package Diagram
Figure 3.4: The **util** Package Diagram

Figure 3.5: The **cert** Package Diagram
Figure 3.6: User interface Log on

Figure 3.7: User operations displayed
When the client chooses the file to download, he will be prompted to open the file or give the path he wants to save the file in.

![User operations displayed](image)

**Figure 3.8:** User operations displayed

Figure 3.9 shows the upload operation, so the user will be prompted to select the file he wants to upload.

Figure 3.10 shows the administrator capabilities: adding users, removing users, adding groups, setting rights, etc.

The snapshot of the SFS provides the login interface via which the services of the SFS system can not be utilized unless the user is already logged in.

### 3.3 Class Diagrams

Figure 3.1 includes most of the classes already present. We will describe a few classes in detail here. All the details regarding the classes are available in the Javadoc.

#### 3.3.1 LDAPConnection

This class provides an abstraction of an LDAP JNDI context, as well as pre-made queries for obtaining user credentials, deleting an user and adding an user in the database.
It depends on SSLConnectionFactory for ensuring that our SSL Connections are set with the proper keys. It also depends on UserCredentials, since this is the data type it returns on a query.

### 3.3.2 UserCredentials

This class encapsulates a user name, a password, and a certificate. It integrates the hashing of plaintext passwords, as well as a matching comparison between two sets of credentials. It depends on TestSSHA for generating and validating the salted SHA1 hash.

### 3.3.3 OptionsFileLoaderSingleton

This class is a singleton, meaning that only up to one instance can exist at any time. It loads and parses a configuration file. It also includes many default keys of the configuration file as constant strings.

### 3.3.4 DatabaseConnection

This class provides an abstraction for an SSL-enabled database connection. Contrary to LDAPConnection, it does not provide high-level methods in it, leaving to the calling code the responsibility
Manage Users and Groups

User Name
Password
Group
Organization
City
State
Country

Add User
Modify User

Manage Groups

Group ID:
Group Name:

Add Group

A == Administrator
U == User
F == Foo
B == Bar
A+ == A+ Students

Ali
Djamal
Serguei
Marc-Andre
test
Moo
Boo

Load User
Delete User

Figure 3.10: User operations displayed
to formulate proper SQL queries.

### 3.4 Data Storage Format

In this section, we provide a description for the database handling the security aspect of the system. It consists of the following entity relation model.

#### 3.4.1 Entity Relationship Diagram

The Groupe entity contains the list of groups a user may belong to. The User entity contains the list of users having right to use the system. The File entity contains information about different files a user can upload, download, delete and view. A user may be an Administrator or normal user. The other relationships (group_user, group_files) are defined between entities Groupe and User and Groupe and File to host different information related to both of them respectively. Hereafter, we provide in Figure 3.11 the Entity Relationship Model of the Security Database.

![Entity Relationship Diagram](image)

Figure 3.11: Entity Relationship Diagram

### 3.5 Options File

A `.config` file is expected in the execution root in order to read the configuration options.
Lines can be comments (#), blank, or containing a key=value pair.

The expected configuration options are:

- **ca_server**: host name of the CA server. This option is reserved for future use.
- **db_server**: host name of the database server.
- **keystore_filepath**: relative or absolute path for the web server’s keys
- **keystore_password**: password for the previously specified keystore
- **ca_certificate_filepath**: path to the CA certificate’s keystore
- **ca_certificate_password**: password for the CA certificate
- **ldap_password**: administrator password for the LDAP server
- **ldap_principal**: administrator user name for the LDAP server
- **ldap_server**: host name of the LDAP server

3.6 Directory Configuration

The LDAP directory is to be structured in an arbitrarily manner, as the DN is not used in queries. However, the UID parameter is used for querying based on the user name. The user information is of type inetOrgPerson, with the fields uid, userPassword and userCertificate for, respectively, the user name, its password (hashed with salted SHA) and its certificate.

3.7 External System Interfaces

The only externally reachable interface to the SFS system is the login page of the web application. This page should be located at /sfs/login.jsp. It is also symlinked to it via index.jsp.

3.7.1 External Systems and Databases

The SFS system is not designed for interacting with any other systems than those described as part of our architecture.
3.8 User Scenarios

3.8.1 Typical Scenario

1. User connects to remote server using a web browser on a secure connection
2. User is prompted with a logon screen, and provides a username and password
3. After validation, the user is logged as a normal user and is shown a list of files to which he or she has access to, as well as their rights
4. The user clicks to download a file and, if the system validates its rights, the download begins

3.8.2 Variant scenario

4. The user chooses to upload a file and the upload begins. The file will be modifyable by the user and according to the default new file ACL.

3.8.3 Variant scenario

4. The user chooses to delete a file to which it has delete rights and the systems perform the deletion

3.9 Administrator Scenarios

3.9.1 Typical Scenario

1. User connects to remote server using a web browser on a secure connection
2. User is prompted with a logon screen, and provides a username and password
3. After validation, the user is logged as an administrator and is shown a menu of options, and chooses to view a list of files in the system
4. The user clicks on the user edit button and changes the access control list of the object.
3.9.2 Variant Scenario

1. User connects to the certificate administration service and generate a certificate for a given subject through a secure connection

2. User connects to remote server on a secure connection

3. User is prompted with a logon screen, and provides username and password

4. After validation, the user is logged as an administrator and is shown the menu

5. The user clicks on the certificate edit button and is shown a screen of certificate maintenance

6. The user uploads the certificate and the system binds it with the certificate’s defined principal (or creates the user if none exists already)

3.9.3 Variant Scenario

1. User connects to remote server using a web browser on a secure connection

2. User is prompted with a logon screen, and provides a username and password

3. After validation, the user is logged as an administrator and is shown a menu of options, and chooses to edit the certificates

4. The user chooses to remove the certificate from a given principal

5. The user connects to the certificate administration service and issues a certificate revocation.
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