Functional Specification

PROJECT NAME

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| Student Name: | Liucija Paulina Adomaviciute |
| Student ID: | 21790411 |
| Student Name: | Eryk Zygmunt Styczynski |
| Student ID: | 21753851 |
| Date of Submission: | /11/2024 |

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# Introduction

## Overview

The main goal of this application is secure messaging. With Double Ratchet protocol combined with Extended Triple Diffie-Hellman key agreement protocol, this application offers secure, peer-to-peer messaging platform with clean and easy-to-use graphical user interface that does not rely on the security of third-parties, such as servers or the service provider. The goal is to not obscure the fact that the communication is happening between two users, but to secure the contents of the conversation.

## Glossary

# General Description

## Product / System Functions

1. Message encryption and identity verification using X3DH with The Double Ratchet Algorithm

2. File compression using Huffman Coding Algorithm

## User Characteristics and Objectives

### User Characteristics

This application is aimed at security and privacy-conscious users who have at least minimal computer skills. The user’s goal is to have secure and private conversations with other users without relying on servers or service provider. The typical customer will use other privacy-enhancing features such as secure browsing and limiting data sharing with third-parties, and carefully select applications they use based on how much data they collect, share and who has access to that data. The main challenge for the user is to find reliable, trustworthy and secure open-source applications to use for daily activities such as conversations and file sharing. To achieve more privacy and security these users are willing to sacrifice some functionality, speed and convenience.

### User Objectives

## Operational Scenarios

1. Log in

2. Identity verification between two actors

3. Sending message between two actors

4. Sending a file between two actors

5. Identity verification between multiple actors

6. Sending message between multiple actors

7. Sending a file between multiple actors

## Constraints

# Functional Requirements

## The X3DH Key Agreement Protocol

* **Description**

X3DH (Extended Triple Diffie-Hellman) is an asymmetric key protocol that establishes a shared secret key between two parties who mutually authenticate each other based on public keys. Due to the server-less nature of the application, instead of the protocol involving three parties, as defined in the whitepaper, it is modified to involve only two – Alice and Bob.

X3DH has three phases:

1. Bob gives his “prekey bundle” (identity key, signed prekey, prekey signature, one-time prekey) to Alice.
2. Alice uses Bob’s “prekey bundle” to send an initial message to Bob.
3. Bob receives and processes Alice’s initial message.

**Publishing Keys**

Identity needs to be generated only once. New signed prekeys and prekey signatures will need to be generated at some interval (once a week or once a month). The new values will replace the previous ones.

Bob creates a set of elliptic curve public keys.

After sharing a new signed prekey, the private key corresponding to the previous signed prekey will be deleted. One-time prekey private keys will be deleted as Bob exports sets containing them.

**Sending the Initial Message**

To perform an X3DH key agreement with Bob, Alice uses the “prekey bundle” to send Bob the initial message.

**Receiving the Initial Message**

Upon receiving Alice’s initial message, Bob retrieves Alice’s identity key and ephemeral key from the message.

If the initial decryption is successful, the protocol is complete and Bob deletes any one-time prekey private key that was used for forward secrecy. Bob then continues to use SK and keys derived from SK for further communication with Alice.

* **Criticality**

Essential.

* **Technical issues**

**Implementation**

No Java libraries available for the protocol – it will need to be implemented from scratch.

**Authentication**

The parties must compare their identity keys through authenticated channel.

**Key Reuse**  
Post-X3DH protocol must randomize the encryption key before Bob sends encrypted data. Failure to do so may cause key reuse and reduced security.

* **Dependencies with other requirements**

None.

## The Double Ratchet Algorithm

* **Description**

The Double Ratchet algorithm is used by two parties (Alice and Bob) to exchange encrypted messages using a shared secret key. To prevent the decryption of future messages due to the theft of one party’s keys, the symmetric-key ratchet is combined with the Diffie-Hellman ratchet, which updates the chain keys based on the Diffie-Hellman output.

The parties derive new keys with Diffie-Hellman calculation results for every message. Because of this, the later keys cannot be calculated using the earlier ones.  If the key is unknown, the output data is indistinguishable from random. Diffie-Hellman public values are attached to the message.

In Double Ratchet between Alice and Bob, Alice initializes with Bob’s public key and the initial root key (shared secret). As part of the initialization, Alice generates a new ratchet key pair using X3DH and feeds the output to the root KDF to calculate a new root key (RK) and send a chain key (CK). The old RK may be deleted. When Alice sends her first message, she applies a symmetric-key ratchet to her sending chain key. The output is a new message key (AM1).

When Alice receives a message from Bob, it will contain a new ratchet public key. Alice applies a Diffie-Hellman ratchet step to derive new receiving and sending chain keys. Then, a symmetric-key ratchet step is applied to the receiving chain to get the message key (BM1) for the received message.

* **Criticality**

Essential.

* **Technical issues**

No Java libraries available for the algorithm – it will need to be implemented from scratch.

* **Dependencies with other requirements**

The Double Ratchet algorithm depends on the output of X3DH.

## Placeholder

* **Description**
* **Criticality** – Essential
* **Technical issues**
* **Dependencies with other requirements**
* **Others as appropriate**

# System Architecture

# High-Level Design

# Preliminary Schedule

# Appendices

## Sources

Marlinspike, Moxie. “The X3DH Key Agreement Protocol.” Open Whisper Systems, 4 Nov. 2016, https://signal.org/docs/specifications/x3dh/. Accessed 5 Nov. 2024.

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