



UNIVERSITÀ DI PISA

Computer Engineering

Foundations of Cybersecurity

secureCom

Group Project Report

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Chapter 1

Specifications

The project consist on an application for secure communication between 2 clients through an intermediate server.

The server have to:

- authenticate clients on connecting to it (with pre-shared public key)
- authenticate ifself with a certificate
- provide the list of online clients
- relay messages from one client to another, together with chat requests and response
- provide to a client the public key of another client, in order to permit a secure communication between them

A client have to:

- authenticate the server on connecting to it (with the certificate)
- authenticate himself with its public key

A client can:

- print the list of online clients
- authenticate another client via its public key obtained from the server
- request to chat with another client
- answer to a chat request (if not already involved in another chat)
- when in a chat, exchange text messages with another client or close the chat

Chapter 2

Design choices

2.1 Client Server Handshake

In order to authenticate themselves and establish a session key to securely communicate, a client and the server have to exchange handshake messages. We implement this protocol to provide perfect forward secrecy, starting from the pre-shared cryptographic quantities (public keys and certificates):

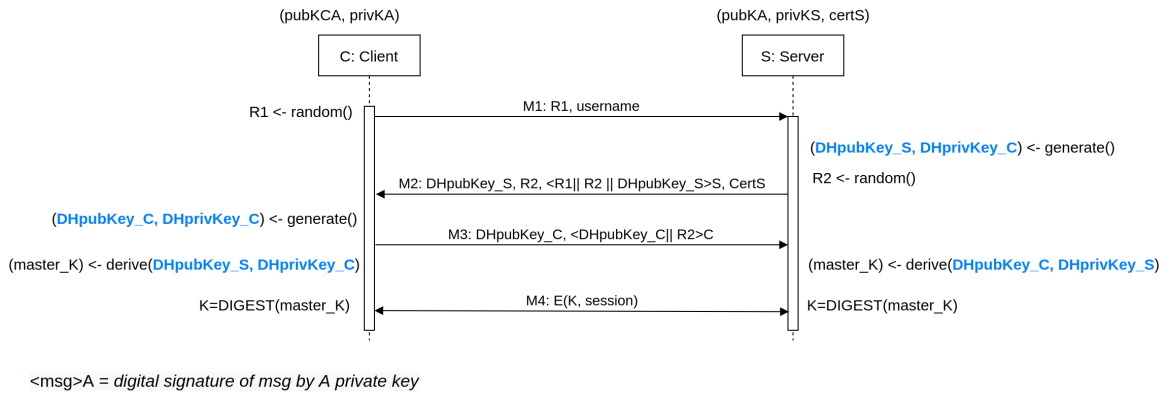


Figure 2.1: Client Server Handshake Protocol Schema

This handshake is a custom implementation of an ephemeral Diffie-Hellman Key Exchange, in which we ensure protection against the man in the middle attack with random nuances (R1 and R2). The client is able to authenticate the server via its certificate, signed by a trusted certification authority (the client is distributed along with CA's self-signed certificate); the server have a built-in list of all client's public keys. DH's private keys are deleted after the handshake and the key is generated by a digest of the shared secret: in this way we provide security against a future disclosure of one of the long term private keys.

2.2 Chat Request

With the client-server handshake we build a secure tunnel between each client and the server. Using this tunnel every client can execute command on the server in a secure way; the most important (and complex) command is a chat request, of which we provide a scheme:

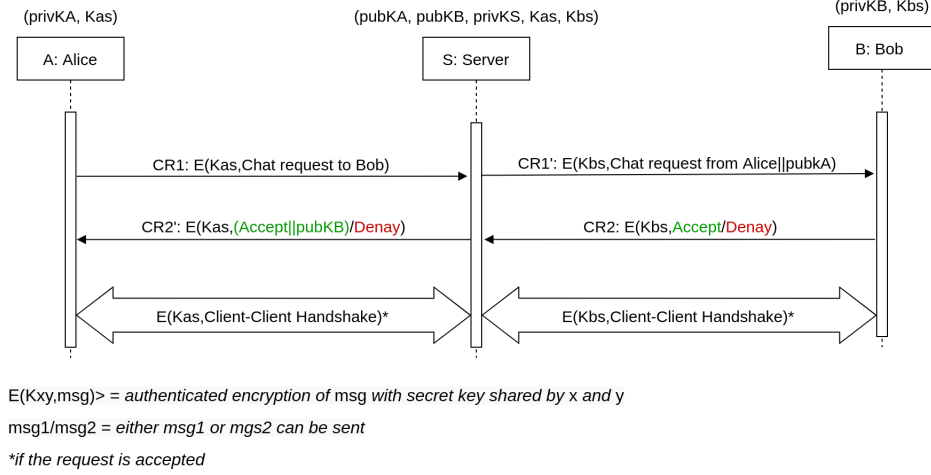


Figure 2.2: Chat Request Protocol Schema

The server is obliged to communicate correct public keys.

2.3 Client to Client handshake

In order to guarantee a secure communication of the clients against the server, we perform an ephemeral Diffie-Hellman Key Exchange before starting the chat. In this case the two parties already know each other public keys, because the server provided them.

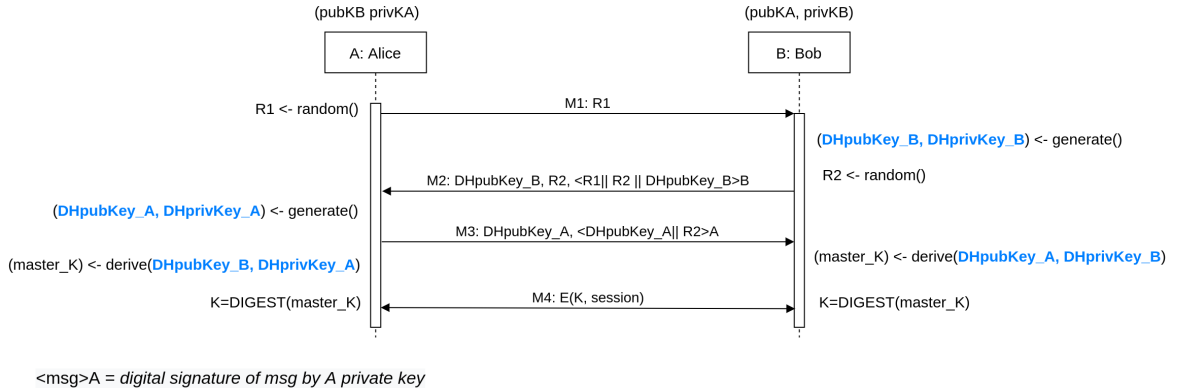


Figure 2.3: Client Client Handshake Protocol Schema

The server is not represented because it only retransmits messages from a client to the other without changing anything; if the server tries to implement a "man in the middle" attack, it will only obtain a denial of service because the protocol is protected by private key signatures. Also in this case, DH keys are discarded after the handshake, and future messages are numbered against reply attacks.

2.4 Algorithms and Protocols

We briefly describe the cypher suite we choose to use in order to guarantee security specifications.

2.4.1 Public Key Authentication

Long Term Keys The Certification Authority (CA) have a **Public Key**, included in a self-signed certificate; the corresponding private key is embedded in the program for certificate generation, SimpleAuthority ¹. CA's certificate and Revocation List (CRL) are exported and distributed with client executable. The server certificate, which is signed by CA, contains the **Public Key** of the server; it is stored server side, and provided to the client during the handshake. Clients **Public Keys** are also stored in the server, while only the client hold its **Private Key**. All keys are **RSA Key Pairs with 2048-bits Public Keys** and are stored in **.pem** format, as certificates and CRLs are.

Short Term Keys Handshakes protocols are performed with the Ephemeral Diffie-Hellman Key Exchange. We choose to use the Elliptic Curve implementation because is very efficient (in term of performance vs security strenght); we use **NID_X9_62_prime256v1** standard parameters that ensure 128-bits security strenght with a 256-bits curve. We use the **SHA-256** digest of the **shared secret** as the session key. To ensure freshness in the challenge-response scheme we use **16 bytes nonces**.

2.4.2 Authenticated Encryption

From the handshake we obtain a 256-bits symmetric key which is used in **AES-256 GCM** authenticated encryption protocol. We use a **16 bytes** tag for authentication of ciphertext and clear fields in the header. GCM scheme ensure a ciphertext size equal to the plaintext size; this makes programming easier, maintaining an optimal resistance against all known attacks. Messages exchanged in sessions are numbered, starting from 1, to a maximum of $2^{32} - 1$ (**0xFFFFFFFF**), which is the maximum integer representable on 32 bits; this will make possible to identify a message reply, done by an attacker. The session is automatically closed when a message with number **0xFFFFFFFF** is received. Clients maintain two counter for the communication with the server: one for the next message to send and another for the next message to receive; the same thing is done for the communication with another client (to prevent the server to reply a message); also the server has to implement this behaviour in sessions with clients.

¹<https://simpleauthority.com>

Chapter 3

Implemetation

3.1 Client

3.1.1 How To Handle The Chat Request

Let's start from the simple case in which a client wants to chat with another client and makes a request to the server:

- The standard channel is used to send either the request for chat and for the server's answers.
- If the target client accepts then the main process receive the confirmation from the server, then the main process set isChatting to true and it starts to chat.

When the server receive the command to chat with someone he has to send the chat request to the given client. Let suppose that Alice wants to chat with Bob. In this case the following steps must be performed:

- The request must be done through the request channel
- The client daemon process (Alice's daemon process) is listening on its socket (see after) and receive the request, then it reads the variable isChatting: if it is true the daemon process refuses automatically the server request, otherwise it ask (HANDSHAKE) to the main process if he wants to speak with Bob.
- The main process answer to the server by means of the daemon tools, if the answer is positive then it sets isChatting to true and so it waits for the message from Bob.

It's important to underline some concepts, first of all on the server side we have one process that handles two socket with the client, one for each channel. The protocol starts with the client that contacts the server, then the server and the client main process establish a connection and starts the protocol to establish a secure communication (Key Exchange). For standard messages this standard channel is used.

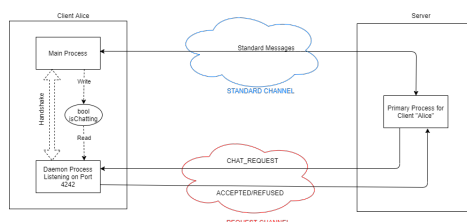


Figure 3.1: Protocol Schema

When the server has to send a chat request to this client the request channel must be used. Thus it establishes a connection with the daemon process of the client that works as a server process and it is listening on port 4242 (see figure 3.1). The security of this secondary channel is ensured by the fact that the messages sent by the server to the client on the request channel are encrypted with the shared key established during the handshake in the standard channel, hence we can say that the authentication problem is not present. In any case to implement a greater security is possible to generate client side a one time password that is sent to the server in the encrypted session through the standard channel, then the server will send this otp to the client daemon process to identify itself.

Other things to take in mind are:

- We assume that who send the chat request is the first to send messages.
- On the server side for each client two socket must be established, one for the standard channel and another one for the request channel but the process for each client is only one.

3.2 Server

Chapter 4

Messages Format

4.1 Handshake

Client Server Handshake

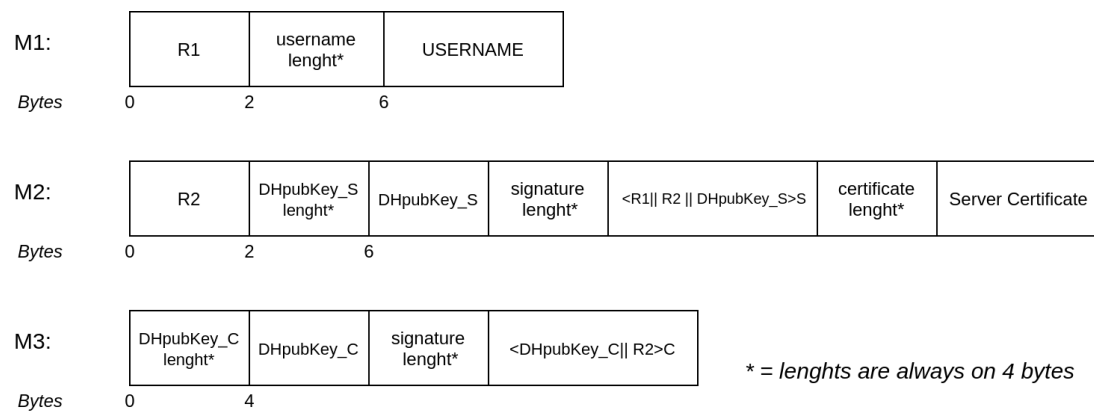


Figure 4.1: Client Server Handshake Message Format

Headers

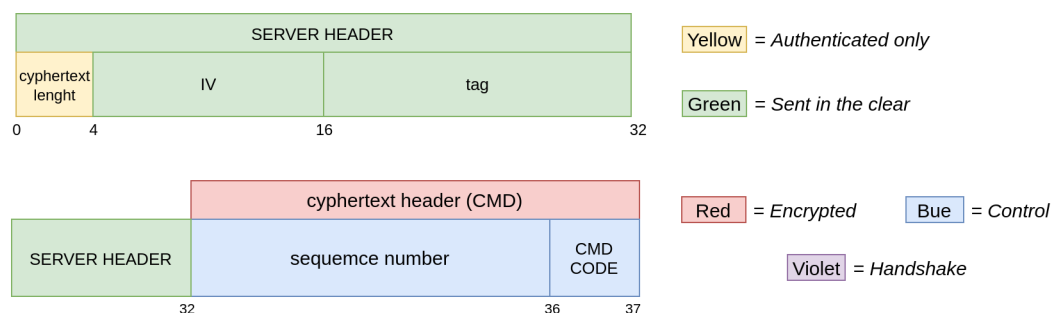


Figure 4.2: Client Server Header Format

Client Client Handshake

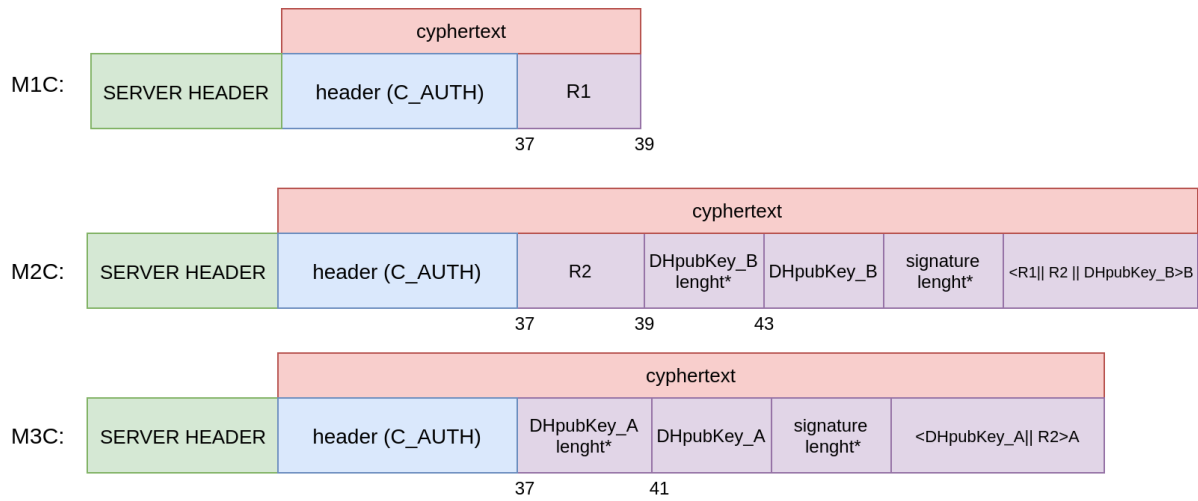


Figure 4.3: Client Client Handshake Message Format

4.2 Commands

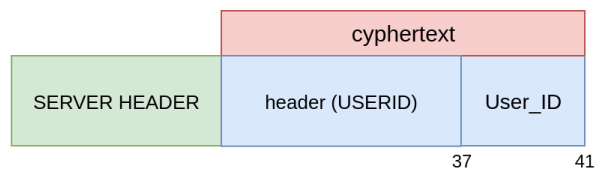


Figure 4.4: First message of every Session: server communicate cliet userID

Client Online List Request and Answer

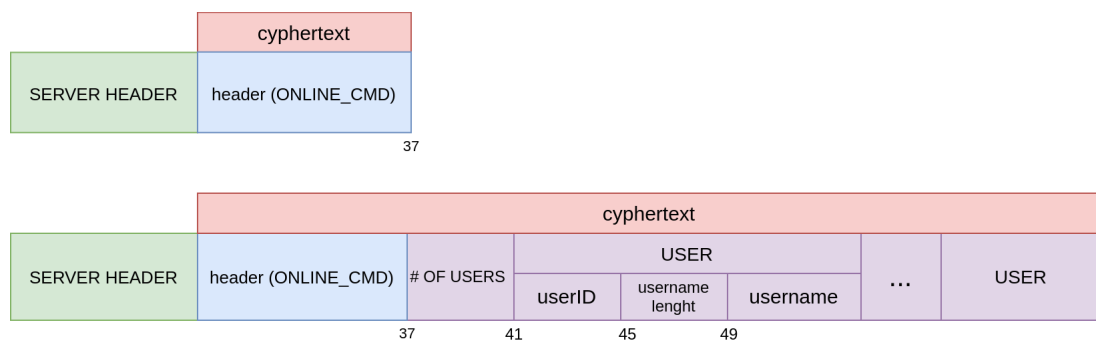


Figure 4.5: Client Online Message Format

Other commands

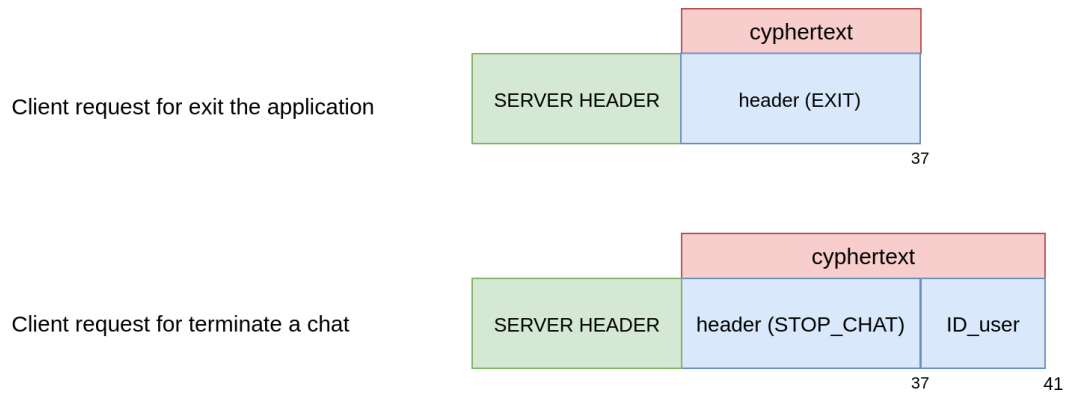


Figure 4.6: Other commands Format

Chat Request and Answers

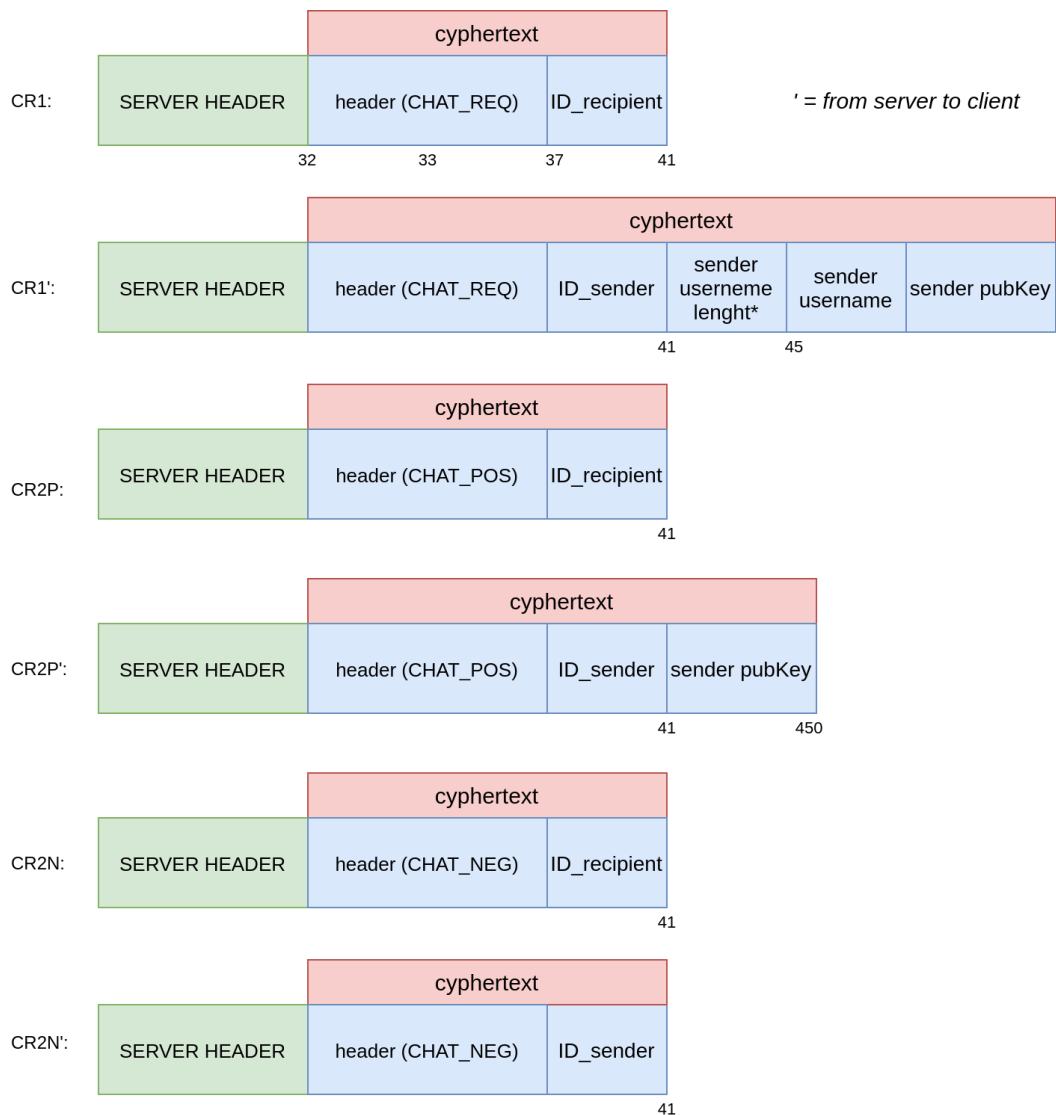


Figure 4.7: Chat Request Message Format

4.3 Chat

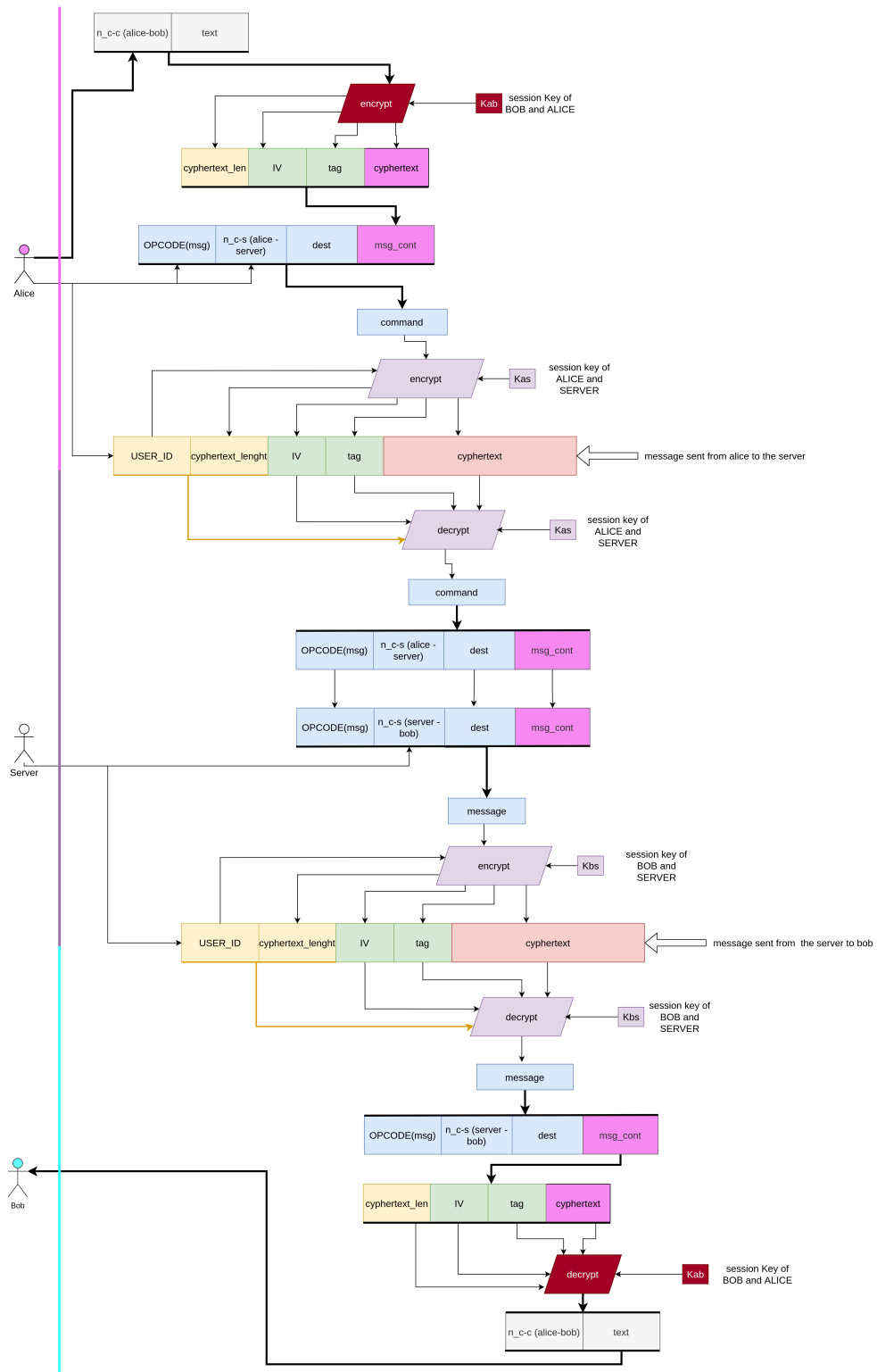


Figure 4.8: Client Client Handshake Protocol Schema