The University of Texas at Dallas

Network Security Project

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Privacy Preserving E-Commerce system

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Contents

1. Introduction and Problem Statement

This project aims to design and implement a privacy-preserving e-commerce system involving three main parties: a customer, a broker, and a merchant. The merchant sells e-products at the same price. Customers interested in purchasing these e-products connect with the broker, who, in turn, connects to the merchant. This process is designed to conceal the customer's identity from the broker.

However, it is crucial that the broker remains unaware of the specific products customers are purchasing, either directly or indirectly, to safeguard their privacy. Therefore, the customer and merchant need to establish a cryptographic tunnel for communication. The merchant can pad data to ensure the broker cannot deduce the e-product based on the file size, as the broker will mediate the file transfer.

The requirements of the system are integrity, confidentiality and authentication. All of the design must be done with certain constraints. The only mechanism available for authentication is public key cryptosystem. The only security primitive available for confidentiality is keyed hash mechanism and similar mechanism maybe used for integrity.

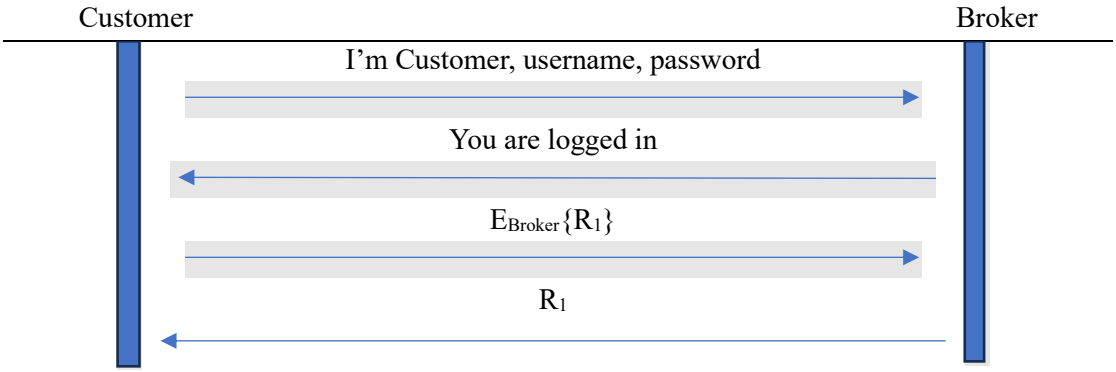
2. Security Features

2.1 Authentication

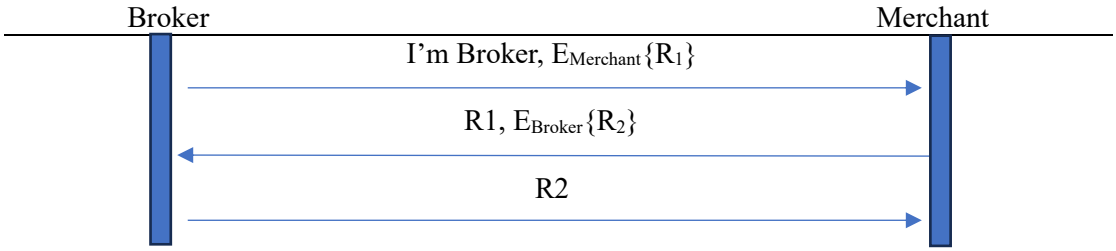
Merchant and Broker have RSA public-private key pairs.

2.1.1 Customer-Broker Mutual Authentication

Customer Authenticated using username, password and broker authenticated using Random number challenge



2.1.2 Broker-Merchant Mutual Authentication



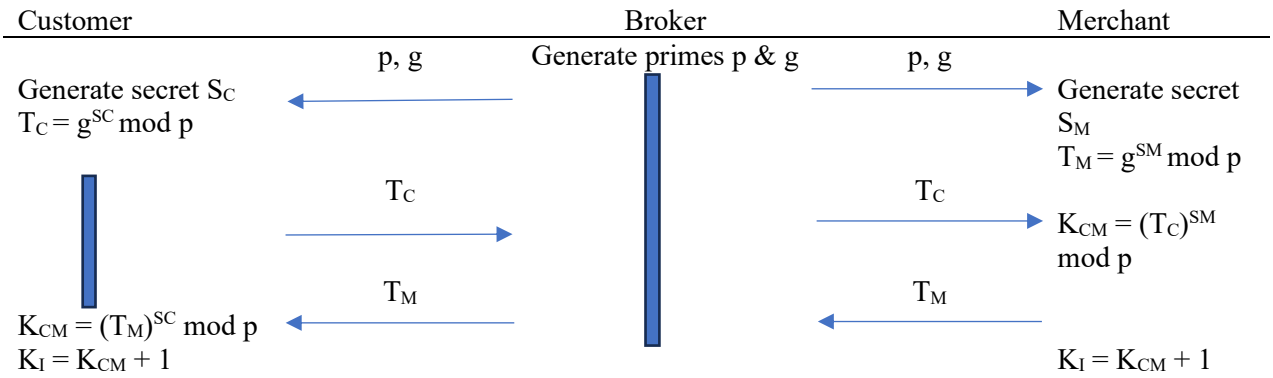
2.1.3 Customer-Merchant Mutual Authentication

Since Broker authenticated Merchant, and Customer authenticated Broker, Customer and Merchant authentication is not required.

2.2 Confidentiality

2.2.1 Session Key generation

Establish DH session key between Customer and Merchant. All further communication between Customer and Merchant via Broker is encrypted with this session key.



2.2.2 Encryption

Encryption is done using "Mixing in the plain text" concept, outlined as follows

Initial Vector – all 0s

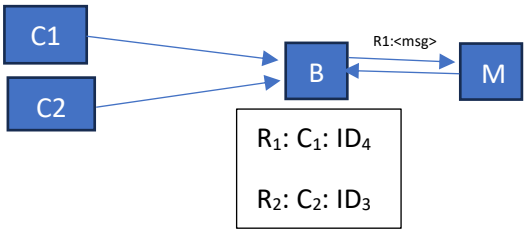
$b_1 = \text{SHA-256}(K_{CM}|IV)$ $\quad c_1 = p_1 \text{ XOR } b_1$
$b_2 = \text{SHA-256}(K_{CM}|c_1)$ $\quad c_2 = p_2 \text{ XOR } b_2$
… $\quad$ …
$b_i = \text{SHA-256}(K_{CM}|c_{i-1})$ $\quad c_i = p_i \text{ XOR } b_i$

2.2.3 Preserving Customer's privacy from Broker (File Padding)

In order to prevent the Broker from deducing a Customer's purchase based on the file size it is transferring, all files are padded to 1KB at the Merchant's side.

2.2.4 Preserving Customer's privacy from Merchant (Request Numbers)

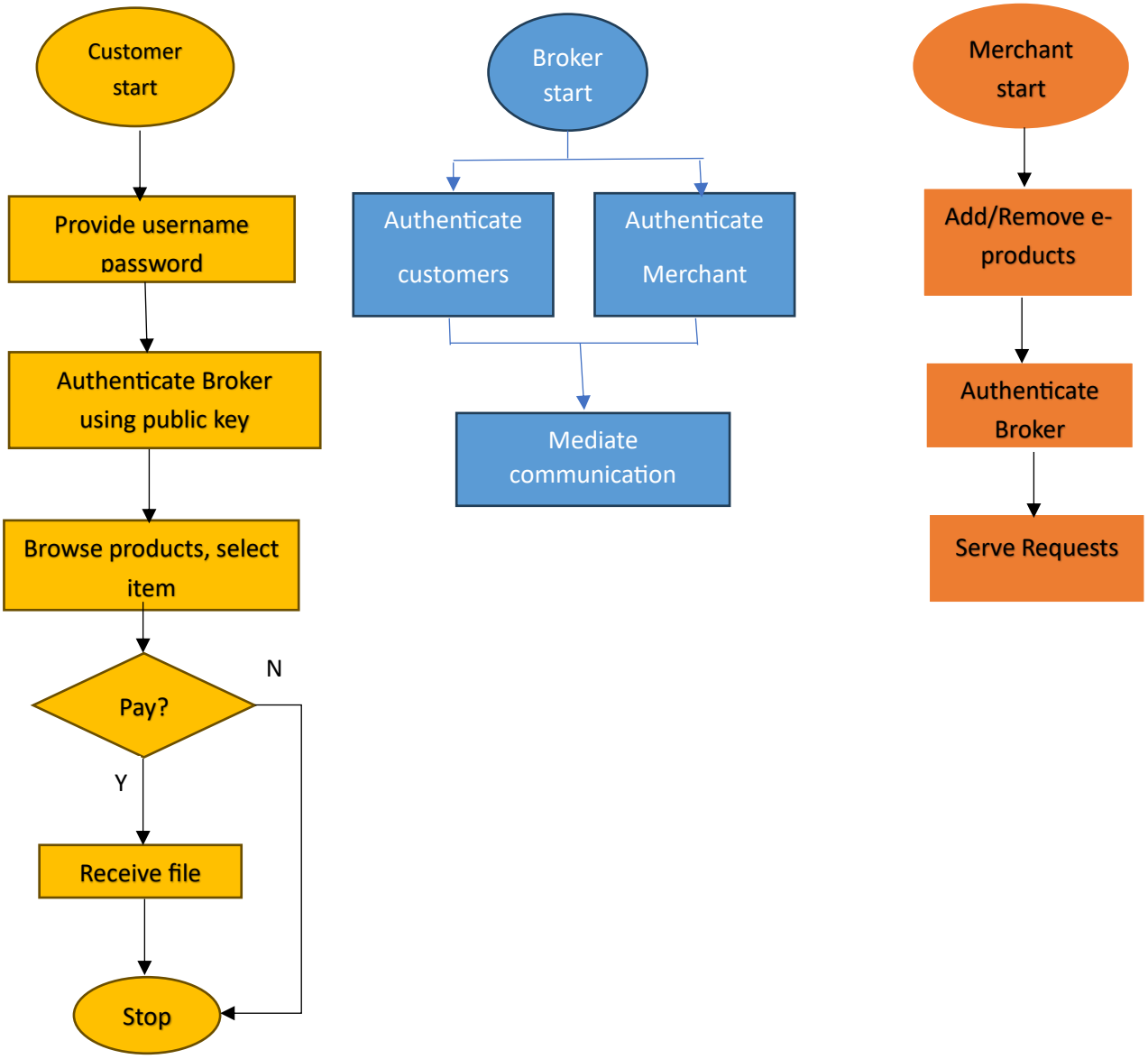
- The merchant shares session keys with multiple customers. However, without revealing the customer's identity, the merchant should be able to encrypt/decrypt a particular customer's request.
- The broker facilitates this by mapping a customer to a request number. The merchant will only be aware of a key associated with a specific request number.
- For every communication from a particular customer, the broker will send the request number along with the message. This process enables the merchant to encrypt/decrypt using the correct key solely based on the request number, without knowing the actual key.



2.3 Integrity

- Integrity key = Diffie-Hellman key + 1
- Integrity is verified by appending the contents with integrity key and then taking a SHA-256 hash (hash(content||K)).
- This is sent by the Merchant along with encrypted files so that Customer can decrypt the contents and verify if the information is untampered.

3. Application Flow



- **E-Product Browsing -** Customer should be able to view the Merchant's product list – Merchant sends the list of products to the Broker. Broker will forward it to Customer.
- **E-Product Checkout -** Customer inputs a product Id, which is confidentiality protected. The broker will forward it to Merchant.
- **E-Product Payment -** Merchant asks broker for payment, Broker asks confirmation from customer. If customer accepts, certain amount will be deducted from the customer and added to merchant and file transfer is initiated.
- **E-Product Delivery –** The file is delivered encrypted with session key. The Customer receives it, decrypts it, removes the padding and integrity checks the contents.
- **E-Product Addition/Removal** – Merchant can add/remove an e-product.

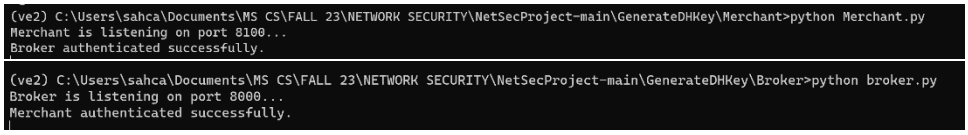
4. Results

4.1 How to run

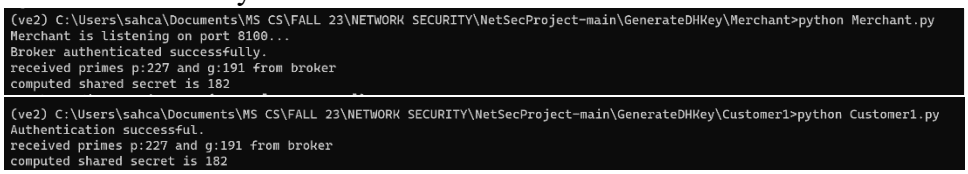
1. Clone the repo to a desired location
2. Ensure all installations are present. (If not, use pip install <library>).
3. Navigate to the Merchant folder and run python Merchant.py
4. Navigate to the Broker folder and run python Broker.py.
5. Navigate to the Customer<#> folder and run Customer<#>.py

4.2 Screenshots

- Mutual authentication

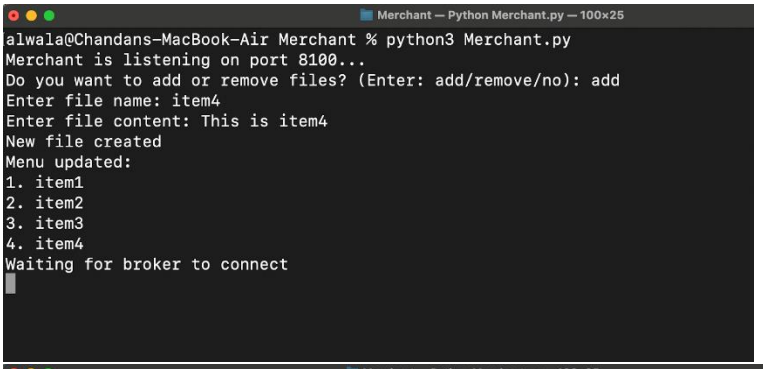


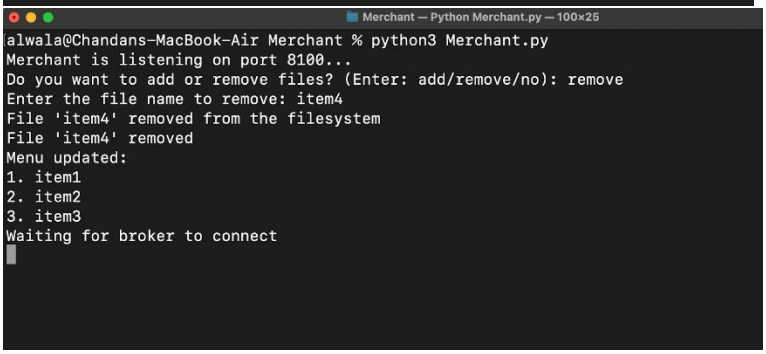
- DH session key between Customer and Merchant

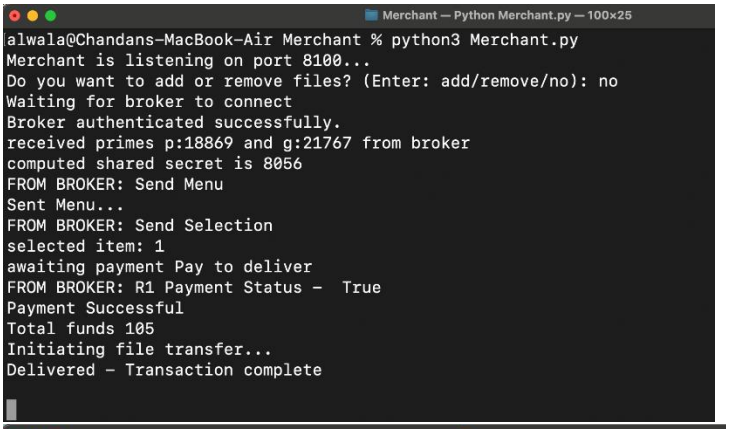


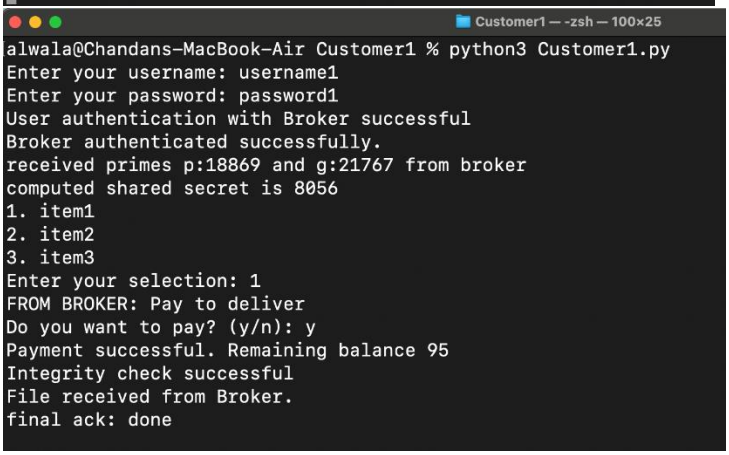
- Successful transaction at Customer

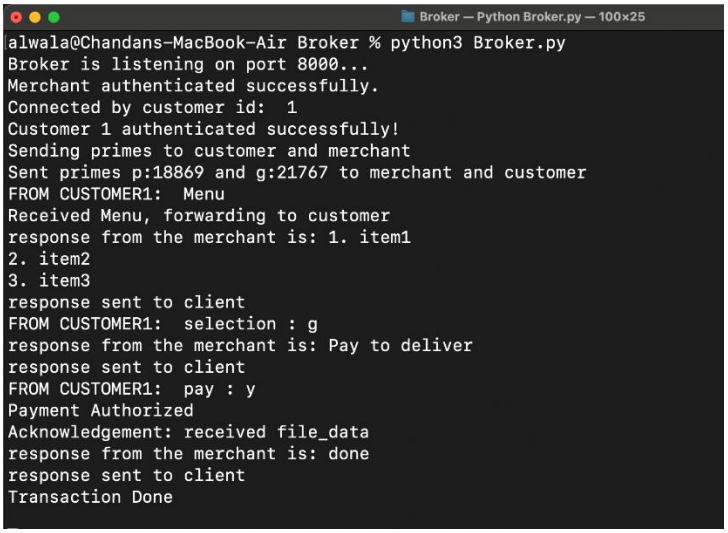
- Entire Flow


Merchant — Python Merchant.py — 100×25
alwala@Chandans-MacBook-Air Merchant % python3 Merchant.py
Merchant is listening on port 8100...
Do you want to add or remove files? (Enter: add/remove/no): add
Enter file name: item4
Enter file content: This is item4
New file created
Menu updated:
1. item1
2. item2
3. item3
4. item4
Waiting for broker to connect

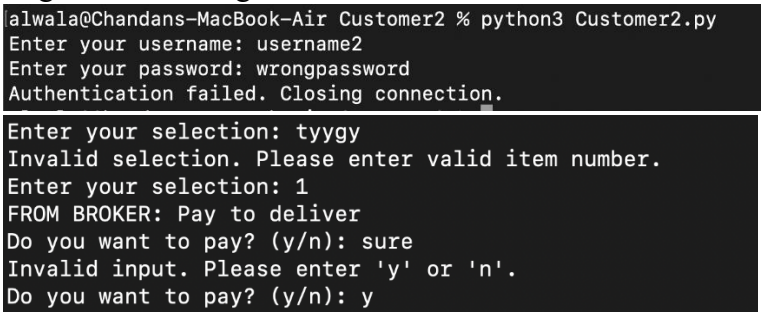

Merchant — Python Merchant.py — 100×25
alwala@Chandans-MacBook-Air Merchant % python3 Merchant.py
Merchant is listening on port 8100...
Do you want to add or remove files? (Enter: add/remove/no): remove
Enter the file name to remove: item4
File 'item4' removed from the filesystem
File 'item4' removed
Menu updated:
1. item1
2. item2
3. item3
Waiting for broker to connect







- Edge case handling



5. Conclusion and Future Work

5.1 Conclusion

The proposed and implemented design successfully satisfies all requirements of the problem statement, along with ensuring perfect forward secrecy .

5.2 Future Work

5.2.1 Potential Threats

- Trudy can get previous eavesdropped message sent by Customer to broker and get it decrypted while authentication – Solution – Introduce structure (odd # by initiator, even by sender).
- Broker is a single point of failure and if Broker is compromised, info about customer and the items they bought is compromised
- Man in the Middle attack during Diffie Hellman key generation.
- These maybe resolved with further research and advanced protocol design

5. 2.2 Other work

- Freshness guarantees may be introduced
- UI may be improved
- Code may be restructured and well-organized