Network Security : Assignment 7

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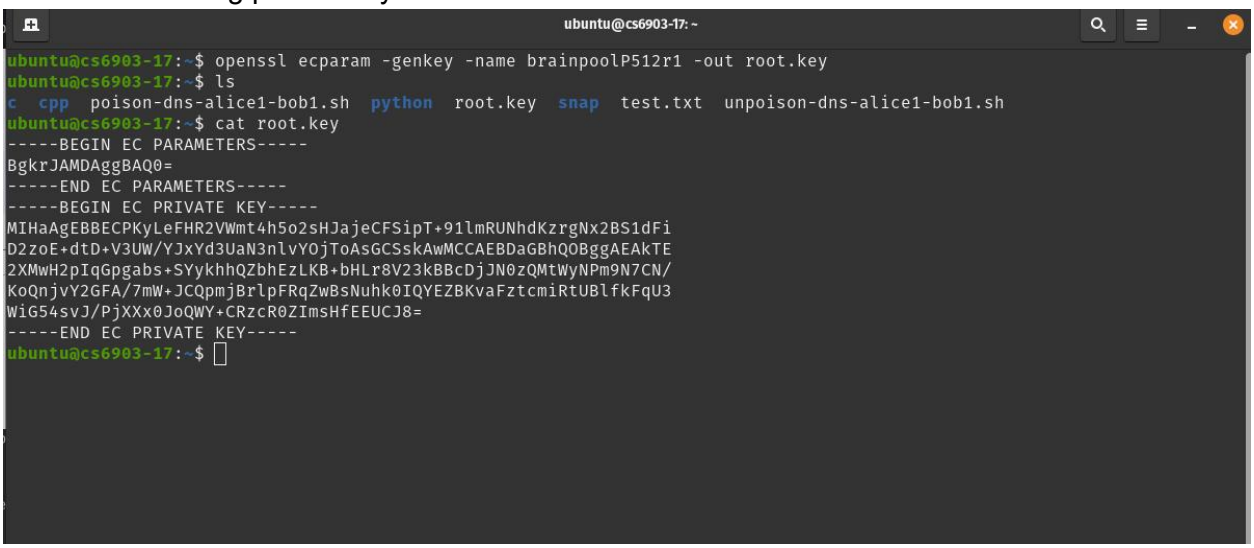
Task A

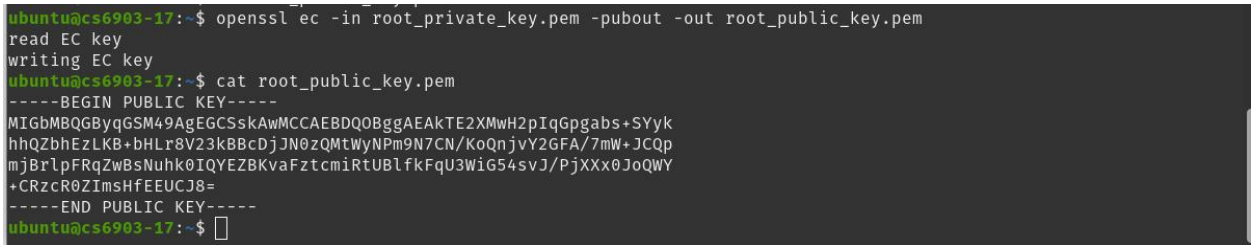
Creating Certificate for Root CA

Steps:

1. Generating private key for root.



2. Now creating a public key for Root CA by using the private key.



3. Now converting root's private key from .key format to .pem format.

```
 200  history
ubuntu@cs6903-17:~$ openssl ec -in root.key -out root_private_key.pem
read EC key
writing EC key
ubuntu@cs6903-17:~$ ls
c    poison-dns-alice1-bob1.sh  root.crt  root.pem              root_public_key.pem  unpoison-dns-alice1-bob1.sh
cpp  python                     root.key  root_private_key.pem  snap
ubuntu@cs6903-17:~$ rm root.pem
ubuntu@cs6903-17:~$ cat root_private_key.pem
-----BEGIN EC PRIVATE KEY-----
MIHaAgEBBECPKyLeFHR2VWmt4h5o2sHJajeCFSipT+91lmRUNhdKzrgNx2BS1dFi
D2zoE+dtD+V3UW/YJxYd3UaN3nlvYOjToAsGCSskAwMCCAEBDaGBhQOBggAEAkTE
2XMwH2pIqGpgabs+SYykhhQZbhEzLKB+bHLr8V23kBBcDjJN0zQMtWyNPm9N7CN/
KoQnjvY2GFA/7mW+JCQpmjBrlpFRqZwBsNuhk0IQYEZBKvaFztcmiRtUBlfkFqU3
WiG54svJ/PjXXx0JoQWY+CRzcR0ZImsHfEEUCJ8=
-----END EC PRIVATE KEY-----
ubuntu@cs6903-17:~$
```

4. This is the config file for root CA

```
ubuntu@cs6903-17:~$ cat root.cnf
[req]
distinguished_name = req_distinguished_name
x509_extensions = v3_ca

[req_distinguished_name]
countryName = IN
stateOrProvinceName = Telangana
localityName = Hyderabad
organizationName = IIT Hyderabad
organizationalUnitName = CSE
commonName = iTS Root R1
emailAddress = cs23mtech11001@iith.ac.in

[v3_ca]
basicConstraints = critical,CA:TRUE
keyUsage = critical,keyCertSign,cRLSign
ubuntu@cs6903-17:~$
```

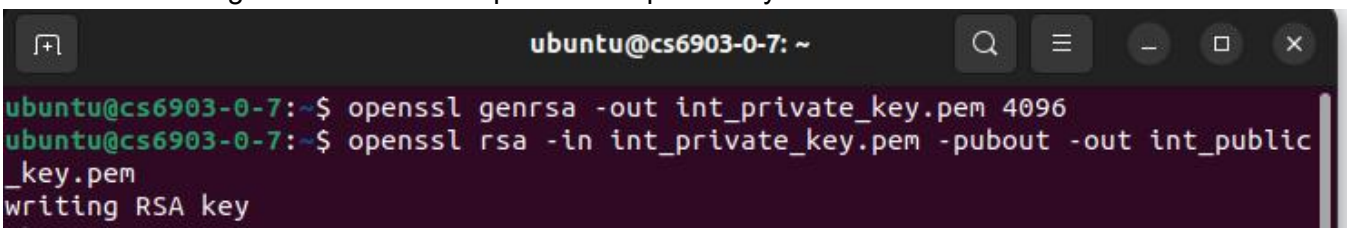
5. Now generating self-signed certificate for root CA

```
ubuntu@cs6903-17:~$ openssl req -x509 -new -key root.key -out root.crt -subj "/C=IN/ST=Telangana/L=Hyderabad/O=IIT H/OU=CSE/CN=iTS ROOT R1" -days 3650 -config root.cnf
ubuntu@cs6903-17:~$ openssl x509 -noout -text -in root.crt
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            4e:9a:1a:67:ab:01:85:e4:cc:1f:1f:05:b4:0d:e1:52:bd:05:8f:09
        Signature Algorithm: ecdsa-with-SHA256
        Issuer: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS ROOT R1
        Validity
            Not Before: Mar 12 10:43:52 2024 GMT
            Not After : Mar 10 10:43:52 2034 GMT
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS ROOT R1
        Subject Public Key Info:
            Public Key Algorithm: id-ecPublicKey
                Public-Key: (512 bit)
                pub:
                    04:02:44:c4:d9:73:30:1f:6a:48:a8:6a:60:69:bb:
                    3e:49:8c:a4:86:14:19:6e:11:33:2c:a0:7e:6c:72:
                    eb:f1:5d:b7:90:10:5c:0e:32:4d:d3:34:0c:b5:6c:
                    8d:3e:6f:4d:ec:23:7f:2a:84:27:8e:f6:36:18:50:
                    3f:ee:65:be:24:24:29:9a:30:6b:96:91:51:a9:9c:
                    01:b0:db:a1:93:42:10:60:46:41:2a:f6:85:ce:d7:
                    26:89:1b:54:06:57:e4:16:a5:37:5a:21:b9:e2:cb:
                    c9:fc:f8:d7:5f:1d:09:a1:05:98:f8:24:73:71:1d:
                    19:22:6b:07:7c:41:14:08:9f
                ASN1 OID: brainpoolP512r1
        X509v3 extensions:
            X509v3 Basic Constraints: critical
                CA:TRUE
            X509v3 Key Usage: critical
                Certificate Sign, CRL Sign
            X509v3 Subject Key Identifier:
                0A:EF:98:B9:E6:14:2C:7C:9F:ED:E2:60:BF:4A:53:EA:84:ED:90:59
    Signature Algorithm: ecdsa-with-SHA256
    Signature Value:
        30:81:84:02:40:3e:2d:a2:de:ae:01:5d:91:17:bd:2d:20:c8:
        29:7a:11:e4:21:93:8a:5e:88:56:71:fb:e5:aa:1a:0f:d7:a0:
        f3:1d:5b:09:d4:ad:67:67:76:fd:92:3c:b0:55:5d:a1:67:1c:
        aa:1c:4a:ec:b0:e0:00:46:39:f8:43:ad:58:27:30:02:40:7f:
        02:ac:7d:1b:d8:a5:03:75:df:c0:e1:f3:91:76:dd:cc:89:c6:
        46:3d:89:56:34:64:50:2d:20:b8:06:56:3b:d2:7e:44:dd:d2:
        12:64:62:82:f6:f5:24:ef:02:54:a8:d9:64:66:1d:66:56:42:
        ba:da:d1:ed:bd:c7:05:1a:ec
ubuntu@cs6903-17:~$
```

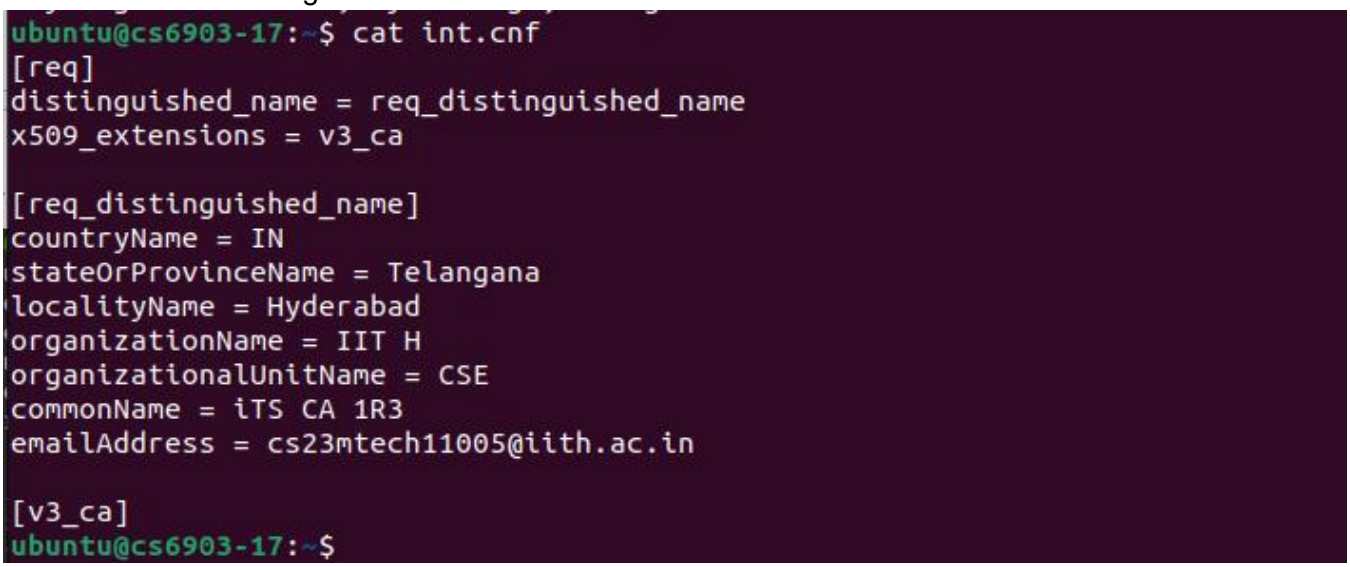
Now Creating certificate for Intermediate CA

Steps:

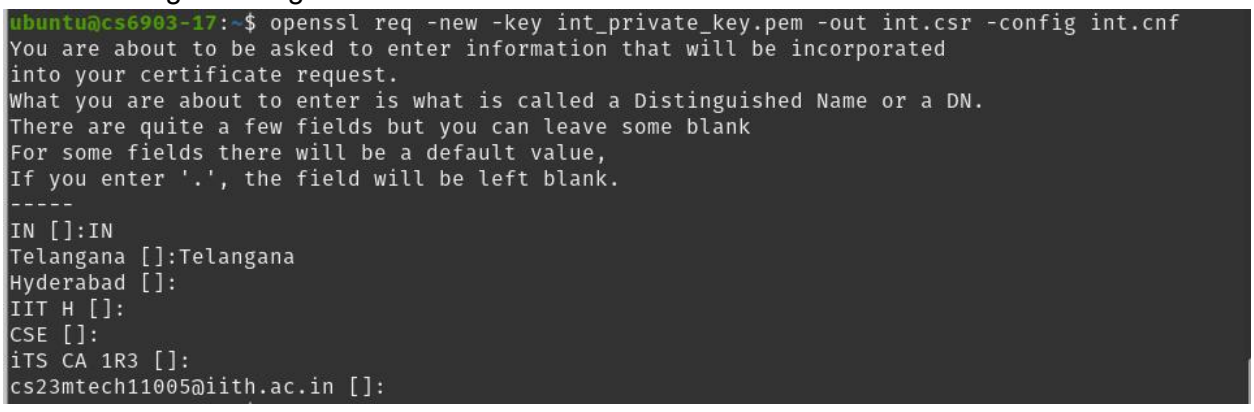
1. Generating Intermediate CA's private and public key



2. This is the config file for intermediate CA



3. Now generating csr file for intermediate CA



```
ubuntu@cs6903-17:~$ cat int.csr
-----BEGIN CERTIFICATE REQUEST-----
MIIE2DCCAsACAQAwgZIxCzAJBgNVBAYTAklOMRIwEAYDVQQIDAlUZWxhbmdhbmEx
EjAQBgNVBAcMCUh5ZGVyYWJhZDEOMAwGA1UECgwFSUlUIEgxDDAKBgNVBAsMA0NT
RTETMBEGA1UEAwwKaVRTIENBIDFSMzEoMCYGCSqGSIb3DQEJARYZY3MyM210ZWNo
MTEwMDVAaWl0aC5hYy5pbjCCAiIwDQYJKoZIhvcNAQEBBQADggIPADCCAgoCggIB
AKLqyPEZXAecsmg9JJ6SfWa7zElcV0tgS7ez7myHMtkia7l4pM6slfY1jOVGx75V
Sms/bPDuVVUoDs/lWw0F2TL6vggRKVDvDiHe+/7FP3VRvN8hhzyLf5KA3DFRLQo1
0tNMIB2MaW3+lKjGmY7baUEeKz++r/pjJOmPXes/urHo8dhyk5Ok+0eMiB4hiHIx
TUTor9kknrtJFBaJP+Ly6ukzRu6edelzO/FQq6qmFtNaIE5XSRxOT1P66NqtgL/V
3bbQu/Kv/cE5mY6t7dhrLV3t/3OYlfhI3chpTxDDbtBpyNKV6x7QpLRAe2/CktyE
j3TOXuzXwZpQWWucNiJMMKKaeytU+TOiAVoEM8fXV3Y9sSJT+w9xFMK63I/oD7gp
KzfvrUceWxNdYBYgiVR0LhQ89wa7/VcU0X7IwO/4c+m8aS3dRoX4S56Q8ArP02ml
m06J6tCVlLWj3TD7lM4VtpGidNxqX+trAbJnbIXx0ngAMyvIX0cX2PYEWAM2A0GI
cR0TezcD6G2OSgfKfG4O9bUAo4UzQYyKM65NlOiLlIu26ldegSP/XUnVZyrmm7Cx
FPKoE8pDtwrKH2aaBmT51GaTcabmX5TGcyrA+L/+ERMG7ZuqJEFC/bOBLRr2oj1f
19baegkINKU7t58hKwXwCTZXoW3rujT8u4C0kJ8rglyZAgMBAAGgADANBgkqhkiG
9w0BAQsFAAOCAgEAUJuvbgtiKG8wbUE4+xr+3fZWLWf/sM2acuETVpHJLM2Xx4X5
pmfxdDSUYiKKlPdglJj5tLohRkrY8OXptoKuG4XYHOTE0j3Ng8h0AB1f7FTUESlb
qotJKs+pQt2HOtU+FOlGgOrIP3ZssUFg+RjOxRJCNNU66qiuwOaU2R5NlyGPpE5V
TNJ8quTqIcwPqK8q9aFcrzGZ3G5Oexn8LQdzxtNOg39UHhX+LDvUfeknw/wSZTQU
H+zKHuapbwfkWCtb6PgaSg9Lwm6n4JKiybIYL/0kaxCI5m1ueBFqATwA5wO/181L
2CsnYfNbNm0lkXnatLkb++hBIFyurD8F2yzE1ofP75qXYkcr0uUzaVOPFC3fWZ1q
3fYzQ4zJ+QOdEnGNVxuBbMpyhjYQ8g6S6INOaheAgBISPwVhSTcrlB5/wMGg9Qzn
ck+v+ZUTm3QFnzGG8u7vWp0ici1YklHPVZwcA9yFhjUlq8LSAlufWv0dtnEQRvyj
DeCxqG/480h9eIDb0yEQTaqPVUhdD/tETHAC2nhtERCt2iXFpVvar7ev1pbVpx99
xnu7vSL5rkZmRqlmYFhip4ulT5ZZQDVFeL9xu5bPN8V3sGKh1devyeIsG5TLp/t6
adUimEnl1uiesLsFrRg3/dNzcfQj5imsldJqofQ2MzjsWEjy6GOILDpW7j0=
-----END CERTIFICATE REQUEST-----
```

4. Now the root will verify the intermediate csr

```
ubuntu@cs6903-17:~$ openssl req -text -noout -verify -in int.csr
Certificate request self-signature verify OK
Certificate Request:
    Data:
        Version: 1 (0x0)
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS CA 1R3, emailAddress = cs23mtech11005@iith.ac.in
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (4096 bit)
                Modulus:
```

5. Now after verifying the intermediate csr the root will generate the certificate of the intermediate CA.

```
ubuntu@cs6903-17:~$ openssl x509 -req -in int.csr -CA root.crt -CAkey root_private_key.pem -CAcreateserial -out int.crt -days 90 -extfile intRoot.cnf -extensions v3_ca
Certificate request self-signature ok
subject=C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS CA 1R3, emailAddress = cs23mtech11005@iith.ac.in
ubuntu@cs6903-17:~$ openssl x509 -noout -text -in int.crt
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            0e:78:e6:85:69:ca:41:fa:07:1d:a4:c3:9b:2c:86:2f:52:87:ba:5c
        Signature Algorithm: ecdsa-with-SHA256
        Issuer: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS ROOT R1
        Validity
            Not Before: Mar 13 06:27:17 2024 GMT
            Not After : Jun 11 06:27:17 2024 GMT
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS CA 1R3, emailAddress = cs23mtech11005@iith.ac.in
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (4096 bit)
                Modulus:
                    00:a2:ea:c8:f1:19:5c:07:9c:b2:68:3d:24:9e:92:
                    7d:66:bb:cc:49:5c:57:4b:60:4b:b7:b3:ee:6c:87:
                    32:d9:22:6b:b9:78:a4:ce:ac:95:f6:35:8c:e5:46:
                    c7:be:55:4a:6b:3f:6c:f0:ee:55:55:28:0e:cf:e5:
                    5b:0d:05:d9:32:fa:be:08:11:29:50:ef:0e:21:de:
                    fb:fe:c5:3f:75:51:bc:df:21:87:3c:8b:7f:92:80:
                    dc:31:51:2d:0a:35:d2:d3:4c:20:1d:8c:69:6d:fe:
                    94:a8:c6:99:8e:db:69:41:1e:2b:3f:be:af:fa:63:
                    24:e9:8f:5d:eb:3f:ba:b1:e8:f1:d8:72:93:93:a4:
                    fb:47:8c:88:1e:21:88:72:31:4d:44:e8:af:d9:24:
                    9e:bb:49:14:16:89:3f:e2:f2:ea:e9:33:46:ee:9e:
                    75:e9:73:3b:f1:50:ab:aa:a6:16:d3:5a:20:4e:57:
                    49:1c:4e:4f:53:fa:e8:da:ad:80:bf:d5:dd:b6:d0:
                    bb:f2:af:fd:c1:39:99:8e:ad:ed:d8:6b:2d:5d:ed:
                    ff:73:98:95:f8:48:dd:c8:69:4f:10:c3:6e:d0:69:
                    c8:d2:95:eb:1e:d0:a4:b4:40:7b:6f:c2:92:dc:84:
                    8f:74:ce:5e:ec:d7:c1:9a:50:59:6b:9c:36:22:4c:
                    30:a2:9a:7b:2b:54:f9:33:a2:01:5a:04:33:c7:d7:
                    57:76:3d:b1:22:53:fb:0f:71:14:c2:ba:dc:8f:e8:
                    0f:b8:29:2b:37:ef:ad:47:1e:5b:13:5d:60:16:20:
                    89:54:74:2e:14:3c:f7:06:bb:fd:57:14:d1:7e:c8:
                    c0:ef:f8:73:e9:bc:69:2d:dd:46:85:f8:4b:9e:90:
                    f0:0a:cf:d3:69:a5:9b:4e:89:ea:d0:95:94:b5:a3:
                    dd:30:fb:94:ce:15:b6:91:a2:74:dc:6a:5f:eb:6b:
                    01:b2:67:6c:85:f1:d2:78:00:33:2b:c8:5f:47:17:
                    d8:f6:04:58:03:36:03:41:88:71:1d:13:7b:37:03:
                    e8:6d:8e:4a:07:ca:7c:6e:0e:f5:b5:00:a3:85:33:
                    41:8c:8a:33:ae:4d:94:e8:8b:94:8b:b6:ea:57:5e:
                    81:23:ff:5d:49:d5:67:2a:e6:9b:b0:b1:14:f2:a8:
```

6. Now the intermediate will verify the certificate sent by the root.

```
ubuntu@cs6903-17:~$ openssl verify -verbose -CAfile root.crt int.crt
int.crt: OK
ubuntu@cs6903-17:~$
```

Now generating Alice certificates.

Steps:

1. Generating Alice's private key

```
root@alice1:~# openssl genrsa -out alice_private_key.pem 1024
Generating RSA private key, 1024 bit long modulus (2 primes)
.....................+++++
......+++++
e is 65537 (0x010001)
root@alice1:~# ls
alice_private_key.pem  snap
root@alice1:~# cat alice_private_key.pem
-----BEGIN RSA PRIVATE KEY-----
MIICXAIBAAKBgQCtWHZaNdDpIktfPAxoNktSEERNGPi6Cfcl0g8+CIbb+vDDfs2/
ESvDfaHoq16yI2+yfbMX5t6AgfAWBlYf4/9DdQGEQykvg1M/0mt5rV7ZFvdaNfP+
8GjtWl1c56x228g8OswJU/lzuBY+2filPxy33FsBx8ReJdpmBbY3TtCsTwIDAQAB
AoGARPSJr/z0a6j+vpWOge4HLE/YO6sRVkAclmjnM1AFBYDfQYUxpy3XcN6LB5kU
BFzgU+p40as/G3OU484FeI4jvjPvZWES8So0S6IrgINEKyZQFxXoeMRECuBUhN95
qBkRWRYl+UAfQx9a8EelfASdqmMhr1SSjFsulSIPF7XW7yECQQDfHfnGgEWuwA9h
HEW8uxGX1QY0NWdkTDYCi8GG+houTZK2s3jYx3t7zwhWc70bJClx39Y+rbCkEFWw
BQCjEKyXAkEAxuSlwvI5nTd5hDD9oSH1Y6V3b7XEaopaF2NCw8C4/tnLR/ggPa3w
8XOK8Bufg03IFtECbXoLTry5vPlK4+6dCQJAezT0XxcqY6uPUpLoN6YduvhZqq7q
30nucU13mu+1UWho4hcNXrgZim7zLbpP7RL1B/sRNh938cFLcB3zEhj9FQJAd7JJ
M/50v/IP1odpTFzUgmilbXxVvcyPlX2uQ4Krkuxd0203cgdJdvYTSpdFM09POLQG
ov4M6hDYMytQb8Y9iQJBAJfyvzMRB7RRE6KpZm91m8flnW5mNGuu3/O7PILLz9w1
XBFNIv1VxCCQlkwbnn3eY7vwreK6+DcNZUkOoLZErto=
-----END RSA PRIVATE KEY-----
root@alice1:~#
```

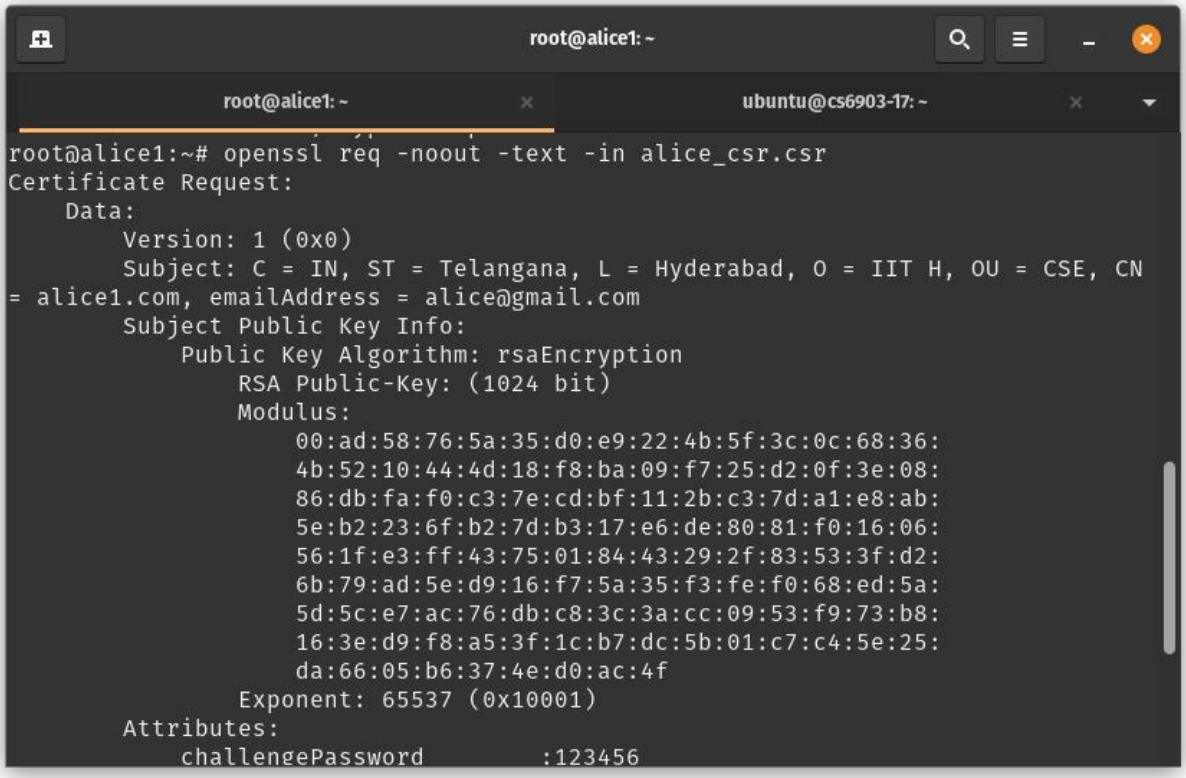
2. Now Generating Alice's public key

```
root@alice1:~# openssl rsa -in alice_private_key.pem -pubout -out alice_public_k
ey.pem
writing RSA key
root@alice1:~# ls
alice_private_key.pem  alice_public_key.pem  snap
root@alice1:~# cat alice_public_key.pem
-----BEGIN PUBLIC KEY-----
MIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQCtWHZaNdDpIktfPAxoNktSEERN
GPi6Cfcl0g8+CIbb+vDDfs2/ESvDfaHoq16yI2+yfbMX5t6AgfAWBlYf4/9DdQGE
Qykvg1M/0mt5rV7ZFvdaNfP+8GjtWl1c56x228g8OswJU/lzuBY+2filPxy33FsB
x8ReJdpmBbY3TtCsTwIDAQAB
-----END PUBLIC KEY-----
root@alice1:~#
```

3. Now Generating Alice's CSR file

```
root@alice1:~# openssl req -new -key alice_private_key.pem -out alice_csr.csr
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:IN
State or Province Name (full name) [Some-State]:Telangana
Locality Name (eg, city) []:Hyderabad
Organization Name (eg, company) [Internet Widgits Pty Ltd]:IIT H
Organizational Unit Name (eg, section) []:CSE
Common Name (e.g. server FQDN or YOUR name) []:alice1.com
```

-> ALICE CSR



4. We have to pull the csr file from alice1 to vm so that intermediate CA can generate a certificate for alice.

Pulling Command: lxc file pull alice1/root/alice_csr.csr /home/ubuntu/

```
ubuntu@cs6903-17:~$ lxc file pull alice1/root/alice_csr.csr /home/ubuntu/
ubuntu@cs6903-17:~$ ls
alice_csr.csr  int.csr                  root.cnf
c              intRoot.cnf              root.crt
commands.txt   int_private_key.pem      root_private_key.pem
cpp            int_public_key.pem       root_public_key.pem
int.cnf        poison-dns-alice1-bob1.sh  snap
int.crt        python                   unpoison-dns-alice1-bob1.sh
```

5. Intermediate will verify that that csr is coming from alice

```
ubuntu@cs6903-17:~$ openssl req -text -noout -verify -in alice_csr.csr
Certificate request self-signature verify OK
Certificate Request:
    Data:
        Version: 1 (0x0)
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = alice1.com, emailAddress = alice@gmail.com
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (1024 bit)
                Modulus:
                    00:ad:58:76:5a:35:d0:e9:22:4b:5f:3c:0c:68:36:
                    4b:52:10:44:4d:18:f8:ba:09:f7:25:d2:0f:3e:08:
                    86:db:fa:f0:c3:7e:cd:bf:11:2b:c3:7d:a1:e8:ab:
                    5e:b2:23:6f:b2:7d:b3:17:e6:de:80:81:f0:16:06:
                    56:1f:e3:ff:43:75:01:84:43:29:2f:83:53:3f:d2:
                    6b:79:ad:5e:d9:16:f7:5a:35:f3:fe:f0:68:ed:5a:
                    5d:5c:e7:ac:76:db:c8:3c:3a:cc:09:53:f9:73:b8:
                    16:3e:d9:f8:a5:3f:1c:b7:dc:5b:01:c7:c4:5e:25:
                    da:66:05:b6:37:4e:d0:ac:4f
                Exponent: 65537 (0x10001)
        Attributes:
            challengePassword        :123456
            Requested Extensions:
    Signature Algorithm: sha256WithRSAEncryption
    Signature Value:
        62:cb:3f:0f:31:22:0c:fc:dc:c9:02:11:3c:8c:e3:4d:af:e0:
        7c:86:1c:1f:d8:ba:a5:9e:20:2c:8a:35:97:86:a3:ea:fa:f7:
        2b:94:2e:13:e8:72:3e:f6:bc:67:e2:09:e3:45:1f:a7:51:5e:
        82:d3:ae:7c:3a:5d:db:87:56:db:ca:fc:38:8b:70:e1:3b:8f:
        57:6b:ab:dd:5f:29:49:59:f9:72:00:ec:d6:57:6e:47:9d:47:
        48:8e:c5:35:4b:16:01:80:fa:58:8b:fe:d3:12:ce:42:6b:98:
        67:35:94:33:58:ec:4e:4c:c4:8c:4e:2e:12:d0:b5:38:50:35:
        11:16
ubuntu@cs6903-17:~$
```

6. intermediate will create a config file

```
ubuntu@cs6903-17:~$ cat aliceInt.cnf
[ req ]
default_bits = 2048
prompt = no
distinguished_name = req_distinguished_name

[ req_distinguished_name ]
C = IN
ST = Telangana
L = IIT H
O = CSE
CN = alice1.com
```

7. intermediate will generate cert for alice

```
ubuntu@cs6903-17:~$ openssl x509 -req -in alice_csr.csr -CA int.crt -CAkey int_private_key.pem -CAcreateserial -out alice_crt.crt -days 90 -extfile aliceInt.cnf -extensions req_ext
Certificate request self-signature ok
subject=C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = alice1.com, emailAddress = alice@gmail.com
```

8. intermediate will push alice_cert.crt and int.crt to alice1
   Command: lxc file push alice_crt.crt alice1/root/

```
ubuntu@cs6903-17:~$ lxc file push alice_crt.crt alice1/root/
ubuntu@cs6903-17:~$
```

9. intermediate will generate certificate chain and send it to Alice

```
ubuntu@cs6903-17:~$ cat alice_crt.crt int.crt root.crt > alice_chain.crt
ubuntu@cs6903-17:~$ ls
aliceInt.cnf      int.cnf                  root.cnf
alice_chain.crt   int.crt                  root.crt
alice_crt.crt     int.csr                  root_private_key.pem
alice_csr.csr     intRoot.cnf              root_public_key.pem
bob.cnf           int_private_key.pem      snap
c                 int_public_key.pem       unpoison-dns-alice1-bob1.sh
commands.txt      poison-dns-alice1-bob1.sh
cpp               python
ubuntu@cs6903-17:~$ lxc file push alice_chain.crt alice1/root/
```

10. Alice will verify that the cert is coming from int.

```
root@alice1:~# openssl verify -CAfile root.crt -untrusted int.crt alice_chain.crt
alice_chain.crt: OK
```

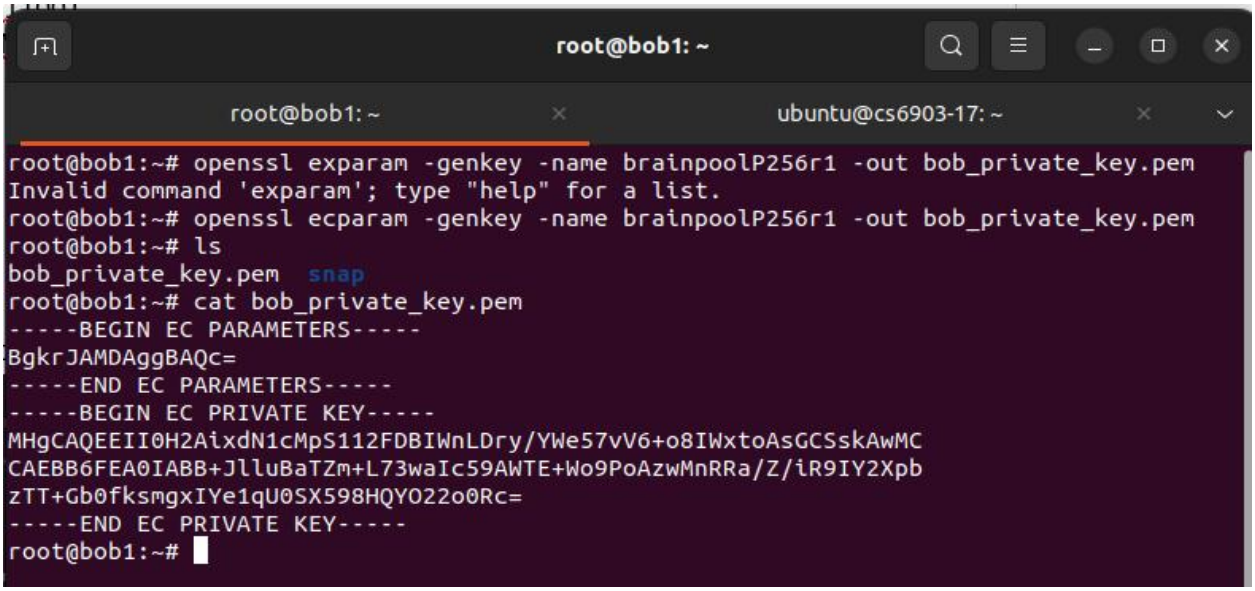
->ALICE CERT

```
ubuntu@cs6903-17:~$ openssl x509 -noout -text -in alice_crt.crt
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            2a:0a:35:31:3c:4a:35:60:c0:ef:7e:7e:7d:eb:45:05:6a:c9:3f:44
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = iTS CA 1R3, emailAddress = cs23mtech11005@iith.ac.in
        Validity
            Not Before: Mar 13 07:10:03 2024 GMT
            Not After : Jun 11 07:10:03 2024 GMT
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = alice1.com, emailAddress = alice@gmail.com
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (1024 bit)
                Modulus:
                    00:ad:58:76:5a:35:d0:e9:22:4b:5f:3c:0c:68:36:
                    4b:52:10:44:4d:18:f8:ba:09:f7:25:d2:0f:3e:08:
                    86:db:fa:f0:c3:7e:cd:bf:11:2b:c3:7d:a1:e8:ab:
                    5e:b2:23:6f:b2:7d:b3:17:e6:de:80:81:f0:16:06:
                    56:1f:e3:ff:43:75:01:84:43:29:2f:83:53:3f:d2:
                    6b:79:ad:5e:d9:16:f7:5a:35:f3:fe:f0:68:ed:5a:
                    5d:5c:e7:ac:76:db:c8:3c:3a:cc:09:53:f9:73:b8:
                    16:3e:d9:f8:a5:3f:1c:b7:dc:5b:01:c7:c4:5e:25:
                    da:66:05:b6:37:4e:d0:ac:4f
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Subject Alternative Name:
                DNS:alice1.com, DNS:www.alice1.com
            X509v3 Subject Key Identifier:
                73:94:58:FA:E6:11:58:7F:74:84:BD:35:5F:AC:B8:1F:B9:2E:98:70
            X509v3 Authority Key Identifier:
                95:E1:93:81:D6:18:DC:E6:E3:87:FD:DD:C1:1A:F2:49:7E:68:0A:EA
    Signature Algorithm: sha256WithRSAEncryption
    Signature Value:
        64:2e:81:51:33:ac:70:4d:26:e3:ab:aa:86:06:ab:76:52:5d:
        a6:27:1d:94:c5:73:f7:75:e7:9d:69:52:11:06:9d:08:33:57:
        e6:c6:6c:7a:94:5a:b5:c6:33:84:e8:af:8a:4c:c2:cc:f4:df:
        75:cd:cb:3b:80:65:a7:dd:cc:4a:6d:1f:c5:db:64:d5:b4:0a:
        10:2f:c8:ce:72:ec:a4:44:7a:f8:f7:c1:ea:bd:71:d6:85:c5:
        79:94:73:b4:b4:56:3b:55:ce:c3:b9:20:88:ac:d5:36:d7:4c:
        f0:47:e6:d8:d7:ab:26:92:3b:02:dd:e0:cf:46:aa:ee:55:0b:
        0d:eb:16:c8:09:b7:fa:cb:27:28:ac:d1:40:06:a0:3e:dc:7e:
        65:43:70:6d:37:bd:60:1b:97:91:35:e4:98:9e:dc:e8:68:ac:
        be:9f:49:fe:ac:8e:a7:5b:d9:33:1d:3c:5a:c7:a9:1b:65:a3:
        79:f0:ce:32:0b:c3:b5:07:79:16:b1:b8:c0:4b:c4:9b:54:0d:
        52:90:84:9d:ee:77:d1:9f:fb:45:c0:f3:e0:e0:a2:f0:ed:f3:
```

Now doing the same thing for Bob

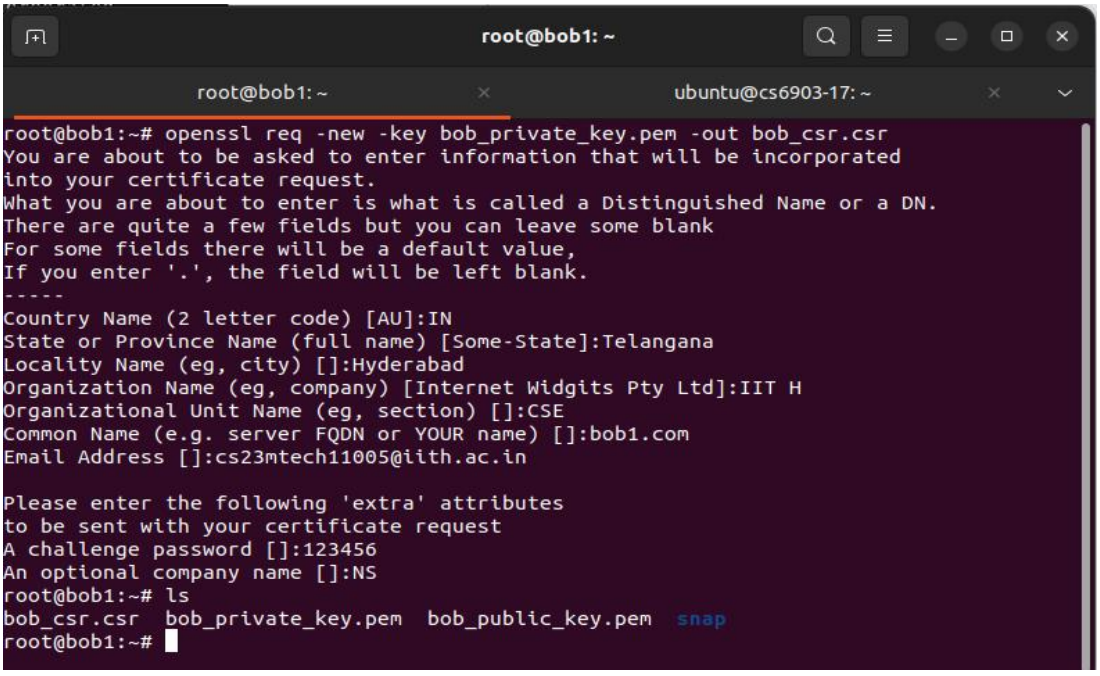
Steps:

1. Generating the private key for the bob.



2. Now generating the public key for bob.

3. Now generating the Bob csr file



```
root@bob1:~# cat bob_csr.csr
-----BEGIN CERTIFICATE REQUEST-----
MIIBdzCCAR4CAQAwgZAxCzAJBgNVBAYTAklOMRIwEAYDVQQIDAlUZWxhbmdhbmEx
EjAQBgNVBAcMCUh5ZGVyYWJhZDEOMAwGA1UECgwFSUlUIEgxDDAKBgNVBAsMA0NT
RTERMA8GA1UEAwwIYm9iMS5jb20xKDAmBgkqhkiG9w0BCQEWGWNzMjNtdGVjaDEx
MDA1QGlpdGguYWMuaW4wWjAUBgcqhkjOPQIBBgkrJAMDAggBAQcDQgAEH4mWW4Fp
Nmb4vvfBohzn0BZMT5aj0+gDPAydFFr9n+JH0hjZelvNNP4ZvR+SyaDEhh7WpTRJ
fn3wdBg7bajRF6AqMBEGCSqGSIb3DQEJAjEEDAJOUzAVBgkqhkiG9w0BCQcxCAwG
MTIzNDU2MAoGCCqGSM49BAMCA0cAMEQCIBVcrd9v9rjQjPPPuZGALRIkJ0o3Tgvb
L3wzMZQWSALCAiB2i1AOz3UNXGMdQ8gCJJLB9wqIXaHUzQqVVxNYj8ngjA==
-----END CERTIFICATE REQUEST-----
root@bob1:~#
```

4. Now we will pull bob.csr from the container to the host VM.

```
ubuntu@cs6903-17:~$ lxc file pull bob1/root/bob_csr.csr /home/ubuntu/
ubuntu@cs6903-17:~$ ls
aliceInt.cnf      c              intRoot.cnf               root.crt
alice_chain.crt   commands.txt   int_private_key.pem       root_private_key.pem
alice_crt.crt     cpp            int_public_key.pem        root_public_key.pem
alice_csr.csr     int.cnf        poison-dns-alice1-bob1.sh snap
bob.cnf           int.crt        python                    unpoison-dns-alice1-bob1.sh
bob_csr.csr       int.csr        root.cnf
ubuntu@cs6903-17:~$
```

5. Now intermediate CA will verify that CSR is indeed coming from Bob

```
ubuntu@cs6903-17:~$ openssl req -text -noout -verify -in bob_csr.csr
Certificate request self-signature verify OK
Certificate Request:
    Data:
        Version: 1 (0x0)
        Subject: C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = bob1.com, emailAddr
ess = cs23mtech11005@iith.ac.in
        Subject Public Key Info:
            Public Key Algorithm: id-ecPublicKey
                Public-Key: (256 bit)
                pub:
                    04:1f:89:96:5b:81:69:36:66:f8:be:f7:c1:a2:1c:
                    e7:d0:16:4c:4f:96:a3:d3:e8:03:3c:0c:9d:14:5a:
                    fd:9f:e2:47:d2:18:d9:7a:5b:cd:34:fe:19:bd:1f:
                    92:c9:a0:c4:86:1e:d6:a5:34:49:7e:7d:f0:74:18:
                    3b:6d:a8:d1:17
                ASN1 OID: brainpoolP256r1
        Attributes:
            unstructuredName         :NS
            challengePassword        :123456
            Requested Extensions:
    Signature Algorithm: ecdsa-with-SHA256
    Signature Value:
        30:44:02:20:15:5c:ad:df:6f:f6:b8:d0:8c:f3:cf:b9:91:80:
        2d:12:24:27:4a:37:4e:0b:db:2f:7c:33:31:94:16:48:02:c2:
        02:20:76:8b:50:0e:cf:75:0d:5c:63:1d:43:c8:02:24:92:c1:
        f7:0a:88:5d:a1:d4:cd:0a:95:57:13:58:8f:c9:e0:8c
ubuntu@cs6903-17:~$
```

6. Now the intermediate CA will make a config file for generating the certificate of Bob.

```
ubuntu@cs6903-17:~$ touch bobInt.cnf
ubuntu@cs6903-17:~$ ls
aliceInt.cnf     bob_csr.csr   int.csr                    root.cnf
alice_chain.crt  c             intRoot.cnf                root.crt
alice_crt.crt    commands.txt  int_private_key.pem        root_private_key.pem
alice_csr.csr    cpp           int_public_key.pem         root_public_key.pem
bob.cnf          int.cnf       poison-dns-alice1-bob1.sh  snap
bobInt.cnf       int.crt       python                     unpoison-dns-alice1-bob1.sh
ubuntu@cs6903-17:~$
```

Now filling information into it.

```
ubuntu@cs6903-17:~$ cat bobInt.cnf
[ req ]
default_bits = 2048
prompt = no
distinguished_name = req_distinguished_name

[ req_distinguished_name ]
C = IN
ST = Telangana
L = IIT H
O = CSE
CN = bob1.com

[ req_ext ]
subjectAltName = @alt_names

[ alt_names ]
DNS.1 = bob1.com
DNS.2 = www.bob1.com
ubuntu@cs6903-17:~$
```

7. Now Intermediate CA will generate certificate for Bob

```
ubuntu@cs6903-17: ~
root@bob1: ~   ×   ubuntu@cs6903-17: ~   ×
ubuntu@cs6903-17:~$ openssl x509 -req -in bob_csr.csr -CA int.crt -CAkey int_private_key
.pem -CAcreateserial -out bob_crt.crt -days 90 -extfile bobInt.cnf -extensions req_ext
Certificate request self-signature ok
subject=C = IN, ST = Telangana, L = Hyderabad, O = IIT H, OU = CSE, CN = bob1.com, email
Address = cs23mtech11005@iith.ac.in
ubuntu@cs6903-17:~$
```

8. Now the intermediate CA will push the certificate of Bob to bob's container.

```
ubuntu@cs6903-17: ~
root@bob1: ~   ×   ubuntu@cs6903-17: ~   ×
ubuntu@cs6903-17:~$ lxc file push bob_crt.crt bob1/root/
ubuntu@cs6903-17:~$
```

```
root@bob1:~# ls
bob_crt.crt  bob_csr.csr  bob_private_key.pem  bob_public_key.pem  snap
root@bob1:~#
```

9. Now Intermediate CA will generate the certificate chain and send it to bob.

```
ubuntu@cs6903-17:~$ cat bob_crt.crt int.crt root.crt > bob_chain.crt
ubuntu@cs6903-17:~$ ls
aliceInt.cnf      bob_crt.crt   int.csr                   root.crt
alice_chain.crt   bob_csr.csr   intRoot.cnf               root_private_key.pem
alice_crt.crt     c             int_private_key.pem       root_public_key.pem
alice_csr.csr     commands.txt  int_public_key.pem        snap
bob.cnf           cpp           poison-dns-alice1-bob1.sh unpoison-dns-alice1-bob1.sh
bobInt.cnf        int.cnf       python
bob_chain.crt     int.crt       root.cnf
ubuntu@cs6903-17:~$ lxc file push bob_chain.crt bob1/root/
ubuntu@cs6903-17:~$
```

```
root@bob1:~# ls
bob_chain.crt  bob_crt.crt  bob_csr.csr  bob_private_key.pem  bob_public_key.pem  snap
root@bob1:~#
```

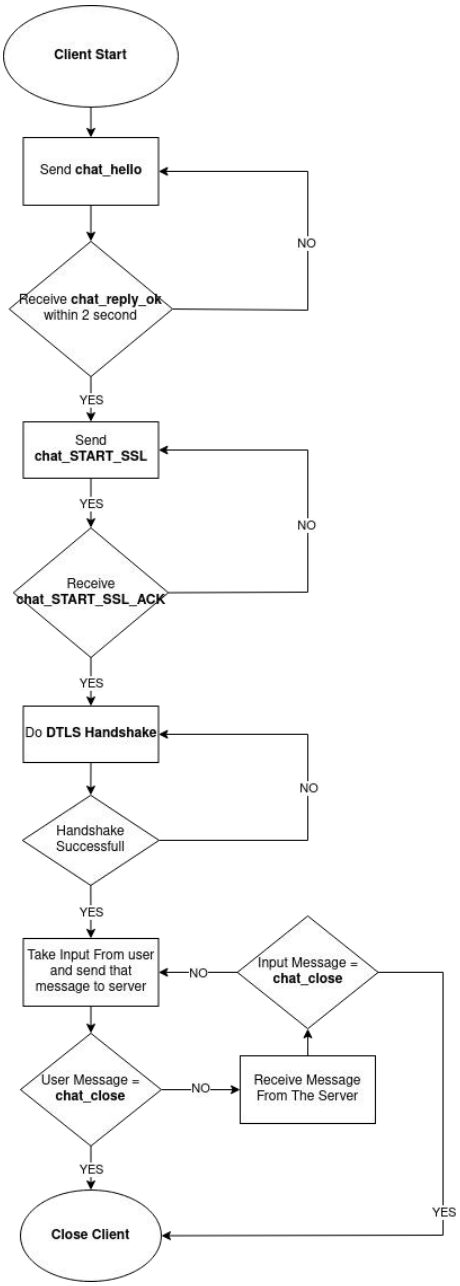
10. Now bob will verify that the certificate is indeed coming from Intermediate CA.

```
root@bob1:~# openssl verify -CAfile root.crt -untrusted int.crt bob_chain.crt
bob_chain.crt: OK
root@bob1:~#
```

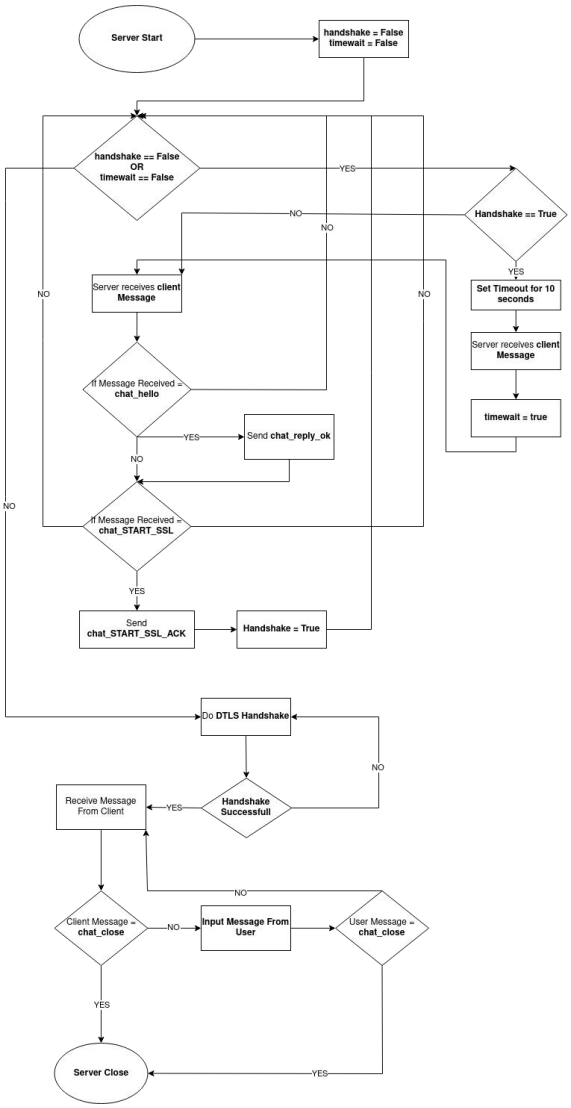
Now for converting every .csr/.crt/.key file to .pem file
By using the command
Openssl rsa/ec -in <filename> -out <filename>

Task 2

Flowchart for Client

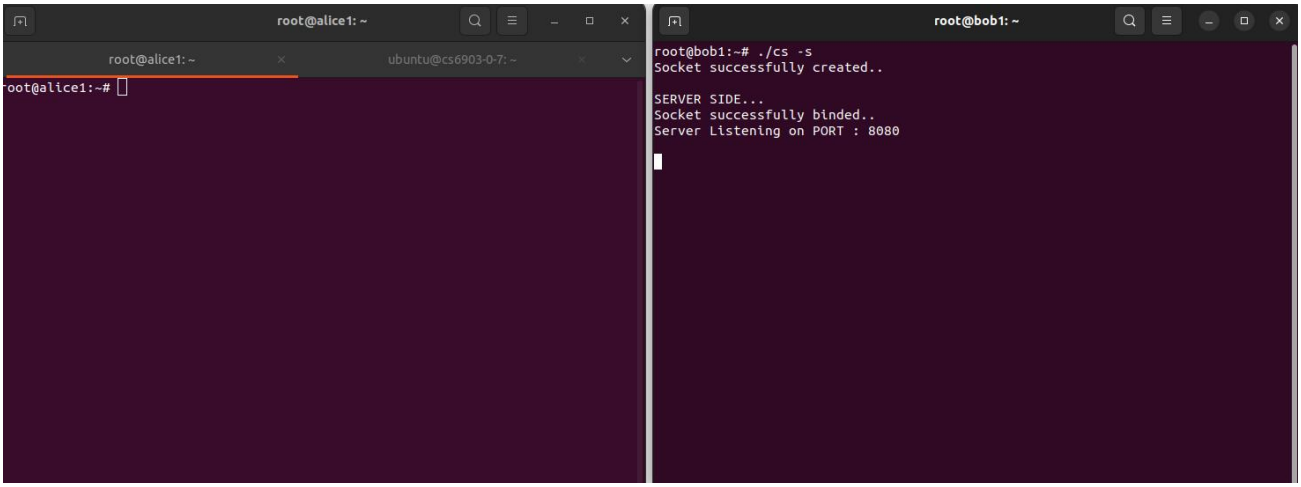


Flow Chart for Server

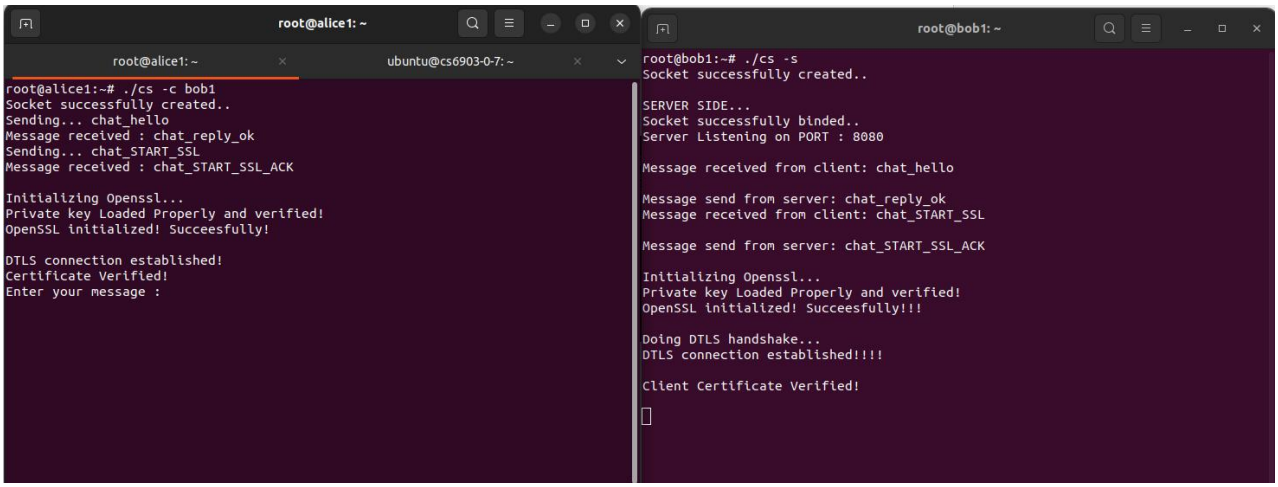


Steps for **without packet loss**:

1. Server Running on Port 8080:

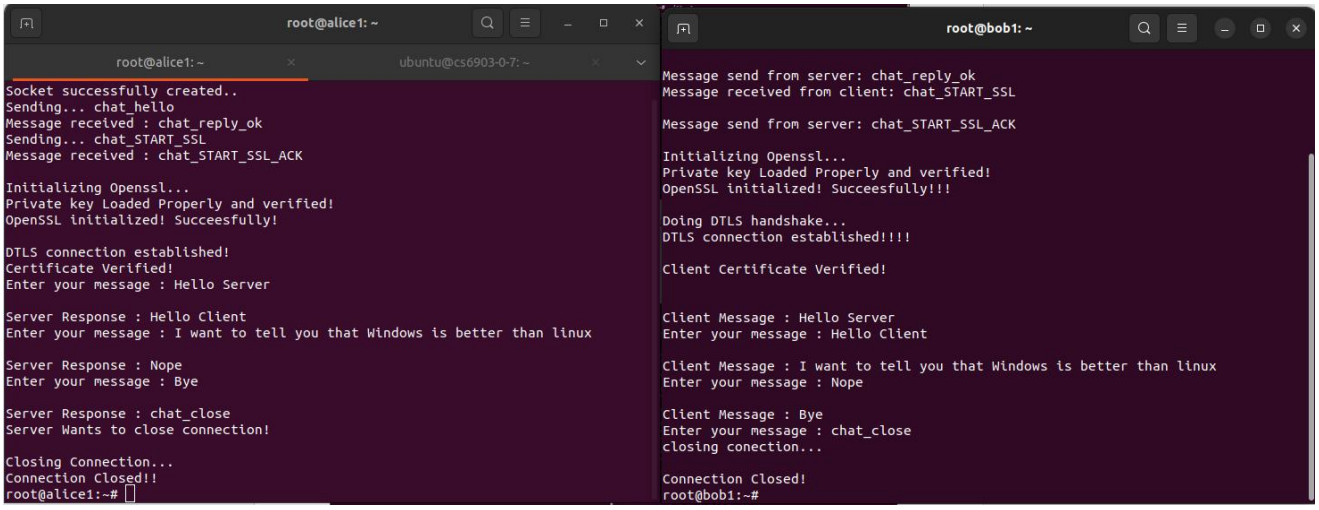


2. Now running the client: As we can see that the client is successfully connected to the server, and
    a. The Initial 4 Messages were sent and received successfully.
    b. OpenSSL Initialized
    c. Keys and certificates are loaded properly
    d. DTLS handshake is done successfully



3. Now Client and Server will chat with each other, such that
    a. First Client will send a message to server

b. Then the server will reply with a message to the client.
c. Now if either of them sends a ***chat_close*** message then both the client and server will stop.



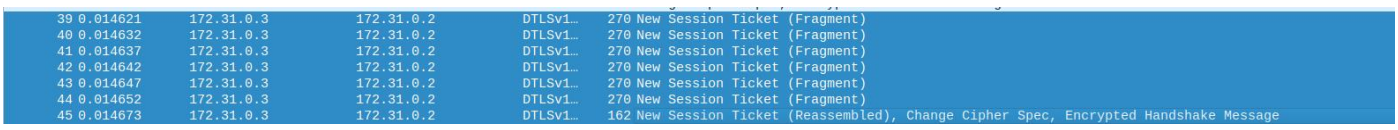
4. This also supports session resumption so here is how server is generating the session cookie

```c
int generateCookie(SSL *ssl_context, unsigned char *session_cookie, unsigned int *cookie_len)
{
    memcpy(session_cookie, "ses_co", 6);
    *cookie_len = 6;

    return 1;
}
```

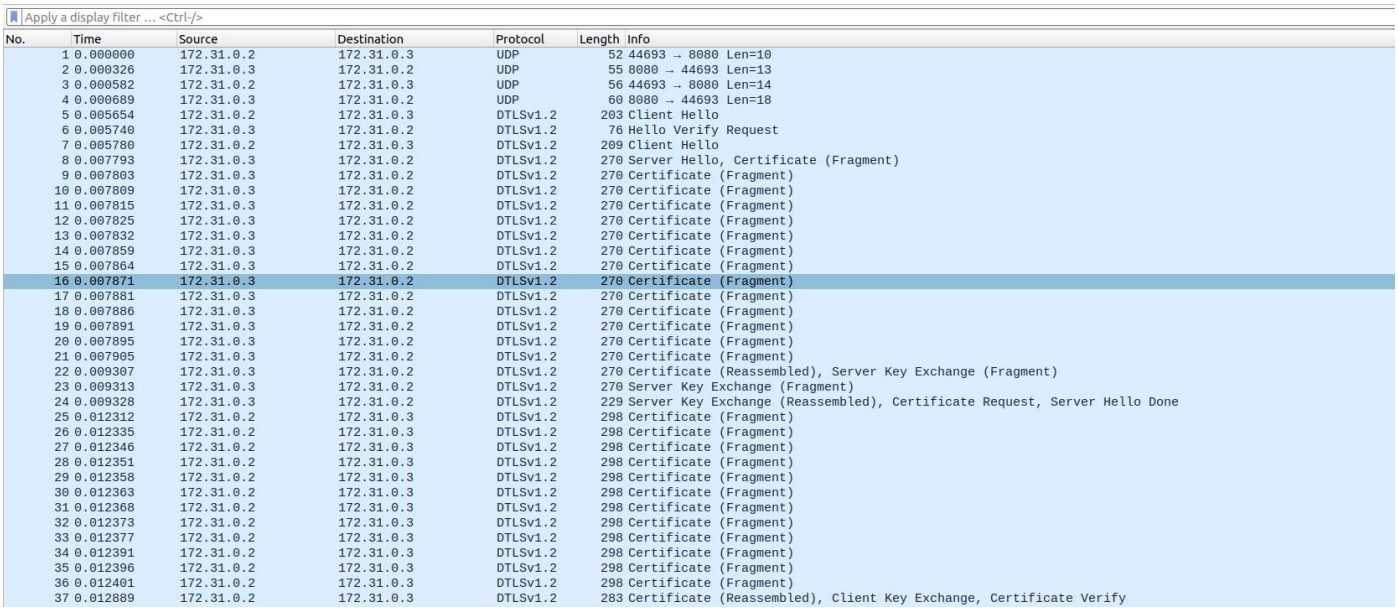
a. This function takes input
    i. The current ssl context
    ii. An empty unsigned char* variable(session_cookie) for filling up with session cookie.
    iii. The length of the cookie

b. Then this function generates a session cookie and copies it in **session_cookie** variable. OBJ

5. We can see the same in Wireshark that server is sending session ticket to the client



6. We can also see in Wireshark that the initial messages are going int UDP plain text then there is certificate exchange over DTLSv 1.2 protocol.



Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	172.31.0.2	172.31.0.3	UDP	52	44693 → 8080 Len=10
2	0.000326	172.31.0.3	172.31.0.2	UDP	55	8080 → 44693 Len=13
3	0.000582	172.31.0.2	172.31.0.3	UDP	56	44693 → 8080 Len=14
4	0.000689	172.31.0.3	172.31.0.2	UDP	60	8080 → 44693 Len=18
5	0.005654	172.31.0.2	172.31.0.3	DTLSv1.2	203	Client Hello
6	0.005740	172.31.0.3	172.31.0.2	DTLSv1.2	76	Hello Verify Request
7	0.005780	172.31.0.2	172.31.0.3	DTLSv1.2	209	Client Hello
8	0.007793	172.31.0.3	172.31.0.2	DTLSv1.2	270	Server Hello, Certificate (Fragment)
9	0.007803	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
10	0.007809	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
11	0.007815	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
12	0.007825	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
13	0.007832	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
14	0.007859	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
15	0.007864	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
16	0.007871	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
17	0.007881	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
18	0.007886	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
19	0.007891	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
20	0.007895	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
21	0.007905	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Fragment)
22	0.009307	172.31.0.3	172.31.0.2	DTLSv1.2	270	Certificate (Reassembled), Server Key Exchange (Fragment)
23	0.009313	172.31.0.3	172.31.0.2	DTLSv1.2	270	Server Key Exchange (Fragment)
24	0.009328	172.31.0.3	172.31.0.2	DTLSv1.2	229	Server Key Exchange (Reassembled), Certificate Request, Server Hello Done
25	0.012312	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
26	0.012335	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
27	0.012346	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
28	0.012351	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
29	0.012358	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
30	0.012363	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
31	0.012368	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
32	0.012373	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
33	0.012377	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
34	0.012391	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
35	0.012396	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
36	0.012401	172.31.0.2	172.31.0.3	DTLSv1.2	298	Certificate (Fragment)
37	0.012889	172.31.0.2	172.31.0.3	DTLSv1.2	283	Certificate (Reassembled), Client Key Exchange, Certificate Verify

7. This is the code snippet which loads and verifies the certificates: On the client side **workAsClient** will be true while on the server side it will be false.

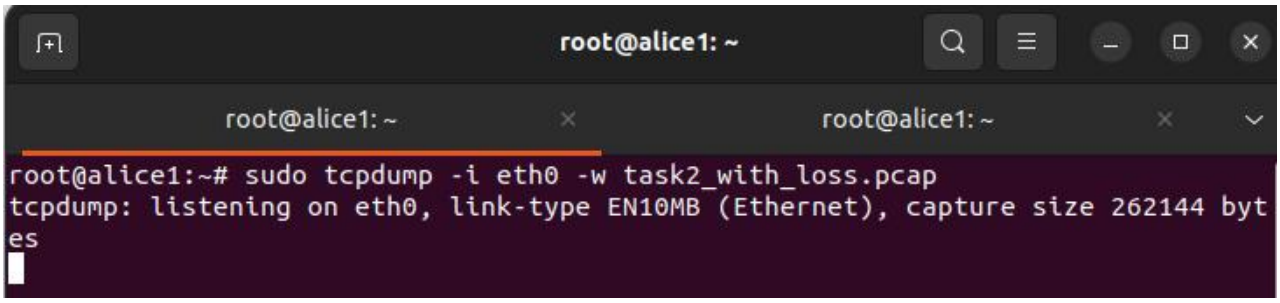
```
void loadCertificates()
{
    const char *certificate;
    const char *privateKey;
    const char *chain;
    const char *CAfile = "CAfile.pem";

    if (workAsClient == true)
    {
        certificate = "alice_crt.pem";
        privateKey = "alice_private_key.pem";
        // chain = "alice_chain.pem";
    }
    else
    {
        certificate = "bob_crt.pem";
        privateKey = "bob_private_key.pem";
        // chain = "bob_chain.pem";
    }

    // Load Certificate
    if (SSL_CTX_use_certificate_file(ssl_context, certificate, SSL_FILETYPE_PEM) <= 0)
    {
        ERR_print_errors_fp(stderr);
        cout << "error in cert\n";
        exit(EXIT_FAILURE);
    }

    // Load Private Key
    if (SSL_CTX_use_PrivateKey_file(ssl_context, privateKey, SSL_FILETYPE_PEM) <= 0)
    {
        ERR_print_errors_fp(stderr);
        cout << "error in key\n";
        exit(EXIT_FAILURE);
    }

    // Verify private key
    if (!SSL_CTX_check_private_key(ssl_context))
    {
        cout << "Private Key Verification failed!\n";
        exit(0);
    }

    cout << "Private key Loaded Properly and verified!!!\n";

    // Load CAfile and verify
    if (!SSL_CTX_load_verify_locations(ssl_context, CAfile, NULL))
    {
        ERR_print_errors_fp(stderr);
        cout << " -CA verification failed \n";
        exit(EXIT_FAILURE);
    }

    // Client/Server Certificate verification
    SSL_CTX_set_verify(ssl_context, SSL_VERIFY_PEER | SSL_VERIFY_FAIL_IF_NO_PEER_CERT, NULL);
}
```

8. We can also see that the application data is going over DTLSv 1.2.

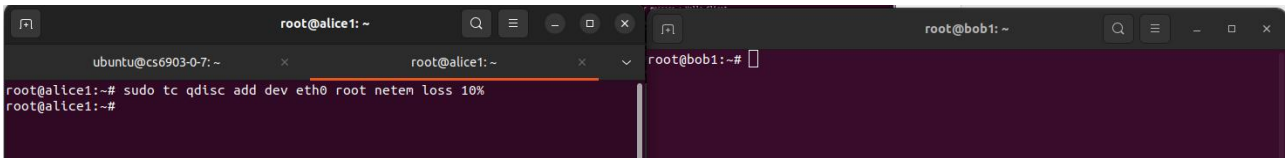
50	17.341578	172.31.0.2	172.31.0.3	DTLSv1.2	91	Application Data
51	22.019881	172.31.0.3	172.31.0.2	DTLSv1.2	91	Application Data
52	68.302001	172.31.0.2	172.31.0.3	DTLSv1.2	131	Application Data
53	72.210166	172.31.0.3	172.31.0.2	DTLSv1.2	83	Application Data
54	73.349652	Xensourc_ae:c3:fd	Xensourc_d2:a2:f0	ARP	42	Who has 172.31.0.3? Tell 172.31.0.2
55	73.349793	Xensourc_d2:a2:f0	Xensourc_ae:c3:fd	ARP	42	172.31.0.3 is at 00:16:3e:d2:a2:f0
56	77.445803	Xensourc_d2:a2:f0	Xensourc_ae:c3:fd	ARP	42	Who has 172.31.0.2? Tell 172.31.0.3
57	77.445848	Xensourc_ae:c3:fd	Xensourc_d2:a2:f0	ARP	42	172.31.0.2 is at 00:16:3e:ae:c3:fd
58	83.611481	172.31.0.2	172.31.0.3	DTLSv1.2	82	Application Data
59	88.369408	172.31.0.3	172.31.0.2	DTLSv1.2	89	Application Data

Steps for **with packet loss**:

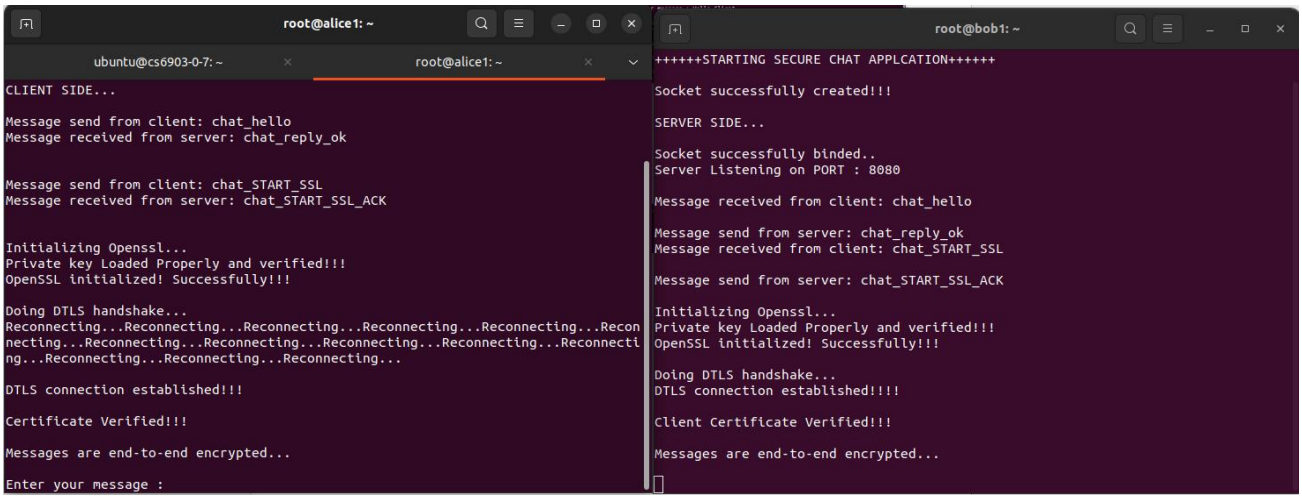
1. Start Capturing TCP DUMP on the Alice side.



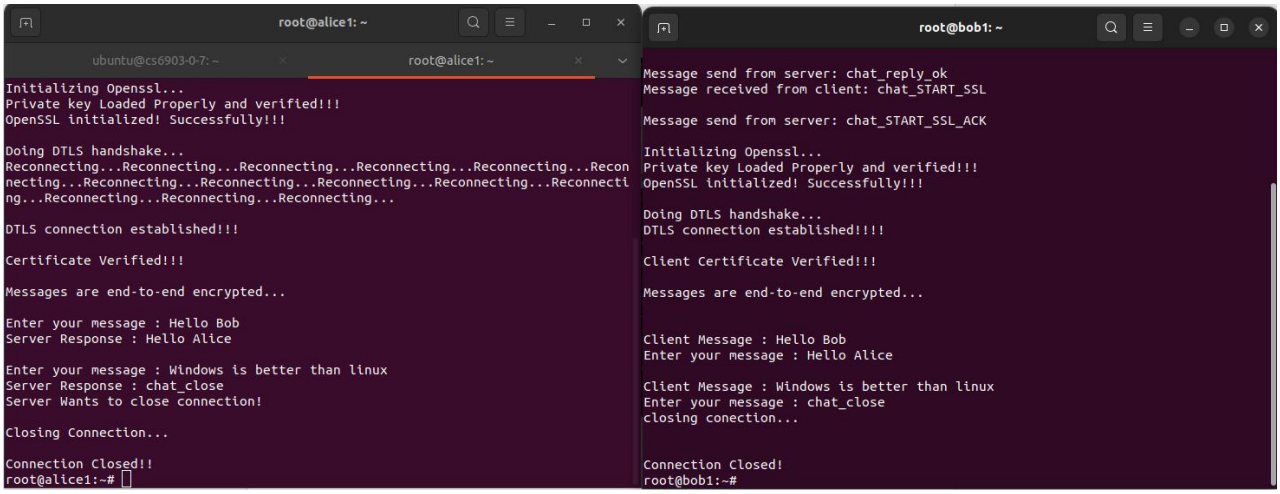
2. Injection Packet loss on the side of Alice.



3. Now running the app again, as we can see that there were packet losses during the DTLS handshake and client is trying multiple times to connect to the server.



4. Now Alice and Bob chat with each other and finally close the chat.



5. For Reliable communication we first un-block the socket using this function, when the socket is int the non-blocking mode the functions like read (), write (), connect (), do not wait for the operations to complete and will return immediately which in turn keeps our code running.

```
int unBlockSocket()
{
    int flags = fcntl(sockfd, F_GETFL, 0);
    if (flags == -1)
    {
        cout << "Error in making the socket non blocking\n Err :: Flag = -1\n";
        perror("fcntl");
        return -1;
    }

    if (fcntl(sockfd, F_SETFL, flags | O_NONBLOCK) == -1)
    {
        cout << "Error in making the socket non blocking\n Err :: fcntrl failed to set the new flag!\n";
        perror("fcntl");
        return -1;
    }

    return 0;
}
```

This function does the following

a. First it will take the file status flag from fcntl function associated with the socket file descriptor(sockfd).
b. Then it will check whether the flag is –1 or not.

c. If it is not –1 then it will set **0_NONBLOCK** flag to the current socket file descriptor.

6. This is how SSL handshake will work on the client side

```
int erprint = 0;

if (workAsClient == true)
{
    int res = 0;
    int ub = -1;
    while (res <= 0)
    {
        while (ub == -1)
        {
            ub = unBlockSocket();
        }

        res = SSL_connect(ssl);

        if (res <= 0)
        {

            ERR_print_errors_fp(stderr);

            int error = SSL_get_error(ssl, res);
            if (erprint == 0)
                cout << "Reconnecting...";

            erprint = (erprint + 1) % 50000;
        }
    }
    cout << "\n\n";
}
```

a. We will keep calling unBlockSocket(), until the socket unblocks.
b. Then we will try to connect to the server using SSL_connect(), now if we get res <= 0, it means that connection failed so it will go back into the loop and will try to connect it again to the sever
c. As it connects to the server it will get out of the loop.

7. This is how SSL handshake works on server side.

```
while (res <= 0)
{
    res = DTLSv1_listen(ssl, (BIO_ADDR *)&addr);
    if (res < 0)
    {
        cout << "Error in connecting to Client Retrying...";
        ERR_print_errors_fp(stderr);
        continue;
    }
}

SSL_SESSION *session = SSL_get_session(ssl);

while (true)
{
    while (ub == -1)
    {
        ub = unBlockSocket();
    }

    int resa = SSL_accept(ssl);
    if (resa > 0)
        break;
    if (resa <= 0)
    {
        cout << "Problem in SSL Accept! Retrying..." << endl;
        continue;
    }
}
```

a. The server will keep listening and if any error comes during listening, then it will go back in loop and listen again.
b. We will keep calling unBlockSocket(), until the socket unblocks.
c. Then the server will accept a connection and if there is any problem in accepting the connection then it will go in accept mode again.
d. If the accept connection is successful, then it will exit the loop.

8. Handling packet loss in initial messages on server side.

Here we are working inside the loop with condition as both **handshake** and **timewait** should be true to end the loop. Basically, we in server side we must receive 2 message **chat_hello** and **chat_START_SSL.** After receiving **chat_hello** server will reply with **chat_reply_ok** and after getting **chat_START_SSL** server will reply **chat_START_SSL _ACK** and set handshake as true. Then in the next iteration since handshake will be true so code will go into if condition and socket will be configured to listen for 10 sec so that if

another message comes client server should listen it and process it. Once time wait is true it will come out of the loop.

```
while (!handShake || !timewait)
{
    if (handShake)
    {
        // cout << "TIMEWAIT>>>\n";
        timewait_handshake.tv_sec = 10;
        timewait_handshake.tv_usec = 0;

        if (setsockopt(sockfd, SOL_SOCKET, SO_RCVTIMEO, (char *)&timewait_handshake, sizeof(timewait_handshake)) < 0)
        {
            std::cerr << "Error setting timeout\n";
            close(sockfd);
            return;
        }

        clientMssg = recvMessage(false);
        timewait = true;
    }

    clientMssg = recvMessage(true);

    if (clientMssg == "chat_hello")
    {
        sendMessage("chat_reply_ok");
    }

    if (clientMssg == "chat_START_SSL")
    {
        sendMessage("chat_START_SSL_ACK");
        handShake = true;
    }
}
```

9. Handling packet loss in initial messages on client side.

Client has to send 2 initial messages **chat_hello** and **chat_START_SSL** so here after sending each message we are waiting to receive some response from server and according to server side as we have seen we are sending **chat_REPLY_OK** and **chat_START_SSL_ACK** respectively after r eceiving these messages.

```
string serverMessage = "";
while (serverMessage == "")
{
    sendMessage("chat_hello");
    serverMessage = recvMessage(true);
    cout << endl;
}

serverMessage = "";

while (serverMessage == "")
{
    sendMessage("chat_START_SSL");
    serverMessage = recvMessage(true);
    cout << endl;
}
```

Q. Compare and Contrast DTLSv 1.2 Handshake with TLSv 1.2 handshake
Similarity between DTLS 1.2 and TLS 1.2 handshake.

Similarity between DTLSv1.2 Handshake and TLSv1.2 Handshake.

1. **Security Goals:** Both DTLS 1.2 and TLS 1.2 aim to establish secure end-to-end connection between client and server, ensuring confidentiality, integrity, authenticity of Data transmission.
2. **Message flow:** The message flow in both is the same. Both protocols follow a similar pattern to establish a secure and authenticated connection between the client and server.

- ClientHello
- ServerHello
- Certificate Exchange
- ServerKeyExchange
- ClientKeyExchange
- Finished Message exchange
- Session Establishment

3. **Verify Authenticity:** During handshake both protocols negotiate cryptographic parameters, exchange keys and certificates. Both protocols verify the identity and authenticity of the communicating

parties. These certificates are used to verify the identities of the communicating parties and establish trust in their authenticity.

4. **Key exchange:** Both protocols facilitate the exchange of cryptographic keys during the handshake to establish a secure connection. This key exchange is essential for enabling encryption and integrity protection of the data transmitted between the client and server.

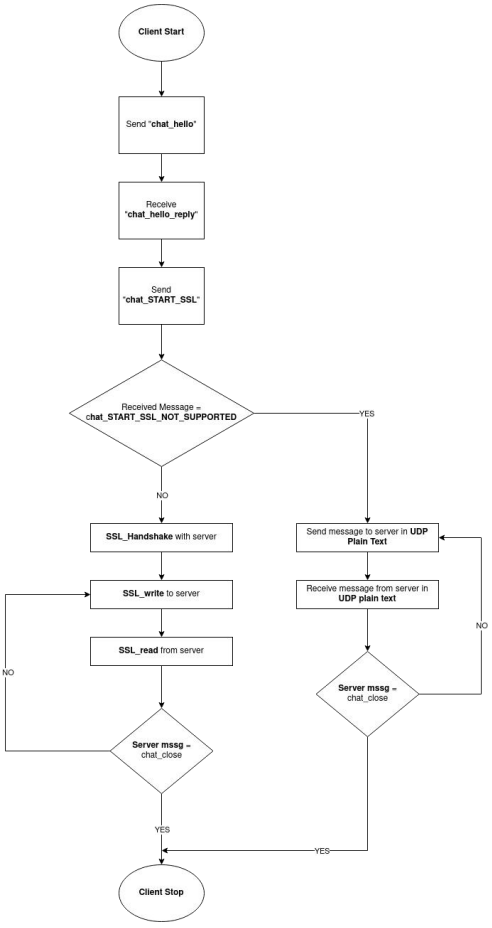
5. **Cipher suites:** Both support cipher suites, which are combinations of cryptographic algorithms used for securing communication. During the handshake, both protocols negotiate and agree upon a cipher suite to use for encrypting and protecting data exchanged between the client and server.

Difference between DTLSv1.2 and TLSv1.2 handshake.

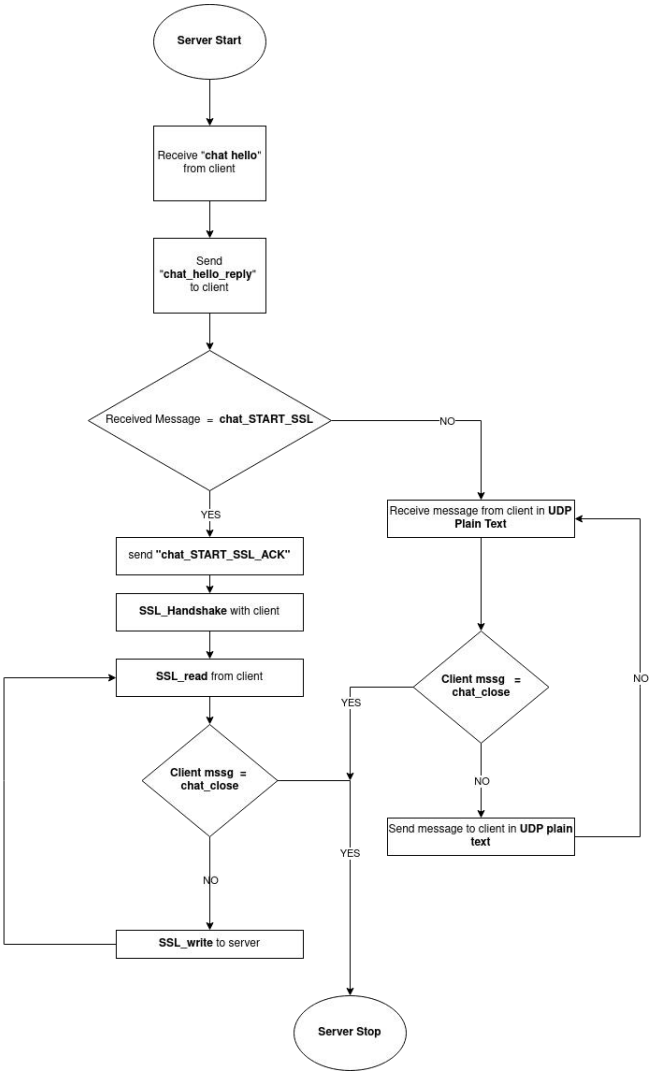
Criteria	DTLS 1.2	TLS 1.2
Underlying Transport layer protocol	DTLS (Datagram Transport Layer Security) is designed for datagram protocols like UDP, which are unreliable and may suffer from packet loss, reordering, or duplication.	TLS (Transport Layer Security) typically operates over reliable stream-oriented protocols like TCP, ensuring in-order and error-free delivery.
Time to establish	Since DTLS 1.2 is established over UDP, time for establishing reliable connection is saved. So, handshake is faster in DTLS	Since TLS 1.2 is established over TCP, it establishes reliable handshake and for that it requires at least 1 RTT time. So, it takes more time to establish connection in TLS 1.2
Reliability Handling	DTLS 1.2 includes mechanisms to handle unreliability in the underlying transport protocol, such as retransmissions and acknowledgment mechanisms during handshake.	TLS 1.2 assumes reliability provided by TCP, so it doesn't include specific mechanisms for handling packet loss or reordering during the handshake.
Record Layer	DTLS 1.2 uses records that can be sent entirely or not.	TLS 1.2 divides data into multiple chunks transparently to applications
Replay Detection	Replay Detection is an optional feature of DTLS 1.2.	Replay Detection is a required feature of TLS 1.2.
IP Spoofing Protection	DTLS 1.2 uses cookies to prevent IP spoofing, allowing communication without revealing the real IP address.	TLS 1.2 relies on the established TCP handshake, making IP spoofing more difficult.

Task 3

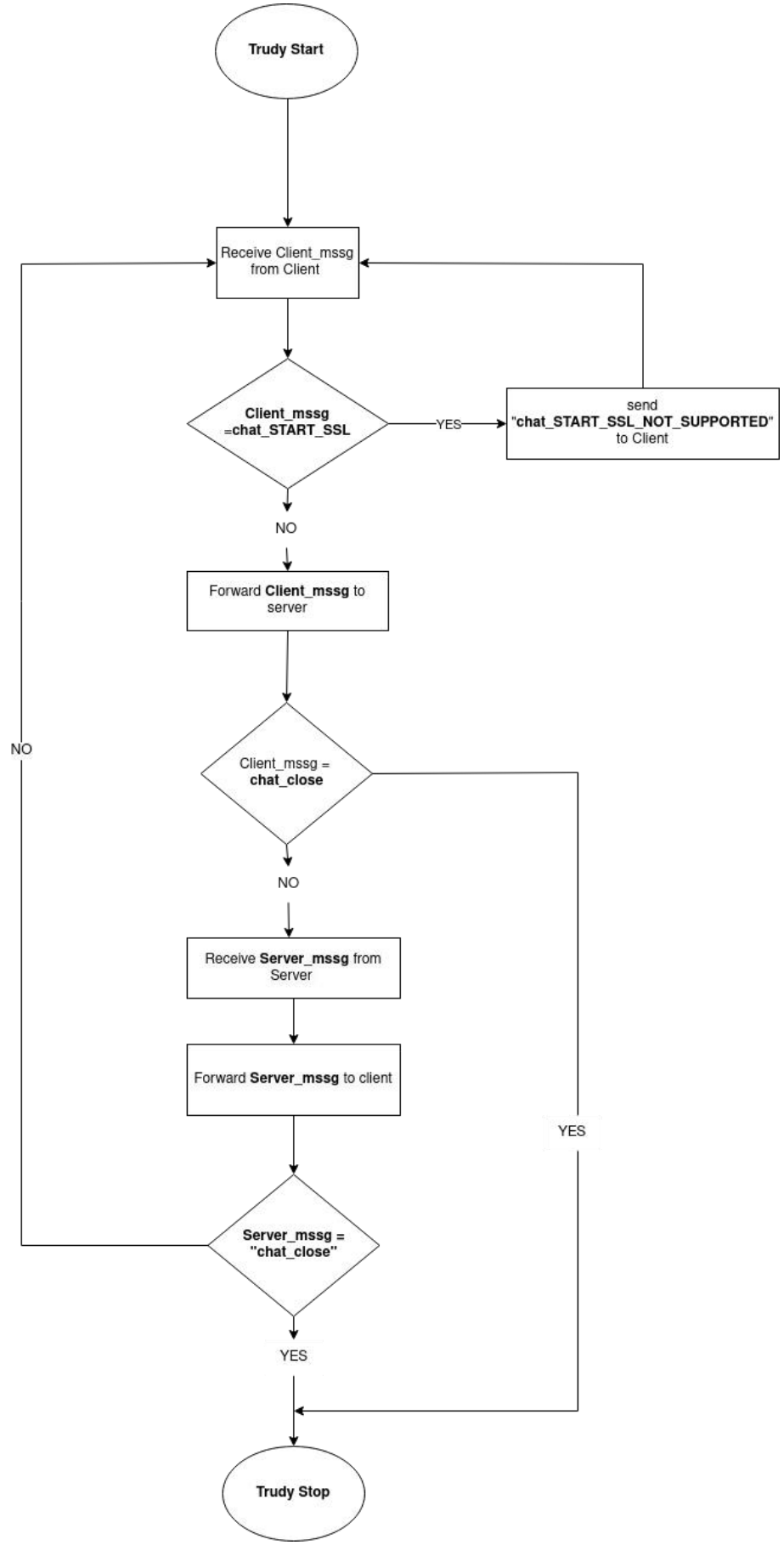
Flowchart For Client



Flowchart for Server

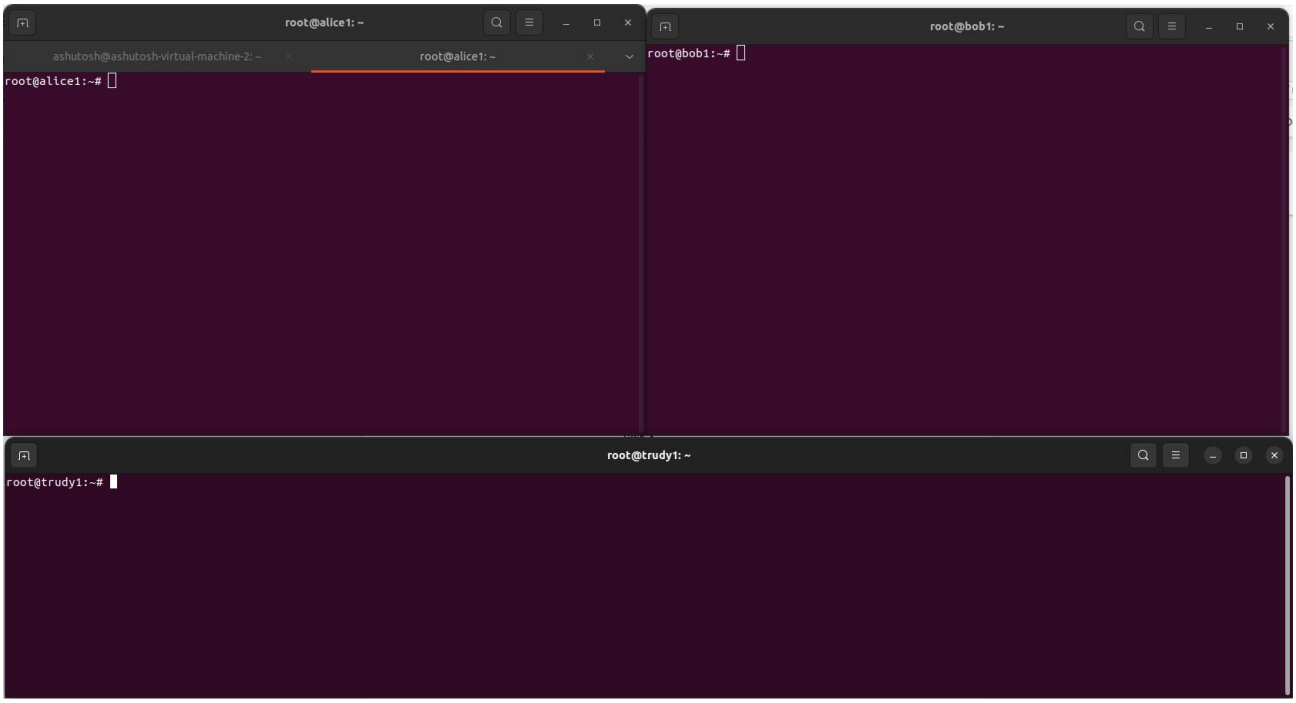


Flowchart for Trudy:

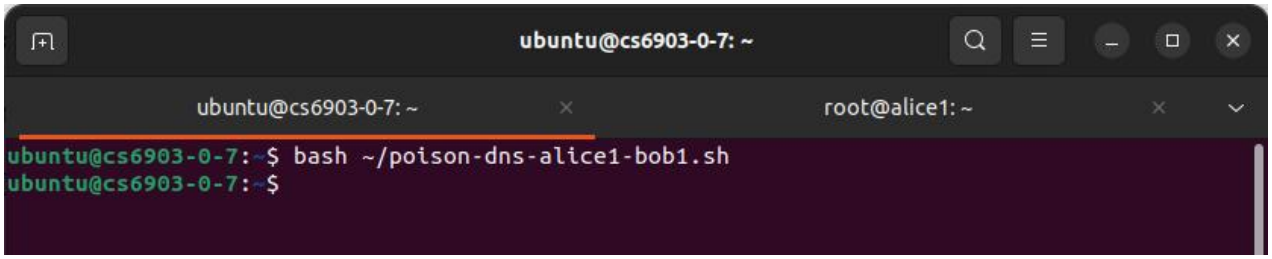


Steps:

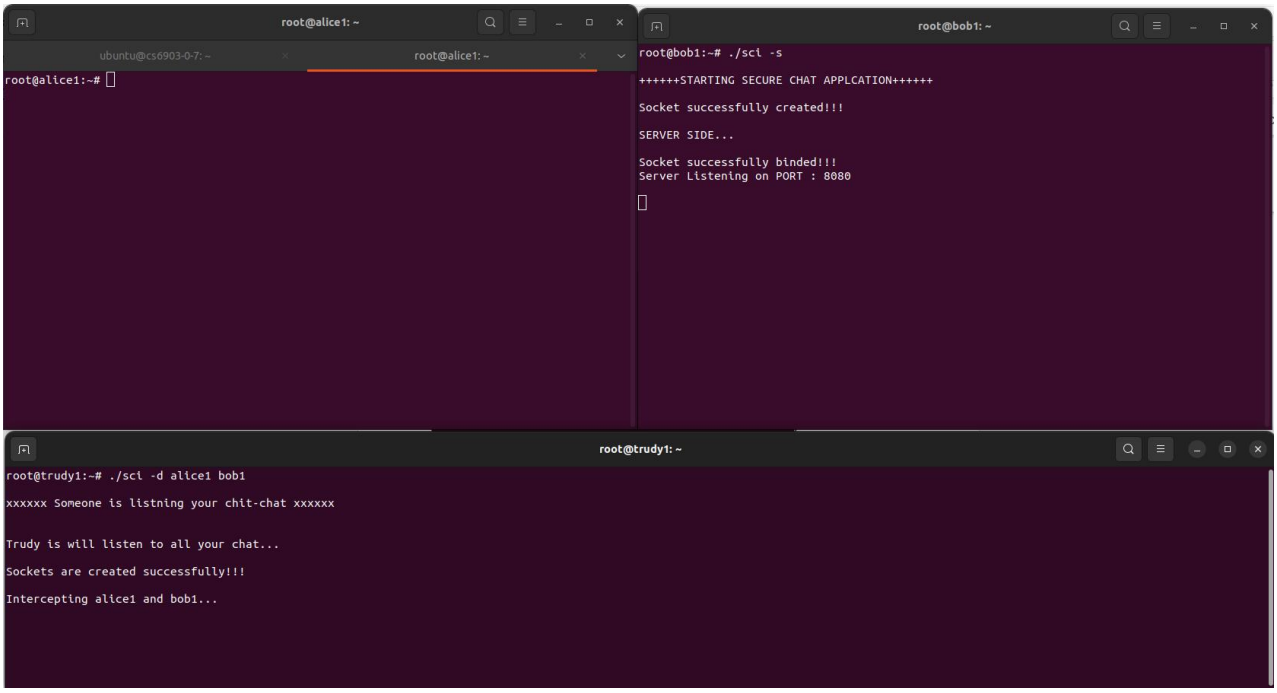
1. Starting Containers of Alice, Bob, trudy



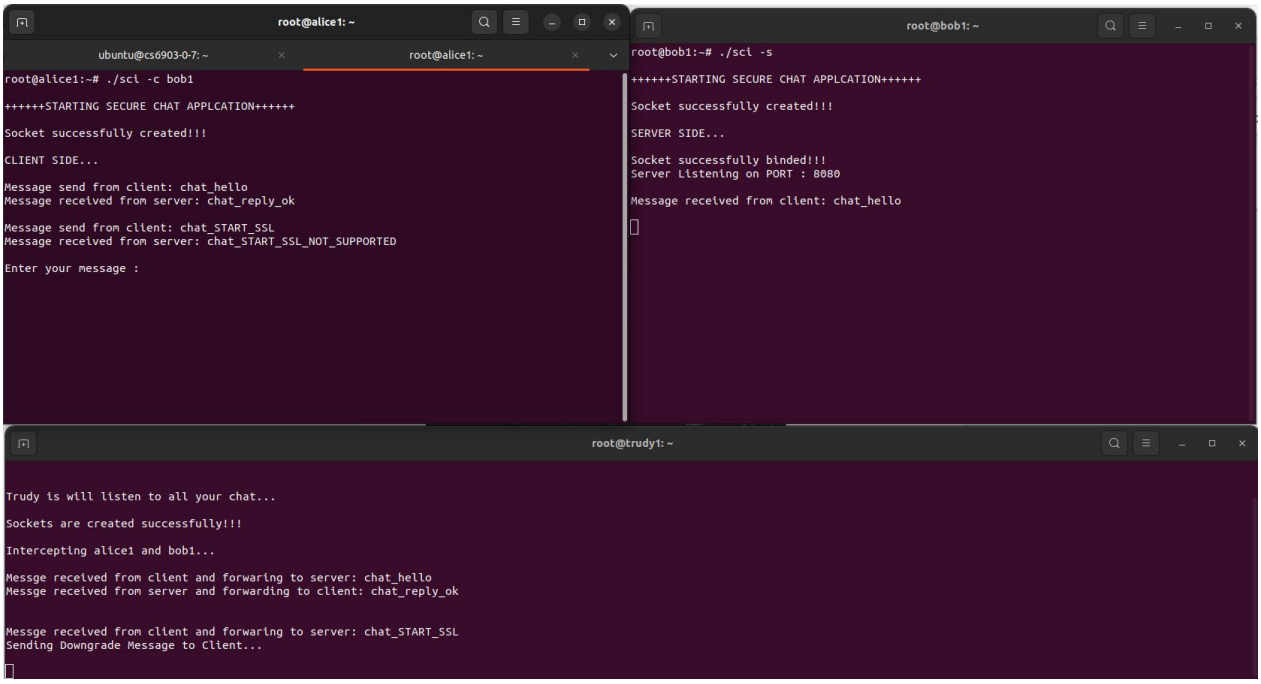
2. Now doing DNS poisoning from the VM



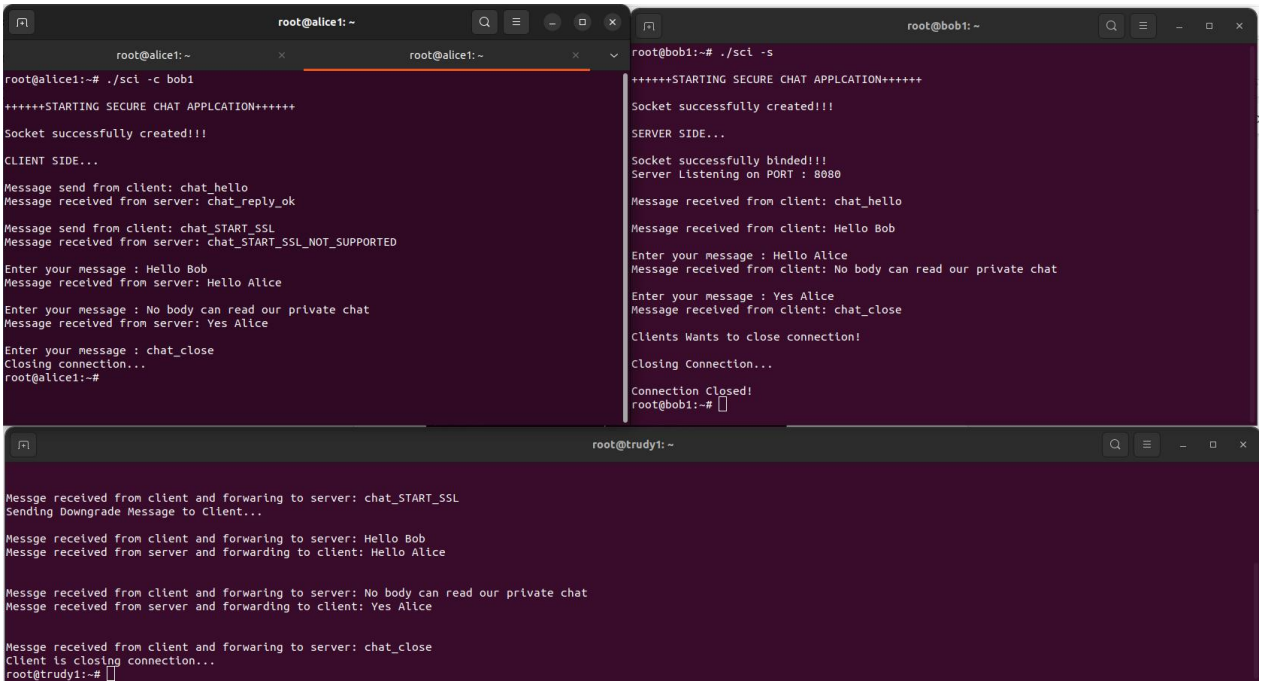
3. Now Running Server at Bob and Trudy



4. Now Connecting Alice with Bob



5. Now Alice and Bob start chatting, and Trudy will now start intercepting



6. There are two sockets in Trudy
    a. Client_socket : which talks with the client
    b. Server_socket: which talks with the server

```
// Client socket will talk to client(Alice)
// Server socket will talk to Server(Bob)
cout << "\nTrudy is will listen to all your chat...\n\n";
int client_sock, server_sock;
socklen_t client_len, server_len;
char buffer[MAX];
struct sockaddr_in client_addr, server_addr;

// Create UDP socket for Alice
if ((client_sock = socket(AF_INET, SOCK_DGRAM, 0)) < 0)
    printf("ERROR opening socket for Alice");

// Create UDP socket for server
if ((server_sock = socket(AF_INET, SOCK_DGRAM, 0)) < 0)
    printf("ERROR opening socket for server");

cout << "Sockets are created successfully!!!\n";

// Initialize Alice address
memset((char *)&client_addr, 0, sizeof(client_addr));
client_addr.sin_family = AF_INET;
client_addr.sin_addr.s_addr = htonl(INADDR_ANY);
client_addr.sin_port = htons(DEFAULT_PORT);

// Initiai=lize server address
memset((char *)&server_addr, 0, sizeof(server_addr));
server_addr.sin_family = AF_INET;
server_addr.sin_port = htons(DEFAULT_PORT);

struct hostent *host_info = gethostbyname(server);
bcopy((char *)host_info->h_addr, (char *)&server_addr.sin_addr.s_addr, host_info->h_length);

// Bind the Alice socket
if (bind(client_sock, (struct sockaddr *)&client_addr, sizeof(client_addr)) < 0)
    printf("ERROR on binding CLIENT socket\n");

cout << "\nIntercepting " << client << " and " << server << "...\n\n";
```

7. This is the heart of the Trudy code

```
client_len = sizeof(client_addr);
memset(buffer, 0, MAX);

int n = recvfrom(client_sock, (char *)buffer, MAX, MSG_WAITALL, (struct sockaddr *)&client_addr, &client_len);
if (n < 0)
{
    printf("ERROR in receiving from from Alice");
}
buffer[n] = '\0';

cout << "Messge received from client and forwaring to server: " << buffer << endl;

if (strcmp(buffer, "chat_START_SSL") == 0)
{
    fillBuffer(buffer, "chat_START_SSL_NOT_SUPPORTED");
    client_len = sizeof(client_addr);
    cout << "Sending Downgrade Message to Client...\n\n";

    if (sendto(client_sock, buffer, strlen(buffer), 0, (struct sockaddr *)&client_addr, client_len) < 0)
        printf("ERROR in sendinf to to Alice");
    continue;
}

server_len = sizeof(server_addr);
if (sendto(server_sock, buffer, strlen(buffer), 0, (struct sockaddr *)&server_addr, server_len) < 0)
    printf("ERROR in sending to server");

if (strcmp(buffer, "chat_close") == 0)
{
    cout << "Client is closing connection...\n";
    break;
}

// Receive response from server
memset(buffer, 0, MAX);
n = recvfrom(server_sock, buffer, MAX, 0, (struct sockaddr *)&server_addr, &server_len);
if (n < 0)
{
    printf("ERROR in receiving from server");
}
buffer[n] = '\0';
cout << "Messge received from server and forwarding to client: " << buffer << endl;

// Forward response from server to Alice
client_len = sizeof(client_addr);
if (sendto(client_sock, buffer, strlen(buffer), 0, (struct sockaddr *)&client_addr, client_len) < 0)
    printf("ERROR in sending to client");

if (strcmp(buffer, "chat_close") == 0)
{
    cout << "Server is closing connection...\n";
    break;
}
cout << "\n\n";
```

Here

a. Trudy will receive the message from the client and then check whether it is **chat_START_SSL** or not, if not then it will simply send the message to the server.

b. But if the message was **chat_START_SSL**, then it will send **chat_START_SSL_NOT_SUPPORTED** to client, and continue the loop means it will be again int the receiving state.
c. After that client and server will now talk in degraded mode

8. This is the code snippet from the server side

```
if (downgradeServer == true)
{
    bool loop = true;
    while (loop == true)
    {
        cout << "Enter your message : ";
        string userInput;
        getline(cin, userInput);

        while (userInput == "")
            ;

        sendMessage(userInput);
        if (userInput == "chat_close")
        {
            cout << "Closing connection...\n\n";
            break;
        }

        string clientMessage = recvMessage(true);
        // cout << "\nClient Message : " << clientMessage << endl;

        if (clientMessage == "chat_close")
        {
            cout << "Clients Wants to close connection!\n\nClosing Connection...";
            break;
        }
    }
}
else
{
    cout << "Message send from server: chat_START_SSL_ACK" << endl;
    sendMessage("chat_START_SSL_ACK");

    // Initializing OpenSSL
    cout << "\nInitializing Openssl... \n";
    initializeOpenSSL();
```

Here what's happening is if the **downgradeServer** is true then server will now send messages in UDP plain text else it will continue with SSL handshake and send messages through DTLSv 1.2.

9. Similarly on the client side we are handling downgrading situation

```
if (downgradeClient)
{
    bool loop = true;
    while (loop == true)
    {
        cout << "Enter your message : ";
        string userInput;

        getline(cin, userInput);

        while (userInput == "")
            ;

        sendMessage(userInput);
        if (userInput == "chat_close")
        {
            cout << "Closing connection... \n";
            break;
        }

        string serverResponse = recvMessage(true);
        // cout << "\nServer Response : " << serverResponse << endl;

        if (serverResponse == "chat_close")
        {
            cout << "Server Wants to close connection!\n\nClosing Connection...\n";
            break;
        }
    }
}
else
{
    // Initializing OpenSSL
    cout << "\nInitializing Openssl... \n";
    initializeOpenSSL();
```

If the client is downgraded, then it will send messages in UDP plain text.

10. Now we are checking this downgrading while receiving the messages
    a. Client
       Side

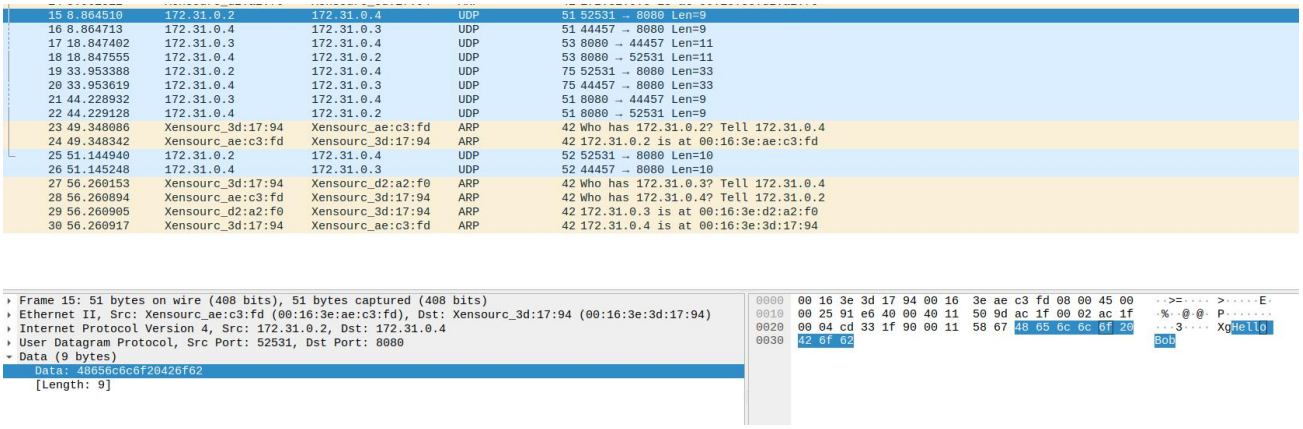
```
    if (ret == "chat_START_SSL_NOT_SUPPORTED")
    {
        downgradeClient = true;
    }
```

b. Server Side

```
if (ret == "chat_START_SSL")
{
    downgradeServer = false;
}
```

where **ret** is the message from the other party.

11. We can see the same thing in Wireshark also on the Trudy side
    a. First Trudy receives a message from Alice: Hello Bob

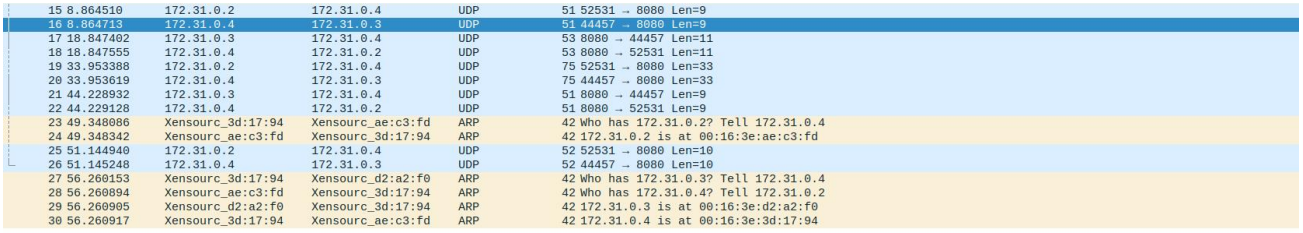


15	8.864510	172.31.0.2	172.31.0.4	UDP	51 52531 → 8080 Len=9
16	8.864713	172.31.0.4	172.31.0.3	UDP	51 44457 → 8080 Len=9
17	18.847402	172.31.0.3	172.31.0.4	UDP	53 8080 → 44457 Len=11
18	18.847555	172.31.0.4	172.31.0.2	UDP	53 8080 → 52531 Len=11
19	33.953388	172.31.0.2	172.31.0.4	UDP	75 52531 → 8080 Len=33
20	33.953619	172.31.0.4	172.31.0.3	UDP	75 44457 → 8080 Len=33
21	44.228932	172.31.0.3	172.31.0.4	UDP	51 8080 → 44457 Len=9
22	44.229128	172.31.0.4	172.31.0.2	UDP	51 8080 → 52531 Len=9
23	49.348086	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 Who has 172.31.0.2? Tell 172.31.0.4
24	49.348342	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 172.31.0.2 is at 00:16:3e:ae:c3:fd
25	51.144940	172.31.0.2	172.31.0.4	UDP	52 52531 → 8080 Len=10
26	51.145248	172.31.0.4	172.31.0.3	UDP	52 44457 → 8080 Len=10
27	56.260153	Xensourc_3d:17:94	Xensourc_d2:a2:f0	ARP	42 Who has 172.31.0.3? Tell 172.31.0.4
28	56.260894	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 Who has 172.31.0.4? Tell 172.31.0.2
29	56.260905	Xensourc_d2:a2:f0	Xensourc_3d:17:94	ARP	42 172.31.0.3 is at 00:16:3e:d2:a2:f0
30	56.260917	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 172.31.0.4 is at 00:16:3e:3d:17:94

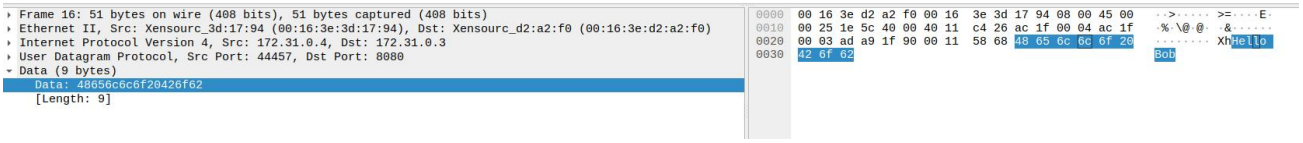

```
▸ Frame 15: 51 bytes on wire (408 bits), 51 bytes captured (408 bits)
▸ Ethernet II, Src: Xensourc_ae:c3:fd (00:16:3e:ae:c3:fd), Dst: Xensourc_3d:17:94 (00:16:3e:3d:17:94)
▸ Internet Protocol Version 4, Src: 172.31.0.2, Dst: 172.31.0.4
▸ User Datagram Protocol, Src Port: 52531, Dst Port: 8080
▾ Data (9 bytes)
    Data: 48656c6c6f20426f62
    [Length: 9]
```

```
0000  00 16 3e 3d 17 94 00 16  3e ae c3 fd 08 00 45 00   ··>=···· >·····E·
0010  00 25 91 e6 40 00 40 11  50 9d ac 1f 00 02 ac 1f   ·%··@·@· P·······
0020  00 04 cd 33 1f 90 00 11  58 67 48 65 6c 6c 6f 20   ···3···· XgHello
0030  42 6f 62                                          Bob
```

    b. Now Trudy will send this message to Bob



15	8.864510	172.31.0.2	172.31.0.4	UDP	51 52531 → 8080 Len=9
16	8.864713	172.31.0.4	172.31.0.3	UDP	51 44457 → 8080 Len=9
17	18.847402	172.31.0.3	172.31.0.4	UDP	53 8080 → 44457 Len=11
18	18.847555	172.31.0.4	172.31.0.2	UDP	53 8080 → 52531 Len=11
19	33.953388	172.31.0.2	172.31.0.4	UDP	75 52531 → 8080 Len=33
20	33.953619	172.31.0.4	172.31.0.3	UDP	75 44457 → 8080 Len=33
21	44.228932	172.31.0.3	172.31.0.4	UDP	51 8080 → 44457 Len=9
22	44.229128	172.31.0.4	172.31.0.2	UDP	51 8080 → 52531 Len=9
23	49.348086	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 Who has 172.31.0.2? Tell 172.31.0.4
24	49.348342	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 172.31.0.2 is at 00:16:3e:ae:c3:fd
25	51.144940	172.31.0.2	172.31.0.4	UDP	52 52531 → 8080 Len=10
26	51.145248	172.31.0.4	172.31.0.3	UDP	52 44457 → 8080 Len=10
27	56.260153	Xensourc_3d:17:94	Xensourc_d2:a2:f0	ARP	42 Who has 172.31.0.3? Tell 172.31.0.4
28	56.260894	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 Who has 172.31.0.4? Tell 172.31.0.2
29	56.260905	Xensourc_d2:a2:f0	Xensourc_3d:17:94	ARP	42 172.31.0.3 is at 00:16:3e:d2:a2:f0
30	56.260917	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 172.31.0.4 is at 00:16:3e:3d:17:94



```
▸ Frame 16: 51 bytes on wire (408 bits), 51 bytes captured (408 bits)
▸ Ethernet II, Src: Xensourc_3d:17:94 (00:16:3e:3d:17:94), Dst: Xensourc_d2:a2:f0 (00:16:3e:d2:a2:f0)
▸ Internet Protocol Version 4, Src: 172.31.0.4, Dst: 172.31.0.3
▸ User Datagram Protocol, Src Port: 44457, Dst Port: 8080
▾ Data (9 bytes)
    Data: 48656c6c6f20426f62
    [Length: 9]
```

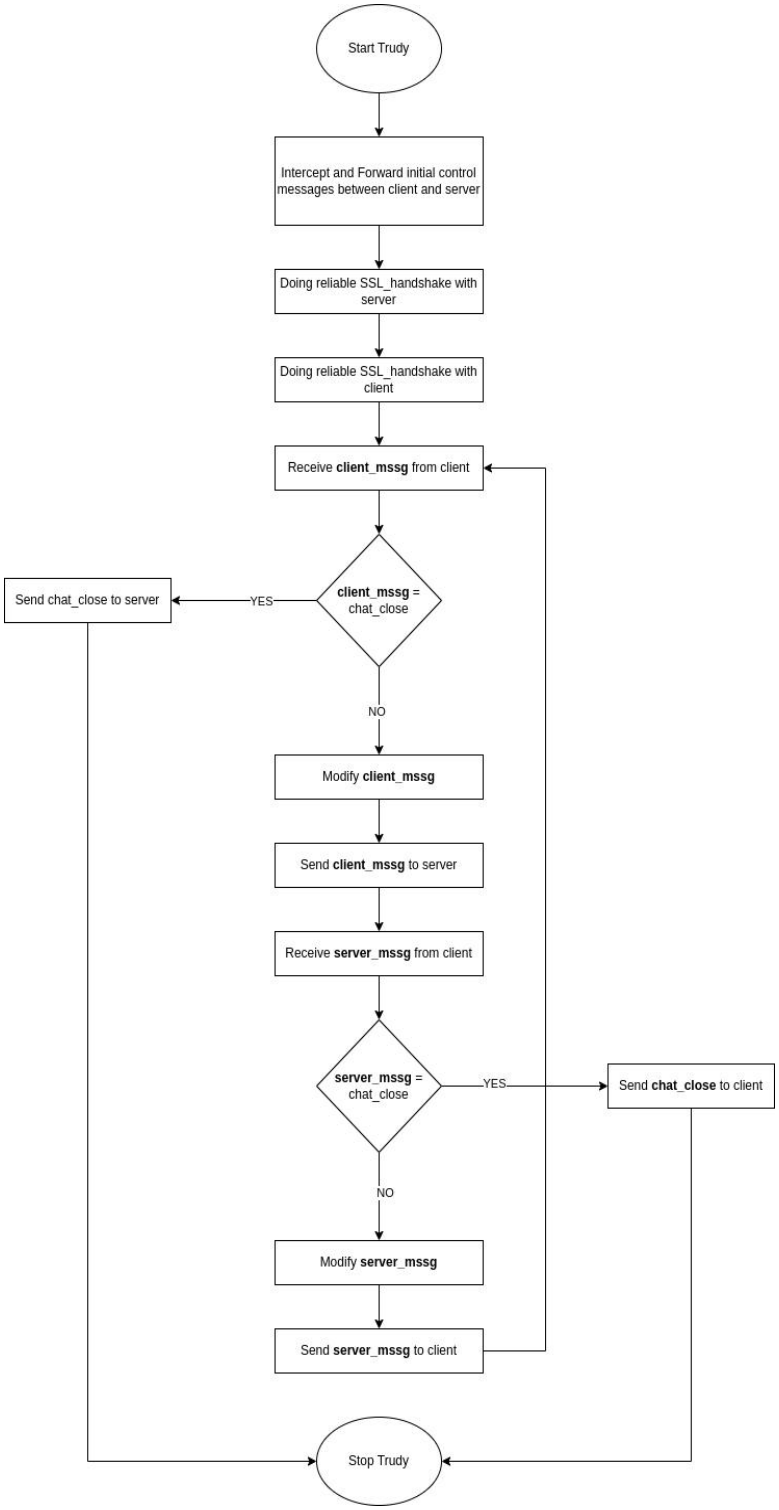
```
0000  00 16 3e d2 a2 f0 00 16  3e 3d 17 94 08 00 45 00   ··>····· >=····E·
0010  00 25 1e 5c 40 00 40 11  c4 26 ac 1f 00 04 ac 1f   ·%·\@·@· ·&······
0020  00 03 ad a9 1f 90 00 11  58 68 48 65 6c 6c 6f 20   ········ XhHello
0030  42 6f 62                                          Bob
```

    c. Similarly, Trudy will send the messages of Bob to Alice, so here Trudy works an eavesdropper. OBJ

Task 4

The Flowchart for Client and Server will be the same as Task 2, as in this part for client and server we are using the same code as in task 2.

Flowchart of Trudy:

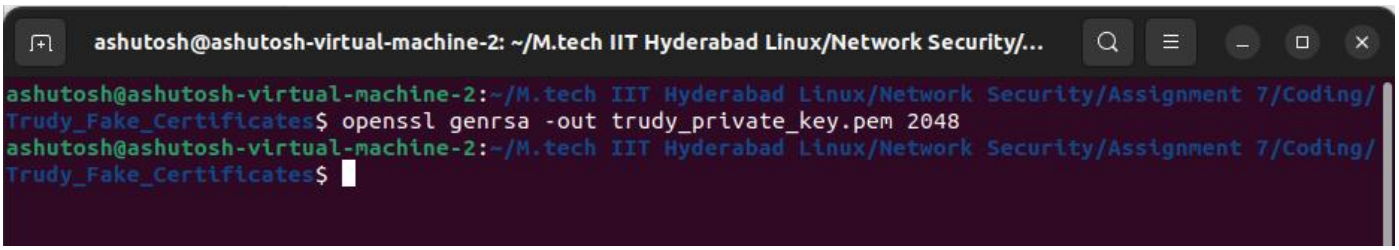


Making Fake Certificates for Alice and Bob

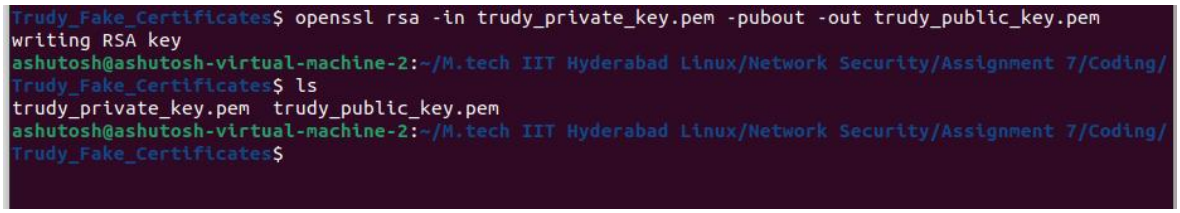
Steps:

1. Making Private Key for

   Trudy

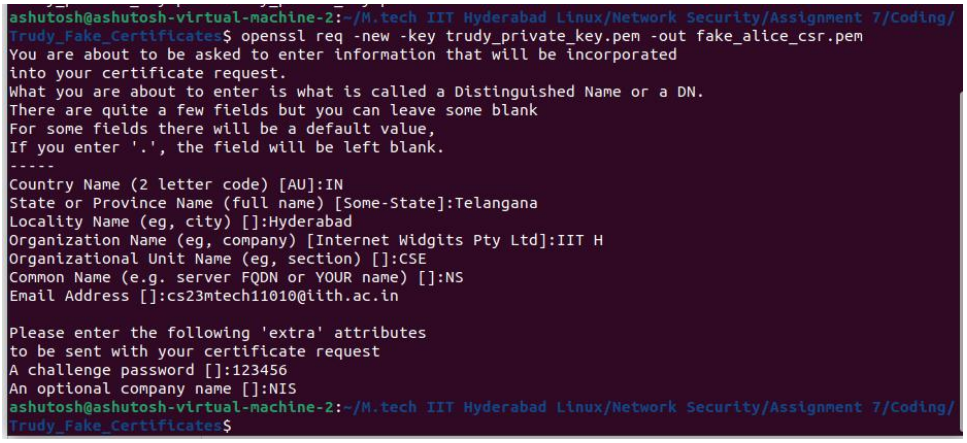


2. Making Public key for Trudy

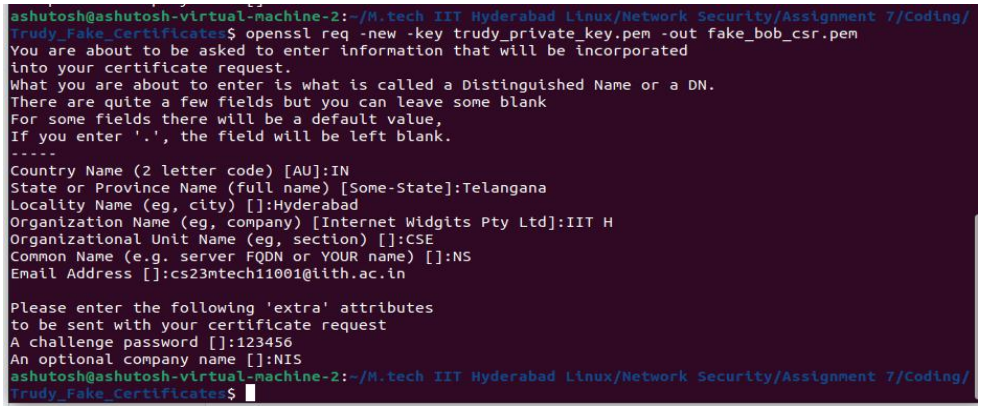


3. Trudy will now generate a fake CSR for Alice & Bob

   a. For Alice



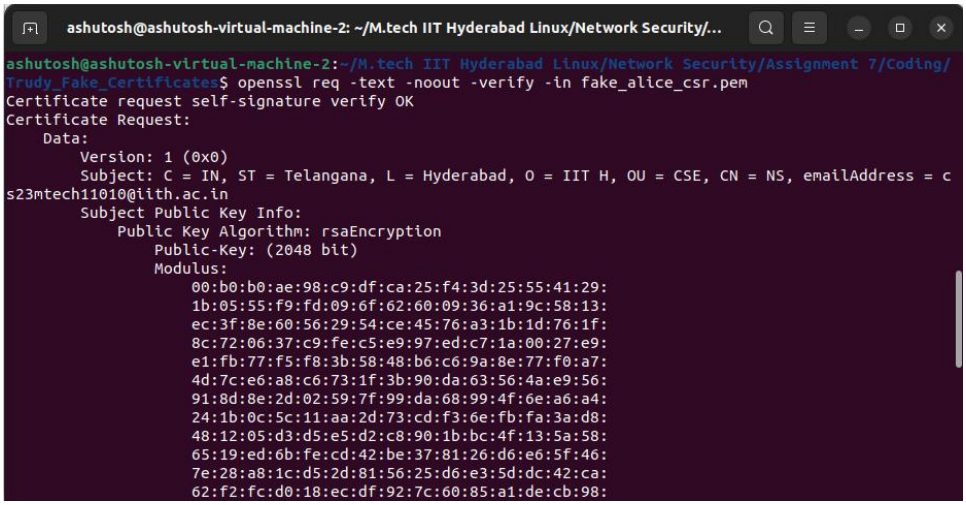
   b. For Bob



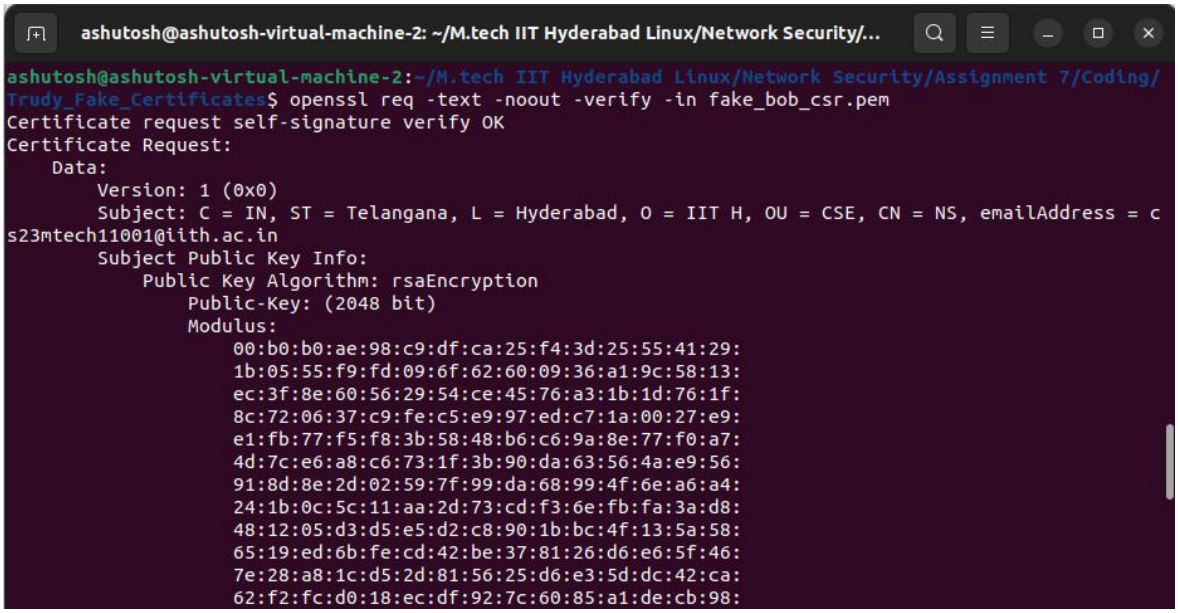
4. Now as Trudy has hacked into Intermediate CA so it will have

a. Intermediate CA Certificate
b. Intermediate CA Private Key
c. Intermediate CA Public Key
d. Root CA Certificate
e. Certificate chain: Root CRT -> Intermediate CRT

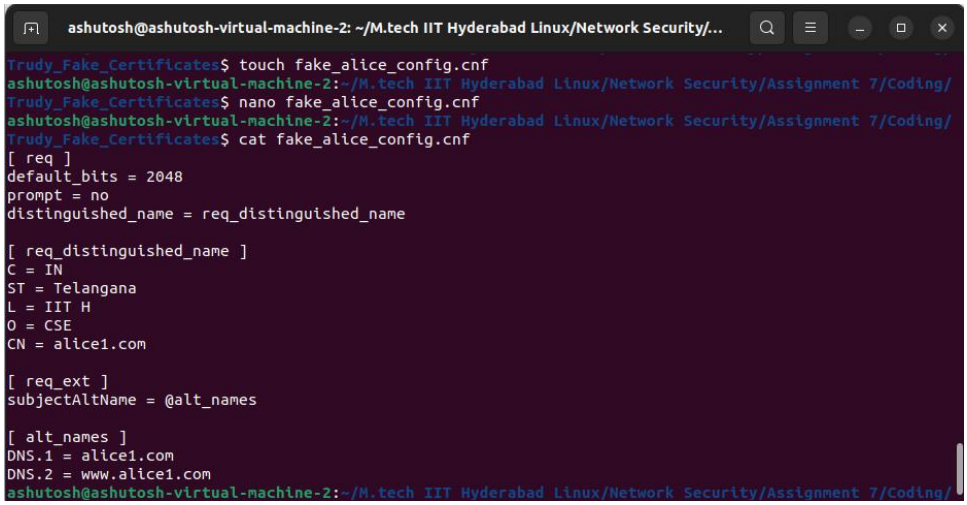
5. Now verifying Alice and Bob Certificate
    a. Verifying Alice csr



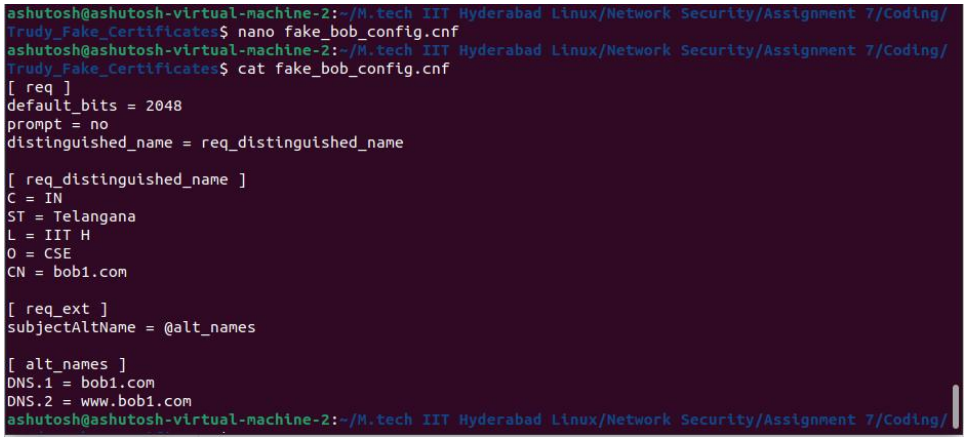
    b. Verifying Bob csr



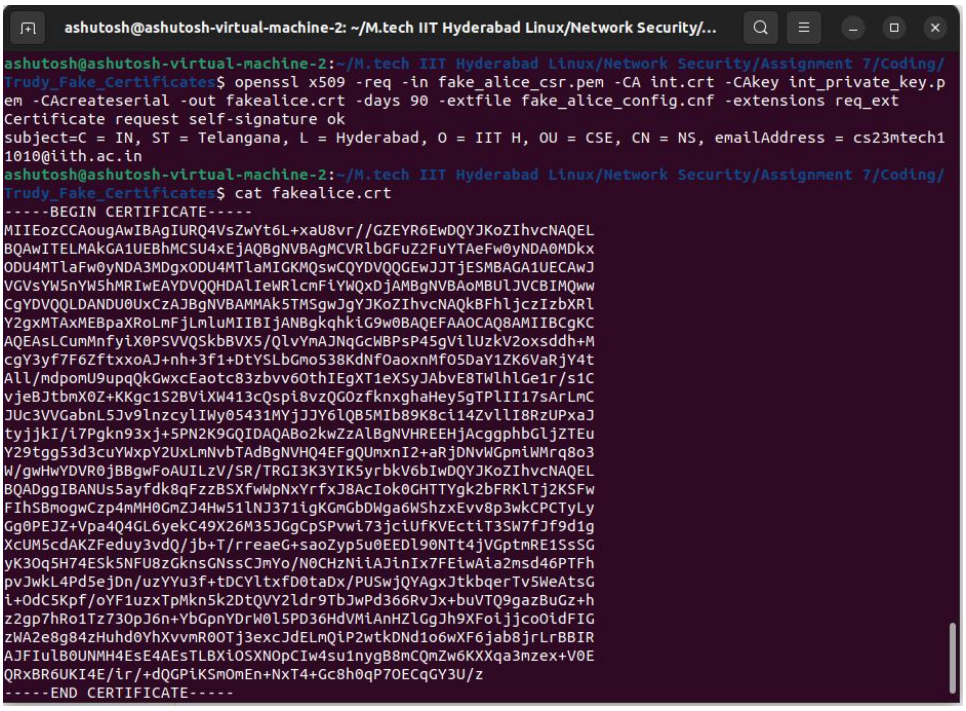
6. Now Trudy will generate a fake config file for Alice and Bob.
    a. Fake Config file for Alice



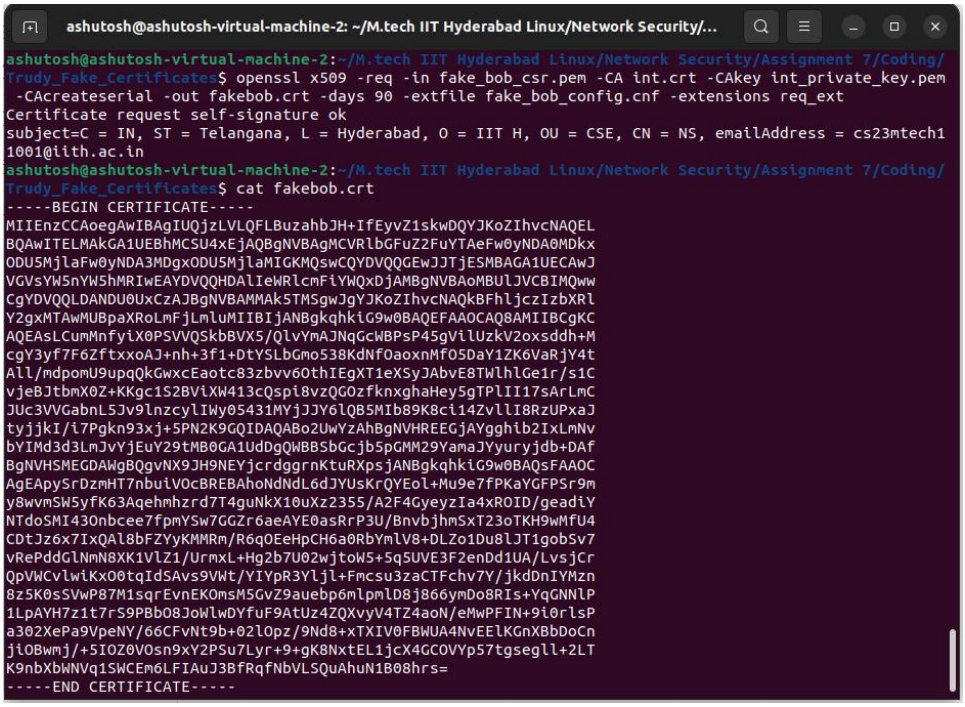
    b. Fake Config File for Bob



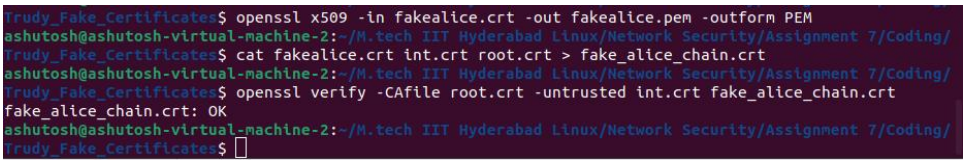
7. Now Trudy will generate fake Certificates for Alice and Bob.
    a. Alice Fake Certificate



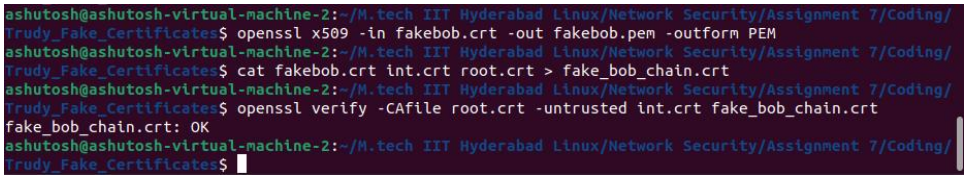
b. Bob Fake Certificate



8. Now converting (.crt to .pem), generating certificate chain and verifying certificate chain of Alice and Bob
   a. Alice generation & verification

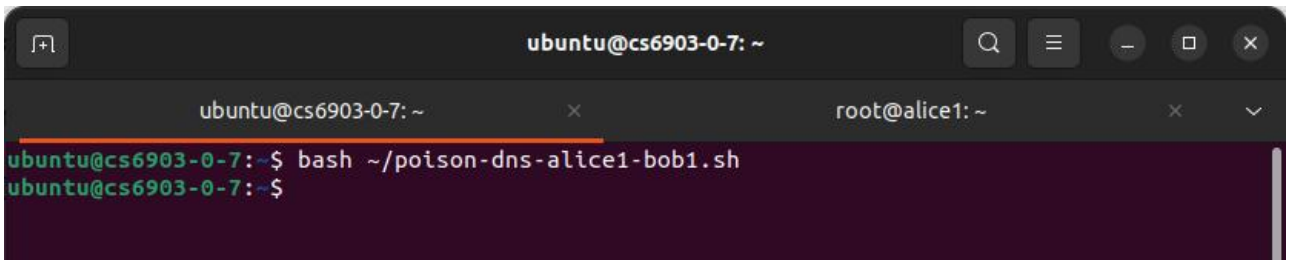


   b. Bob generation & verification

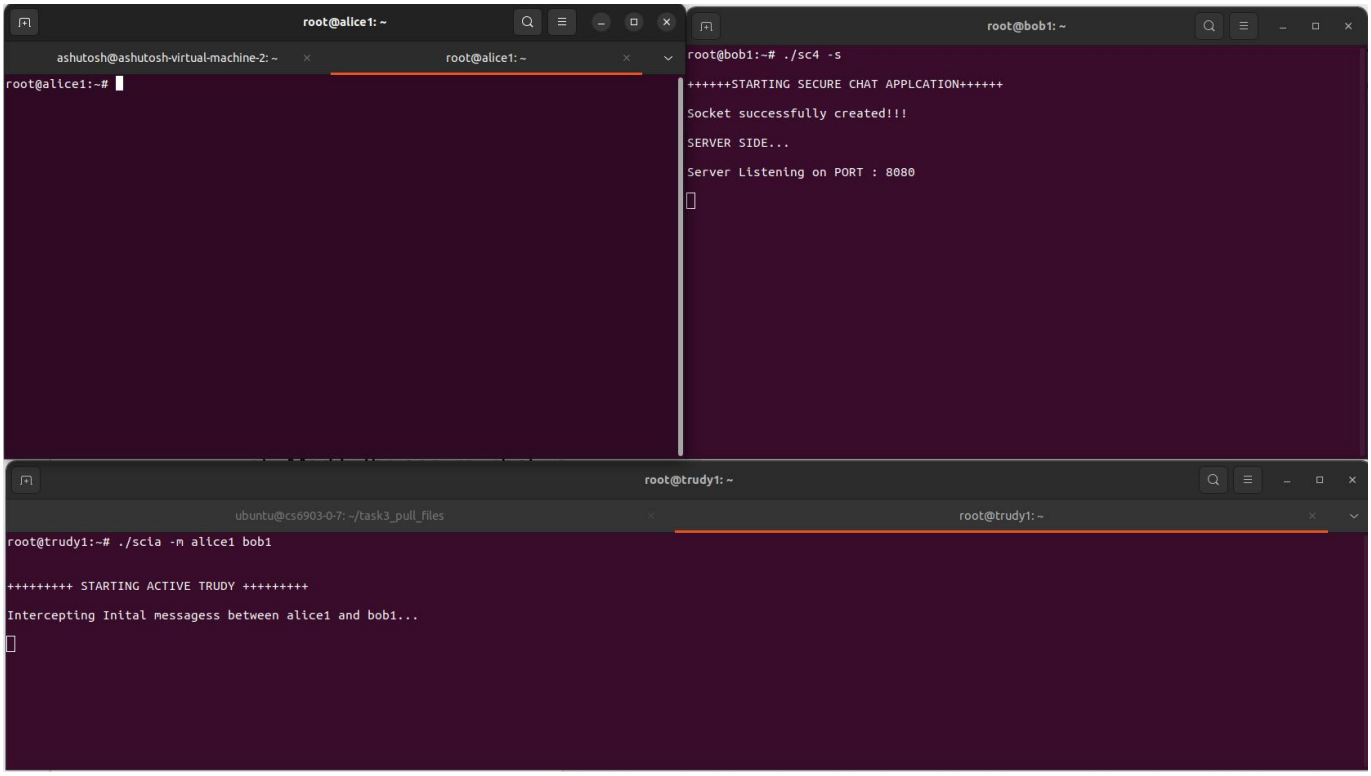


Doing Active Interception Steps **without packet loss**:

1. Doing DNS poisoning from the VM

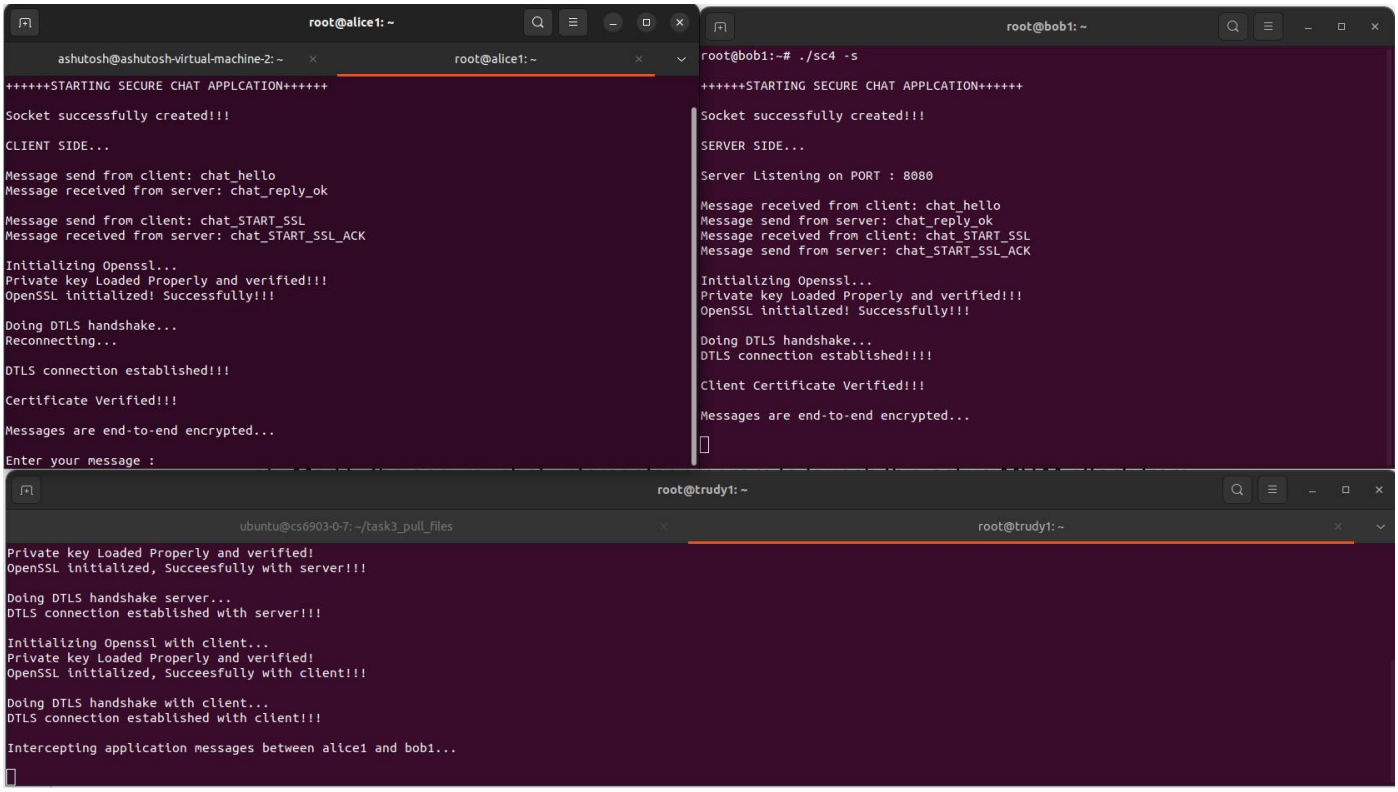


2. Now Running Trudy and Bob

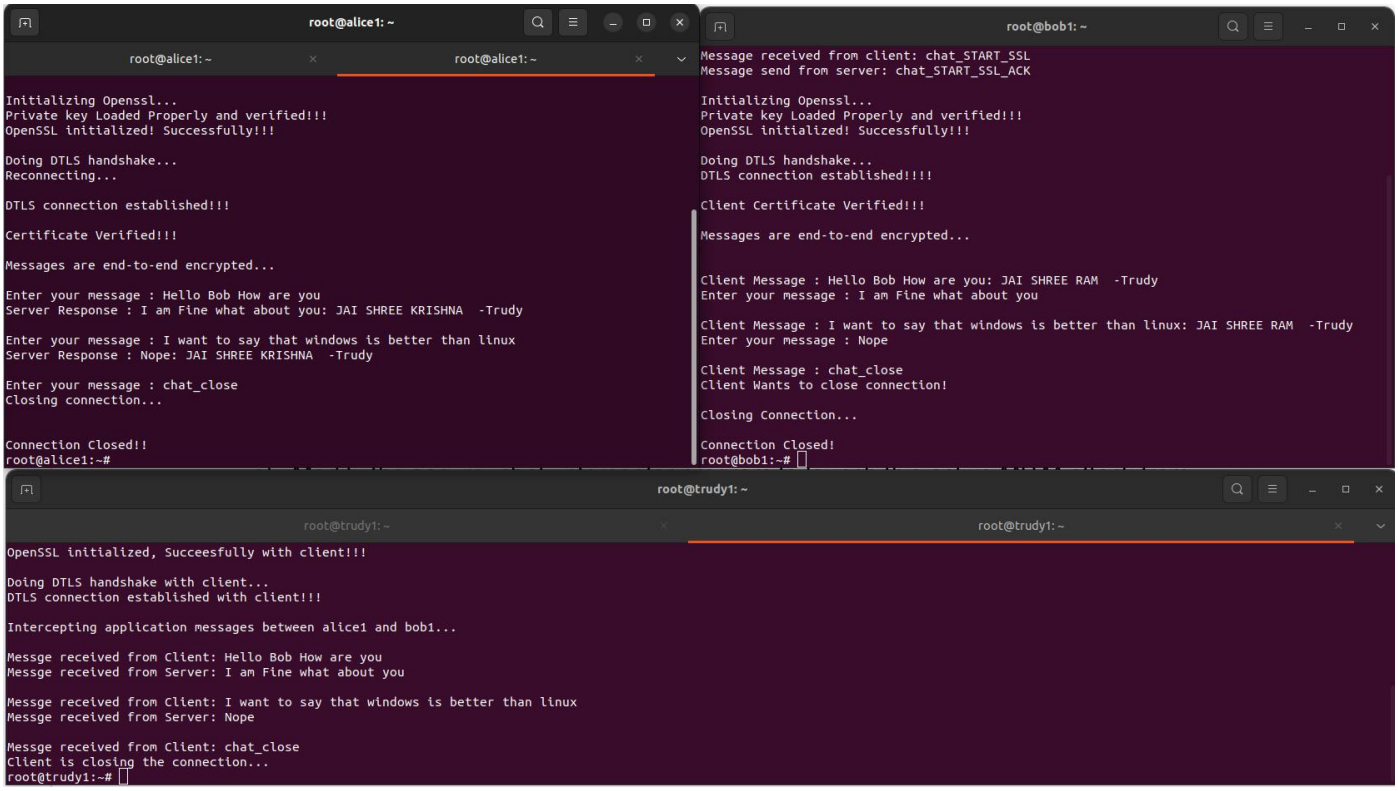


3. Now when we run Alice, we can see that a DTLS connection is made between Alice and trudy, and Trudy and

Bob

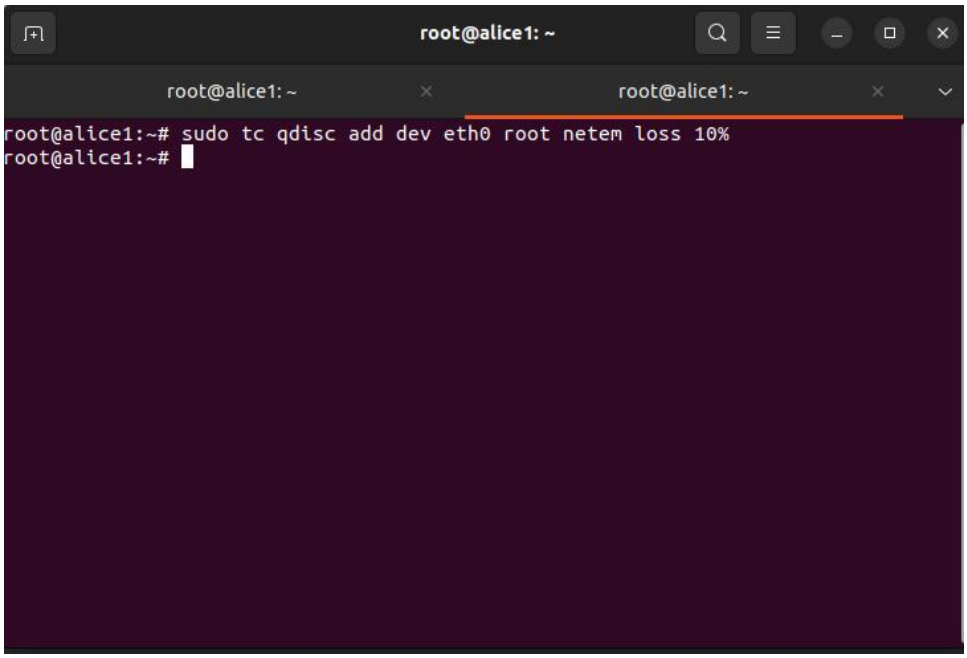


4. Now Alice and Bob chat with each other, while Trudy will now intercept their messages and alter the messages

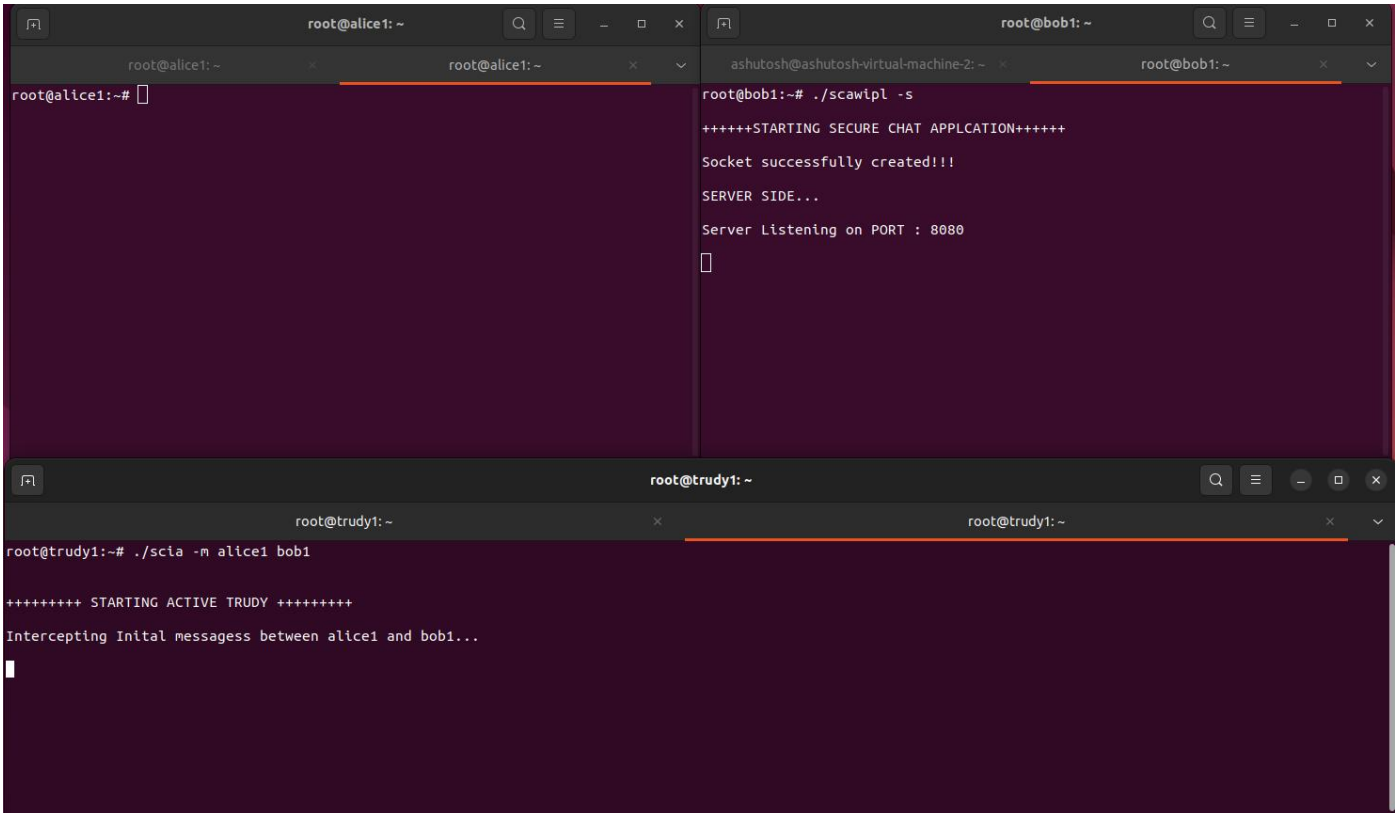


Doing Active Interception **with packet loss** Steps:

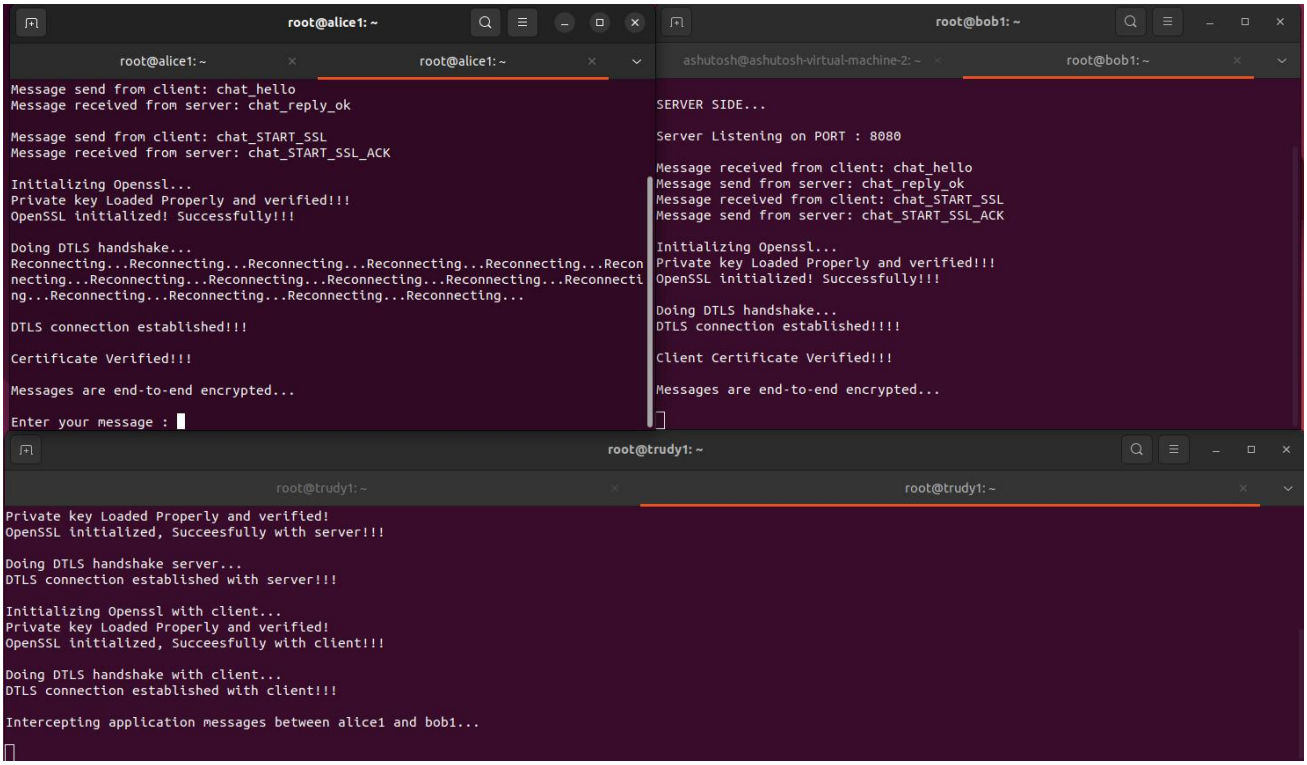
1. Injecting packet loss at Alice



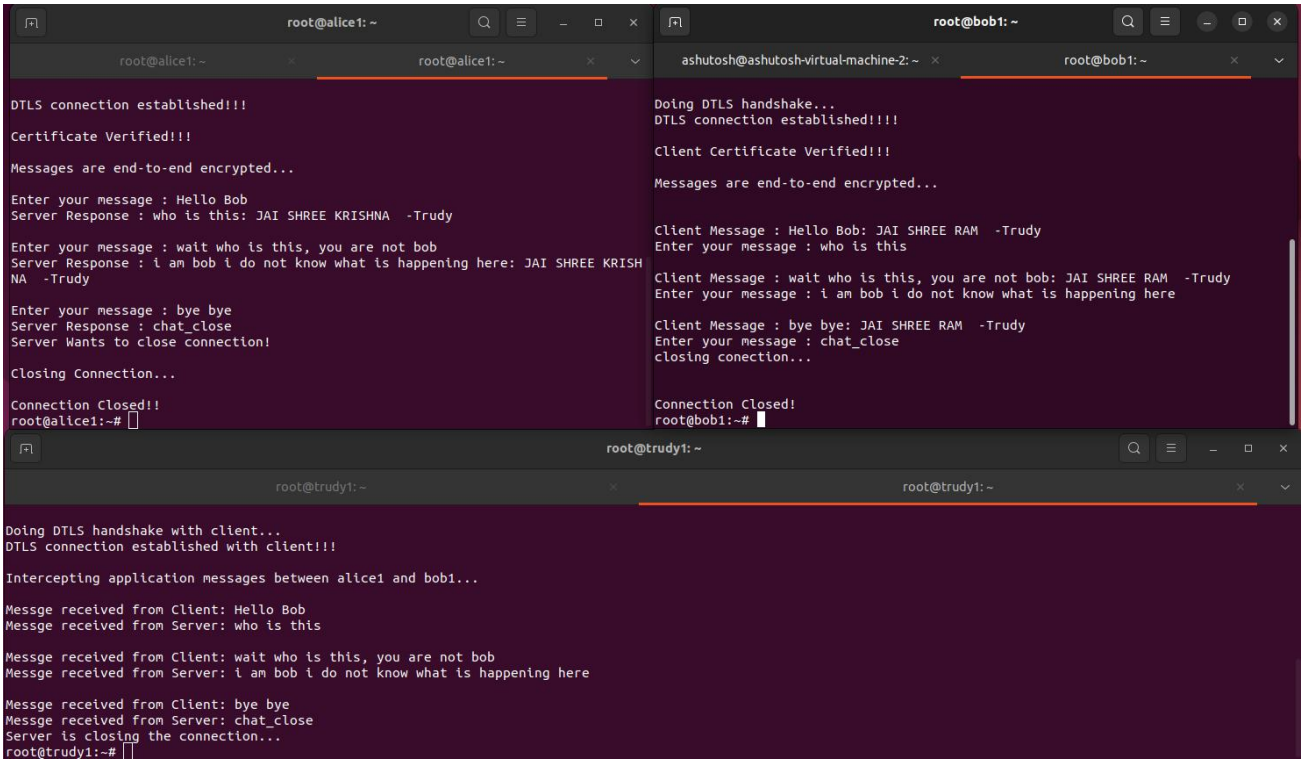
2. Now Running Trudy and Bob



3. Now we will run Alice, and as we can see there were packet losses during the handshake process, and we can also see that Alice is retransmitting the packets which are lost.



4. Now Alice and bob chat and Trudy will intercept



5. Below we can see that we are loading the fake certificates for Bob and Alice and Trudy's private key.

```
void loadCertificates(bool workAsClient, SSL_CTX *&ssl_context)
{
    const char *certificate;
    const char *privateKey;
    const char *chain;
    const char *CAfile = "CAfile.pem";

    if (workAsClient == true)
    {
        certificate = "fakealice.pem";
        privateKey = "trudy_private_key.pem";
        // chain = "alice_chain.pem";
    }
    else
    {
        certificate = "fakebob.pem";
        privateKey = "trudy_private_key.pem";
        // chain = "bob_chain.pem";
    }

    // Load Certificate
    if (SSL_CTX_use_certificate_file(ssl_context, certificate, SSL_FILETYPE_PEM) <= 0)
    {
        ERR_print_errors_fp(stderr);
        cout << "error in cert\n";
        exit(EXIT_FAILURE);
    }

    // Load Private Key
    if (SSL_CTX_use_PrivateKey_file(ssl_context, privateKey, SSL_FILETYPE_PEM) <= 0)
    {
        ERR_print_errors_fp(stderr);
        cout << "error in key\n";
        exit(EXIT_FAILURE);
    }

    // Verify private key
    if (!SSL_CTX_check_private_key(ssl_context))
    {
        cout << "Private Key Verification failed!\n";
        exit(0);
    }

    cout << "Private key Loaded Properly and verified!\n";

    // Load CAfile and verify
    if (!SSL_CTX_load_verify_locations(ssl_context, CAfile, NULL))
    {
        ERR_print_errors_fp(stderr);
        cout << " -CA verification failed \n";
        exit(EXIT_FAILURE);
    }

    // Client/Server Certificate verification
    SSL_CTX_set_verify(ssl_context, SSL_VERIFY_PEER | SSL_VERIFY_FAIL_IF_NO_PEER_CERT, NULL);
}
```

Here the last line of code : **SSL_CTX_set_verify(ssl_context, SSL_VERIFY_PEER | SSL_VERIFY_FAIL_IF_NO_PEER_CERT, NULL);**

a) Checks the certificate of the other party(peer)
b) If there is no certificate of the peer, then verification will fail.

6. Now like in task 3 here also trudy will have two socket one for client and another for server, but here Trudy will intercept the DTLS messages by doing the handshake with client and
server

```
SSL_CTX *ssl_context_client, *ssl_context_server;
SSL *ssl_client, *ssl_server;

// ---- For Client
// Initializing OpenSSL
cout << "Initializing Openssl with server...\n";
initializeOpenSSL(true, ssl_context_server);
cout << "OpenSSL initialized, Succeesfully with server!!!\n\n";

// Doing Handshake
cout << "Doing DTLS handshake server...\n";
SSL_handshake(server_addr, true, ssl_context_server, ssl_server);
cout << "DTLS connection established with server!!!\n\n";

// ----- For Server
// Initializing OpenSSL
cout << "Initializing Openssl with client...\n";
initializeOpenSSL(false, ssl_context_client);
cout << "OpenSSL initialized, Succeesfully with client!!!\n\n";

// Doing Handshake
cout << "Doing DTLS handshake with client...\n";
SSL_handshake(client_addr, false, ssl_context_client, ssl_client);
cout << "DTLS connection established with client!!!\n\n";

cout << "Intercepting application messages between " << client << " and " << server << "...\n\n";
```

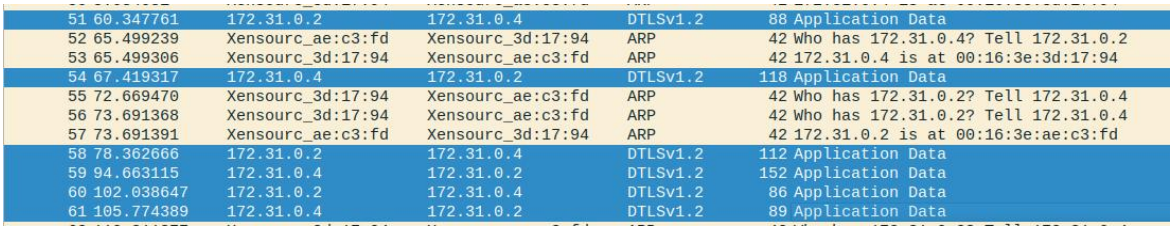
   a. Client_socket : which talks with client
   b. Server_socket : which talks with server
   c. ssl_context_client : ssl context for the client socket
   d. Ssl_context_server : ssl context for the server socket
   e. Ssl_client : ssl for the client socket
   f. Ssl_server : ssl for the server socket
   g. First, we initialize openssl for server socket
   h. Then we will do SSL handshake with server
   i. Then we will initialize openssl with client
   j. Then we will do ssl handshake with client
   k. Then we will simply intercept the messages by encrypting and decrypting it.

7. This is the function which we are using for modifying messages.

```
string changing_client_mssg(string message)
{
    if(message != "chat_close")
     message += ": JAI SHREE RAM  -Trudy ";
    return message;
}

string changing_server_mssg(string message)
{
    if(message != "chat_close")
     message += ": JAI SHREE KRISHNA  -Trudy ";
    return message;
}
```

   a. When the message comes from the client side, we will call the function changing_client_mssg(string message).
   b. When the message comes from the server side, we will call the function changing_server_mssg(string message).
   c. In both functions if the message is **chat_close**, then we will not modify it.

8. We can also look in wireshark



51	60.347761	172.31.0.2	172.31.0.4	DTLSv1.2	88 Application Data
52	65.499239	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 Who has 172.31.0.4? Tell 172.31.0.2
53	65.499306	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 172.31.0.4 is at 00:16:3e:3d:17:94
54	67.419317	172.31.0.4	172.31.0.2	DTLSv1.2	118 Application Data
55	72.669470	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 Who has 172.31.0.2? Tell 172.31.0.4
56	73.691368	Xensourc_3d:17:94	Xensourc_ae:c3:fd	ARP	42 Who has 172.31.0.2? Tell 172.31.0.4
57	73.691391	Xensourc_ae:c3:fd	Xensourc_3d:17:94	ARP	42 172.31.0.2 is at 00:16:3e:ae:c3:fd
58	78.362666	172.31.0.2	172.31.0.4	DTLSv1.2	112 Application Data
59	94.663115	172.31.0.4	172.31.0.2	DTLSv1.2	152 Application Data
60	102.038647	172.31.0.2	172.31.0.4	DTLSv1.2	86 Application Data
61	105.774389	172.31.0.4	172.31.0.2	DTLSv1.2	89 Application Data

   a. Messages are coming from Alice going to Trudy and then from Trudy to Bob.
   b. Messages which are coming from Bob are going to Trudy and then from Trudy to Alice.

Task 5

For task 5, we decided to do ARP poisoning.ARP poisoning involves manipulating ARP messages to associate an attacker's MAC address with the IP address of another device on the network.
The attacker sends ARP reply messages to the victim, associating the attacker's MAC address with the victim's IP address. Consequently, traffic destined for the victim is redirected to the attacker, allowing for interception, modification, or eavesdropping on the traffic.

Explanation :
1. It first includes all the necessary header files and libraries
2. Now the getMACAddress function retrieves the MAC address of a Specified network interface.
3. Now in the sendARP method

After poisioning we can see that Alice MAC address has changed

```
root@alice1:~# arp
Address                  HWtype  HWaddress           Flags Mask            Iface
172.31.0.4               ether   00:16:3e:3d:17:94   C                     eth0
bob1                     ether   00:16:3e:d2:a2:f0   C                     eth0
_gateway                 ether   00:16:3e:ca:16:47   C                     eth0
root@alice1:~# arp
Address                  HWtype  HWaddress           Flags Mask            Iface
172.31.0.4               ether   00:16:3e:3d:17:94   C                     eth0
bob1                     ether   00:16:3e:3d:17:94   C                     eth0
_gateway                 ether   00:16:3e:ca:16:47   C                     eth0
```

Credit Statement

Credit Statement	Contribution
Ashutosh Rajput	Task 1 & Task 2 & Report
Akshat Gupta	Task 4 & Reliability & Flow Charts & Readme
Malsawmsanga Sailo	Task 3 & Task 5 & Video Editing

ANTI-PLAGIARISM STATEMENT

We certify that this assignment/report is our own work, based on our personal study and/or research and that we have acknowledged all material and sources used in its preparation, whether they be books, articles, packages, datasets, reports, lecture notes, and any other kind of document, electronic or personal communication. We also certify that this assignment/report has not previously been submitted for assessment/project in any other course lab, except where specific permission has been granted from all course instructors involved, or at any other time in this course, and that we have not copied in part or whole or otherwise plagiarized the work of other students and/or persons. We pledge to uphold the principles of honesty and responsibility at CSE@IITH. In addition, We understand my responsibility to report honor violations by other students if we become aware of it.

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