Exercise 11

Setting up SSL security for some of our existing services

Prior Knowledge
Previous exercises

Objectives
Understanding SSL certificates
Understanding TLS configuration

Software Requirements
(see separate document for installation of these)

- Node.js and Express
- OpenSSL
- Python

Overview
In this lab we are going to create SSL/TLS certificates for both the server and the client, and validate them to ensure encryption, integrity and authentication.

Steps

1. Check that openssl is installed on your Ubuntu server:
   ```
   sudo apt install openssl
   ```
   Hopefully its already at the latest level.

2. The first step is that we are going to create a certificate authority (CA). This is because we don't want to have to go through the rigmarole of paying a real CA.

   Hint: if you are willing to host a real server on a real fully-qualified DNS name, then you can get a free certificate from the EFF via certbot. However, we aren't able to do that today.

   Hint 2: If you really do want to create a CA, do not follow these instructions. They are far too insecure. You should read widely, but this is a good starting place: https://jamielinux.com/docs/openssl-certificate-authority/

3. Make some directories:
   ```
   mkdir -p ~/sec/ca/private
   mkdir -p ~/sec/server/keys/private
   mkdir -p ~/sec/client/keys/private
   ```

4. We are going to act as several different roles in this lab. The first role is going to be the **CA Administrator**.

   Let's make a private key for the CA:

   ```
   cd ~/sec/ca
   openssl genrsa -aes256 -out private/ca.key.pem 4096

   Generating RSA private key, 4096 bit long modulus
   ..........................................................
   ...........................++
   ..........................................................
   ....++
   e is 65537 (0x10001)
   Enter pass phrase for private/ca.key.pem:
   ```

   Enter a password. Probably best to use something insecure like "**password**" since this is not for real.

   ```
   Verifying - Enter pass phrase for private/ca.key.pem:
   ```

   Re-enter the password.

   We put the key into the private directory so we can keep track of which parts need security and which don't.

5. We now need a certificate for the CA.

   ```
   openssl req -key private/ca.key.pem -new -x509 -days 8000 -
   sha256 -out ca.cert.pem
   ```

   (All on one line)

   First enter your password.

   ```
    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]:UK
    State or Province Name (full name) [Some-State]:Oxfordshire
    Locality Name (eg, city) []:Oxford
    Organization Name (eg, company) [Internet Widgits Pty
    Ltd]:Comlab CA
    Organizational Unit Name (eg, section) []:
    Common Name (e.g. server FQDN or YOUR name) []:
    Email Address []:
   ```

   Now enter the following **bold items**. Hit enter for the others.

This *ca.cert.pem* file doesn't need securing. In fact we want to share this certificate as widely as possible.

6. That is our CA created. We can now "switch hats" and be the **Server administrator**.
   ```
   cd ~/sec/server/keys
   ```

7. The server needs a private key. This doesn't need to be a secure as the CA key (lasts a year instead of 20 years!) so we can use 2048 bits.

   ```
   openssl genrsa –aes256 –out private/server.key.pem 2048
   ```

   ```
   Generating RSA private key, 2048 bit long modulus
   .................+++
   ................................................................
   ................................................................
   ..............................................+++
   e is 65537 (0x10001)
   Enter pass phrase for private/server.key.pem:
   Verifying - Enter pass phrase for private/server.key.pem:
   ```

   I propose you use "password" again.

8. No-one will trust this key because it hasn't been signed. In order to create trust we need to get a CA to sign this key. Luckily we know a friendly CA (ourselves). To ask the CA to sign the key, we create a Certificate Signing Request (csr).

   ```
   openssl req -key private/server.key.pem -new -sha256 -out
   server.csr.pem
   ```

   Again all on one line
   Now use the following **bold** entries. The only really important one is the FQDN (**localhost**) since this will be checked against the DNS name of the server.

   ```
   Enter pass phrase for private/server.key.pem:
   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]:UK
   State or Province Name (full name) [Some-State]:Oxfordshire
   Locality Name (eg, city) []:Oxford
   Organization Name (eg, company) [Internet Widgits Pty Ltd]:Localhost Website
   Organizational Unit Name (eg, section) []:
   Common Name (e.g. server FQDN or YOUR name) []:localhost
   Email Address []:

   Please enter the following 'extra' attributes
   to be sent with your certificate request
   A challenge password []:
   An optional company name []:
   ```

9. We now need to "send" that CSR to the CA:
   ```
   cp server.csr.pem ~/sec/ca/
   ```

10. Now we need to switch back to being the CA:
    ```
    cd ~/sec/ca
    ```

11. Recent versions of Chrome and other browsers require an extra field in the certificate called the Subject Alternative Name. This must match the Common Name. This is a bit of a pain, as OpenSSL makes this quite hard to set.

12. You need to create a file called extfile, with the following contents (available here: https://freo.me/extfile):

```
authorityKeyIdentifier=keyid,issuer
basicConstraints=CA:FALSE
keyUsage = digitalSignature, nonRepudiation, keyEncipherment, dataEncipherment
subjectAltName=DNS:localhost
```

13. We now need to sign the CSR (as the CA).

    ```
    openssl x509 -req -days 365 -in server.csr.pem -CAkey
    private/ca.key.pem -CA ca.cert.pem -out server.cert.pem
    -CAcreateserial -extfile extfile
    ```

    (All on one line)

    ```
    Signature ok
    subject=/C=UK/ST=Oxfordshire/L=Oxford/O=Localhost
    Website/CN=localhost
    Getting CA Private Key
    Enter pass phrase for private/ca.key.pem:
    ```

14. Now "send" the certificate back to the Server Admin:

    ```
    cp server.cert.pem ~/sec/server/key
    ```

15. The server also needs the CA's certificate:

    ```
    cp ca.cert.pem ~/sec/server/keys
    ```

16. Switch back to being a Server Administrator:

    ```
    cd ~/sec/server
    ```

17. Download updated code that now configures SSL with our newly created keys:

    ```
    cd ~/sec/server
    curl -L http://freo.me/sec-rand -o server.js
    ```

18. Here is the code to look at. This should all be fairly obvious.

    ```
    var https = require('https'),
        fs = require('fs'),
        express = require('express'),
        app = express();

    app.get("/",function(req,res){

        obj = {random : Math.floor((Math.random() * 100) + 1)};
          res.json(obj);

    });

    var secureServer = https.createServer({
        key: fs.readFileSync('./keys/private/server.key.pem'),
        cert: fs.readFileSync('./keys/server.cert.pem'),
        ca: fs.readFileSync('./keys/ca.cert.pem'),
        requestCert: true,
        passphrase: "password",
        ciphers: "TLSv1.2",
        rejectUnauthorized: false
    }, app).listen('8443', function() {
        console.log("Secure Express server listening on port 8443");
    });
    ```

19. Your **~/sec directory** should look like:

```
oxsoa@oxsoa:~/sec$ tree
.
├── ca
│   ├── ca.cert.pem
│   ├── ca.srl
│   ├── extfile
│   ├── private
│   │   └── ca.key.pem
│   ├── server.cert.pem
│   └── server.csr.pem
├── client
│   └── keys
│       └── private
└── server
    ├── keys
    │   ├── ca.cert.pem
    │   ├── private
    │   │   └── server.key.pem
    │   ├── server.cert.pem
    │   └── server.csr.pem
    ├── server.cert.pem
    └── server.js

8 directories, 12 files
```

20. Make sure express is installed:
```
cd ~/sec/server
npm install express
```

21. Run it:
```
node server.js
```

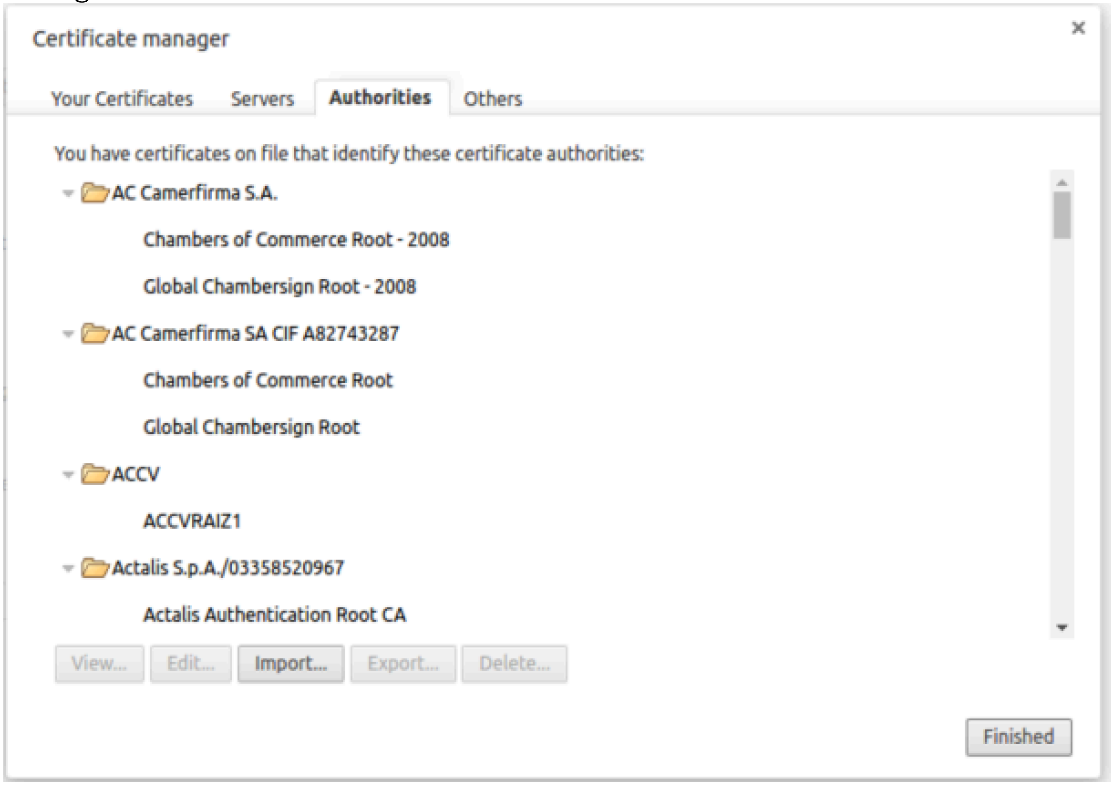
22. Browse to https://localhost:8443
You should get a security error.

23. They say you get what you pay for, and in this case we didn't pay for our certificate. When you pay for a certificate, what you are really paying for is that the CA is trusted and hence browser manufacturers, SSL libraries, etc include the Root Certificate in their clients.

However, we can do that ourselves.

24. Do not accept it but instead add the certificate. In Chromium:
Edit -> Preferences.
Show advanced settings
Manage Certificates

25. Now go to Authorities:

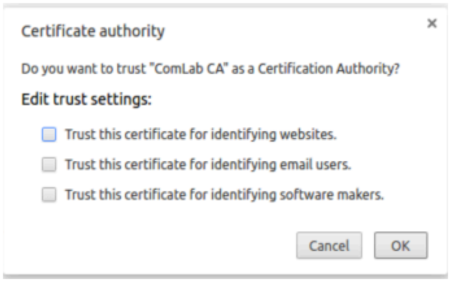


You have certificates on file that identify these certificate authorities:

- AC Camerfirma S.A.
  - Chambers of Commerce Root - 2008
  - Global Chambersign Root - 2008
- AC Camerfirma SA CIF A82743287
  - Chambers of Commerce Root
  - Global Chambersign Root
- ACCV
  - ACCVRAIZ1
- Actalis S.p.A./03358520967
  - Actalis Authentication Root CA

Click **Import**
Browse to **ca.cert.pem**

26. You should see:



Do you want to trust "ComLab CA" as a Certification Authority?

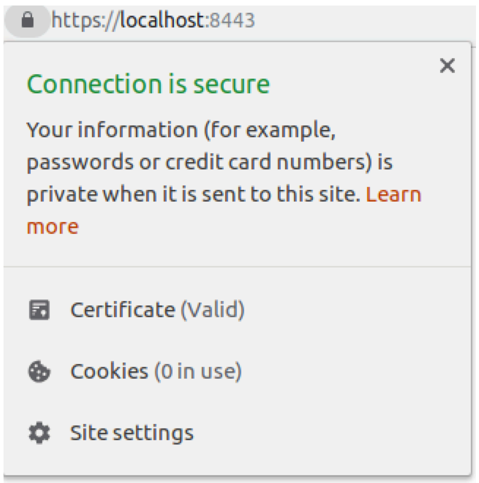
Edit trust settings:

- [ ] Trust this certificate for identifying websites.
- [ ] Trust this certificate for identifying email users.
- [ ] Trust this certificate for identifying software makers.

27. Click **Trust this certificate for identifying websites.**

28. Click Finished and then close the settings.

29. Now try browsing again. You should have a lovely secured padlock next to the server name in the URL bar. Click on it:


https://localhost:8443

Connection is secure

Your information (for example, passwords or credit card numbers) is private when it is sent to this site. Learn more

Client

30. Now we'd like to get our client working with this encryption.

31. First let's find our random JSON client. In a new terminal window:

```
c
cd ~/sec/client
curl -L http://freo.me/rand-client -o random-client.py
```

32. Edit the client to use the URL: https://localhost:8443

33. Run it. As expected, it fails because the python runtime does not know about the CA certificate.

34. We *could* work around this:

```
h = httplib2.Http(disable_ssl_certificate_validation=True)
```

However, this puts us in danger of Man in the Middle attacks.

35. **Instead**, modify the client to use the following:

```
h = httplib2.Http(ca_certs="./keys/ca.cert.pem");
```

36. Copy the ca.cert.pem into the client directory:

```
cp ~/sec/ca/ca.cert.pem ~/sec/client/keys
```

37. Try it again. Bingo! We now have encryption.

Authentication using a client certificate

38. We would like to authenticate the client as well as the server. One approach is to use a client certificate.
    First we need to create a client key etc.

```
cd ~/sec/client/keys
openssl genrsa -aes256 -out private/client.key.pem 2048
 Generating RSA private key, 2048 bit long modulus
 ..........................................................
 ............................................+++
 .................+++
 e is 65537 (0x10001)
 Enter pass phrase for private/server.key.pem:
 Verifying - Enter pass phrase for private/server.key.pem:
```

Use password again.

39. Now we need to create a CSR again.

```
openssl req -key private/client.key.pem -new -sha256 -out
client.csr.pem

 Enter pass phrase for private/client.key.pem:
 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]:UK
 State or Province Name (full name) [Some-State]:Oxfordshire
 Locality Name (eg, city) []:Oxford
 Organization Name (eg, company) [Internet Widgits Pty Ltd]:SEP
 Organizational Unit Name (eg, section) []:
 Common Name (e.g. server FQDN or YOUR name) []:paul@fremantle.org
 Email Address []:

 Please enter the following 'extra' attributes
 to be sent with your certificate request
 A challenge password []:
 An optional company name []:
```

40. There are two ways that we could validate the client certificate.
    The *proper way* is to get the CA (or another CA) to sign the certificate and then we can validate the certificate chain. The second more hacky way is to self-sign the certificate and hard code some attribute into our server logic to identify it.

    We are going to do both!

41. First, lets self-sign the certificate:
    ```
    openssl x509 -req -days 365 -in client.csr.pem -signkey
    private/client.key.pem -out self-sign.cert.pem
    ```

    ```
    Signature ok
    subject=/C=UK/ST=Oxfordshire/L=Oxford/O=SEP/CN=paul@fremantle.org
    Getting Private key
    Enter pass phrase for private/client.key.pem:
    ```

42. Now lets get the CA to sign the same request:
    ```
    cp client.csr.pem ~/sec/ca/
    cd ~/sec/ca/

    openssl x509 -req -days 365 -in client.csr.pem -CAkey
    private/ca.key.pem -CA ca.cert.pem -out client.cert.pem
    ```
    All on one line

    ```
    Signature ok
    subject=/C=UK/ST=Oxfordshire/L=Oxford/O=SEP/CN=paul@fremantle.org
    Getting CA Private Key
    Enter pass phrase for private/ca.key.pem:
    ```

43. Copy the new certificate back to the client:
    ```
    cp client.cert.pem ~/sec/client/keys/
    ```

44. Now we adjust the client code to use one or other of these certificates.
    ```
    cd ~/sec/client
    ```

45. We don't want to encode our password into the client. In fact its better to have no password on the client key and to rely on storing it securely.

    ```
    openssl rsa -in keys/private/client.key.pem -out
    keys/private/nopass.key.pem
    ```

46. Edit random-client.py and add the italic line.

    ```
    import httplib2
    import json

    url = "https://localhost:8443"

    h = httplib2.Http(ca_certs="./keys/ca.cert.pem")
    h.add_certificate(key='./keys/private/nopass.key.pem',
      cert='./keys/self-sign.cert.pem', domain='')
    resp, content = h.request(url, "GET")

    print "return code: " + resp['status']
    result = json.loads(content)
    print "random number: " + str(result['random'])
    ```

47. Now try the client. It will work, but there is no client authentication, because the client cert is not being checked.

48. Let’s find the serial number from the certificate.
```
openssl x509 -text  -noout  -in keys/self-sign.cert.pem
```

```
 Certificate:
     Data:
         Version: 1 (0x0)
         Serial Number: 13419741791119112890 (0xba3c800ee51e7aba)
     Signature Algorithm: sha256WithRSAEncryption
         Issuer: C=UK, ST=Ox, L=Ox, O=Student, CN=Paul Fremantle
         Validity
             Not Before: Jan  3 15:43:57 2018 GMT
             Not After : Jan  3 15:43:57 2019 GMT
```

49. Let’s edit our server code to check for this serial. Modify it to look like:

```
app.get("/",function(req,res){
  console.log(req.socket.getPeerCertificate());
  if   (req.socket.getPeerCertificate().serialNumber==" BA3C800EE51E7ABA")
  {
    obj = {random : Math.floor((Math.random() * 100) + 1)};
    res.json(obj);
  }
  else {
    res.sendStatus(403); // forbidden
  }
});
```

Of course you need to use your own serial number, not mine. You also need to convert it to uppercase!

50. You could also check other aspects such as the DN, but these will be less secure since this is self-signed. You could also write a registration process that grabs the serial number during a certain phase and then looks for it later.

51. Now let’s enforce CA checking. Edit the server.js to read:

```
var secureServer = https.createServer({
    key: fs.readFileSync('./keys/private/server.key.pem'),
    cert: fs.readFileSync('./keys/server.cert.pem'),
    ca: fs.readFileSync('./keys/ca.cert.pem'),
    requestCert: true,
    passphrase: "password",
    ciphers: "TLSv1.2",
    rejectUnauthorized: true
}, app).listen('8443', function() {
    console.log("Secure Express server listening on port 8443");
});
```

52. Comment out the serial check in server.js at the same time.

53. Restart the server.

54. Try your client. It won't even connect as the server rejects it at the TLS layer.

55. Now edit the client to use **client.cert.pem** instead of self-sign.

56. Try again. You will now need to update the check for a different certificate Serial Number since the client is sending a different cert.

57. Now that we have a CA trust, we could trust entries in the client certificate, so we could validate the CN for example.

58. *Recap:*
    This has been a long lab, but security is a complex aspect.
    What we have done is to set up mutual SSL with both the client and server authenticating via certificates. We have also explored server-only certificates and self-signed approaches.