HyperionDev

Windows Guide to Web Server Hardening

Additional Reading

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Introduction

In this guide, we will walk you through the installation and configuration of the Apache web server on Windows, followed by the steps to secure the Apache web server.

Development Environment

These instructions were developed using the following operating system and software:

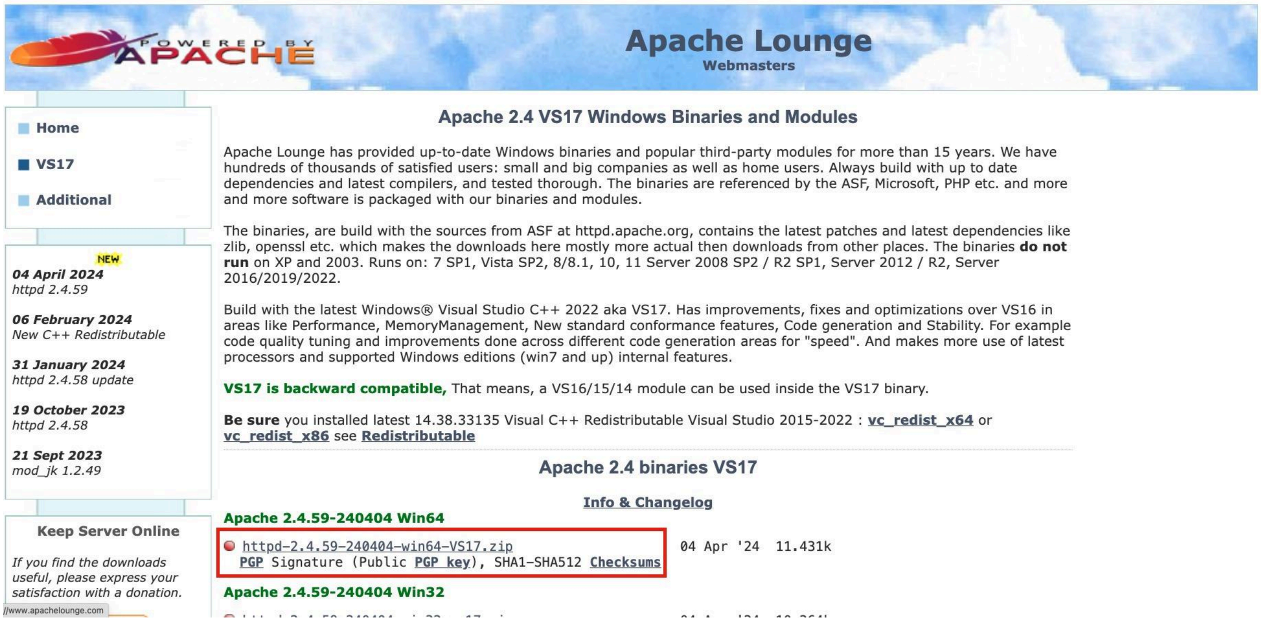
- **Operating system:** Microsoft Windows 11, Version 10.0.22621
- **Web browser:** Microsoft Edge, Version 123.0.2420.53

While these are the specific systems and software versions used, the instructions should also be applicable to your setup.

Setting up Apache

The following instructions will show you how to download, configure, and start the Apache web server on your Windows client.

1. Visit the **Apache HTTP Server download page** and download the appropriate version for your system (32-bit or 64-bit). For example, download the ZIP file corresponding to your system as illustrated in the screenshot below:



04 April 2024
httpd 2.4.59

06 February 2024
New C++ Redistributable

31 January 2024
httpd 2.4.58 update

19 October 2023
httpd 2.4.58

21 Sept 2023
mod_jk 1.2.49

If you find the downloads useful, please express your satisfaction with a donation.

Apache 2.4 VS17 Windows Binaries and Modules

Apache Lounge has provided up-to-date Windows binaries and popular third-party modules for more than 15 years. We have hundreds of thousands of satisfied users: small and big companies as well as home users. Always build with up to date dependencies and latest compilers, and tested thorough. The binaries are referenced by the ASF, Microsoft, PHP etc. and more and more software is packaged with our binaries and modules.

The binaries, are build with the sources from ASF at httpd.apache.org, contains the latest patches and latest dependencies like zlib, openssl etc. which makes the downloads here mostly more actual then downloads from other places. The binaries **do not run** on XP and 2003. Runs on: 7 SP1, Vista SP2, 8/8.1, 10, 11 Server 2008 SP2 / R2 SP1, Server 2012 / R2, Server 2016/2019/2022.

Build with the latest Windows® Visual Studio C++ 2022 aka VS17. Has improvements, fixes and optimizations over VS16 in areas like Performance, MemoryManagement, New standard conformance features, Code generation and Stability. For example code quality tuning and improvements done across different code generation areas for "speed". And makes more use of latest processors and supported Windows editions (win7 and up) internal features.

VS17 is backward compatible, That means, a VS16/15/14 module can be used inside the VS17 binary.

Be sure you installed latest 14.38.33135 Visual C++ Redistributable Visual Studio 2015-2022 : **vc_redist_x64** or **vc_redist_x86** see **Redistributable**

Apache 2.4 binaries VS17

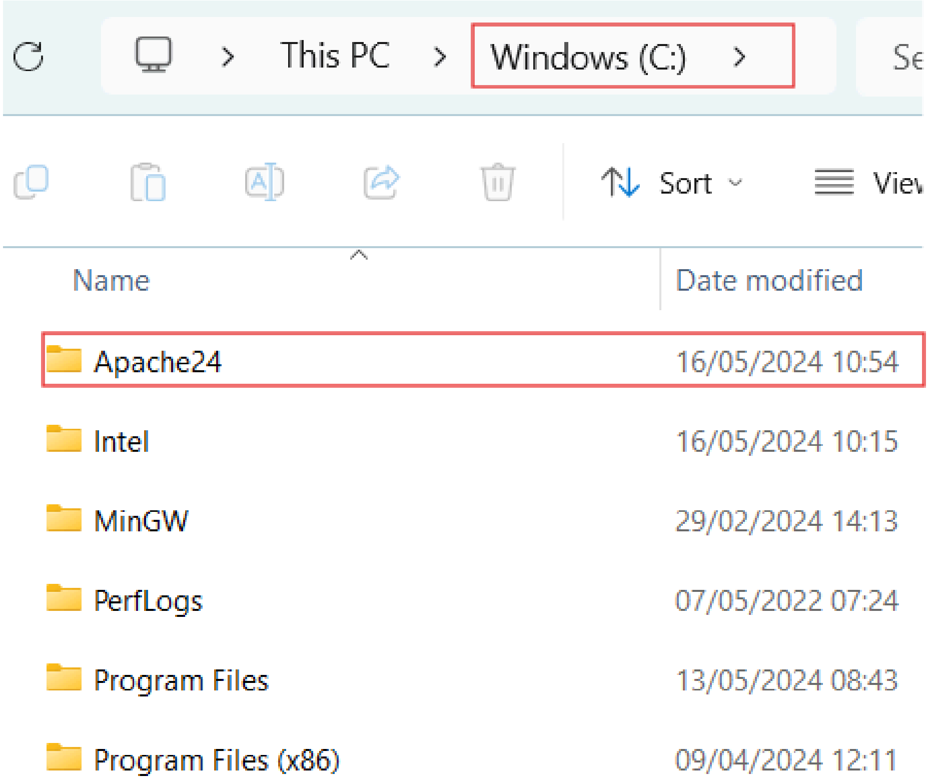
Info & Changelog

Apache 2.4.59-240404 Win64

```
● httpd-2.4.59-240404-win64-VS17.zip                04 Apr '24  11.431k
  PGP Signature (Public PGP key), SHA1-SHA512 Checksums
```

Apache 2.4.59-240404 Win32

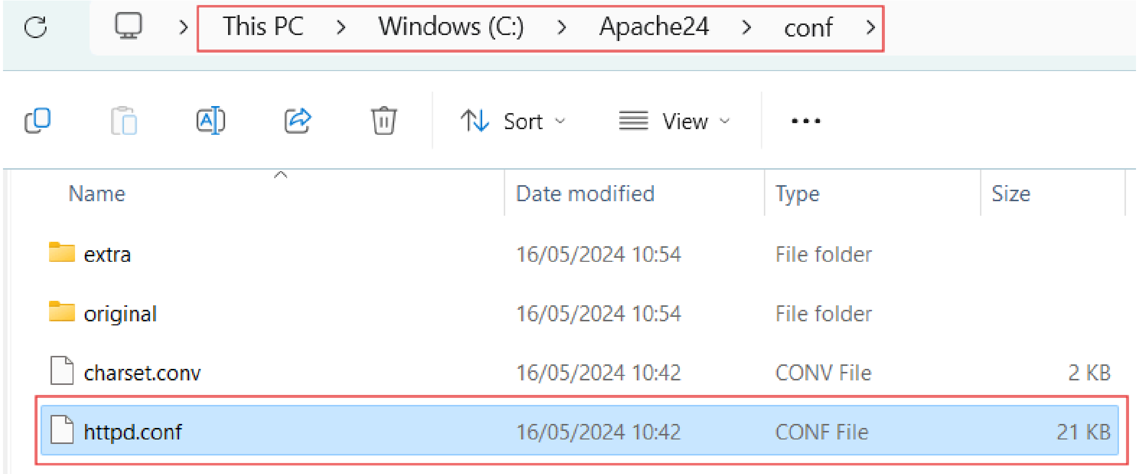
2. Unzip the downloaded ZIP file to extract its contents. Within the unzipped folder, locate another folder named **Apache24**. Copy this folder and navigate to the root directory of your C drive by opening File Explorer and going to '**This PC'**. Paste the **Apache24** folder into the root directory so that it resides at **C:\Apache24**. If you have trouble finding the root directory, note that it may be labelled as "Windows (C:)" or "Local Disk (C:)" (see screenshot below for reference).



This PC > Windows (C:) >

Name	Date modified
Apache24	16/05/2024 10:54
Intel	16/05/2024 10:15
MinGW	29/02/2024 14:13
PerfLogs	07/05/2022 07:24
Program Files	13/05/2024 08:43
Program Files (x86)	09/04/2024 12:11

3. Within the **Apache24** folder, navigate to the subfolder titled **conf** and locate a file named **httpd.conf**.

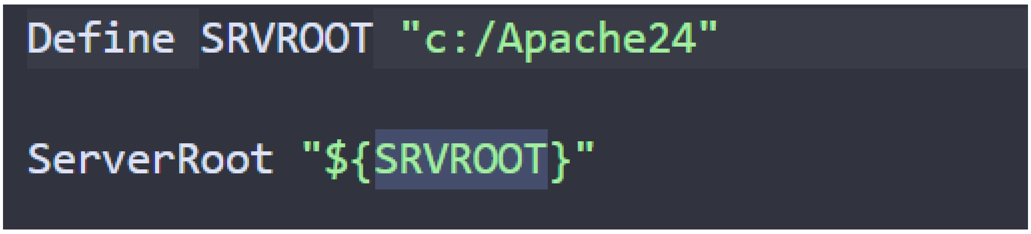


This PC > Windows (C:) > Apache24 > conf >

Name	Date modified	Type	Size
extra	16/05/2024 10:54	File folder	
original	16/05/2024 10:54	File folder	
charset.conv	16/05/2024 10:42	CONV File	2 KB
httpd.conf	16/05/2024 10:42	CONF File	21 KB

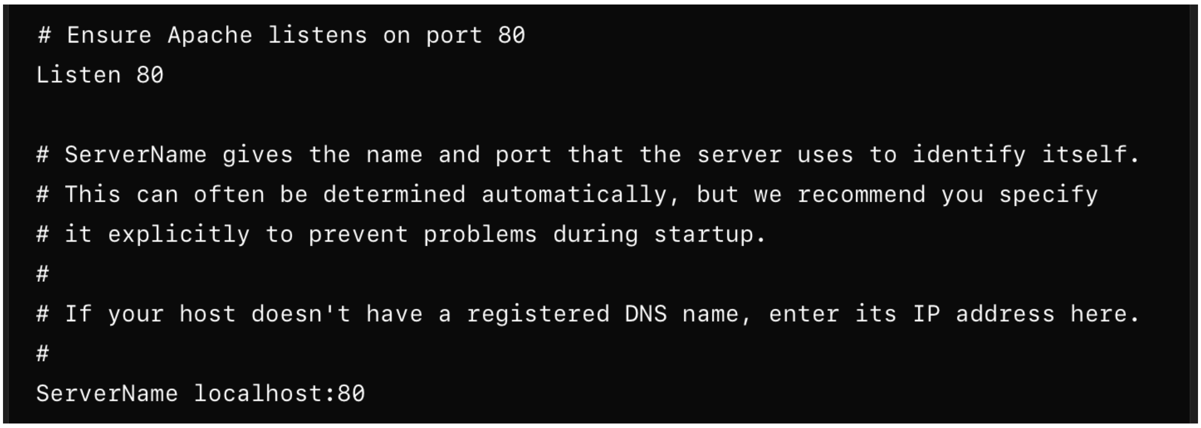
Open this file using a text editor such as Notepad or Visual Studio Code. Once opened, locate the following settings and make the specified changes if needed:

a. Scroll down to the **SRVROOT** setting and ensure it reads `Define SRVROOT C:/Apache24`. If it's commented out, uncomment it to define the SRVROOT variable and instruct Apache to use the specified directory path as the root directory.



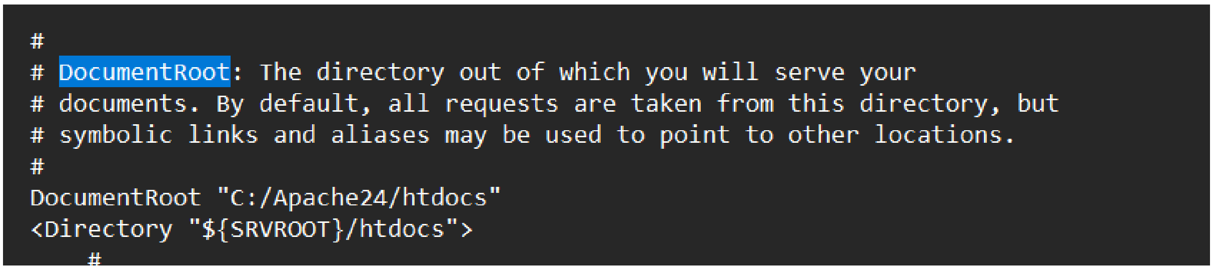
```
Define SRVROOT "c:/Apache24"

ServerRoot "${SRVROOT}"
```

b. Next, scroll through the **httpd.conf** file and locate the ServerName directive. Set it to `localhost:80`. If this line is commented out, remove the hash symbol (#) at the beginning to uncomment it. Also, search for the `Listen 80` directive. If it is commented out, uncomment it to ensure Apache listens on port 80.



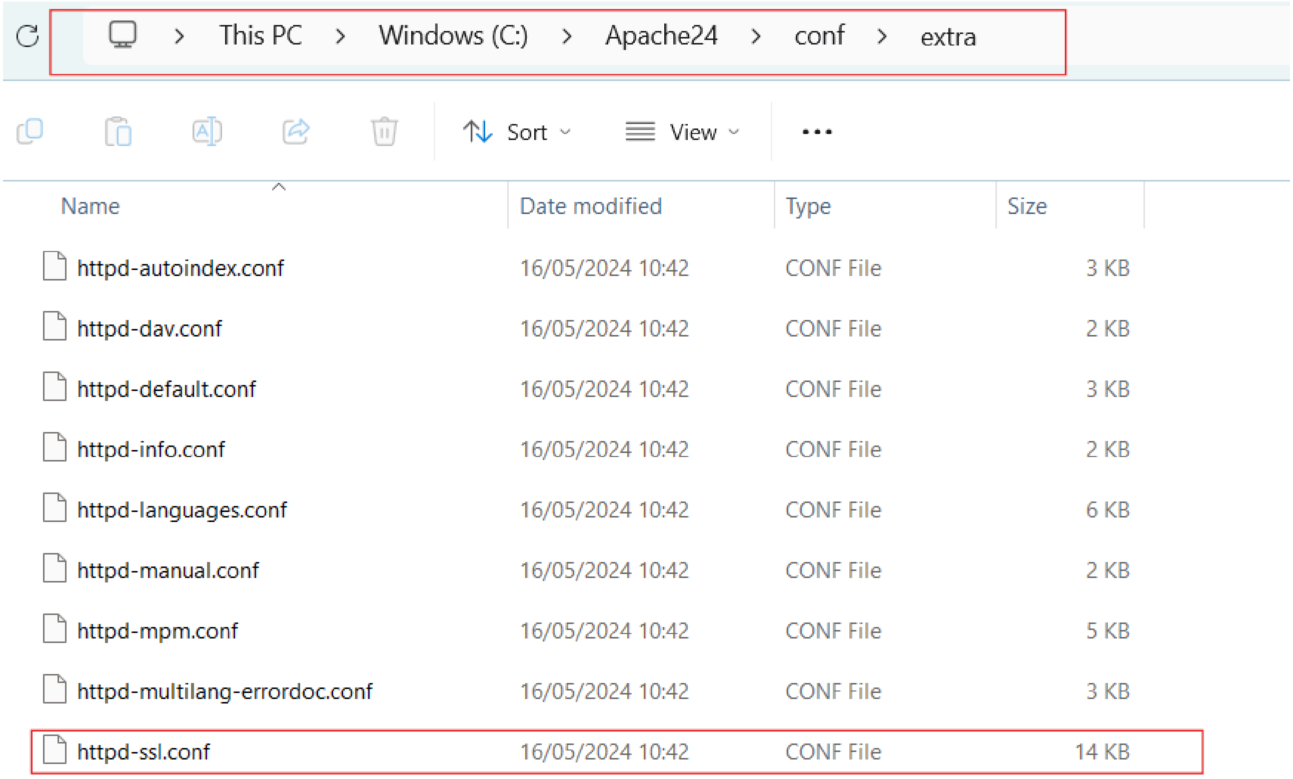
```
# Ensure Apache listens on port 80
Listen 80

# ServerName gives the name and port that the server uses to identify itself.
# This can often be determined automatically, but we recommend you specify
# it explicitly to prevent problems during startup.
#
# If your host doesn't have a registered DNS name, enter its IP address here.
#
ServerName localhost:80
```

c. Additionally, set the “DocumentRoot” to **C:/Apache24/htdocs.** If this line is commented out, remove the hash symbol (#) at the beginning to uncomment it. Ensure the line matches the example shown in the screenshot below:



```
#
# DocumentRoot: The directory out of which you will serve your
# documents. By default, all requests are taken from this directory, but
# symbolic links and aliases may be used to point to other locations.
#
DocumentRoot "C:/Apache24/htdocs"
<Directory "${SRVROOT}/htdocs">
    #
```

4. In your file explorer, navigate to the **C:/Apache24/conf/extra/** directory and locate the file named **httpd-ssl.conf**. Open this file using a text editor.

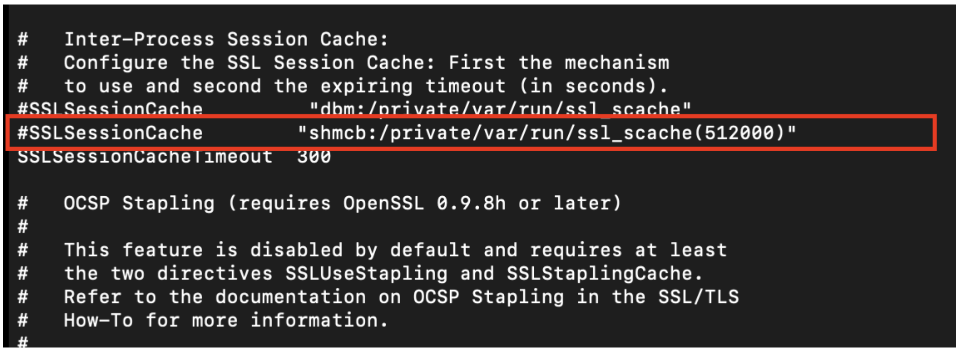


Name	Date modified	Type	Size
httpd-autoindex.conf	16/05/2024 10:42	CONF File	3 KB
httpd-dav.conf	16/05/2024 10:42	CONF File	2 KB
httpd-default.conf	16/05/2024 10:42	CONF File	3 KB
httpd-info.conf	16/05/2024 10:42	CONF File	2 KB
httpd-languages.conf	16/05/2024 10:42	CONF File	6 KB
httpd-manual.conf	16/05/2024 10:42	CONF File	2 KB
httpd-mpm.conf	16/05/2024 10:42	CONF File	5 KB
httpd-multilang-errordoc.conf	16/05/2024 10:42	CONF File	3 KB
httpd-ssl.conf	16/05/2024 10:42	CONF File	14 KB

Once opened, find the line containing the `SSLSessionCache` directive:

```
SSLSessionCache "shmcb:${SRVROOT}/logs/ssl_scache(512000)."
```

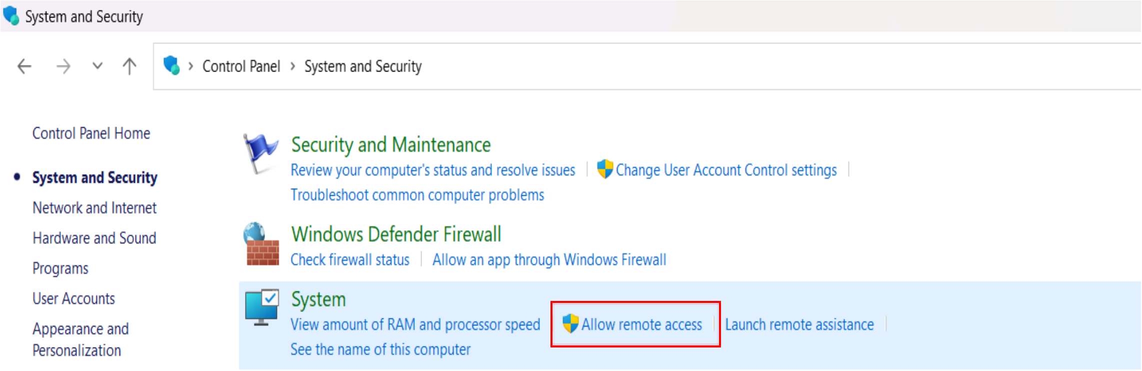
If this line is not already commented out, add a hash symbol (#) at the beginning to comment it out. This directive configures caching for SSL/TLS session information, which enhances performance by reusing session parameters. However, for this task, session caching is not required.



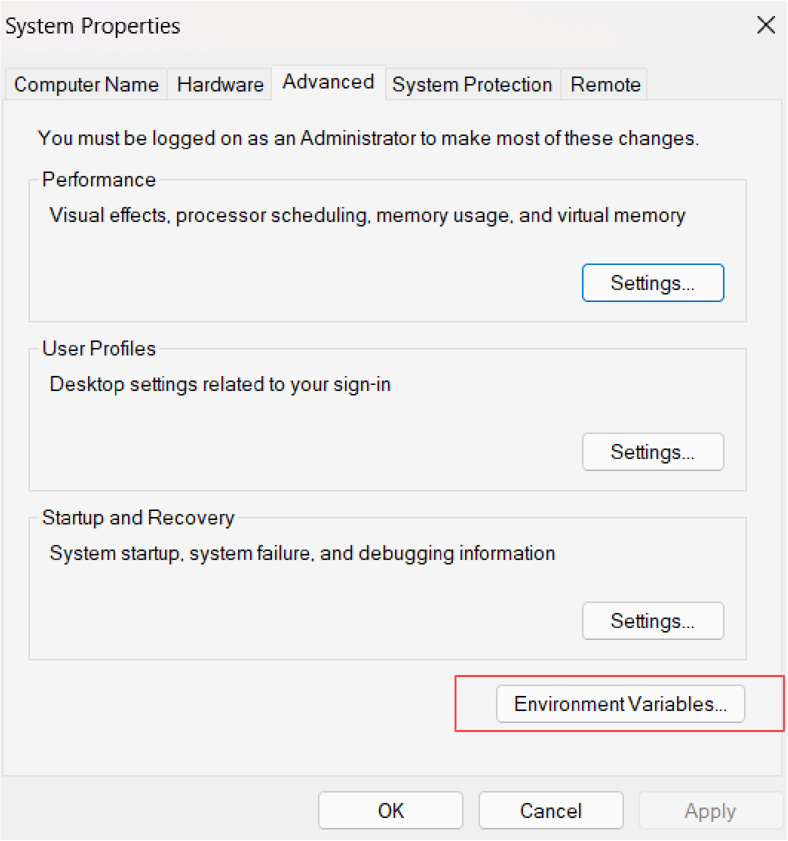
```
#   Inter-Process Session Cache:
#   Configure the SSL Session Cache: First the mechanism
#   to use and second the expiring timeout (in seconds).
#SSLSessionCache         "dbm:/private/var/run/ssl_scache"
#SSLSessionCache        "shmcb:/private/var/run/ssl_scache(512000)"
SSLSessionCacheTimeout  300

#   OCSP Stapling (requires OpenSSL 0.9.8h or later)
#
#   This feature is disabled by default and requires at least
#   the two directives SSLUseStapling and SSLStaplingCache.
#   Refer to the documentation on OCSP Stapling in the SSL/TLS
#   How-To for more information.
#
```

5. Add the path **C:/Apache24/bin** to the Windows PATH environment variable as follows:

   - You can find and edit the PATH variable by opening the Windows Control Panel and navigating to “System and Security”, then “System”, and selecting “Advanced system settings”. This will open the System Properties dialog box where you can click on “Environment Variables” to edit the PATH variable.


System and Security
Control Panel › System and Security
Control Panel Home
System and Security
Network and Internet
Hardware and Sound
Programs
User Accounts
Appearance and Personalization
Security and Maintenance
Review your computer's status and resolve issues
Change User Account Control settings
Troubleshoot common computer problems
Windows Defender Firewall
Check firewall status
Allow an app through Windows Firewall
System
View amount of RAM and processor speed
Allow remote access
Launch remote assistance
See the name of this computer

- Once the “System Properties” dialogue box is open, go to the “Advanced” tab and click on “Environment Variables”.



You must be logged on as an Administrator to make most of these changes.

Performance

Visual effects, processor scheduling, memory usage, and virtual memory

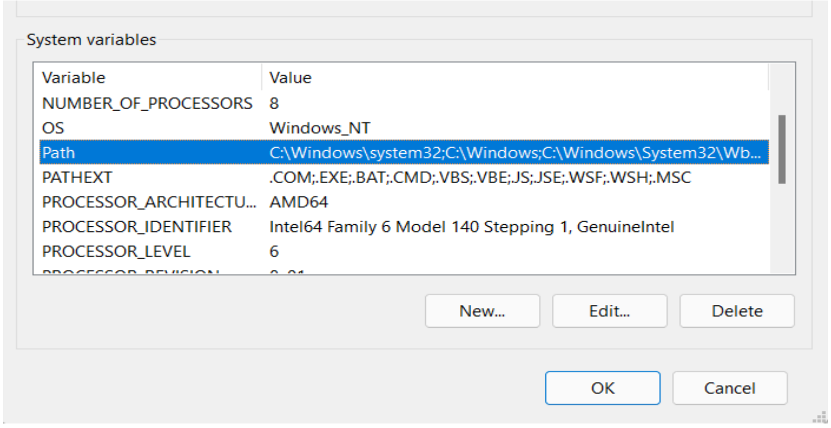
User Profiles

Desktop settings related to your sign-in

Startup and Recovery

System startup, system failure, and debugging information

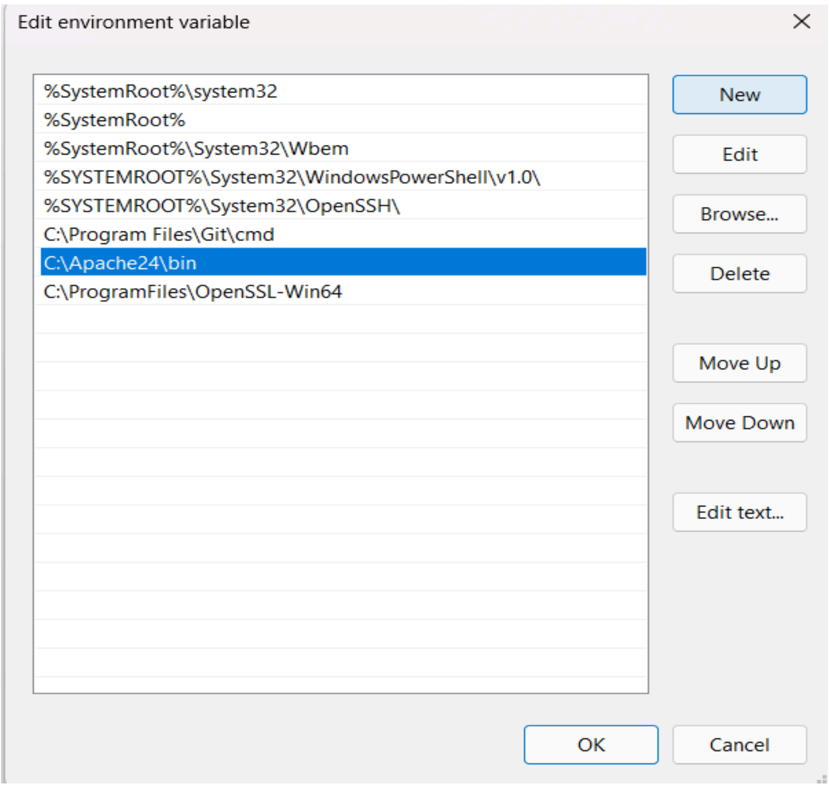
- In the “Environment Variables” window, you will see two sections: “User variables” and “System variables”.
- Scroll through the “System variables” section and find the variable named “Path”. Select it and click “Edit”.



System variables

Variable	Value
NUMBER_OF_PROCESSORS	8
OS	Windows_NT
Path	C:\Windows\system32;C:\Windows;C:\Windows\System32\Wb...
PATHEXT	.COM;.EXE;.BAT;.CMD;.VBS;.VBE;.JS;.JSE;.WSF;.WSH;.MSC
PROCESSOR_ARCHITECTU...	AMD64
PROCESSOR_IDENTIFIER	Intel64 Family 6 Model 140 Stepping 1, GenuineIntel
PROCESSOR_LEVEL	6

- In the “Edit environment variable” dialogue box, click “New” and add the path **C:\Apache24\bin.** Ensure there are no typos and use backslashes (\) for consistency with other entries. Click OK until all dialogue boxes are closed.



Edit environment variable

%SystemRoot%\system32
%SystemRoot%
%SystemRoot%\System32\Wbem
%SYSTEMROOT%\System32\WindowsPowerShell\v1.0\
%SYSTEMROOT%\System32\OpenSSH\
C:\Program Files\Git\cmd
C:\Apache24\bin
C:\ProgramFiles\OpenSSL-Win64

6. Open the Command Prompt as an administrator. To start the Apache server, follow these steps:

   - Navigate to the **bin** directory using this command:

```
cd C:/Apache24/bin/
```

   - Install the Apache 2.4 service with the following command:

```
httpd -k install
```

- Then start the Apache server using this command:

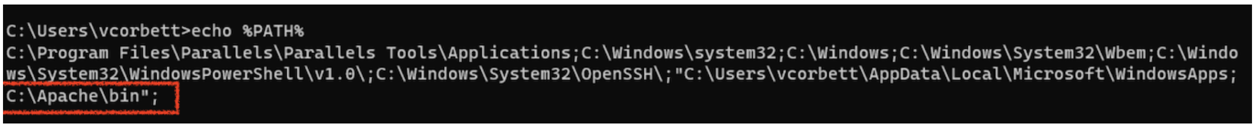
```
httpd.exe -k start
```

- To stop the Apache server use this command:

```
httpd.exe -k stop
```

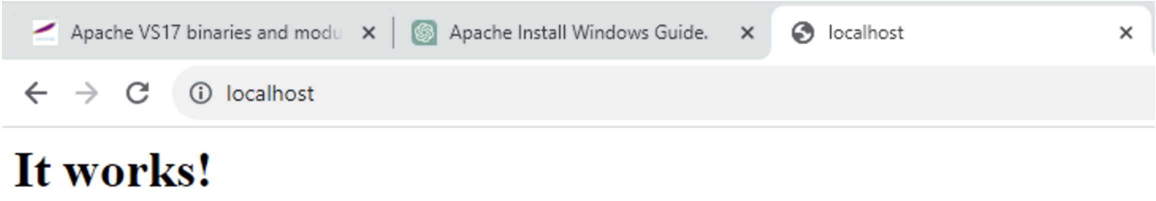
Take note

If you encounter difficulties at this stage, review the error messages generated by the command. These messages usually pertain to directory structure errors. For example, ensure that the PATH command has been updated with the correct Apache directory structure by executing the following command in the Windows terminal: `echo  %PATH%`. You should receive output similar to the following:



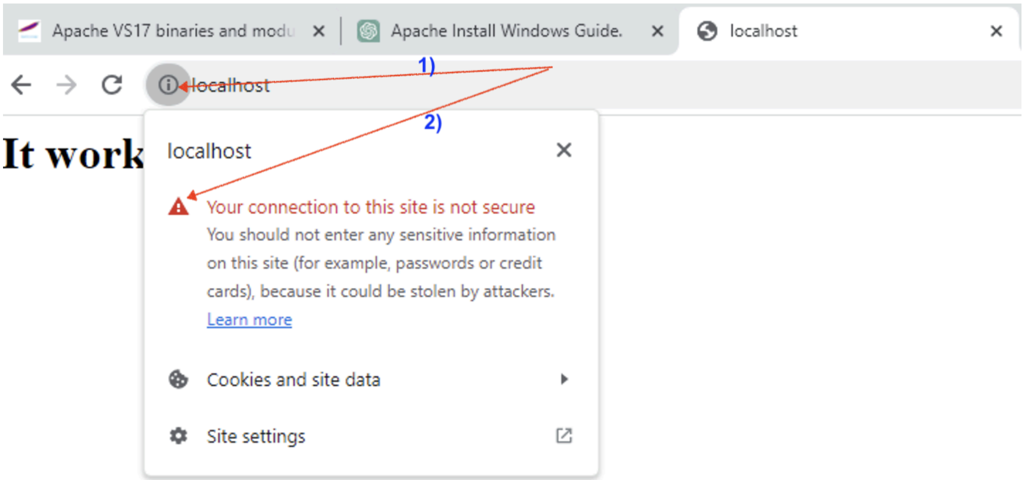
```
C:\Users\vcorbett>echo %PATH%
C:\Program Files\Parallels\Parallels Tools\Applications;C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;C:\Windo
ws\System32\WindowsPowerShell\v1.0\;C:\Windows\System32\OpenSSH\;"C:\Users\vcorbett\AppData\Local\Microsoft\WindowsApps;
C:\Apache\bin";
```

7. Test the Apache web server by opening a web browser and navigating to **http://localhost**. You should see a web page that resembles the following:



It works!

Afterwards, click on the “**i**” icon located to the left of “localhost”. You should encounter a display similar to the following, indicating that the connection is not secure:



Your connection to this site is not secure

You should not enter any sensitive information on this site (for example, passwords or credit cards), because it could be stolen by attackers.

This happens because you are using the HTTP protocol, which lacks encryption, authentication, data integrity, and secure communication channels provided by the SSL protocol (HTTPS). As a result, all your conversations can be eavesdropped on and tampered with.

Creating a Certificate Authority

We will first create a local certificate authority (CA) to prepare for the hardening of the Apache web server. A CA is a commercial, third-party, trusted authority, such as **GoDaddy** and **Verisign**. CAs issue digital certificates, which are used to secure communication between two parties. You typically purchase the services of a CA to obtain such a certificate, ensuring secure communication, for example, between the Apache web server and its clients (i.e., web browsers).

We will establish a CA by creating a “self-signed” certificate. This certificate acts as a template for services like the Apache web server to generate their own certificate. Thus, Apache's web server certificate, signed by the CA, verifies the server's identity to web browsers requesting its service(s).

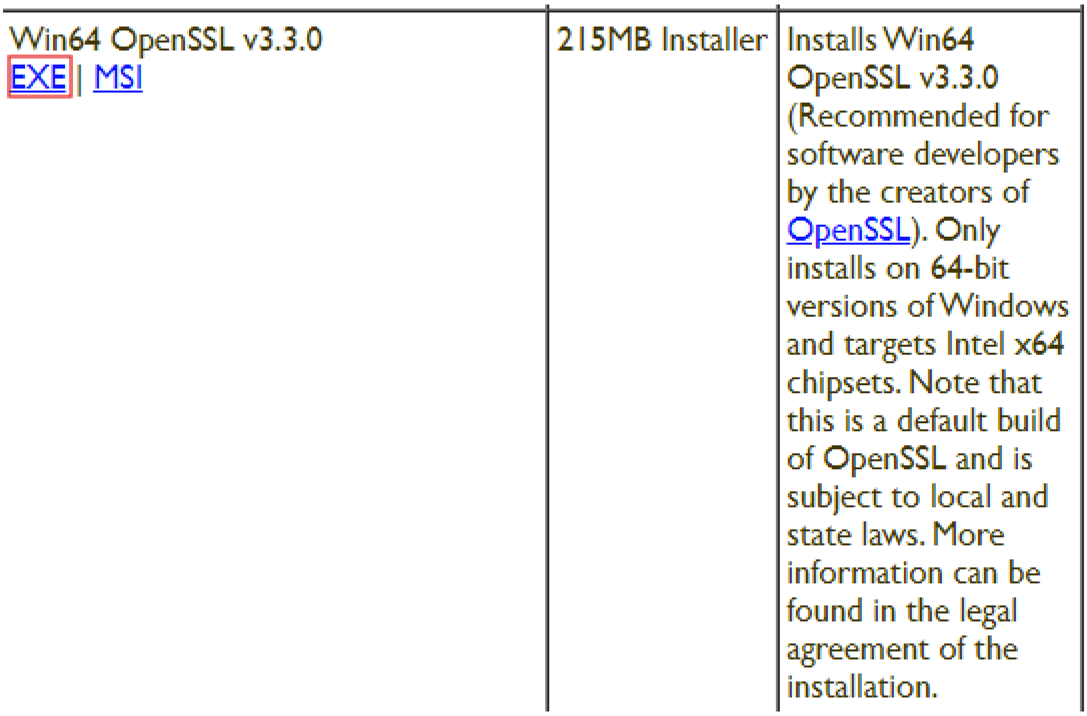
It is important to note that a self-signed CA certificate should only be used in lab environments. For production environments, it is necessary to use the services of a commercial CA to obtain a digital certificate.

OpenSSL toolkit

To “harden” the Apache web server, you will need to download the OpenSSL toolkit using the following instructions:

1. Visit the **OpenSSL download page**.

2. Choose the appropriate version of OpenSSL for your Windows system (32-bit or 64-bit) and download the installer.

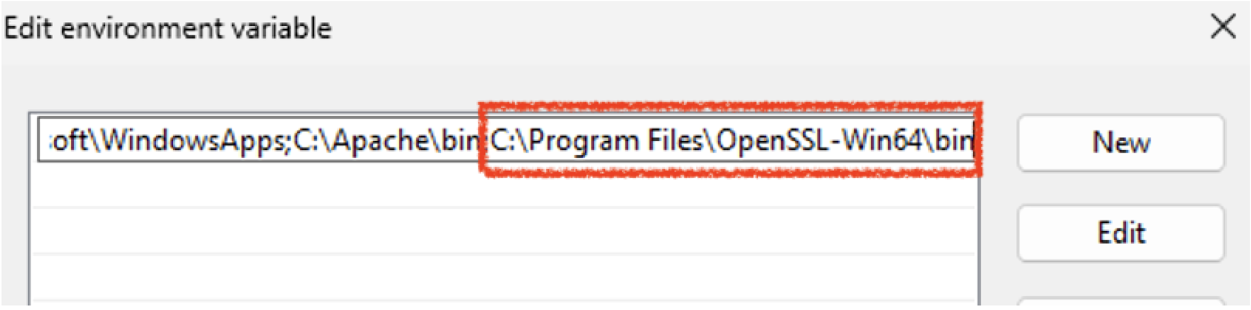


Win64 OpenSSL v3.3.0 EXE | MSI	215MB Installer	Installs Win64 OpenSSL v3.3.0 (Recommended for software developers by the creators of OpenSSL). Only installs on 64-bit versions of Windows and targets Intel x64 chipsets. Note that this is a default build of OpenSSL and is subject to local and state laws. More information can be found in the legal agreement of the installation.

3. Double-click on the downloaded installer to start the installation process.

4. Follow the on-screen instructions provided by the installer. Typically, you'll need to agree to the license agreement and choose the installation directory (**C:/ProgramFiles/OpenSSL-Win64/**). Simply follow the installation prompts until the installation is complete.

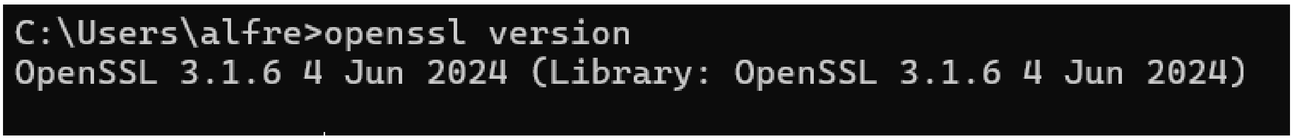
5. To augment your Windows PATH environment variable with the OpenSSL directory, add **C:\Program Files\OpenSSL-Win64\** to the list. Follow the instructions above to navigate to the Windows Environment Variables editor. Once there, click **New** and carefully enter the path **C:\Program Files\OpenSSL-Win64**\, ensuring there are no typos.



Edit environment variable

oft\WindowsApps;C:\Apache\bin;C:\Program Files\OpenSSL-Win64\bin

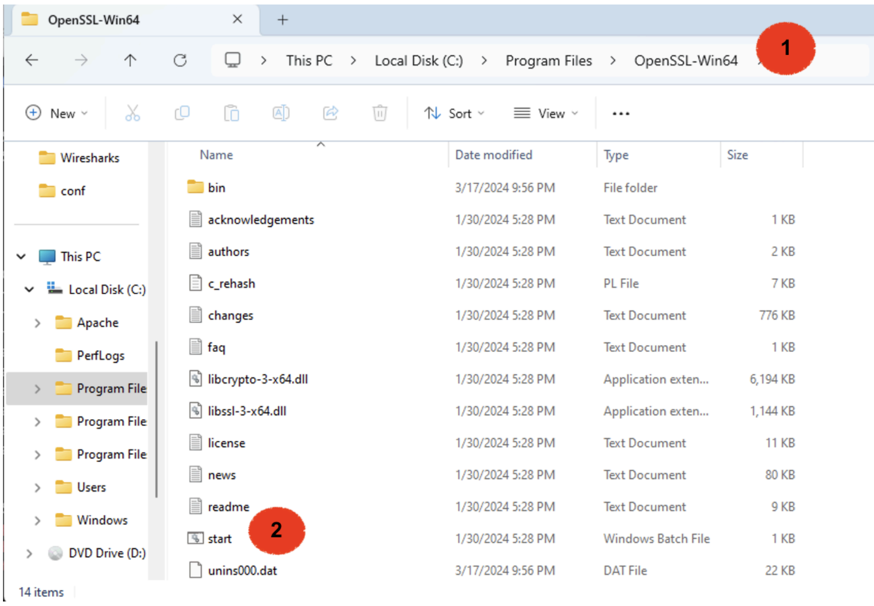
6. Verify the installation by opening a Command Prompt and typing `openssl version`. You should see the version information for OpenSSL if the installation was successful.



```
C:\Users\alfre>openssl version
OpenSSL 3.1.6 4 Jun 2024 (Library: OpenSSL 3.1.6 4 Jun 2024)
```

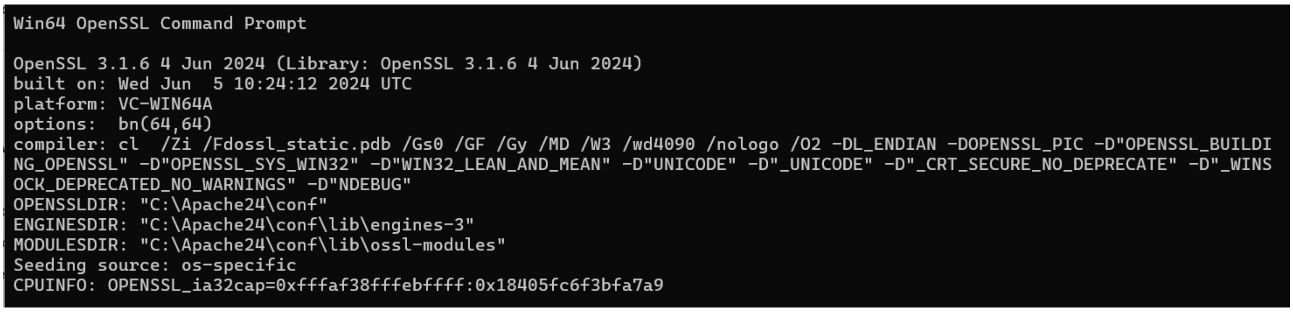
Certificate Authority

1. In the Windows File Explorer, navigate to the newly created SSL directory **C:\Program Files\OpenSSL-Win64\**, marked (1) in the screenshot below, and double-click on `start.bat`, marked (2) in the screenshot below. This will lead you to the Command Prompt.



Name	Date modified	Type	Size
bin	3/17/2024 9:56 PM	File folder	
acknowledgements	1/30/2024 5:28 PM	Text Document	1 KB
authors	1/30/2024 5:28 PM	Text Document	2 KB
c_rehash	1/30/2024 5:28 PM	PL File	7 KB
changes	1/30/2024 5:28 PM	Text Document	776 KB
faq	1/30/2024 5:28 PM	Text Document	1 KB
libcrypto-3-x64.dll	1/30/2024 5:28 PM	Application exten...	6,194 KB
libssl-3-x64.dll	1/30/2024 5:28 PM	Application exten...	1,144 KB
license	1/30/2024 5:28 PM	Text Document	11 KB
news	1/30/2024 5:28 PM	Text Document	80 KB
readme	1/30/2024 5:28 PM	Text Document	9 KB
start	1/30/2024 5:28 PM	Windows Batch File	1 KB
unins000.dat	3/17/2024 9:56 PM	DAT File	22 KB

The Command Prompt :



```
Win64 OpenSSL Command Prompt

OpenSSL 3.1.6 4 Jun 2024 (Library: OpenSSL 3.1.6 4 Jun 2024)
built on: Wed Jun  5 10:24:12 2024 UTC
platform: VC-WIN64A
options:  bn(64,64)
compiler: cl  /Zi /Fdossl_static.pdb /Gs0 /GF /Gy /MD /W3 /wd4090 /nologo /O2 -DL_ENDIAN -DOPENSSL_PIC -D"OPENSSL_BUILDI
NG_OPENSSL" -D"OPENSSL_SYS_WIN32" -D"WIN32_LEAN_AND_MEAN" -D"UNICODE" -D"_UNICODE" -D"_CRT_SECURE_NO_DEPRECATE" -D"_WINS
OCK_DEPRECATED_NO_WARNINGS" -D"NDEBUG"
OPENSSLDIR: "C:\Apache24\conf"
ENGINESDIR: "C:\Apache24\conf\lib\engines-3"
MODULESDIR: "C:\Apache24\conf\lib\ossl-modules"
Seeding source: os-specific
CPUINFO: OPENSSL_ia32cap=0xfffaf38fffebffff:0x18405fc6f3bfa7a9
```

2. Navigate to the new directory **C:/Apache24/conf** via the following command:

```
cd C:/Apache24/conf
```

3. Create the file san_config in the same directory. You can create it using the `echo . > san_config` command in Command Prompt. Open the file using Notepad or VS Code, then add the code below. This file will be used in the subsequent

OpenSSL commands to create a CA certificate with a Subject Alternative Name (SAN) of “localhost”. Please review the command parameters below for more information on these and other characteristics of the digital certificate you are going to create.

```
[req]
default_bits = 2048
prompt = no
default_md = sha256
distinguished_name = dn
req_extensions = req_ext

[dn]
CN = localhost

[req_ext]
subjectAltName = @alt_names
basicConstraints = critical, CA:true

[alt_names]
DNS.1 = localhost
```

Explanation of parameters for `[req]` section:

- `default_bits = 2048` specifies the default key size in bits for the generated RSA private key. In this case, it's set to 2048 bits.
- `prompt = no` disables prompting for information during the certificate signing request (CSR) generation process.
- `default_md = sha256` sets the default message digest algorithm to SHA-256 for generating the CSR.
- `distinguished_name = dn` (see `[dn]` section below)
- `req_extensions = req_ext` specifies that the extensions to be added to the certificate request are defined in the `req_ext` section. It links the extensions defined in `[req_ext]` to the certificate request.

Explanation of parameters for `[dn]` section:

- `CN = localhost` specifies the common name (CN) associated with the certificate. In this case, it means that the certificate is intended for use with the hostname "localhost”. The CA will use this information to issue a certificate with the specified CN.

Explanation of parameters for `[req_ext]` section:

- `subjectAltName = @alt_names` specifies that the SAN extension should be included in the certificate request and takes values from the `alt_names`.

- `basicConstraints = critical, CA:true` defines the basic constraints for the certificate. In this case, it indicates that the certificate to be issued is a CA certificate.

Explanation of parameters for `[alt_names]` section:

- `DNS.1 = localhost` specifies an alternative DNS name (SAN) for the certificate. In this case, it's set to "localhost”, allowing the certificate to be valid for this name in addition to the CN specified in the `[dn]` section. Note that specifying the SAN is required for later versions of the Chrome and Chromium browsers.

4. The following command will generate a new private key (server.key) and a certificate signing request (server.csr). The parameters are explained below: "localhost" is defined as the Common Name (CN). The CN is a certificate field that identifies the entity for which the certificate is created, typically the domain name of your organization's website. Since we are creating a self-signed certificate for testing purposes, we are defining the CN as "localhost".

   Command:

   ```
   openssl req -newkey rsa:2048 -nodes -keyout server.key -out server.csr
   -subj "/CN=localhost" -config san_config
   ```

   Here is an explanation of each parameter:

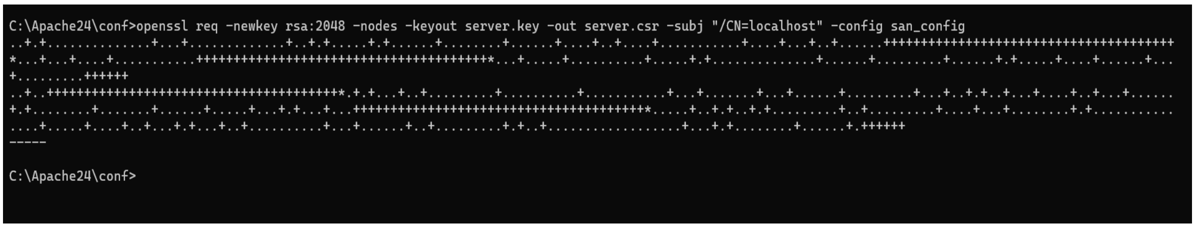
   - `openssl req` is used for generating a CSR.

   - **`-newkey rsa:2048`** specifies that a new private key and CSR will be generated. The `rsa:2048` option indicates that an RSA key with a length of 2048 bits will be used. This part of the command combines the key generation and CSR creation into a single step.

   - `-nodes` option specifies that the private key should not be encrypted. This means that the private key file (`server.key` in this case) will be written without a passphrase, allowing it to be used directly without prompting for a password.

- `-keyout server.key` specifies the filename (`server.key`) where the generated private key will be saved.
- `-out server.csr` specifies the filename (`server.csr`) where the generated CSR will be saved. The CSR contains information about the entity requesting the certificate, such as the CN and organisation.
- `-subj "/CN=localhost"` specifies the subject (i.e., information about the entity) for the CSR. In this case, the subject is set to `/CN=localhost`, where `/CN=` indicates the CN field of the certificate. The CN is typically the domain name or hostname of the entity for which the certificate is being issued. In this example, the CN is set to "localhost", indicating that the certificate will be valid for the domain name "localhost".
- `-config san_config` is used to specify a custom configuration file for Apache.

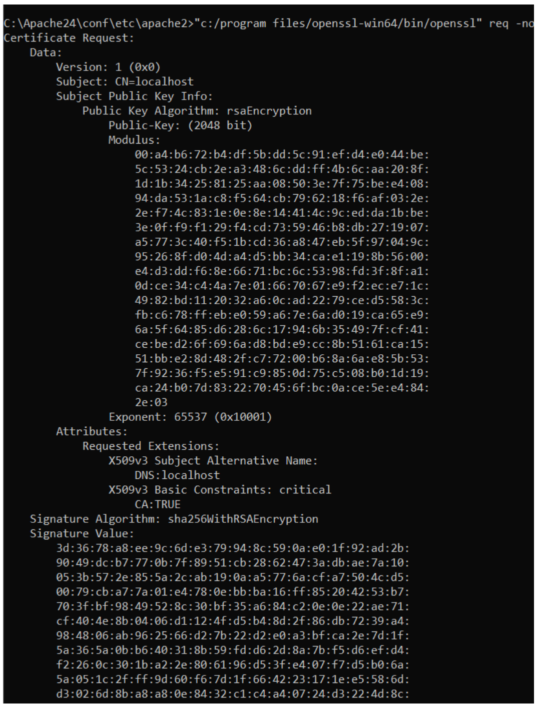
  Sample output:



```
C:\Apache24\conf>openssl req -newkey rsa:2048 -nodes -keyout server.key -out server.csr -subj "/CN=localhost" -config san_config
..+.+..............+...+............+..+.+.....+.+......+........+......+....+..+....+..........+....+...+..+......++++++++++++++++++++++++++++++++++++++++
*...+...+....+..........++++++++++++++++++++++++++++++++++++++++*...+.....+..........+.....+.+..............+......+.........+......+.+.....+....+......+...
+.........++++++
..+..++++++++++++++++++++++++++++++++++++++++*.+.+...+..+.........+..........+...........+...+.......+...+......+.........+...+..+.+..+...+....+..+...+......
+.+........+.......+......+.....+...+.+...+...++++++++++++++++++++++++++++++++++++++++*.....+..+.+..+.+.........+..+.........+....+...+........+.+..........
....+.....+....+..+...+.+...+..+..........+...+......+..+.........+.+..+.................+...+.+........+......+.++++++
-----

C:\Apache24\conf>
```

Issue the following command to confirm that the CSR file has been created specifying a CA certificate with SAN value of “localhost”. Here is the command and corresponding sample output:

```
"C:/program files/openssl-win64/bin/openssl" req -noout -text -in
C:\Apache24\conf\server.csr
```



```
C:\Apache24\conf\etc\apache2>"c:/program files/openssl-win64/bin/openssl" req -no
Certificate Request:
    Data:
        Version: 1 (0x0)
        Subject: CN=localhost
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:a4:b6:72:b4:df:5b:dd:5c:91:ef:d4:e0:44:be:
                    5c:53:24:cb:2e:a3:48:6c:dd:ff:4b:6c:aa:20:8f:
                    1d:1b:34:25:81:25:aa:08:50:3e:7f:75:be:e4:08:
                    94:da:53:1a:c8:f5:64:cb:79:62:18:f6:af:03:2e:
                    2e:f7:4c:83:1e:0e:8e:14:41:4c:9c:ed:da:1b:be:
                    3e:0f:f9:f1:29:f4:cd:73:59:46:b8:db:27:19:07:
                    a5:77:3c:40:f5:1b:cd:36:a8:47:eb:5f:97:04:9c:
                    95:26:8f:d0:4d:a4:d5:bb:34:ca:e1:19:8b:56:00:
                    e4:d3:dd:f6:8e:66:71:bc:6c:53:98:fd:3f:8f:a1:
                    0d:ce:34:c4:4a:7e:01:66:70:67:e9:f2:ec:e7:1c:
                    49:82:bd:11:20:32:a6:0c:ad:22:79:ce:d5:58:3c:
                    fb:c6:78:ff:eb:e0:59:a6:7e:6a:d0:19:ca:65:e9:
                    6a:5f:64:85:d6:28:6c:17:94:6b:35:49:7f:cf:41:
                    ce:be:d2:6f:69:6a:d8:bd:e9:cc:8b:51:61:ca:15:
                    51:bb:e2:8d:48:2f:c7:72:00:b6:8a:6a:e8:5b:53:
                    7f:92:36:f5:e5:91:c9:85:0d:75:c5:08:b0:1d:19:
                    ca:24:b0:7d:83:22:70:45:6f:bc:0a:ce:5e:e4:84:
                    2e:03
                Exponent: 65537 (0x10001)
        Attributes:
            Requested Extensions:
                X509v3 Subject Alternative Name:
                    DNS:localhost
                X509v3 Basic Constraints: critical
                    CA:TRUE
    Signature Algorithm: sha256WithRSAEncryption
    Signature Value:
        3d:36:78:a8:ee:9c:6d:e3:79:94:8c:59:0a:e0:1f:92:ad:2b:
        90:49:dc:b7:77:0b:7f:89:51:cb:28:62:47:3a:db:ae:7a:10:
        05:3b:57:2e:85:5a:2c:ab:19:0a:a5:77:6a:cf:a7:50:4c:d5:
        00:79:cb:a7:7a:01:e4:78:0e:bb:ba:16:ff:85:20:42:53:b7:
        70:3f:bf:98:49:52:8c:30:bf:35:a6:84:c2:0e:0e:22:ae:71:
        cf:40:4e:8b:04:06:d1:12:4f:d5:b4:8d:2f:86:db:72:39:a4:
        98:48:06:ab:96:25:66:d2:7b:22:d2:e0:a3:bf:ca:2e:7d:1f:
        5a:36:5a:0b:b6:40:31:8b:59:fd:d6:2d:8a:7b:f5:d6:ef:d4:
        f2:26:0c:30:1b:a2:2e:80:61:96:d5:3f:e4:07:f7:d5:b0:6a:
        5a:05:1c:2f:ff:9d:60:f6:7d:1f:66:42:23:17:1e:e5:58:6d:
        d3:02:6d:8b:a8:a8:0e:84:32:c1:c4:a4:07:24:d3:22:4d:8c:
```

5. The following command is used to create a digital certificate. We will use this certificate to enable the Apache web server to provide secure connections.

```
openssl x509 -req -in server.csr -signkey server.key -out server.crt
-days 365 -sha256 -extensions req_ext -extfile san_config
```

Here is an explanation of each parameter:

- `openssl`: This invokes the OpenSSL command-line tool for cryptographic operations.

- `x509`: This command is used to manage X.509 certificates.

- `-req` specifies that the input file (`server.csr`) is a CSR rather than a certificate.

- `-in server.csr` specifies the input file containing the CSR (`server.csr`). The CSR contains the information required to generate the certificate, including the public key and details about the entity requesting the certificate.

- `-signkey server.key` specifies the private key (`server.key)` that will be used to sign the certificate. The private key is necessary for generating a self-signed certificate.

- `-out server.crt` specifies the output file where the generated certificate will be saved. In this case, the certificate will be saved as `server.crt.`

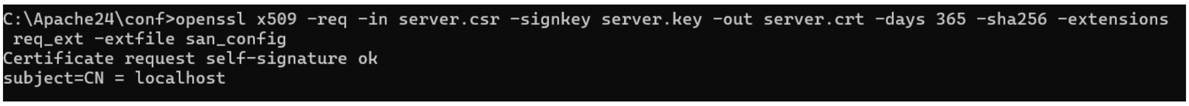
- `-days 365` specifies the validity period of the generated certificate in days. In this case, the certificate will be valid for 365 days from the time it is generated.

- `-sha256`: Specifies the hash algorithm to be used for signing the certificate. In this case, SHA-256 is used.

- `-extensions req_ext:` Specifies the section in the configuration file (san_config) that contains the extensions to be added to the certificate.

- `-extfile san_config:` Specifies the configuration file (san_config) that includes the additional settings, such as Subject Alternative Names (SANs), to be included in the certificate.

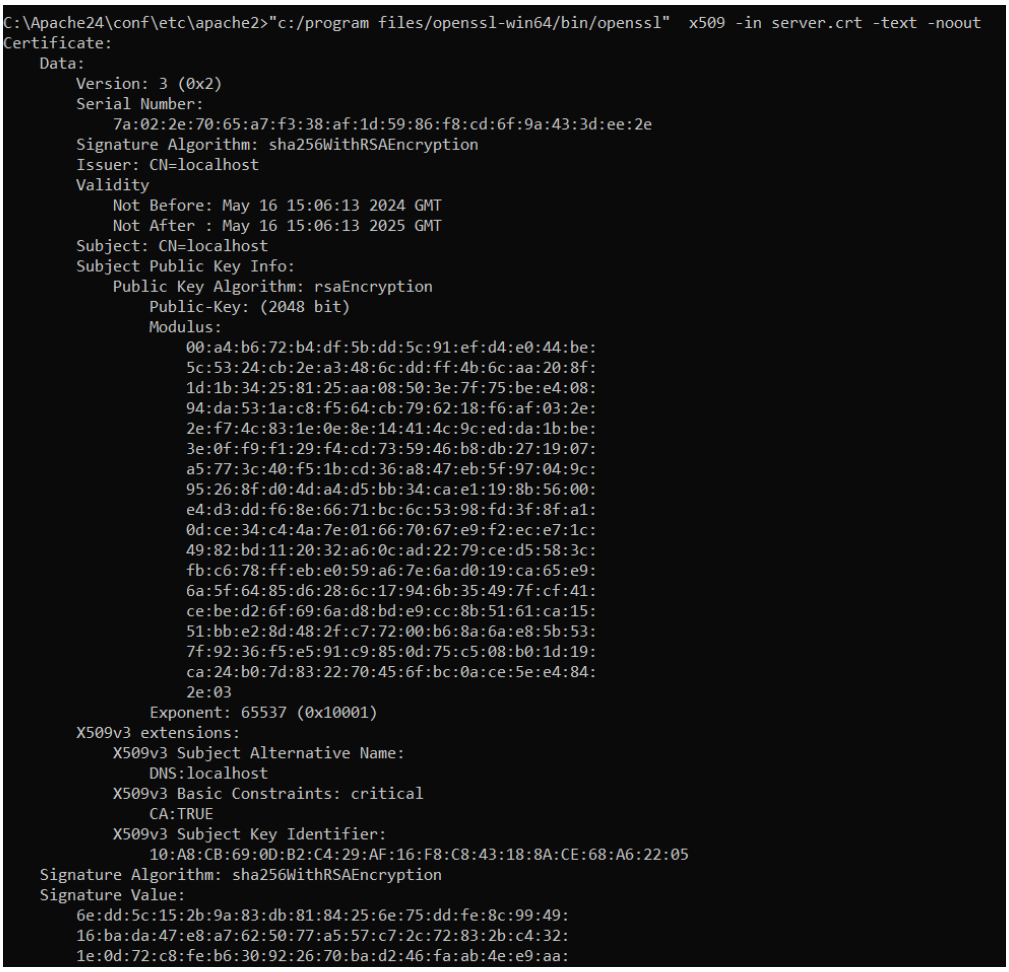
  Command and sample output should be:



```
C:\Apache24\conf>openssl x509 -req -in server.csr -signkey server.key -out server.crt -days 365 -sha256 -extensions
 req_ext -extfile san_config
Certificate request self-signature ok
subject=CN = localhost
```

  Issue the following command to confirm that the digital certificate has been created correctly, specifying a CA certificate with SAN value of “localhost”. Here is the command and corresponding output snippet:

```
"c:/program files/openssl-win64/bin/openssl" x509 -in server.crt
-text -noout
```



```
C:\Apache24\conf\etc\apache2>"c:/program files/openssl-win64/bin/openssl"  x509 -in server.crt -text -noout
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            7a:02:2e:70:65:a7:f3:38:af:1d:59:86:f8:cd:6f:9a:43:3d:ee:2e
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: CN=localhost
        Validity
            Not Before: May 16 15:06:13 2024 GMT
            Not After : May 16 15:06:13 2025 GMT
        Subject: CN=localhost
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:a4:b6:72:b4:df:5b:dd:5c:91:ef:d4:e0:44:be:
                    5c:53:24:cb:2e:a3:48:6c:dd:ff:4b:6c:aa:20:8f:
                    1d:1b:34:25:81:25:aa:08:50:3e:7f:75:be:e4:08:
                    94:da:53:1a:c8:f5:64:cb:79:62:18:f6:af:03:2e:
                    2e:f7:4c:83:1e:0e:8e:14:41:4c:9c:ed:da:1b:be:
                    3e:0f:f9:f1:29:f4:cd:73:59:46:b8:db:27:19:07:
                    a5:77:3c:40:f5:1b:cd:36:a8:47:eb:5f:97:04:9c:
                    95:26:8f:d0:4d:a4:d5:bb:34:ca:e1:19:8b:56:00:
                    e4:d3:dd:f6:8e:66:71:bc:6c:53:98:fd:3f:8f:a1:
                    0d:ce:34:c4:4a:7e:01:66:70:67:e9:f2:ec:e7:1c:
                    49:82:bd:11:20:32:a6:0c:ad:22:79:ce:d5:58:3c:
                    fb:c6:78:ff:eb:e0:59:a6:7e:6a:d0:19:ca:65:e9:
                    6a:5f:64:85:d6:28:6c:17:94:6b:35:49:7f:cf:41:
                    ce:be:d2:6f:69:6a:d8:bd:e9:cc:8b:51:61:ca:15:
                    51:bb:e2:8d:48:2f:c7:72:00:b6:8a:6a:e8:5b:53:
                    7f:92:36:f5:e5:91:c9:85:0d:75:c5:08:b0:1d:19:
                    ca:24:b0:7d:83:22:70:45:6f:bc:0a:ce:5e:e4:84:
                    2e:03
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Subject Alternative Name:
                DNS:localhost
            X509v3 Basic Constraints: critical
                CA:TRUE
            X509v3 Subject Key Identifier:
                10:A8:CB:69:0D:B2:C4:29:AF:16:F8:C8:43:18:8A:CE:68:A6:22:05
    Signature Algorithm: sha256WithRSAEncryption
    Signature Value:
        6e:dd:5c:15:2b:9a:83:db:81:84:25:6e:75:dd:fe:8c:99:49:
        16:ba:da:47:e8:a7:62:50:77:a5:57:c7:2c:72:83:2b:c4:32:
        1e:0d:72:c8:fe:b6:30:92:26:70:ba:d2:46:fa:ab:4e:e9:aa:
```

Securing the Apache web server with the SSL/TLS using the CA certificate

Now, let's discuss the process of hardening the Apache web server, which involves implementing the SSL/TLS protocol. This protocol relies on the digital certificate created earlier. When a web browser connects to the website via **https://**, it utilises the HTTPS protocol, and the Apache web server presents its digital certificate, issued by the local CA, to the browser. After the browser validates the certificate's validity, the SSL protocol establishes an encrypted and secure communication channel between the client and the server, protecting all data from eavesdropping and tampering.

In summary, the SSL protocol will provide the following critical security functions:

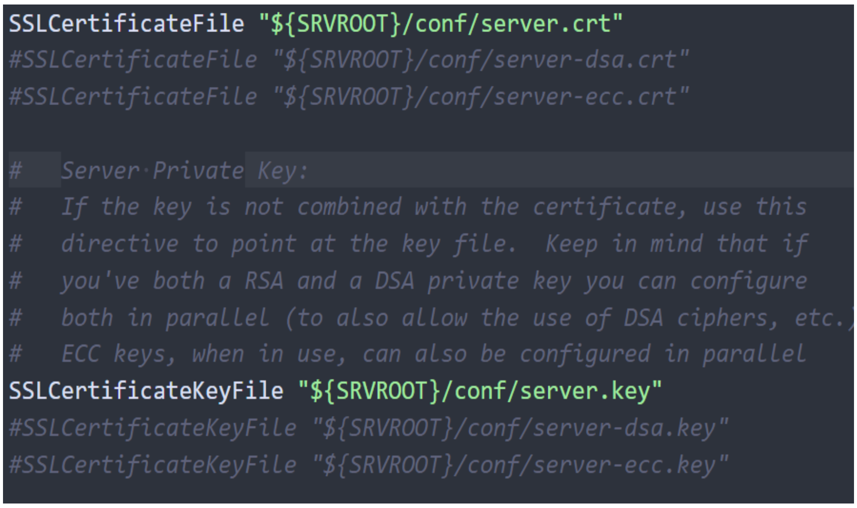
- Integrity: Data in transit remains intact and unaltered.
- Confidentiality: Data in transit is encrypted and, as such, it cannot be eavesdropped.

- Authentication: Digital certificates will verify the identity of the servers, reducing the risk of man-in-the-middle attacks.

For more information on SSL, visit this **web page**.

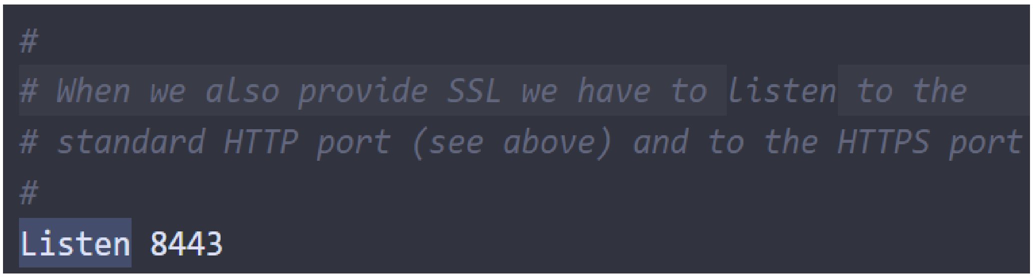
To configure the Apache web server, follow these steps:

1. In the **C:/Apache24/conf/extra/httpd-ssl.conf** file, confirm that the two lines shown in the screenshot below are uncommented. When uncommented, the Apache service will use the certification files indicated to start its SSL service. You can open this file using Notepad or VS Code. it will be easier to search for lines of code using Ctrl-F to locate the line you're looking for.



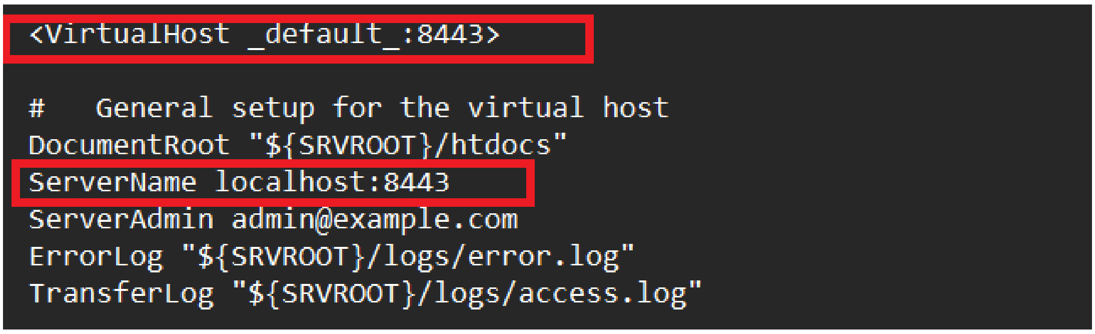
```
SSLCertificateFile "${SRVROOT}/conf/server.crt"
#SSLCertificateFile "${SRVROOT}/conf/server-dsa.crt"
#SSLCertificateFile "${SRVROOT}/conf/server-ecc.crt"

#   Server Private Key:
#   If the key is not combined with the certificate, use this
#   directive to point at the key file.  Keep in mind that if
#   you've both a RSA and a DSA private key you can configure
#   both in parallel (to also allow the use of DSA ciphers, etc.)
#   ECC keys, when in use, can also be configured in parallel
SSLCertificateKeyFile "${SRVROOT}/conf/server.key"
#SSLCertificateKeyFile "${SRVROOT}/conf/server-dsa.key"
#SSLCertificateKeyFile "${SRVROOT}/conf/server-ecc.key"
```

2. While still in **C:/Apache24/conf/extra/httpd-ssl.conf**, add the `Listen 8443` command and ensure it's not commented out (i.e., no leading `#`), to instruct Apache to listen for SSL connections on port 8443.



```
#
# When we also provide SSL we have to listen to the
# standard HTTP port (see above) and to the HTTPS port
#
Listen 8443
```

Also in **C:/Apache/conf/extra/httpd-ssl.conf**, modify the `ServerName` variable as follows and ensure that the `Virtualhost` is set to port `8443` along with the `ServerName`.

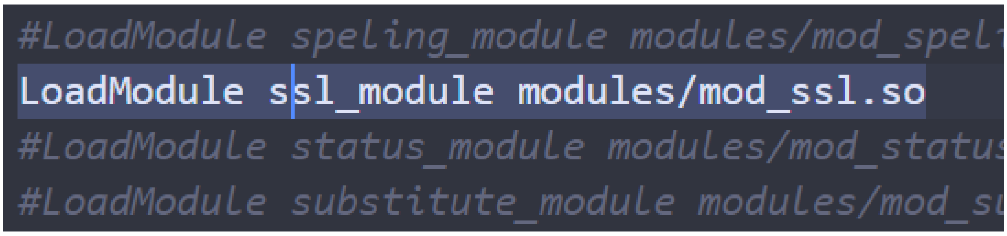


```
<VirtualHost _default_:8443>

#   General setup for the virtual host
DocumentRoot "${SRVROOT}/htdocs"
ServerName localhost:8443
ServerAdmin admin@example.com
ErrorLog "${SRVROOT}/logs/error.log"
TransferLog "${SRVROOT}/logs/access.log"
```

3. To enable and load the SSL module, follow these steps:

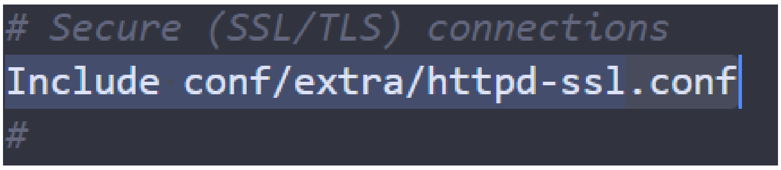
    - Open the **httpd.conf** file located at **C:/Apache24/conf/httpd.conf.**

    - Uncomment the line **LoadModule ssl_module modules/mod_ssl.so** to enable the SSL module.



```
#LoadModule speling_module modules/mod_spel
LoadModule ssl_module modules/mod_ssl.so
#LoadModule status_module modules/mod_status
#LoadModule substitute_module modules/mod_su
```

    - Uncomment the line **Include conf/extra/httpd-ssl.conf** to include (or activate) the configuration directives from the **httpd-ssl.conf** file located in the conf/extra/ directory



```
# Secure (SSL/TLS) connections
Include conf/extra/httpd-ssl.conf
#
```

Testing Apache's HTTPS

You would work through the following steps to test Apache's HTTPS

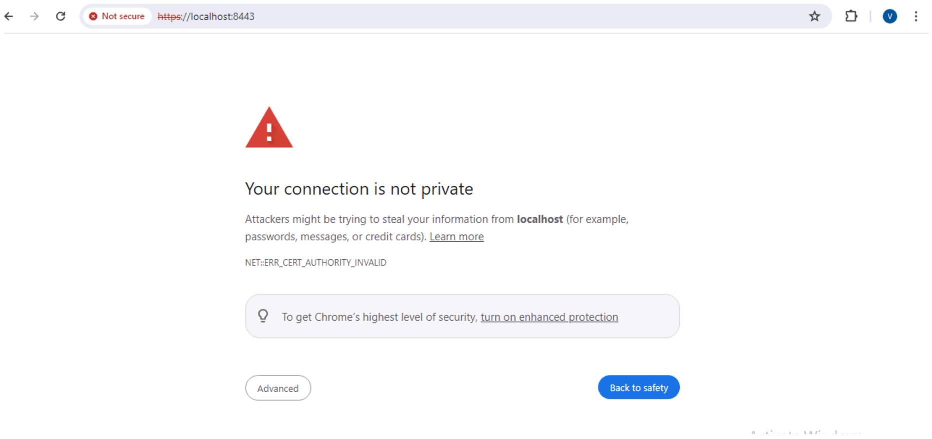
1. Install the **Chrome browser**, if you don't have it installed.

2. If Apache is still running, stop it by issuing Ctrl-c or exiting the terminal.

3. Start the Apache server using: `C:/Apache24/bin/httpd.exe`

4. Alternatively, you can start or stop Apache using the method referenced above.

5. In your browser, navigate to **https://localhost:8443,** which should result in the following:



Your connection is not private

Attackers might be trying to steal your information from **localhost** (for example, passwords, messages, or credit cards). Learn more

NET::ERR_CERT_AUTHORITY_INVALID

To get Chrome's highest level of security, turn on enhanced protection

Take note

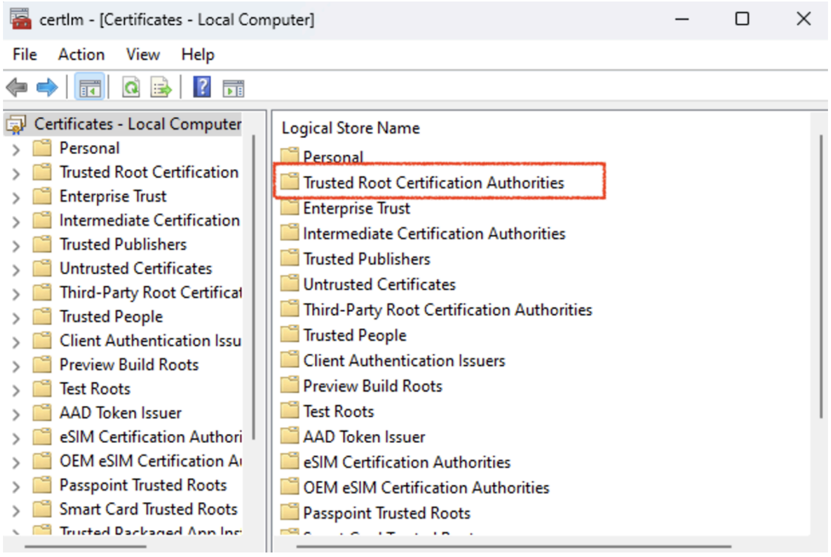
The warning is generated because your browser doesn't recognise the SSL certificate. It hasn't been issued by a trusted CA (e.g., Verisign). This behaviour is expected because we have created a self-signed certificate. Therefore, we can safely ignore the error.

6. Add the self-signed certificate to the Microsoft certificate database. Navigate to **C:/Apache/conf** using this command: `cd /Apache24/conf`

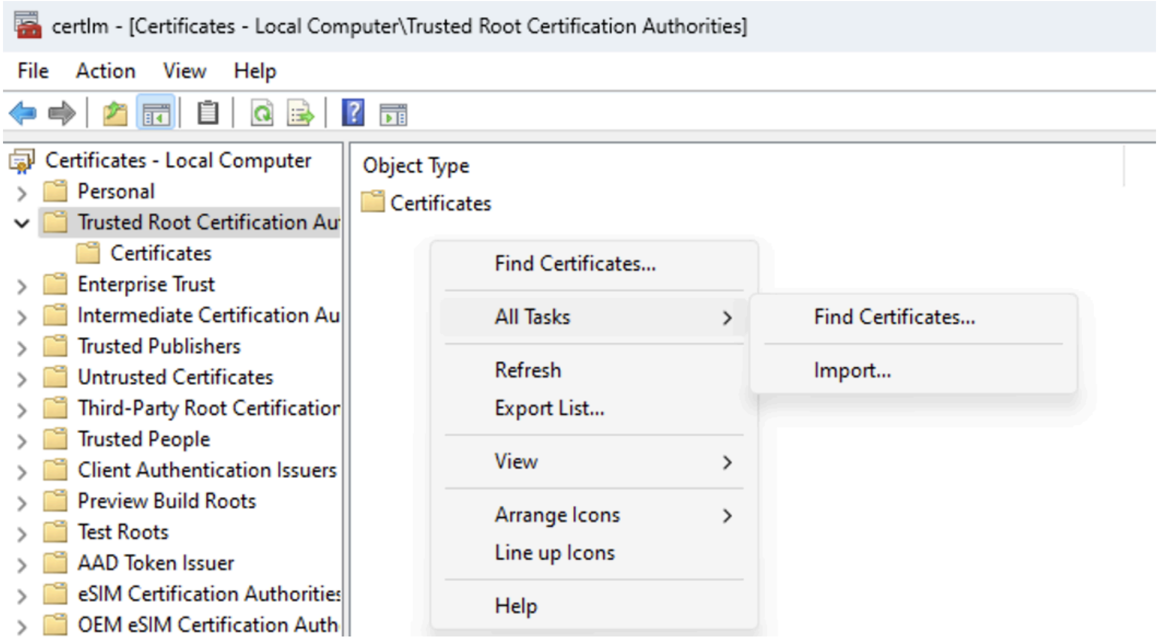
7. Export the certificate from Apache via the following command:

```
openssl x509 -outform der -in server.crt -out server.der
```

8. In Windows, search for “Manage Computer Certificates” and navigate to a folder named "Trusted Root Certification Authorities”.

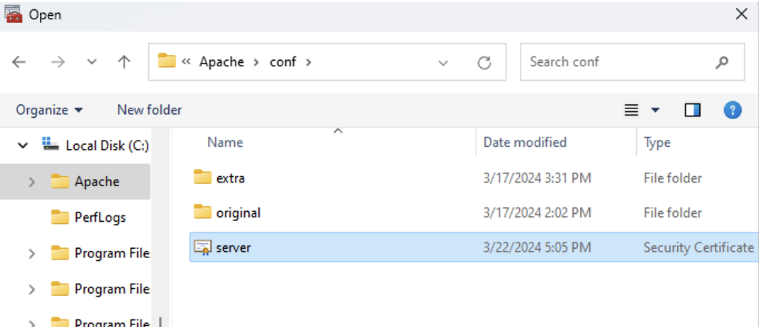

certlm - [Certificates - Local Computer]
File
Action
View
Help
Certificates - Local Computer
Personal
Trusted Root Certification
Enterprise Trust
Intermediate Certification
Trusted Publishers
Untrusted Certificates
Third-Party Root Certificat
Trusted People
Client Authentication Issu
Preview Build Roots
Test Roots
AAD Token Issuer
eSIM Certification Authori
OEM eSIM Certification A
Passpoint Trusted Roots
Smart Card Trusted Roots
Trusted Packaged App Ins
Logical Store Name
Personal
Trusted Root Certification Authorities
Enterprise Trust
Intermediate Certification Authorities
Trusted Publishers
Untrusted Certificates
Third-Party Root Certification Authorities
Trusted People
Client Authentication Issuers
Preview Build Roots
Test Roots
AAD Token Issuer
eSIM Certification Authorities
OEM eSIM Certification Authorities
Passpoint Trusted Roots

9. Right-click on an empty area in the right pane, select “All Tasks”, and then choose “Import” from the context menu.



10. In the Certificate Import Wizard, click “Next”.

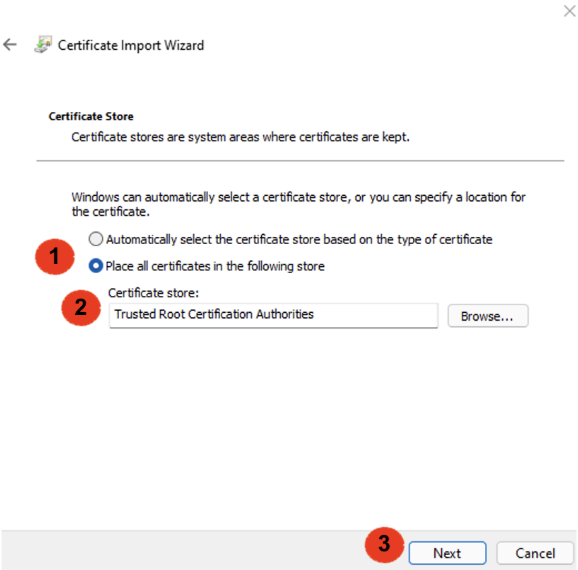
11. Continue to the import screen, click “Browse” and then select **server.der**.



Name	Date modified	Type
extra	3/17/2024 3:31 PM	File folder
original	3/17/2024 2:02 PM	File folder
server	3/22/2024 5:05 PM	Security Certificate

12. Click “Next”.

13. Choose the option “Place all certificates in the following store” (step (1) below) and complete the window as shown below (step (2)). Then click “Next” (step (3)).



Certificate Store

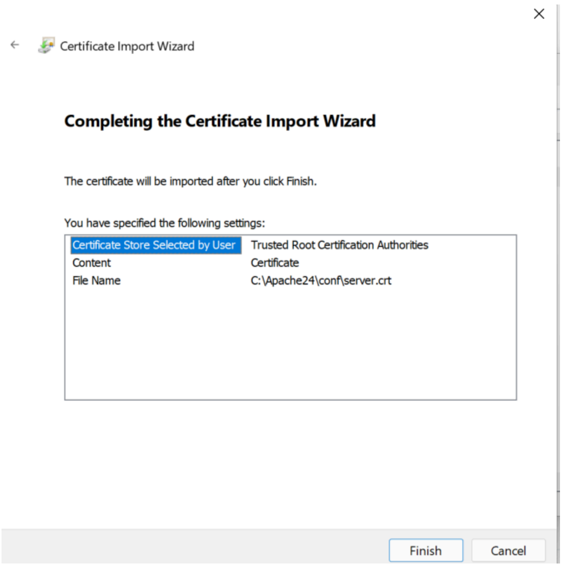
Certificate stores are system areas where certificates are kept.

Windows can automatically select a certificate store, or you can specify a location for the certificate.

○ Automatically select the certificate store based on the type of certificate

● Place all certificates in the following store

Certificate store: Trusted Root Certification Authorities



Completing the Certificate Import Wizard

The certificate will be imported after you click Finish.

You have specified the following settings:

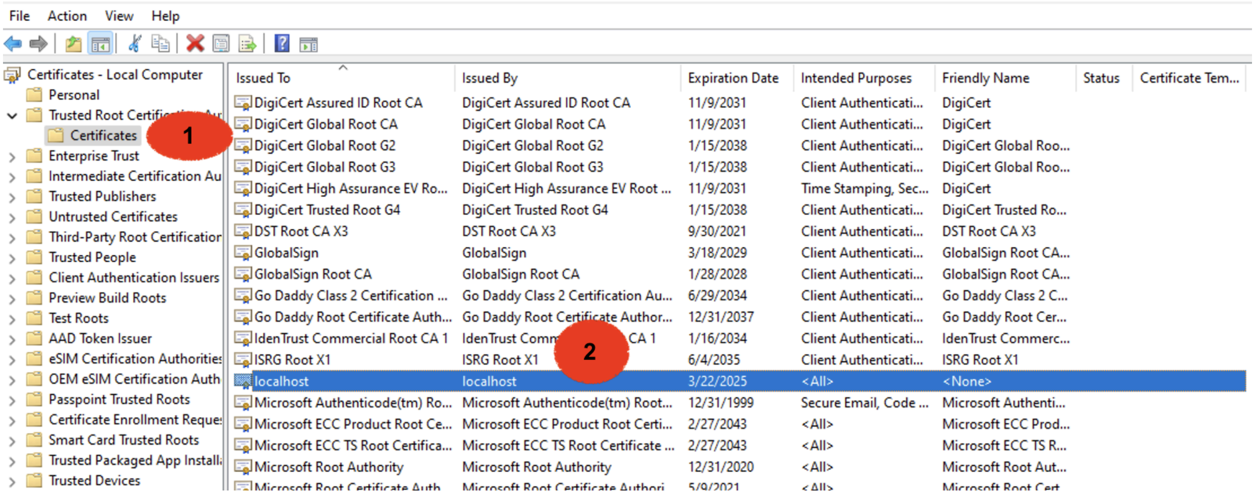
Certificate Store Selected by User	Trusted Root Certification Authorities
Content	Certificate
File Name	C:\Apache24\conf\server.crt

14. After confirming the import, you should receive a message indicating that the import was successful.

15. Now, start Apache again by entering: **C:/Apache24/bin/httpd.exe**

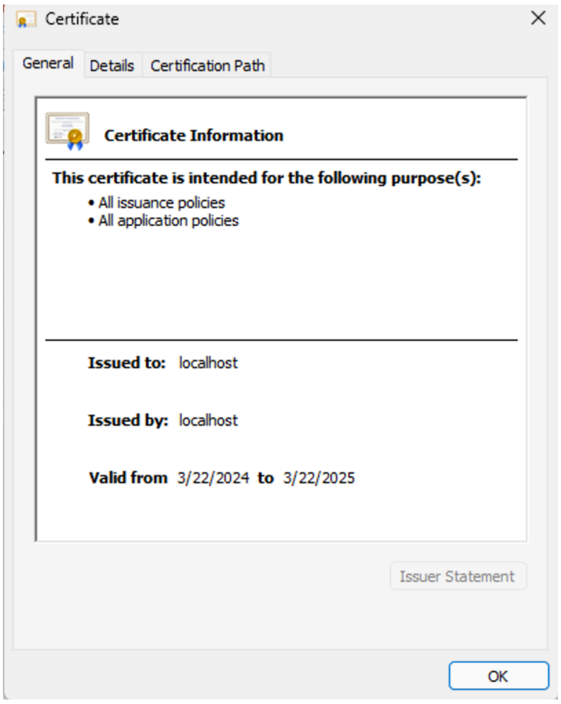
16. Browse to **https://localhost:8443** using the Chrome browser again.

17. Confirm that your certificate is now listed in the “Trusted Root Certificate Authorities” folder in the certificate manager:


File
Action
View
Help
Certificates - Local Computer
Personal
Trusted Root Certification Au
Certificates
Enterprise Trust
Intermediate Certification Au
Trusted Publishers
Untrusted Certificates
Third-Party Root Certification
Trusted People
Client Authentication Issuers
Preview Build Roots
Test Roots
AAD Token Issuer
eSIM Certification Authorities
OEM eSIM Certification Auth
Passpoint Trusted Roots
Certificate Enrollment Reques
Smart Card Trusted Roots
Trusted Packaged App Install
Trusted Devices
1
2

Issued To	Issued By	Expiration Date	Intended Purposes	Friendly Name	Status	Certificate Tem...
DigiCert Assured ID Root CA	DigiCert Assured ID Root CA	11/9/2031	Client Authenticati...	DigiCert		
DigiCert Global Root CA	DigiCert Global Root CA	11/9/2031	Client Authenticati...	DigiCert		
DigiCert Global Root G2	DigiCert Global Root G2	1/15/2038	Client Authenticati...	DigiCert Global Roo...		
DigiCert Global Root G3	DigiCert Global Root G3	1/15/2038	Client Authenticati...	DigiCert Global Roo...		
DigiCert High Assurance EV Ro...	DigiCert High Assurance EV Root ...	11/9/2031	Time Stamping, Sec...	DigiCert		
DigiCert Trusted Root G4	DigiCert Trusted Root G4	1/15/2038	Client Authenticati...	DigiCert Trusted Ro...		
DST Root CA X3	DST Root CA X3	9/30/2021	Client Authenticati...	DST Root CA X3		
GlobalSign	GlobalSign	3/18/2029	Client Authenticati...	GlobalSign Root CA...		
GlobalSign Root CA	GlobalSign Root CA	1/28/2028	Client Authenticati...	GlobalSign Root CA...		
Go Daddy Class 2 Certification ...	Go Daddy Class 2 Certification Au...	6/29/2034	Client Authenticati...	Go Daddy Class 2 C...		
Go Daddy Root Certificate Auth...	Go Daddy Root Certificate Author...	12/31/2037	Client Authenticati...	Go Daddy Root Cer...		
IdenTrust Commercial Root CA 1	IdenTrust Comm [illegible] CA 1	1/16/2034	Client Authenticati...	IdenTrust Commerc...		
ISRG Root X1	ISRG Root X1	6/4/2035	Client Authenticati...	ISRG Root X1		
localhost	localhost	3/22/2025	<All>	<None>		
Microsoft Authenticode(tm) Ro...	Microsoft Authenticode(tm) Root...	12/31/1999	Secure Email, Code ...	Microsoft Authenti...		
Microsoft ECC Product Root Ce...	Microsoft ECC Product Root Certi...	2/27/2043	<All>	Microsoft ECC Prod...		
Microsoft ECC TS Root Certifica...	Microsoft ECC TS Root Certificate ...	2/27/2043	<All>	Microsoft ECC TS R...		
Microsoft Root Authority	Microsoft Root Authority	12/31/2020	<All>	Microsoft Root Aut...		
Microsoft Root Certificate Auth	Microsoft Root Certificate Authori	5/9/2021	<All>	Microsoft Root Cert		

18. Now, let’s take a look at the details by clicking on the certificate:



Certificate Information

This certificate is intended for the following purpose(s):
- All issuance policies
- All application policies

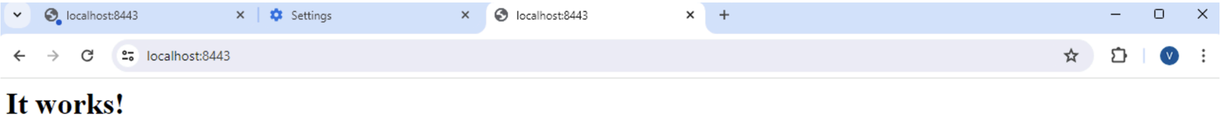
Issued to: localhost

Issued by: localhost

Valid from 3/22/2024 to 3/22/2025

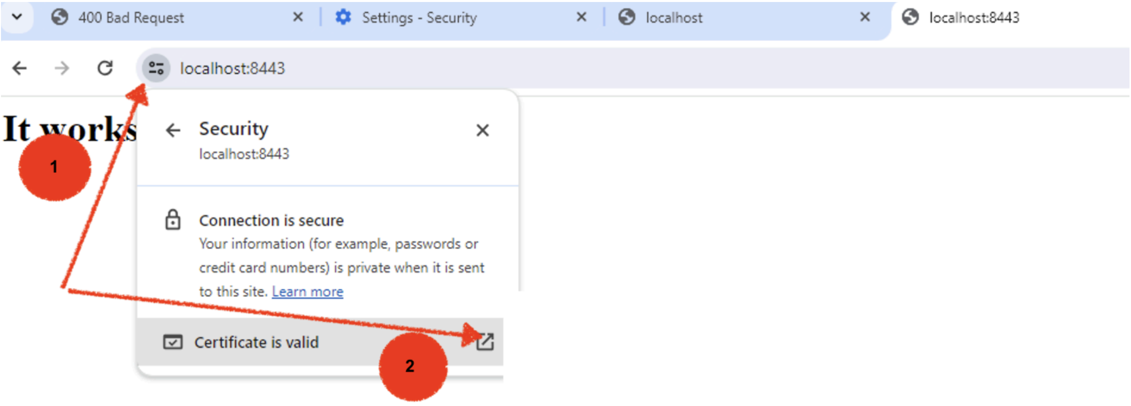
19. You’ll notice that the “Issued to” and “Issued by” are “localhost”.

20. Remember to stop and restart your Apache after making changes. Then in your Chrome browser, browse to **https://localhost:8443**. You should see a screen similar to the following:



It works!

21. Open the certificate:

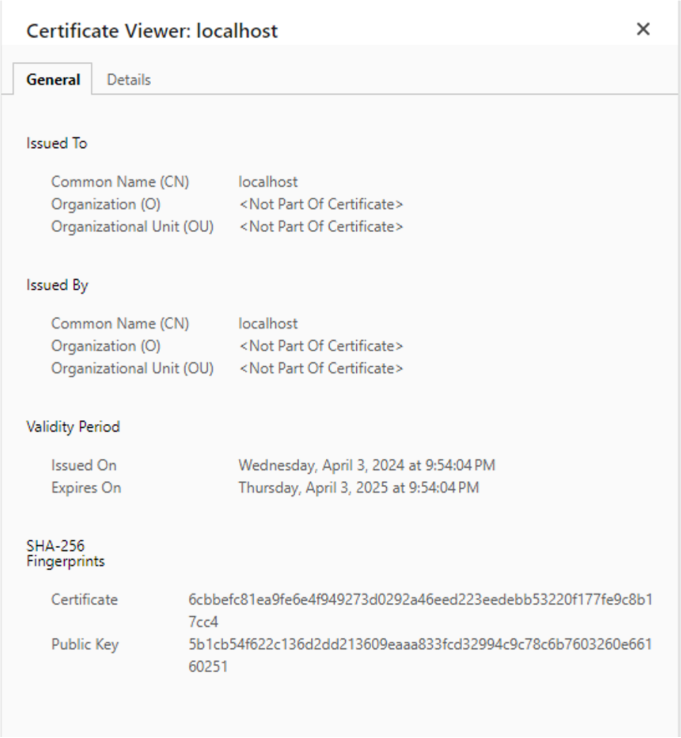


Security
localhost:8443

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

Certificate is valid

22. If you look at the certificate, you should see the same information as you saw above in the Microsoft CA.



Certificate Viewer: localhost

General | Details

Issued To

Common Name (CN) localhost
Organization (O) <Not Part Of Certificate>
Organizational Unit (OU) <Not Part Of Certificate>

Issued By

Common Name (CN) localhost
Organization (O) <Not Part Of Certificate>
Organizational Unit (OU) <Not Part Of Certificate>

Validity Period

Issued On Wednesday, April 3, 2024 at 9:54:04 PM
Expires On Thursday, April 3, 2025 at 9:54:04 PM

SHA-256 Fingerprints

Certificate 6cbbefc81ea9fe6e4f949273d0292a46eed223eedebb53220f177fe9c8b17cc4
Public Key 5b1cb54f622c136d2dd213609eaaa833fcd32994c9c78c6b7603260e66160251

23. In the “General” tab, the certificate issuer and validity period are displayed. You should verify whether it matches what you observed in the Microsoft CA.

Summary

In this document, you have seen how using SSL/TLS protocols in conjunction with a digital certificate ensures encrypted communication between a client (e.g., web browser) and server (e.g., web server), safeguarding against interception. The PKI certificate you created establishes trust by verifying the server’s identity, thereby mitigating risks associated with unauthorized access or man-in-the-middle attacks common in HTTP-based connections.