ESP8266 SSL User Manual

Version 2.1

About This Guide

This document is a Secure Sockets Layer (SSL) user manual based on ESP8266_NONOS_SDK.

The document is structured as follows.

Chapter	Title	Content
Chapter 1	Overview	An overview of the SSL function.
Chapter 2	Setting Up the Environment	How to set up the environment for compiling.
Chapter 3	ESP8266 working as an SSL server	Instructions on how to configure the ESP8266 to work as an SSL server.
Chapter 4	ESP8266 working as an SSL client	Instructions on how to configure the ESP8266 to work as an SSL client.
Chapter 5	Application Interfaces	Lists ESP8266_NONOS_SDK SSL-related APIs.

Release Notes

Date	Version	Release notes
2016.11	V1.0	First release.
2018.01	V2.0	Major revision.
2023.06	V2.1	• Added NRND in title page and footer; • Note that this document is no longer being updated.

Documentation Change Notification

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Certificates

Please download the product certificate(s) *here*.

Table of Contents

1. Overview

Transport Layer Security (TLS) is a cryptographic protocols that provides communication security and prevents session hijacking over a network. TLS has been based on the Secure Sockets Layer protocol, which is also known as SSL. TLS (or SSL) runs on top of a reliable transport protocol, e.g., the Transmission Control Protocol (TCP), and provides encryption to higher layers. For example, the HTTPS (HTTP Secure), is an adaptation of the Hypertext Transfer Protocol (HTTP) for secure communication, where HTTP operates on top of TLS (or SSL).

In this document, we use SSL to represent both TLS and SSL.

- When establishing SSL-based encrypted commutation channels, the authentication is optional.
- In general, the SSL client needs to authenticate the SSL server, which is called "unidirectional authentication" in this document.
- When both the SSL client and the SSL server need to authenticate each other, this is a process we call "bidirectional authentication" in this document.
- Certification authority (CA) is a third party that is trusted by both the SSL client and the SSL server. It will issue digital certificates to reliable clients and servers, as well as manage these certificates. Then the SSL client and the SSL server can authenticate each other with the certificates issued by the CA.

📖 ***Notes:***

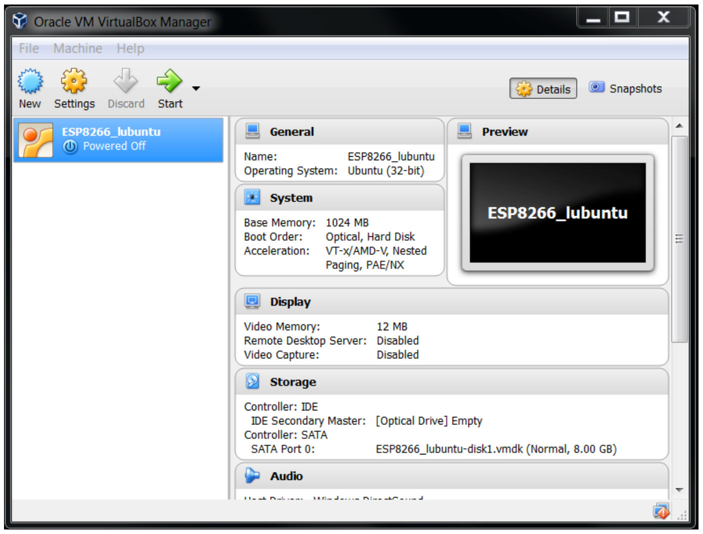
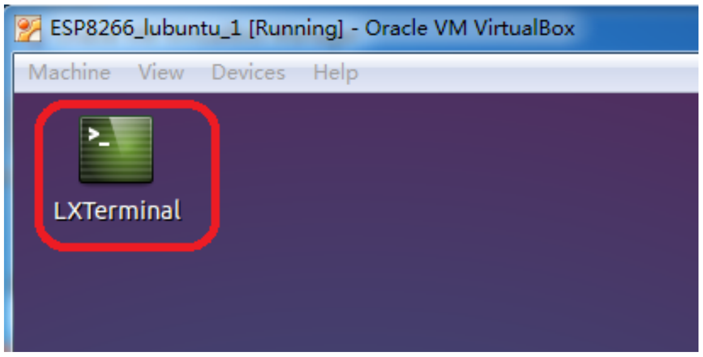
- *For more information, please visit: http://blog.csdn.net/ustccw/article/details/76691248.*
- *Terms:*
  - *Unidirectional Authentication: only the client will verify the SSL server's certificate.*
  - *Bidirectional Authentication: both the SSL client and the SSL server will mutually verify each other's certificates.*

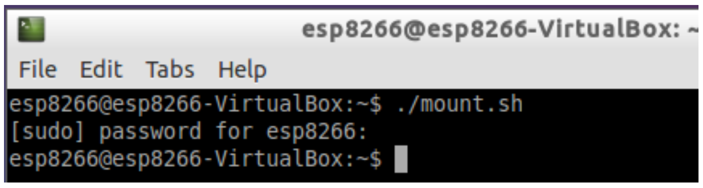
In this document we offer guidance on how to use ESP8266 as an SSL server, and how to use ESP8266 as an SSL client for the SSL encryption based on ESP8266_NONOS_SDK.

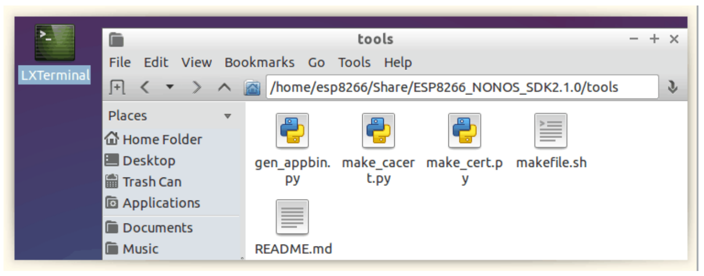
- If the ESP8266 works as an SSL server,
  - Unidirectional Authentication: the ESP8266 will send its certificate to the SSL client, and the client will decide whether to verify the server's certificate or not;
  - Bidirectional Authentication: both the ESP8266 and the client will authenticate each other by verifying each other's certificates.
- If the ESP8266 works as an SSL client,
  - Unidirectional Authentication: the ESP8266 will receive SSL server's certificate and decide whether to verify it or not;
  - Bidirectional Authentication: both the ESP8266 and the SSL server authenticate each other by verifying each other's certificates.

2. Setting Up the Environment

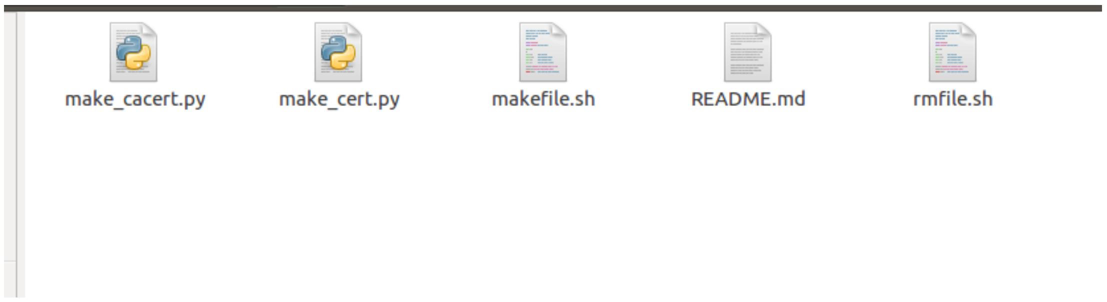
If you use Windows OS on your PC, please refer to the steps below to set up a Linux compiling environment.

Steps	Results
1. Start Windows OS and install the lubuntu virtual machine.	
• More details about setting up the environment can be found in the [ESP8266 SDK Getting Started Guide]().	 **General** Name: ESP8266_lubuntu Operating System: Ubuntu (32-bit) **System** Base Memory: 1024 MB Boot Order: Optical, Hard Disk Acceleration: VT-x/AMD-V, Nested Paging, PAE/NX **Display** Video Memory: 12 MB Remote Desktop Server: Disabled Video Capture: Disabled **Storage** Controller: IDE IDE Secondary Master: [Optical Drive] Empty Controller: SATA SATA Port 0: ESP8266_lubuntu-disk1.vmdk (Normal, 8.00 GB) **Audio**
2. Mount the shared folder.	
• Open ***LXTerminal*** on the virtual desktop.	

• Input command: ***./mount.sh***
• Then input password: ***espressif***
	 `esp8266@esp8266-VirtualBox:~$ ./mount.sh`
	`[sudo] password for esp8266:`
	`esp8266@esp8266-VirtualBox:~$`

• Copy the script ***ESP8266_NONOS_SDK*** into the shared folder of lubantu; • Open the shared folder in lubantu, where finding the ***makefile.sh*** means that mounting has been successful.	 LXTerminal tools File Edit View Bookmarks Go Tools Help /home/esp8266/Share/ESP8266_NONOS_SDK2.1.0/tools Places Home Folder Desktop Trash Can Applications Documents Music gen_appbin.py make_cacert.py make_cert.py makefile.sh README.md

The generating tools of SSL certificates are provided in the *ESP8266_NONOS_SDK/tools*, which are displayed below:



- ***makefile.sh***: converts the formats of SSL certificates, and generates scripts.
  - ***make_cacert.py*** and ***make_cert.py*** are used for the format conversion and generation of SLL certificate.
- ***rmfile.sh***: deletes all of the generated files.

3. ESP8266 Works as an SSL Server

To make the ESP8266 work as an SSL server, the steps below must be followed:

- ***cert.h*** and ***private_key.h***, which are the header files for SSL encryption, must be generated and included.
- CA Authentication is disabled by default, but the user can enable it with ***espconn_secure_ca_enable***. If the CA Authentication is enabled, the ***esp_ca_cert.bin*** must be generated by converting the CA certificates, and downloaded into flash.

An example of creating an SSL server is provided in the ***ESP8266_NONOS_SDK/ examples/**IoT_Demo*, marked with `#define SERVER_SSL_ENABLE`.

3.1. Generating a Certificate

Please choose one of the methods below according to your actual use case, to generate the ***cert.h*** and ***private_key.h*** for the general SSL server, and also to generate the ***esp_ca_cert.bin*** for the CA authentication, if needed.

3.1.1. Having No Certificate from the CA

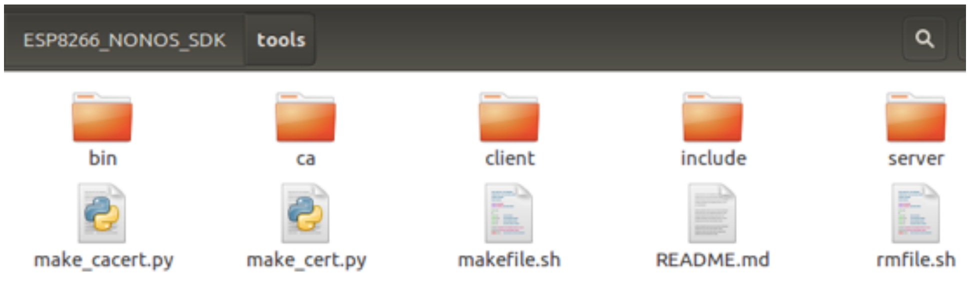
If you do not have any certificate issued by the CA, the ***makefile.sh*** in ***ESP8266_NONOS_SDK/tools*** can generate a self-issued certificate for testing only.

The necessary steps for this process are given below:

1. Change the value of ***CN*** in the ***makefile.sh***, from 1***92.168.111.100*** to the actual IP address of the ESP8266.
2. Run ***makefile.sh*** to generate certificates.

```
./makefile.sh
```

Results:



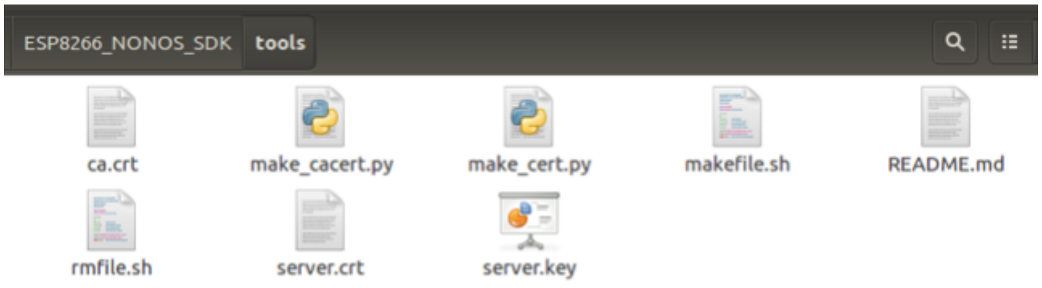
- The ***cert.h*** and ***private_key.h*** are in the ***include*** folder.
- The ***esp_ca_cert.bin*** is in the ***bin*** folder.

📖 ***Notes:***

- *The certificates generated in the **ca** folder are self-issued certificates, which are not issued by the CA.*
- *Users can change the 1024-bit encryption (by default) in the **makefile.sh** to a 512-bit encryption or other encryptions, according to their own use cases.*

3.1.2. Having Both a Private Key And Certificates from the CA

If you do have the private key (***server.key***), ***ca.crt*** of the CA's, and also the ***server.crt*** issued by the CA, please copy them to the ***ESP8266_NONOS_SDK/tools*** folder.



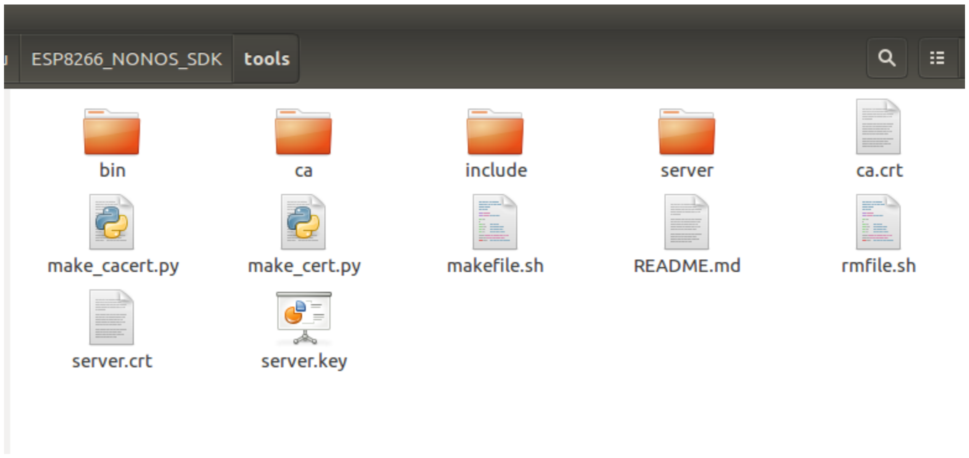
⚠️ ***Notices:***

- *If certificates' names are not the same as in the example above, please rename them as **server.key**, **ca.crt** and **server.crt**.*
- ***ca.crt** and **server.crt** must be in PEM format.*

Then run the ***makefile.sh*** to generate certificates for the SSL.

```
./makefile.sh
```

Results:



- The ***cert.h*** and ***private_key.h*** are in the ***include*** folder.
- The ***esp_ca_cert.bin*** is in the ***bin*** folder.

3.2. Programming Guide

An example of creating an SSL server is provided in the ***ESP8266_NONOS_SDK/ examples/****IoT_Demo*, marked with `#define SERVER_SSL_ENABLE`.

Notes:

- ***espconn_secure_set_default_certificate*** has to be called to input ***cert.h***.
- ***espconn_secure_set_default_private_key*** has to be called to input ***private_key.h***.
- If the user wants to enable the CA authentication, the steps below must be followed:
    - ***espconn_secure_ca_enable*** should be called to specify the address of the certificate. More details can be found in **Chapter 5**.
    - ***esp_ca_cert.bin*** has to be downloaded into the flash at the address specified by ***espconn_secure_ca_enable***.
- The SSL function requires a lot of RAM memory; therefore, users need to make sure that there is enough space before running the application.
    - If the SSL buffer is 8 KB (set by ***espconn_secure_set_size***), then at least 22 KB of memory size are required to run the SSL function.
    - The specific memory size required varies from the actual size of the certificates used by the SSL server.
    - If there is not enough memory, the SSL handshake will fail.
- If the SSL bidirectional authentication is enabled, due to memory limitations, the SSL buffer size allowed to be set by ***espconn_secure_set_size*** is 3,072 bytes at most. If there is not enough memory, the SSL memory size must be set to the minimum.

4. ESP8266 Works as an SSL Client

When the ESP8266 works as an SSL client, certificates should be generated according to the actual use case.

- Unidirectional Authentication: only ESP8266, which works as an SSL client, will authenticate the SSL server.
  - CA authentication is disabled by default. ***espconn_secure_ca_enable*** can be called to enable the CA authentication.
  - ***esp_ca_cert.bin*** needs to be downloaded into the flash at the address set by ***espconn_secure_ca_enable***.
- Bidirectional Authentication: both ESP8266 and the SSL server will authenticate each other.
  - ***esp_ca_cert.bin*** and ***esp_cert_private_key.bin*** need to be downloaded into flash.

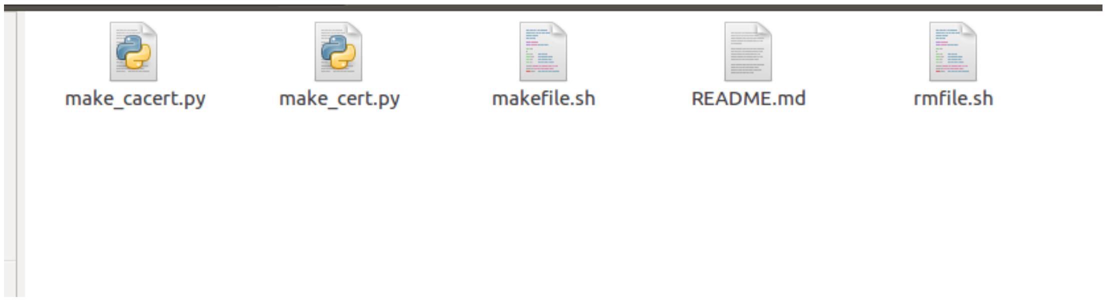
An example of an SSL client is provided in the *esp_mqtt_demo*, marked with `#define MQTT_SSL_ENABLE`.

4.1. Generating a Certificate

Please choose one of the methods below, according to your actual use case, to generate certificates required for the SSL encryption.

4.1.1. Having No Certificate from the CA

If you do not have any certificate issued by the CA, the ***makefile.sh*** in ***ESP8266_NONOS_SDK/tools*** will generate a self-issued certificate (***ca.crt*** + ***ca.key***) for testing.



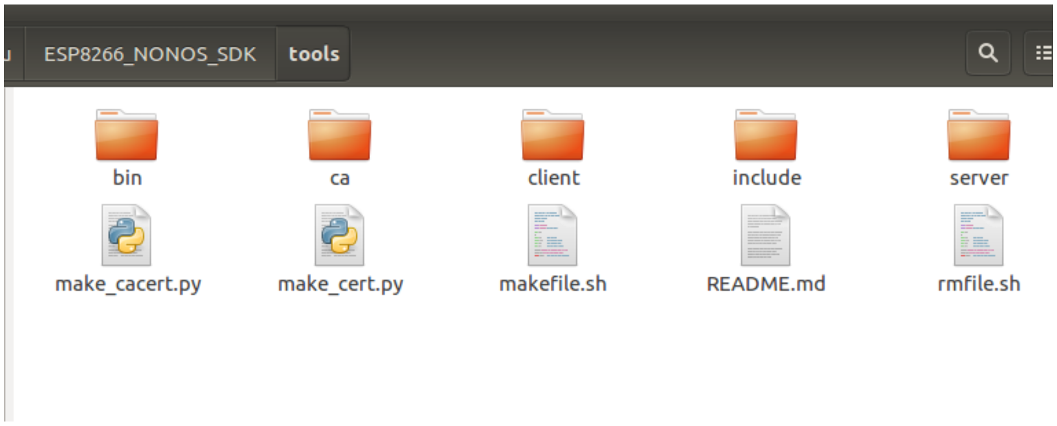
The steps in this process are outlined below:

1. Change the value of ***CN*** in the ***makefile.sh*** from ***192.168.111.100*** to the actual IP address of the SSL server.

2. Run the ***makefile.sh*** to generate certificates.

```
./makefile.sh
```

Results:



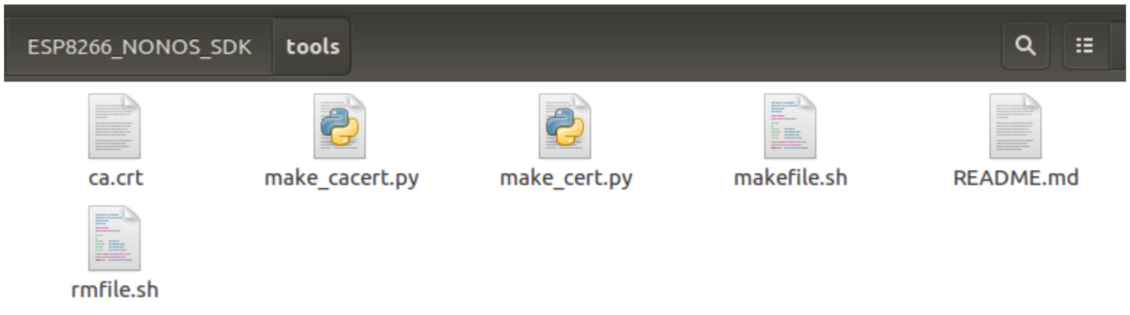
The CA certificate ***esp_ca_cert.bin***, and the private key ***esp_cert_private_key.bin*** will be generated in the ***bin*** folder.

📖 ***Notes:***

- *The certificates generated in the* ***ca*** *folder are self-issued certificates, which are not issued by the CA.*
- *Users can change the 1024-bit encryption (by default) in the* ***makefile.sh*** *to a 512-bit encryption or other encryptions, according to their own use cases.*

4.1.2. Having Only the Certificate from the CA

If you do have the certificate ***ca.crt*** from the CA, please copy it to the ***ESP8266_NONOS_SDK/tools***.



⚠️ ***Notice:***

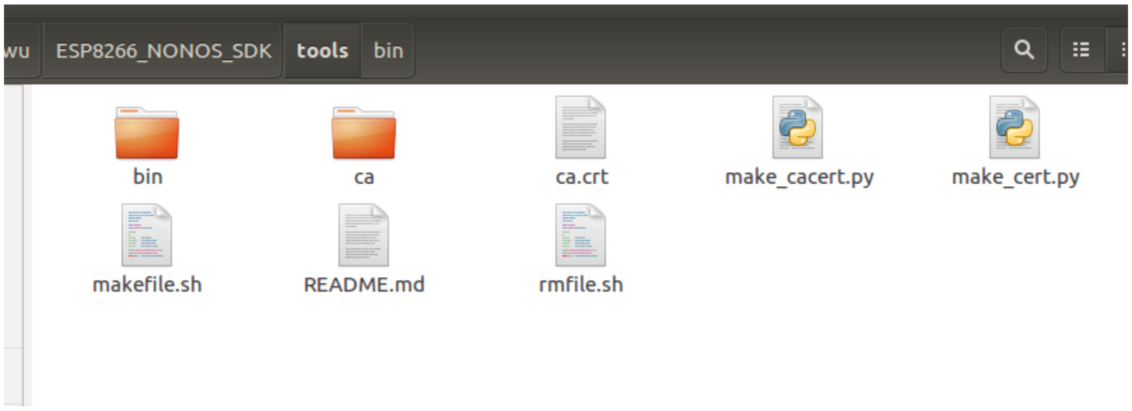
- *If the certificate name is not the same as in the example above, please rename it as* ***ca.crt***.
- ***ca.crt*** *has to be in PEM format.*

Then run the ***makefile.sh*** to generate certificates for SSL.

```
./makefile.sh
```

Not Recommended For New Designs (NRND)

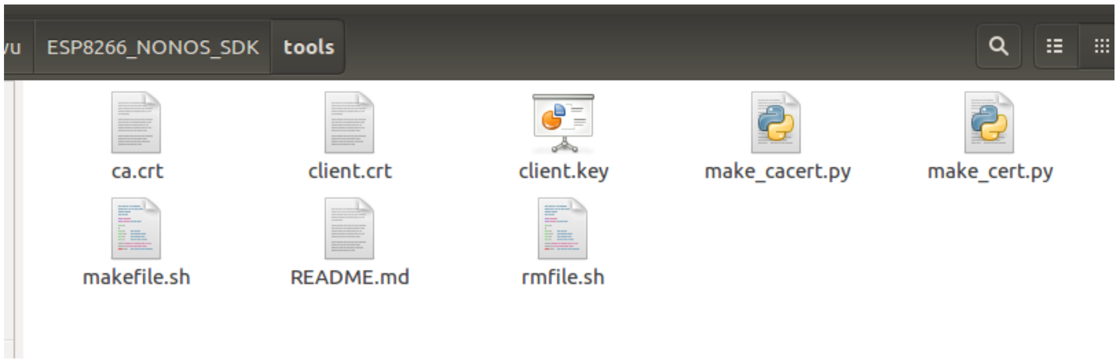
Results:



The CA certificate ***esp_ca_cert.bin*** will be generated in the ***bin*** folder.

4.1.3. Having Both a Private Key And a Certificate from the CA

If you do have the private key (***client.key***), ***ca.crt*** of the CA's and also the ***client.crt*** issued by the CA, please copy them to the ***ESP8266_NONOS_SDK/tools***.



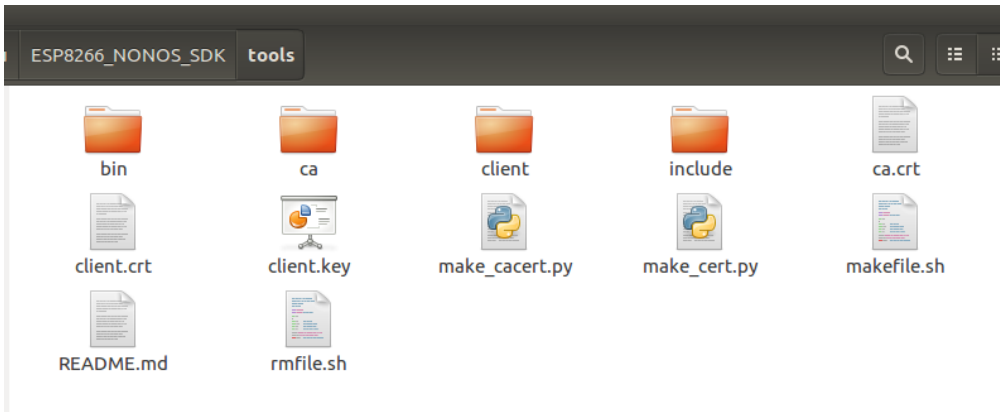
⚠ ***Notices:***

- *If certificates' names are not the same as the ones mentioned above, please rename them as **client.key**, **ca.crt** and **client.crt**.*
- ***ca.crt** and **client.crt** have to be in PEM format.*

Then run the ***makefile.sh*** to generate certificates for the SSL encryption.

```
./makefile.sh
```

Results:



The CA certificate ***esp_ca_cert.bin*** and the private key ***esp_cert_private_key.bin*** will be generated in the ***bin*** folder.

4.2. Programming Guide

An example of an SSL client is provided in ***ESP8266_NONOS_SDK/examples/*** *esp_mqtt_proj*, marked with `#define MQTT_SSL_ENABLE`.

Notes:

- To enable unidirectional authentication, where only the ESP8266 authenticates the SSL server,
  - ***espconn_secure_ca_enable*** should be called to enable the CA authentication;
  - ***esp_ca_cert.bin*** has to be downloaded into the flash at the address specified by the second parameter of ***espconn_secure_ca_enable***.
- To enable bidirectional authentication, where both ESP8266 and the SSL server will authenticate each other,
  - not only ***espconn_secure_ca_enable***, but also ***espconn_secure_cert_req_enable*** should be called to enable bidirectional authentication;
  - ***esp_ca_cert.bin*** has to be downloaded into the flash at the address specified by the second parameter of ***espconn_secure_ca_enable***.
  - ***esp_cert_private_key.bin*** needs to be downloaded into the flash at the address specified by the second parameter of ***espconn_secure_cert_req_enable***.
- The SSL function requires a lot of RAM memory; therefore, users need to make sure that there is enough space before running the application.
  - If the SSL buffer is 8 KB set by ***espconn_secure_set_size***, then at least 22 KB of memory size are required to run the SSL function.
  - The specific memory size required varies from the actual size of the certificates used by the SSL server.
  - If there is not enough memory, the SSL handshake will fail.
- If the SSL bidirectional authentication is enabled, due to memory limitations, the SSL buffer size allowed to be set by ***espconn_secure_set_size is*** 3,072 bytes at most. If there is not enough memory, the SSL handshake will fail.

5. API Reference

The SSL connection is processed differently from the normal TCP connection in the ESP8266 system. So, please make sure you use the following APIs appropriately.

In SSL connection, only the APIs below can be used:

- ***espconn_secure_XXX*** APIs, which are SSL-related;
- ***espconn_regist_XXX*** APIs to register callbacks, except for ***espconn_regist_write_finish***;
- ***espconn_port*** to get an available port.

In this manual, only ***espconn_secure_XXX*** APIs are introduced in detail. For more information about other software APIs, please consult the ESP8266 Non-OS SDK API Reference.

5.1. *espconn_secure_accept*

Function	Creates an SSL TCP server, and monitors SSL handshakes
Prototype	***sint8 espconn_secure_accept(struct espconn *espconn)***
Parameter	***struct espconn *espconn***: A structural body that corresponds to the network connection.
Return	• ***0***: Success • Others: Errors - ***ESPCONN_MEM***: Out of memory. - ***ESPCONN_ISCONN***: Connected already. - ***ESPCONN_ARG***: illegal parameter; cannot find any TCP connection according to structure ***espconn***.
Notes	• This API can be called only once. Only one SSL server is allowed to be created, and only one SSL client can be connected. • If the SSL encrypted packet size is larger than ESP8266's SSL buffer size (default 2 KB, set by ***espconn_secure_set_size***), the SSL connection will fail, and ESP8266 will call ***espconn_reconnect_callback***. • SSL-related APIs, i.e. ***espconn_secure_XXX***, are different from common TCP APIs, and must not be used inappropriately. In an SSL connection, only ***espconn_secure_XXX*** APIs, ***espconn_regist_XXXcb*** APIs (register callback functions) and ***espconn_port*** (obtain an available port) can be used. • Users should call APIs ***espconn_secure_set_default_certificate*** and ***espconn_secure_set_default_private_key*** to input an SSL certificate and private key first.

5.2. *espconn_secure_delete*

Function	Deletes the SSL connection when ESP8266 works as an SSL server.
Prototype	***sint8 espconn_secure_delete(struct espconn *espconn)***
Parameter	***struct espconn *espconn***: A structural body that corresponds to the network connection.
Return	• ***0***: Success; • Others: Errors - ***ESPCONN_ARG***: illegal parameter; cannot find any TCP connection according to structure ***espconn***. - ***ESPCONN_INPROGRESS***: the SSL connection is still in progress, please call ***espconn_secure_disconnect*** to disconnect before deleting this connection.

5.3. *espconn_secure_set_size*

Function	Sets the buffer size of encrypted data (SSL).
Prototype	***bool espconn_secure_set_size (uint8 level, uint16 size)***
Parameter	• ***uint8 level***: sets buffer for ESP8266 SSL server/client: - ***0x01***: SSL client; - ***0x02***: SSL server; - ***0x03***: both SSL client and SSL server • ***uint16 size***: buffer size, 2,048 byte by default, ranging from 1 ~ 8,192 byte.
Return	• ***true***: Success • ***false***: Failure
Note	The default buffer size is 2 KB. To change the buffer size, please call this API before calling: • ***espconn_secure_accept*** (when ESP8266 is configured as an SSL server) • ***espconn_secure_connect*** (when ESP8266 is configured as an SSL client).

5.4. *espconn_secure_get_size*

Function	Gets the buffer size of the encrypted data (SSL).
Prototype	***sint16 espconn_secure_get_size (uint8 level)***
Parameter	***uint8 level***: specifies the buffer is effective when ESP8266 works as a server, client or both. • ***0x01***: SSL client; • ***0x02***: SSL server; • ***0x03***: both SSL client and SSL server
Return	The buffer size of the encrypted data (SSL)

5.5. *espconn_secure_connect*

Function	Securely connects (SSL) to an SSL server (ESP8266 acts as an SSL client).
Prototype	***sint8 espconn_secure_connect (struct espconn *espconn)***
Parameter	***struct espconn *espconn***: A structural body that corresponds to the network connection.
Return	• ***0***: Success • Others: Errors - ***ESPCONN_MEM***: Out of memory. - ***ESPCONN_ISCONN***: Connected already. - ***ESPCONN_ARG***: illegal parameter; cannot find any TCP connection according to structure ***espconn***.
Notes	• If ***espconn_secure_connect*** fails, an error code will be returned. Since the connection fails, ESP8266 will not call any ***espconn*** callback. • Only one connection is allowed when the ESP8266 acts as a SSL client. This API can be called only once. Users can call ***espconn_secure_disconnect*** to disconnect the connection, before calling this API to create another SSL connection. • If the SSL encrypted packet size is larger than the ESP8266 SSL buffer size (2 KB by default, set by ***espconn_secure_set_size***), the SSL connection will fail, and the ESP8266 will call ***espconn_reconnect_callback***. • SSL-related APIs, i.e. ***espconn_secure_XXX***, are different from common TCP APIs, and must not be used inappropriately. In an SSL connection, only ***espconn_secure_XXX*** APIs, ***espconn_regist_XXXcb*** APIs (register callback functions) and ***espconn_port*** (obtain an available port) can be used.

5.6. *espconn_secure_send*

Function	Sends encrypted data (SSL).

Prototype	***sint8 espconn_secure_send (***
	    struct espconn *espconn,
	    uint8 *psent,
	    uint16 length
	)

Parameter	***struct espconn *espconn***: A structural body that corresponds to the network connection. ***uint8 *psent***: sents data pointer. ***uint16 length***: sents data length.
Return	***0***: Success ***ESPCONN_ARG***: illegal parameter; cannot find any connection according to structure ***espconn***.
Notes	• Please only call this API when the previous packet has been sent successfully, i.e. ***espconn_sent_callback*** is called. • The unencrypted data can be 1,024 bytes per packet at most; the encrypted data can be 1,460 bytes per packet at most.

5.7. *espconn_secure_disconnect*

Function	Ends an SSL connection.
Prototype	***sint8 espconn_secure_disconnect(struct espconn *espconn)***
Parameter	***struct espconn *espconn***: A structural body that corresponds to the network connection.
Return	• ***0***: Success • ***ESPCONN_ARG***: illegal parameter; cannot find any connection according to structure ***espconn***.
Note	Do not call this API in any ***espconn*** callback to end a connection. If needed, please call ***system_os_task*** and ***system_os_post*** to trigger ***espconn_secure_disconnect***.

5.8. *espconn_secure_ca_enable*

Function	Enables the SSL CA authentication.
Prototype	***bool espconn_secure_ca_enable (uint8 level, uint32 flash_sector)***
Parameter	• ***uint8 level***: specifies the buffer is effective when ESP8266 works as a server, client or both. - ***0x01***: SSL client; - ***0x02***: SSL server; - ***0x03***: both SSL client and SSL server • ***uint32 flash_sector***: sets the flash sector in which the CA (***esp_ca_cert.bin***) is downloaded. For example, if the ***flash_sector*** is ***0x7B***, then ***esp_ca_cert.bin*** must be downloaded to flash at ***0x7B000***.
Return	• ***true***: Success • ***false***: Failure
Notes	• CA function is disabled by default. • This API must be called before calling: - ***espconn_secure_accept*** (when the ESP8266 acts as an SSL server) - ***espconn_secure_connect*** (when the ESP8266 acts as an SSL client).

5.9. *espconn_secure_ca_disable*

Function	Disables the SSL CA authentication.
Prototype	***bool espconn_secure_ca_disable (uint8 level)***
Parameter	***uint8 level***: specifies the buffer is effective when ESP8266 works as a server, client or both. • ***0x01***: SSL client; • ***0x02***: SSL server; • ***0x03***: both SSL client and SSL server
Return	• ***true***: Success • ***false***: Failure
Notes	• CA function is disabled by default. • This API must be called before calling: - ***espconn_secure_accept*** (when the ESP8266 acts as an SSL server) - ***espconn_secure_connect*** (when the ESP8266 acts as an SSL client).

5.10. espconn_secure_cert_req_enable

Function	Enables the authentication when ESP8266 works as an SSL client.
Prototype	***bool espconn_secure_cert_req_enable (uint8 level, uint32 flash_sector)***
Parameter	***uint8 level***: can only be set as ***0x01*** when ESP8266 works as SSL client; ***uint32 flash_sector***: sets the address where the private key ***esp_cert_private_key.bin*** will be downloaded in the flash. For example, parameters ***0x7A*** should be written into the flash at the address ***0x7A000***. Please note that the private key written into flash must not overlap with code binaries or system parameter binaries in the flash memory.
Return	• ***true***: Success • ***false***: Failure
Notes	• Authentication is disabled by default. If the SSL server does not require to verify certificate, it is not necessary to call this API. • This API must be called before calling ***espconn_secure_connect***.

5.11. espconn_secure_cert_req_disable

Function	Disables the authentication when ESP8266 works as an SSL client.
Prototype	***bool espconn_secure_ca_disable (uint8 level)***
Parameter	***uint8 level***: can only be set as ***0x01*** when ESP8266 works as an SSL client.
Return	• ***true***: Success • ***false***: Failure
Note	The certification's verification function is disabled by default.

5.12. espconn_secure_set_default_certificate

Function	Sets the certificate when ESP8266 runs as an SSL server.
Prototype	***bool espconn_secure_set_default_certificate (const uint8_t* certificate, uint16_t length)***
Parameter	• ***const uint8_t* certificate***: pointer to the certificate; • ***uint16_t length***: length of the certificate.
Return	• ***true***: Success • ***false***: Failure
Notes	• Demos can be found in ***ESP8266_NONOS_SDK/examples/IoT_Demo***; • This API has to be called before ***espconn_secure_accept*** to input the certificate.

5.13. espconn_secure_set_default_private_key

Function	Sets the private key when ESP8266 works as an SSL server.
Prototype	***bool espconn_secure_set_default_private_key (const uint8_t* key, uint16_t length)***
Parameter	• ***const uint8_t* key***: pointer to the private keys; • ***uint16_t length***: length of the private keys.
Return	• ***true***: Success • ***false***: Failure
Notes	• Demos can be found in ***ESP8266_NONOS_SDK/examples/IoT_Demo***; • This API has to be called before ***espconn_secure_accept*** to input the private key.