ESP8266 SSL User Manual

Version 1.4

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http://bbs.espressif.com/

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1. Preambles

This manual introduces how to implement SSL encryption when ESP8266 runs as either SSL server or SSL client.

SSL function usually requires a lot of RAM memory, therefore, users need to make sure that there is enough space before running the application. If the space occupied by SSL buffer is 8KB defined by `espconn_secure_set_size`, then at least 22KB memory size is required if SSL function is to be implemented. The specific memory size required varies with the actual size of data sending from SSL server.

If the SSL bi-directional verification is enabled, the SSL buffer size allowed to set by `espconn_secure_set_size` is 3072 bytes at most. The specific size allowed to set depends on the actual size of heap available.

Demo and scripts on how to generate SSL certificate can be downloaded via http://bbs.espressif.com/viewtopic.php?f=51&t=1025.

Please visit http://bbs.espressif.com/ for more information about ESP8266 solution.

2. ESP8266 as SSL server

When ESP8266 is running as a SSL server, header files cert.h and private_key.h required for SSL encryption can be generated when encryption certificate is provided. Users can refer to sample codes defined by macro definition `#define SERVER_SSL_ENABLE` in IoT_Demo on how to implement SSL server.

CA verification function is disabled by default, however, it can be enabled by calling `espconn_secure_ca_enable`.

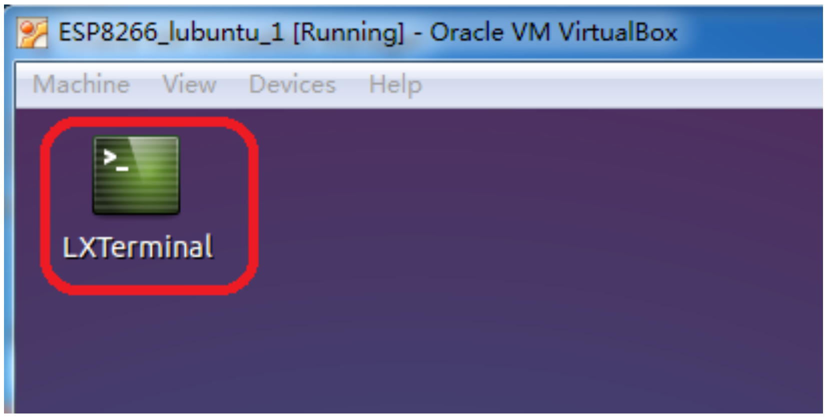
2.1. Generate certificate

(1) Copy script "**makefile.sh**" to lubuntu virtual box share folder.

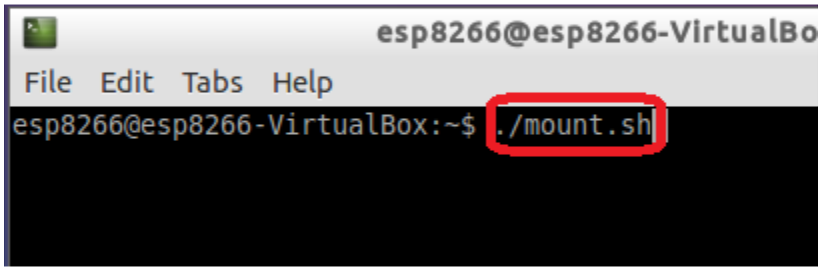
- Please refer to BBS http://bbs.espressif.com/viewtopic.php?f=21&t=86 on how to set up linux (Lubuntu) compile environment.

(2) Mount the share folder

- Open "LXTerminal" in virtual box

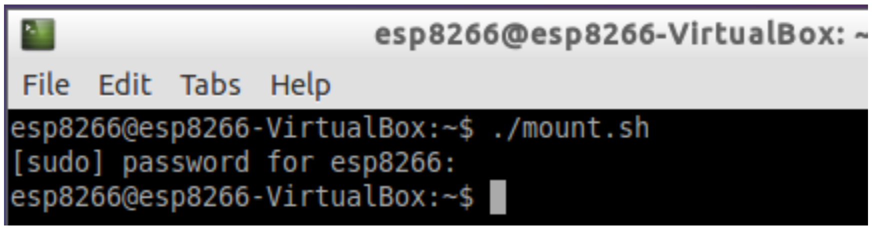

ESP8266_lubuntu_1 [Running] - Oracle VM VirtualBox
Machine View Devices Help
LXTerminal

- Enter command `./mount.sh`, press "Enter" key.



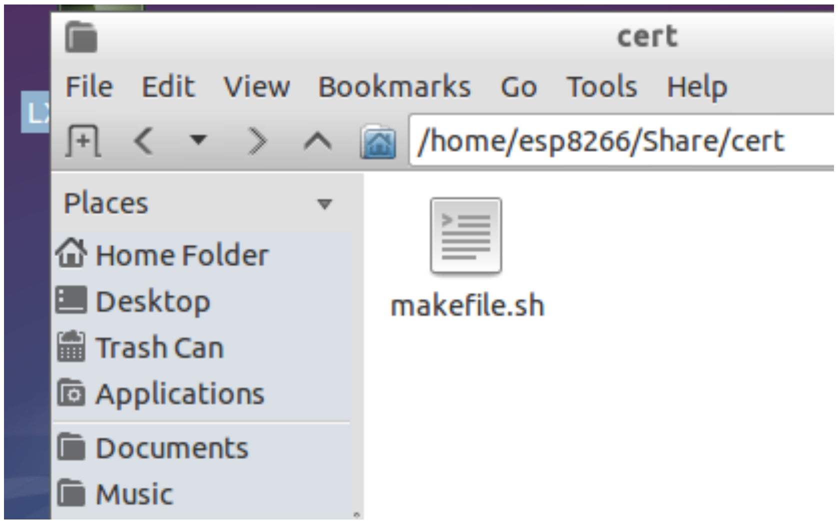
```
esp8266@esp8266-VirtualBox:~$ ./mount.sh
```

- Enter password: **espressif**, press "Enter" key.

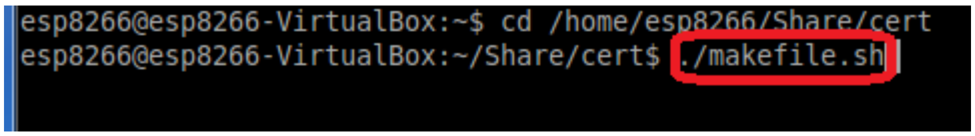


```
esp8266@esp8266-VirtualBox:~$ ./mount.sh
[sudo] password for esp8266:
esp8266@esp8266-VirtualBox:~$ 
```

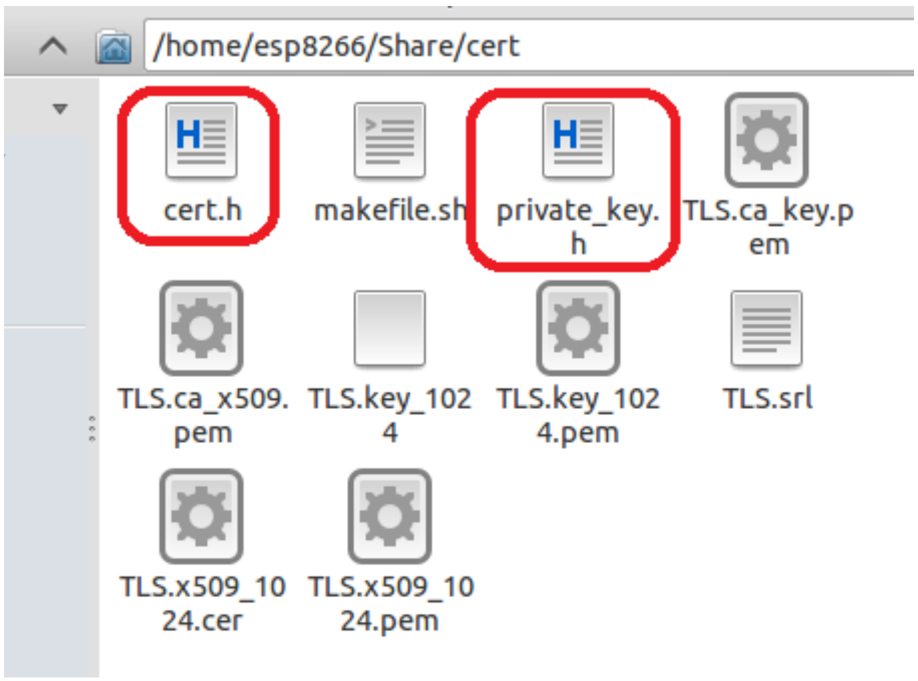
(3) Open share folder in virtual box, and get script "makefile.sh" there.



(4) Enter command `./makefile.sh`, and run script "makefile.sh", then two header files `cert.h` and `private_key.h` will be generated. Please use theses two header files according to the IoT Demo.

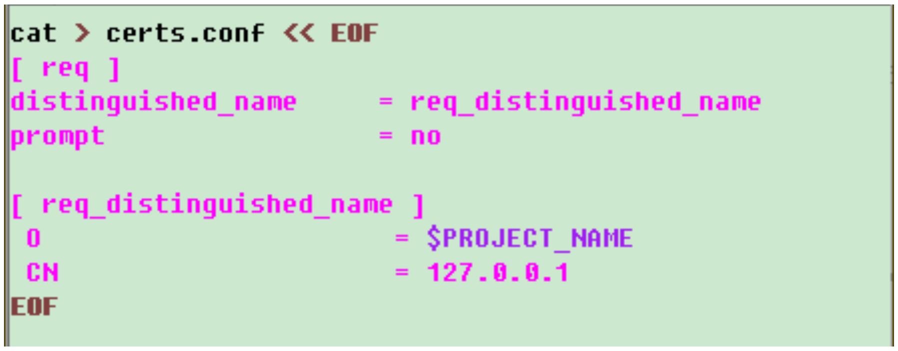


```
esp8266@esp8266-VirtualBox:~$ cd /home/esp8266/Share/cert
esp8266@esp8266-VirtualBox:~/Share/cert$ ./makefile.sh
```



Note:

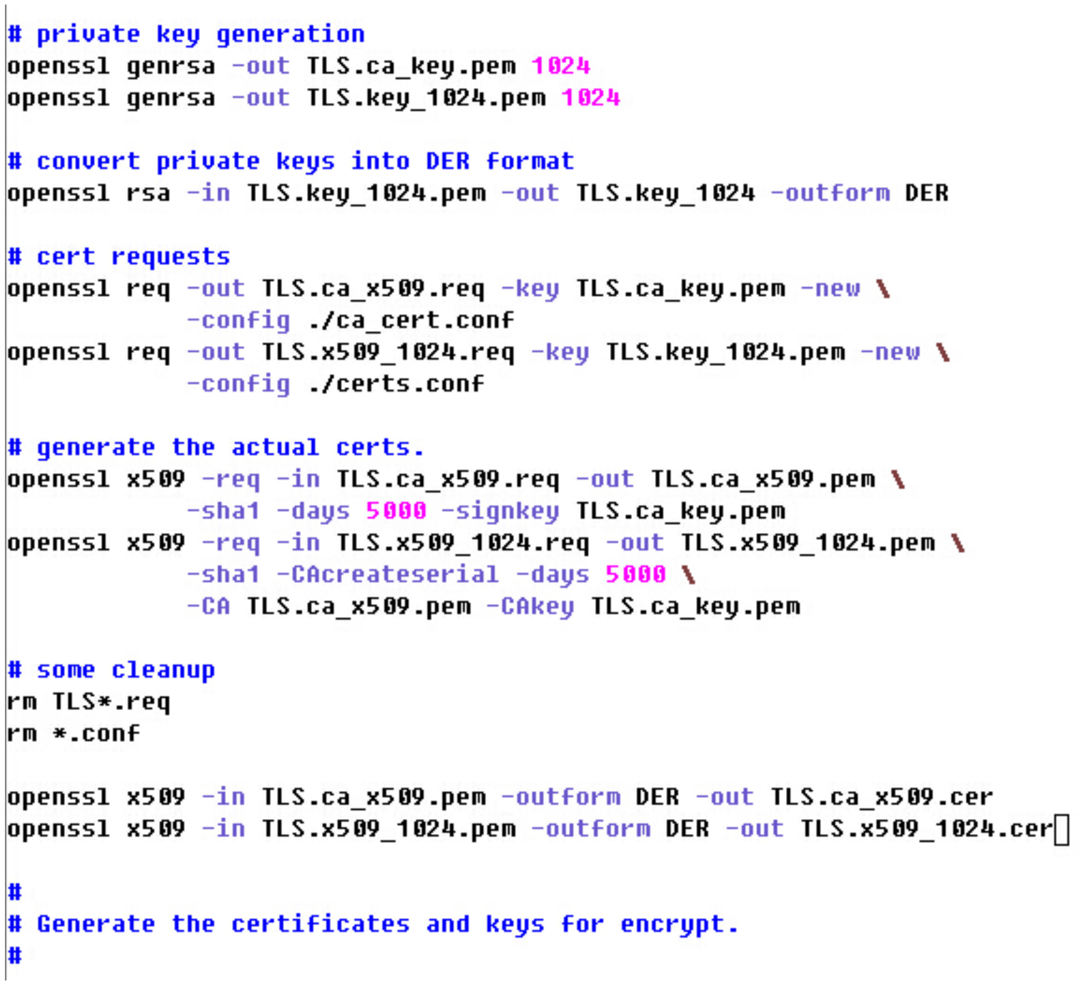
- IP address in script "makefile.sh" should be the actual SSL server IP address, as is shown in the picture below:



```
cat > certs.conf << EOF
[ req ]
distinguished_name      = req_distinguished_name
prompt                  = no

[ req_distinguished_name ]
 O                       = $PROJECT_NAME
 CN                      = 127.0.0.1
EOF
```

- Script “makefile.sh” adopts 1024 bit encryption algorithm by default. If users need to adopt 512 bit encryption algorithm, please change the number 1024 in script “makefile.sh” to 512.



```
# private key generation
openssl genrsa -out TLS.ca_key.pem 1024
openssl genrsa -out TLS.key_1024.pem 1024

# convert private keys into DER format
openssl rsa -in TLS.key_1024.pem -out TLS.key_1024 -outform DER

# cert requests
openssl req -out TLS.ca_x509.req -key TLS.ca_key.pem -new \
            -config ./ca_cert.conf
openssl req -out TLS.x509_1024.req -key TLS.key_1024.pem -new \
            -config ./certs.conf

# generate the actual certs.
openssl x509 -req -in TLS.ca_x509.req -out TLS.ca_x509.pem \
            -sha1 -days 5000 -signkey TLS.ca_key.pem
openssl x509 -req -in TLS.x509_1024.req -out TLS.x509_1024.pem \
            -sha1 -CAcreateserial -days 5000 \
            -CA TLS.ca_x509.pem -CAkey TLS.ca_key.pem

# some cleanup
rm TLS*.req
rm *.conf

openssl x509 -in TLS.ca_x509.pem -outform DER -out TLS.ca_x509.cer
openssl x509 -in TLS.x509_1024.pem -outform DER -out TLS.x509_1024.cer

#
# Generate the certificates and keys for encrypt.
#
```

Notice:

- Since `esp_iot_sdk_v1.4.0`, users should call `espconn_secure_set_default_certificate` and `espconn_secure_set_default_private_key` to set SSL certificate and secure key.
- SSL server certificate generated above is issued by Espressif Systems, not CA. Users who requires CA certificate can add `TLS.ca_x509.cer` which generated as above into SSL client’s trust anchor, then generate `esp_ca_cert.bin` by script “**make_cacert.py**” according to **3.1 Generate CA Certificate**, and download `esp_ca_cert.bin` generated by CA certificate into the corresponding addresses in the flash.

3. ESP8266 as SSL client

Sample code of ESP8266 running as SSL client is defined by macro definition `#define CLIENT_SSL_ENABLE` in IOT_Demo. When running as a client, bi-directional verification is supported.

CA verification function is disabled by default, however, it can be invoked by calling function `espconn_secure_ca_enable`.

Demonstration of SSL certificate, TLS_BiDirectVerif_Demo, can be downloaded from BBS.

Link： http://bbs.espressif.com/viewtopic.php?f=51&t=1025.

3.1. Generate CA Certificate

(1) Revise script "`makefile.sh`" and generate a CA certificate issued by developers themselves. For example, `TLS.ca_x509.cer`, as is shown in the "TLS_BiDirectVerif_Demo".

(2) Generate a SSL client certificate using the CA certificate issued. For example, as is shown in the "TLS_BiDirectVerif_Demo", the `TLS.x509_1024.cer`.

(3) Take out the secure key that is used during SSL certificate generation. For example, `TLS.key_1024`, as is shown in the "TLS_BiDirectVerif_Demo".

(4) Move script "**make_cacert.py**" and CA certificate files (for example, `TLS.ca_x509.cer`) to the same directory.

(5) Run script "**make_cacert.py**", then it will combine with CA files in the same directory and generate `esp_ca_cert.bin`. The address that `esp_ca_cert.bin` will be written need to be set by calling `espconn_secure_ca_enable`.

(6) Rename the certificate (such as `TLS.x509_1024.cer`) as `certificate.cer`; rename the secure key (such as `TLS.key_1024`) as `private_key.key_1024`. Please be noted that both the certificates and the secure keys should be renamed in this procedure, otherwise certification will fail.

(7) Copy and move the renamed files to the same directory of "**make_cert.py**".

(8) Run script "**make_cert.py**" and `esp_cert_private_key.bin` will be generated. The address that `esp_cert_private_key.bin` will be written is set by calling `espconn_secure_cert_req_enable`.

4. Software APIs

SSL related APIs are different from normal TCP APIs in terms of the basis software processing methods. Therefore, please don't mix them up. In SSL connection, only the below APIs can be used:

- espconn_secure_XXX APIs which are SSL related APIs;
- `espconn_regist_XXX` APIs to register callbacks;
- `espconn_port` to get an available port.

Herein this manual, only `espconn_secure_XXX` APIs are introduced in detail. For more information about other software APIs please refer to documentation "2C-ESP8266__SDK__Programming Guide".

One demo of SSL connection can be found via: http://bbs.espressif.com/viewtopic.php?f=21&t=389

4.1. espconn_secure_ca_enable

```
Function:
   Enable SSL CA (certificate authenticate) function
Note:
   • CA function is disabled by default
   • esp_ca_cert.bin must be written when this API is called
   • If user want to call this API, please call the below APIs before
        encryption (SSL) is established:
      ‣ ESP8266 as TCP SSL server: call this API before
           espconn_secure_accept is called;
      ‣ ESP8266 as TCP SSL client: call this API before
           espconn_secure_connect is called.
Prototype:
   bool espconn_secure_ca_enable (uint8 level, uint8 flash_sector)
```

```
Parameter:
   uint8 level : set configuration for ESP8266 SSL server/client:

                 0x01  SSL client;

                 0x02  SSL server;

                 0x03  both SSL client and SSL server
   uint8 flash_sector : Flash sector in which CA certificate
   (esp_ca_cert.bin) is written into. For example, parameters 0x3B
   should be written into Flash 0x3B000 in the flash. Please be noted
   that sectors used for storing codes and system parameters must not
   be covered.

Return:
   true      : succeed
   false    : fail
```

4.2. espconn_secure_ca_disable

```
Function:
   Disable SSL CA verification function

Note:

   •  CA verification function is disabled by default

Prototype:
   bool espconn_secure_ca_disable (uint8 level)

Parameter:
   uint8 level :  when ESP8266 runs as SSL server/client:

                 0x01  SSL client;

                 0x02  SSL server;

                 0x03  SSL client and SSL server
Return:
   true     : succeed
   false    : fail
```

4.3. espconn_secure_cert_req_enable

Function:

Enable certification verification function when ESP8266 runs as SSL client

Note:

- Certification verification function is disabled by defaults
- Call this API before espconn_secure_connect is called

Prototype:

```
bool espconn_secure_cert_req_enable (uint8 level, uint8 flash_sector)
```

Parameter:

uint8 level : can only be set as 0x01 when ESP8266 runs as SSL client;

uint8 flash_sector : set the address where secure key (esp_cert_private_key.bin) will be written into the flash. For example, parameters 0x3A should be written into Flash 0x3A000 in the flash. Please be noted that sectors used for storing codes and system parameters must not be covered.

Return:

```
true    : succeed
false   : fail
```

4.4. espconn_secure_cert_req_disable

Function:

Disable certification verification function when ESP8266 runs as SSL client

Note:

- Certification verification function is disabled by default

Prototype:

```
bool espconn_secure_ca_disable (uint8 level)
```

Parameter:

`uint8 level` : can only be set as `0x01` when ESP8266 runs as SSL client;

Return:

```
true     : succeed
false    : fail
```

4.5. espconn_secure_set_default_certificate

Function:

Set the certificate when ESP8266 runs as SSL server

Note:

- Demos can be found in esp_iot_sdk\examples\IoT_Demo
- This API has to be called before `espconn_secure_accept`.

Prototype:

```
bool espconn_secure_set_default_certificate (const uint8_t*
certificate, uint16_t length)
```

Parameter:

`const uint8_t* certificate` : pointer of the certificate

`uint16_t length` : length of the certificate

Return:

```
true     : succeed
false    : fail
```

4.6. espconn_secure_set_default_private_key

Function:

Set the secure key when ESP8266 runs as SSL server

Note:

- Demos can be found in esp_iot_sdk\examples\IoT_Demo.

- This API has to be called before espconn_secure_accept.

Prototype:

```
bool espconn_secure_set_default_private_key (const uint8_t* key,
uint16_t length)
```

Parameter:

const uint8_t* key : pointer of the secure key

uint16_t length : length of the secure key

Return:

```
true     : succeed
false    : fail
```

4.7. espconn_secure_accept

Function:

Create a SSL TCP server, intercept SSL handshake

Note:

- 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 size of SSL encrypted data patch is larger than the buffer size defined by espconn_secure_set_size, and is beyond the processing capability of ESP8266, then SSL will be disconnected, and callback function espconn_reconnect_callback will be invoked.
- Users should call API espconn_secure_set_default_certificate and espconn_secure_set_default_private_key to set SSL certificate and secure key first.

Prototype:

```
sint8 espconn_secure_accept(struct espconn *espconn)
```

Parameter:

struct espconn *espconn : architecture of the web connection

Return:

```
0        : succeed
Non-0    : fail, errors will be returned
```

```
            ESPCONN_ARG - TCP connection corresponding with parameter
      espconn cannot be found
            ESPCONN_MEM - memory size is not enough
            ESPCONN_ISCONN - connection succeeded
```

4.8. espconn_secure_set_size

Function:

Set buffer size of encrypted data (SSL)

Note:

Buffer size default to be 2KBytes. Before modification, please call this API before encryption (SSL) connection is established:

- ESP8266 as TCP SSL server: call this API before espconn_secure_accept is called;
- ESP8266 as TCP SSL client: call this API before espconn_secure_connect is called.

Prototype:

```
bool espconn_secure_set_size (uint8 level, uint16 size)
```

Parameters:

uint8 level : set buffer for ESP8266 SSL server/client:

0x01	SSL client;
0x02	SSL server;
0x03	both SSL client and SSL server

uint16 size : buffer size, range: 1 ~ 8192, unit: byte, default is 2048

Return:

```
true   : succeed
false  : fail
```

4.9. espconn_secure_get_size

Function:

Get buffer size of encrypted data (SSL)

Prototype:

`sint16 espconn_secure_get_size (uint8 level)`

Parameters:

`uint8 level` : buffer for ESP8266 SSL server/client:

0x01	SSL client;
0x02	SSL server;
0x03	both SSL client and SSL server

Return:

buffer size

4.10. espconn_secure_connect

Function:

Secure connect (SSL) to a TCP server (ESP8266 is acting as TCP client.)

Note:

- Only one connection is allowed when ESP8266 as SSL client, please call espconn_secure_disconnect first, if you want to create another SSL connection.
- If SSL encrypted packet size is larger than ESP8266 SSL buffer size (default 2KB, set by espconn_secure_set_size), SSL connection will fail, will enter espconn_reconnect_callback

Prototype:

`sint8 espconn_secure_connect (struct espconn *espconn)`

Parameters:

`struct espconn *espconn` : corresponding connected control block structure

```
Return:
   0      : succeed
   Non-0  : error code

            ESPCONN_MEM - Out of memory

            ESPCONN_ISCONN - Already connected

            ESPCONN_ARG - illegal argument, can't find TCP connection
   according to structure espconn
```

4.11. espconn_secure_send

```
Function: send encrypted data (SSL)

Note:

Please call espconn_secure_send after espconn_sent_callback of the pre-
   packet.

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

Parameters:
   struct espconn *espconn : corresponding connected control block
   structure
   uint8 *psent : sent data pointer
   uint16 length : sent data length

Return:
   0      : succeed
   Non-0  : error code ESPCONN_ARG - illegal argument, can't find TCP
   connection according to structure espconn
```

4.12. espconn_secure_disconnect

```
Function: secure TCP disconnection(SSL)
```

Prototype:

```
sint8 espconn_secure_disconnect(struct espconn *espconn)
```

Parameters:

`struct espconn *espconn` : corresponding connected control block structure

Return:

```
0      : succeed
Non-0  : error code ESPCONN_ARG - illegal argument, can’t find TCP
connection according to structure espconn
```