AN3967
Application note

Secure socket layer (SSL) for STM32F417xx microcontrollers

1 Introduction

STM32F417xx microcontrollers feature a complete 10/100 Mbit/s Ethernet peripheral that supports both the Media Independent Interface (MII) and Reduced Media Independent Interface (RMII) to interface with the Physical Layer (PHY), with hardware checksums of the IP, UDP, TCP and ICMP protocols.

One of the advanced features of the STM32F417xx is the hardware cryptographic processor for AES/128/192/256, Triple DES, DES, SHA-1, MD5 and RNG.

Secure Sockets Layer (SSL) and Transport Layer Security (TLS) cryptographic protocols provide security for communications over networks, such as the Internet, and allow client and server applications to communicate in a way that is private and secure.

The purpose of this application note is to present a demonstration package built on top of a free SSL/TLS library: the PolarSSL library.

This application note is structured as follows:

- A short glossary is provided in *Section 2*.
- A general introduction to SSL/TLS is presented in *Section 3*.
- *Section 4* introduces the PolarSSL library.
- *Section 5* describes the STM32F417xx hardware cryptographic processors.
- Lastly, *Section 6* describes the demonstration package for STM32F417xx.

Note: This application targets only STM32F417xx devices, since the cryptographic acceleration is not embedded in STM32F407xx devices, and it uses the STM3241G-EVAL board as a hardware platform.

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2 Acronyms and definitions

Table 1. Acronyms and definitions

Acronym	Definition
AES	Advanced Encryption Standard
ANSI	American National Standards Institute
API	Application Programming Interface
ARC4	Alleged Rivest Cipher 4
ARP	Address Resolution Protocol
CA	Certification Authority
CBC	Cipher Block Chaining
CTR	Counter
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DHM	Diffie–Hellman key exchange
ECB	Electronic Codebook
FIPS	Federal Information Processing Standard
HAVEGE	Hardware Volatile Entropy Gathering and Expansion
HMAC	Hash Message Authentication Code
HTTP	Hypertext Transfer Protocol
HTTPS	Secure Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
LwIP	Lightweight IP
MAC	Message Authentication Code
MAC address	Media Access Control address
MCO	Microcontroller Clock Output
MD2	Message Digest Algorithm 2
MII	Media Independent Interface
PPP	Point-to-Point Protocol
RMII	Reduced Media Independent Interface
RNG	Random Number Generator
RSA	Rivest, Shamir, & Adleman
SHA-1	Secure Hashing Algorithm 1
SNMP	Simple Network Management Protocol

Table 1. Acronyms and definitions (continued)

Acronym	Definition
SSL	Secure Sockets Layer
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security
UDP	User Datagram Protocol
URL	Uniform Resource Locator
USART	Universal Synchronous & Asynchronous Receiver Transmitter

3 SSL / TLS protocol overview

The Secure Socket Layer (SSL) and Transport Layer Security (TLS) protocols provide communications security over the Internet and allow client/server applications to communicate in a way that is private and reliable. These protocols are layered above a transport protocol such as TCP/IP.

SSL is the standard security technology for creating an encrypted link between server and client. This link ensures that all communication data remains private and secure.

The major objectives of SSL/TLS are:

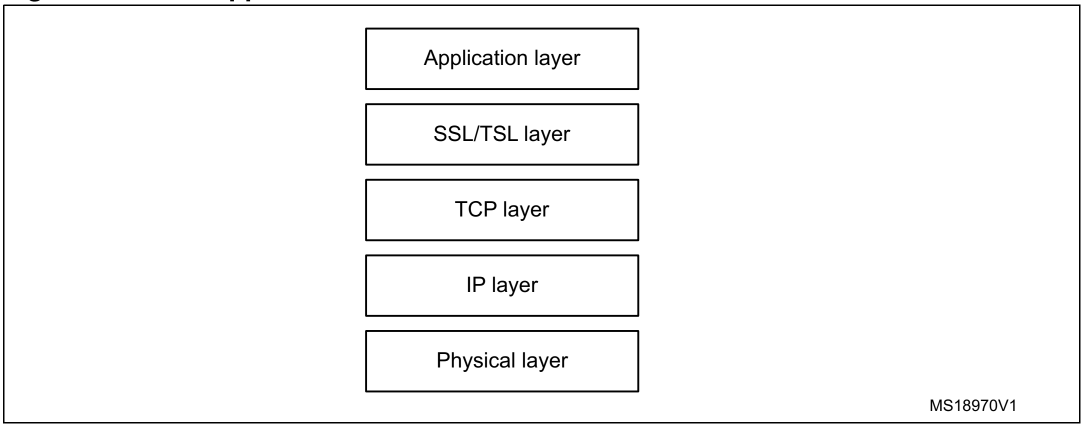
- Provide data integrity between two communicating applications.
- Protect information transmitted between server and client.
- Authenticate the server to the client.
- Allow the client and server to select the cryptographic algorithms that they both support.
- Optionally authenticate the client to the server.
- Use public-key encryption techniques to generate shared secrets.
- Establish an encrypted SSL connection.

3.1 SSL application layers

The SSL/TLS application consists of five layers:

- Application layer: the Application Layer refers to the higher-level protocols used by most applications for network communication.
- SSL/TLS layer: the SSL/TLS layer provides security communication over the Internet.
- TCP layer: the Transport Layer's responsibilities include end-to-end message transfer capabilities independent of the underlying network, along with error control, segmentation, flow control, congestion control, and application addressing.
- IP layer: the Internet Protocol layer is responsible for addressing hosts and routing packets from a source host to the destination host.
- Physical layer: the Physical Layer consists of the basic hardware transmission technologies of a network.

Figure 1. SSL application architecture



3.2 History of the SSL / TLS protocols

SSL was developed by Netscape in 1994 to secure transactions over the Internet. Soon after, the Internet Engineering Task Force (IETF) began work to develop a standard protocol to provide the same functionality.

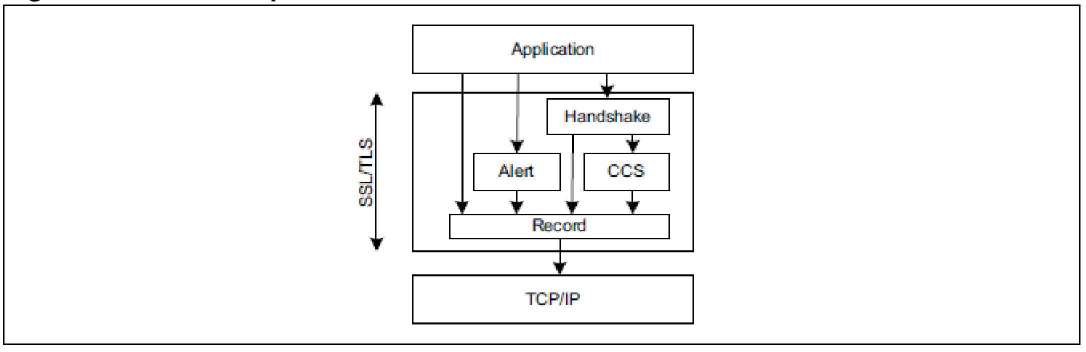
- SSL 1.0 (Netscape, 1993): Internal Netscape design.
- SSL 2.0 (Netscape, 1994): This version contained a number of security flaws.
- SSL 3.0 (Netscape, 1996): All Internet browsers support this version of the protocol.
- TLS 1.0 (IETF, 1999): This version was defined in RFC 2246 as an upgrade to SSL 3.0. “The differences between this protocol and SSL 3.0 are not dramatic, but they are significant enough that TLS 1.0 and SSL 3.0 do not interoperate”: *[1]: RFC 2246: The TLS protocol version 1.0*

Note: The “SSL/TLS” protocols is referred to as “SSL” throughout this document.

3.3 SSL / TLS sub-protocols

The SSL protocol includes four sub-protocols: the SSL Record protocol, the SSL Handshake protocol, the SSL Alert protocol and the SSL Change Cipher Spec protocol.

Figure 2. SSL sub-protocols

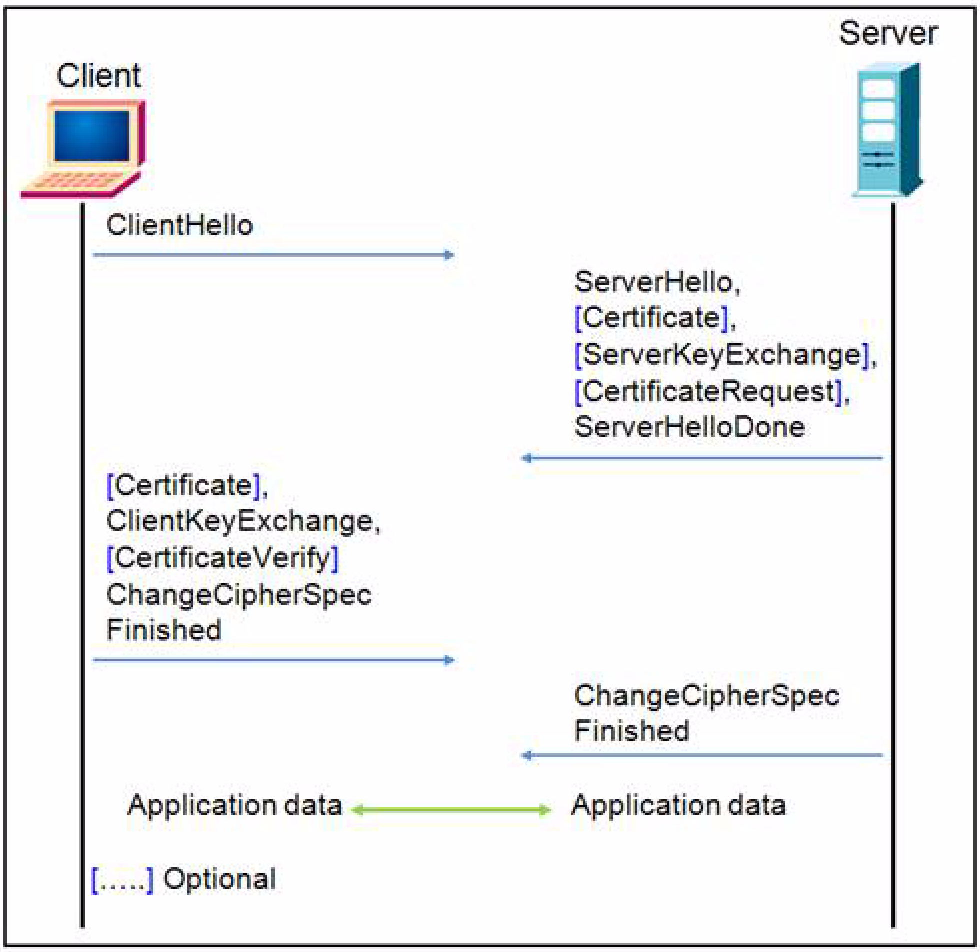


3.3.1 SSL Handshake protocol

The SSL session state is controlled by the SSL Handshake protocol. This protocol involves using the SSL record protocol to exchange a series of messages between SSL server and SSL client when they first start communicating. This exchange of messages is designed to facilitate the following actions:

- The protocol version SSL 3.0 or TLS 1.0
- Allow the client and server to select the cryptographic algorithms, or ciphers, that they both support
- Authenticate the server to the client
- Optionally authenticate the client to the server
- Use public-key encryption techniques to generate shared secrets
- Establish an encrypted SSL connection

Figure 3. SSL Handshake protocol



The following is the procedure for SSL Handshake protocol:

1. The client sends a ClientHello message specifying the highest SSL protocol version (SSL 3.0 or TLS 1.0) it supports, a random number, a list of cipher suites and compression methods.
2. Server responds with a ServerHello message that contains the chosen protocol version, another random number, cipher suite and compression method from the choices offered by the client, and the session ID.

Note: The client and the server must support at least one common cipher suite, or else the Handshake protocol fails. The server generally chooses the strongest common cipher suite they both support.

3. The server sends its digital certificate in an optional certificate message, for example, the server uses X.509 digital certificates.
4. If no certificate is sent, an optional ServerKeyExchange message is sent containing the server public information.
5. If the server requires a digital certificate for client authentication, an optional CertificateRequest message is appended.
6. The server sends a ServerHelloDone message indicating the end of this phase of negotiation.
7. If the server has sent a CertificateRequest message, the client must send its X.509 client certificate in a Certificate message.
8. The client sends a ClientKeyExchange message. This message contains the pre-master secret number used in the generation of the symmetric encryption keys and the message authentication code (MAC) keys. The client encrypts pre-master secret number with the public key of the server.

Note: The public key is sent by the server in the digital certificate or in ServerKeyExchange message.

9. If the client sent a digital certificate to the server, the client sends a CertificateVerify message signed with the client's private key. By verifying the signature of this message, the server can explicitly verify the ownership of the client digital certificate.
10. The client sends a ChangeCipherSpec message announcing that the new parameters (cipher method, keys) have been loaded.
11. The client sends a Finished message; it is the first message encrypted with the new cipher method and keys.
12. The server responds with a ChangeCipherSpec and a Finished message from its end.
13. The SSL Handshake protocol ends and the encrypted exchange of application data can be started.

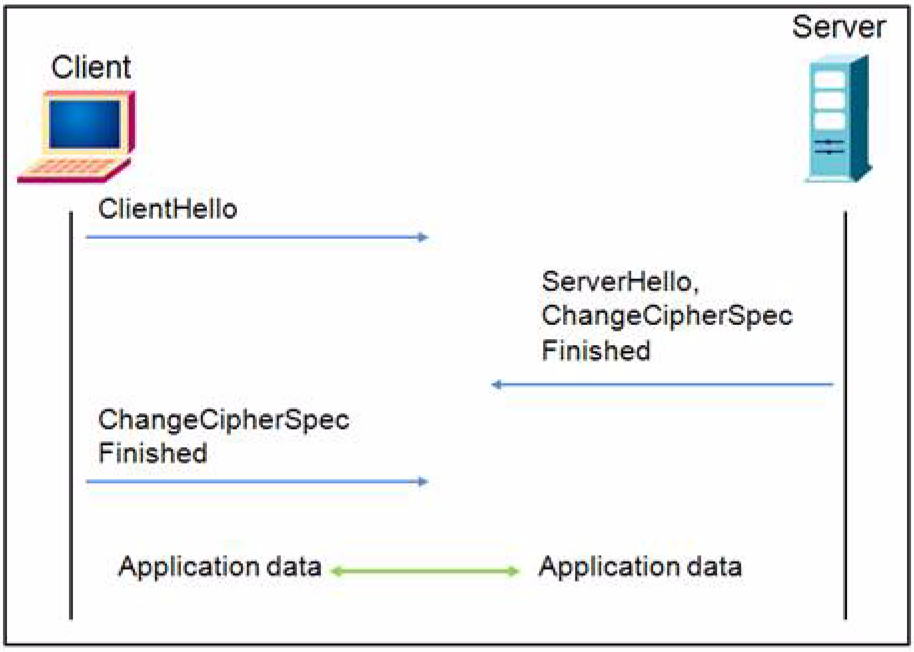
Resuming SSL session

When the client and the server decide to resume a previous session or to duplicate an existing session (instead of negotiating new security parameters), the message flow is as follows:

1. The client sends a ClientHello message using the Session ID of the session to be resumed.
2. The server checks its session cache for a match. If a match is found, and the server is willing to re-establish the connection under the specified session state, it sends a ServerHello message with the same Session ID value.
3. Both client and server must send ChangeCipherSpec messages and proceed directly to the Finished messages.
4. Once the re-establishment is complete, the client and server may begin to exchange encrypted application data.

Note: If a Session ID match is not found, the server generates a new session ID and the client and server perform a full Handshake protocol [1]: RFC 2246: The TLS protocol version 1.0.

Figure 4. Handshake protocol to resume an SSL session

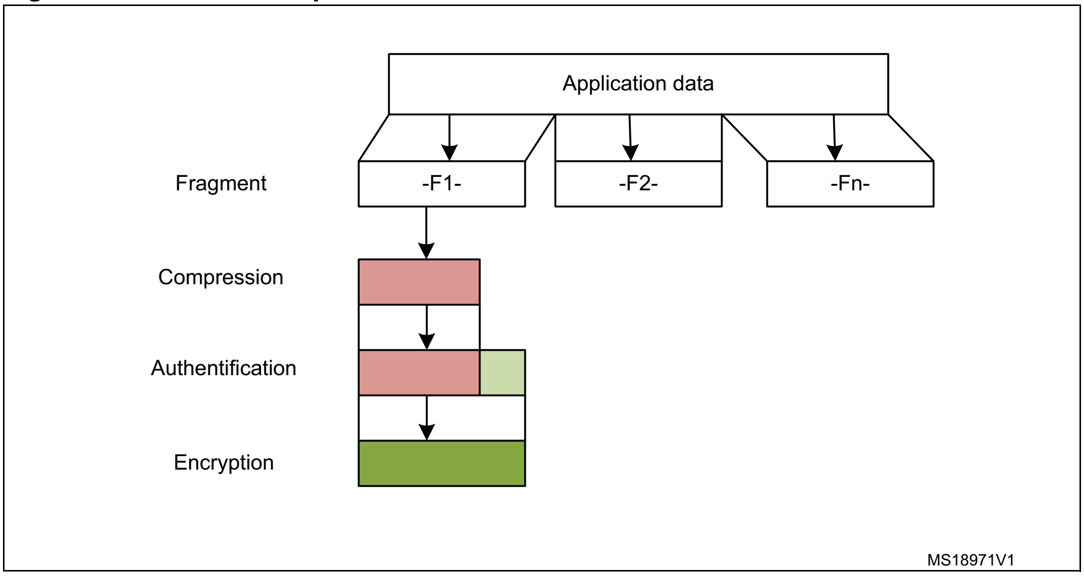


3.3.2 SSL Record protocol

The Record protocol takes messages to be transmitted, fragments the data into manageable blocks, optionally compresses the data, applies a MAC, encrypts, and transmits the results.

The received data is decrypted, verified, decompressed, and reassembled, then delivered to higher level clients.

Figure 5. SSL Record protocol



3.3.3 SSL Alert protocol

The SSL Alert protocol signals problems with the SSL session ranging from simple warnings (unknown certificate, revoked certificate, expired certificate) to fatal error messages that immediately terminate the SSL connection.

3.3.4 Change Cipher Spec protocol

The SSL Change Cipher Spec protocol consists of a single message that indicates the end of the SSL Handshake protocol.

Note: For more information about SSL protocols, please refer to [1]: RFC 2246: The TLS protocol version 1.0.

4 PolarSSL library

PolarSSL is a light-weight open source cryptographic and SSL/TLS library written in C. This library contains all needed functions to implement an SSL/TLS server or client. It contains also a set of hashing functions and cryptographic algorithms.

Features:

- SSL 3.0 and TLS 1.0 client/server support
- X.509 digital certificate
- Symmetric encryption algorithms: AES, Triple DES, DES, ARC4, Camellia,…
- Hash functions: MD2, MD4, MD5, SHA-1, SHA-256, SHA-384, SHA-512
- Message authentication code: HMAC MD2, HMAC MD4, HMAC MD5, HMAC SHA-1
- Software random number generator: HAVEGE
- Public key cryptography: RSA and Diffie-Hellman (DHM) key exchange

The source code of the PolarSSL library can be downloaded from this link: http://polarssl.org/download_overview

4.1 License

PolarSSL is licensed according to the dual licensing model. PolarSSL is available under the open source GPL version 2 license, as well as under a commercial license for closed source projects.

For detailed information about licensing, please refer to the PolarSSL licensing webpage http://polarssl.org/licensing

5 STM32F417xx hardware cryptography

As described in *Section 4*, the PolarSSL library contains a set of symmetric encryption algorithms (AES 128/192/256, Triple DES), hashing functions (MD5, SHA-1) and a software random number generator (HAVEGE). All these functions and algorithms are needed to implement an SSL/TLS application.

To off-load the CPU from encryption/decryption, hash and RNG (random number generator) tasks, all these functions and algorithms are implemented using the hardware acceleration AES 128/192/256, Triple DES, MD5, SHA-1 and analog RNG embedded in STM32F417xx.

5.1 Cryptographic processor

The cryptographic processor can be used to both encipher and decipher data using the Triple-DES or AES algorithm. It is a fully compliant implementation of the following standards:

- The data encryption standard (DES) and Triple-DES (TDES) as defined by the Federal Information Processing Standards Publication “FIPS PUB 46-3, 1999 October 25”. It follows the American National Standards Institute (ANSI) X9.52 standard.
- The advanced encryption standard (AES) as defined by Federal Information Processing Standards Publication “FIPS PUB 197, 2001 November 26”

The CRYP processor may be used for both encryption and decryption in the Electronic codebook (ECB) mode, the Cipher block chaining (CBC) mode or the Counter (CTR) mode (in AES only).

5.2 Random number generator

The RNG processor is a random number generator, based on a continuous analog noise, that provides a random 32-bit value to the host when read.

5.3 Hash processor

The hash processor is a fully compliant implementation of the secure hash algorithm (SHA-1), the MD5 (message-digest algorithm 5) hash algorithm and the HMAC (keyed-hash message authentication code) algorithm suitable for a variety of applications. It computes a message digest (160 bits for the SHA-1 algorithm, 128 bits for the MD5 algorithm) for messages of up to (2^{64} - 1) bits, while HMAC algorithms provide a way of authenticating messages by means of hash functions. HMAC algorithms consist in calling the SHA-1 or MD5 hash function twice.

Note: For more detailed information, please refer to the CRYP, HASH and RNG sections of [2]: RM0090: STM32F405xx, STM32F407xx, STM32F415xx and STM32F417xx microcontroller family reference manual.

6 Description of the demonstration package

The demonstration package contains two demonstrations running on top of the PolarSSL library and LwIP stack:

- SSL Client demonstration: This demonstration proves the ability of the STM32F417xx device to exchange messages with a server over TCP/IP connectivity through a SSL connection. This demonstration allows you to connect the STM3241G-EVAL board to a secure web server with SSL protocol.
- SSL server demonstration: SSL server is a combination of HTTP with SSL protocol to provide encryption and secure identification of the server. This demonstration allows you to connect from a web browser to a STM3241G-EVAL board using SSL protocol.

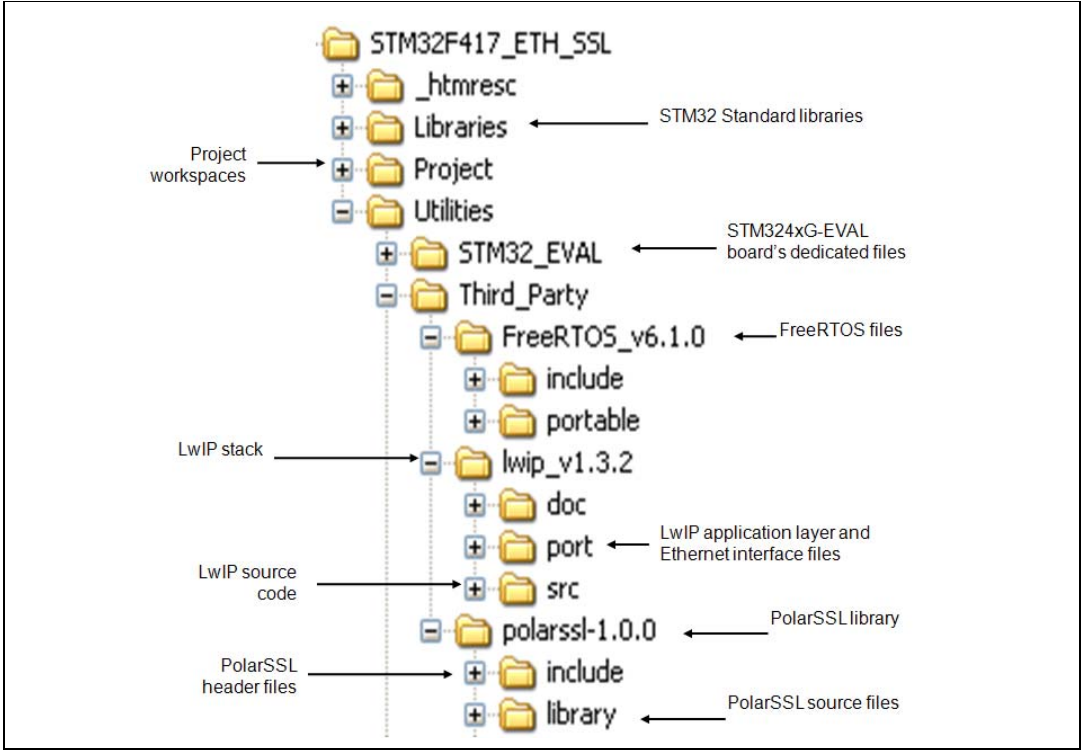
6.1 Package directories and firmware components

6.1.1 Package directories

The demonstration package consists of five main folders listed below:

- Libraries: This folder contains all the subdirectories and files that make up the core of the STM32F4xx Standard Peripheral library.
- Project: This folder contains the demo header and source files.
- FreeRTOS: This folder contains the real-time kernel source code and all directories associated with the scheduler source code.
  - include: contains the scheduler header files.
  - portable: contains the STM32 specific code, scheduler port layer for compiler and memory management files.
- LwIP: This folder contains all the header and source files for the TCP/IP stack.
- PolarSSL: This folder contains all the header and source files for the PolarSSL-1.0.0 library.

Figure 6. Demonstration package structure



6.1.2 Firmware components

Both demonstrations are based on three software modules: LwIP-1.3.2 (a free TCP/IP stack), PolarSSL-1.0.0 (a free SSL/TLS library) and FreeRTOS-6.1.0 (a free real-time kernel). These modules are described below.

LwIP stack

LwIP is a free TCP/IP stack developed by Adam Dunkels at the Swedish Institute of Computer Science (SICS) and licensed under the BSD license. The source code can be downloaded from this link: http://download.savannah.gnu.org/releases/lwip/

The lwIP TCP/IP stack supports the following protocols: IPv4, IPv6, UDP, TCP, ICMP, IGMP, SNMP, ARP and PPP. It does not include protocols from the application layer, like HTTP or HTTPS.

The lwIP offers three types of API (application programming interface):

- Raw API: native API designed to be used without an operating system. This API is used by the core stack for interaction between the various protocols.
- Netconn API: sequential API with a higher level of abstraction than the raw API. To use the Netconn API, an operating system is needed. All packet processing (input and output) is done inside a dedicated thread (the TCP/IP thread). The application threads communicate with this core thread using message boxes and semaphores.
- Socket API: based on the Berkeley socket interface (BSD Socket). To use the Socket API, an operating system is needed.

PolarSSL library

PolarSSL is a free library used to implement a secure application based on SSL/TLS protocols.

The official release of this library does not provide any port to any microcontroller: you need to do it by yourself. The PolarSSL library comes with a file called net.c that works as an interface between the library and the LwIP stack. To use PolarSSL, you need to modify this file to support the specified stack.

net.c contains functions that ensure the transfer of the frames between PolarSSL and the lwIP stack. Its main functions are:

- net_recv which should be called when a packet is ready to be read from the stack.
- net_send which should be called when a packet is ready to be send to the stack.

The connection layer of PolarSSL uses the socket API to communicate with the TCP/IP stack.

Note: The API used to build the demonstration is the socket API, which is shared between PolarSSL and the LwIP stack.

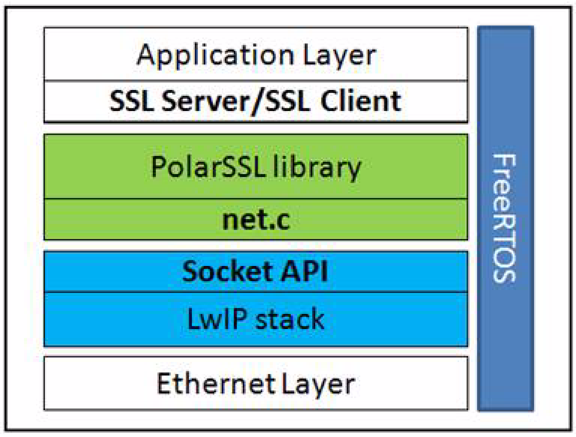
FreeRTOS

FreeRTOS is an open-source mini real-time Kernel for embedded devices. The source code can be downloaded from this link: http://www.freertos.org/

Features:

- Scheduler operation:
  – Preemptive: always runs the highest priority available task.
  – Cooperative: context switches only occur if a task blocks, or explicitly calls task YIELD() (macro used to force a context switch).
- Inter-Process Communication: the communication between tasks is achieved via the message queue and the binary semaphores.
- The number of available priorities can be changed as needed.

Figure 7. PolarSSL & LwIP connection



6.2 Demonstration settings

6.2.1 PHY interface configuration

The demonstration firmware is used to interface the PHY with the two modes: MII and RMII. To select the PHY interface mode you wish to use, go to the `main.h` file and choose one of the two defines:

```
#define MII_MODE
```

```
#define RMII_MODE
```

For the MII mode, the PHY clock can be taken from the external crystal or provided by the STM32 via the MCO pin if both MII_MODE and PHY_CLOCK_MCO are defined in the `main.h` file.

Note: For RMII mode you have to provide the 50 MHz clock by soldering a 50 MHz oscillator (ref SM7745HEV-50.0M or equivalent) on the U3 footprint located under CN3 and also removing jumper on JP5. This oscillator is not provided with the board. For more details, please refer to STM3240G-EVAL evaluation board User manual UM1461.

6.2.2 MAC and IP address settings

The default MAC address is fixed to 00:00:00:00:00:01. To change this address, you can modify the six bytes defined in the main.h file.

In the SSL client demonstration, the IP address is set as static, the default IP address is 192.168.0.8 defined in the main.h file.

In SSL server demonstration the IP address can be set either as a static address, equal to 192.168.0.8, or as a dynamic address, assigned by a DHCP server.

The selection of the IP address configuration mode is done in the main.h file:

- Uncomment #define USE_DHCP to configure the IP address by DHCP
- Comment #define USE_DHCP to use the static address (192.168.0.8)

Note: If you choose to configure the IP address by DHCP and the application does not find a DHCP server on the network to which it is already connected, the IP address is automatically set to the static address (192.168.0.8).

6.2.3 STM3241G-EVAL settings

Once you have set the PHY interface mode, the MAC address and the IP address, you need to configure the STM3241G-EVAL evaluation board as shown in the following table.

Table 2. STM3241G-EVAL jumpers configuration

Jumper	MII mode configuration	RMII mode configuration
JP5	1-2: provide 25 MHz clock by external crystal 2-3: provide 25 MHz clock by MCO at PA8	Not fitted
JP6	2-3: MII interface mode is enabled	1-2: RMII interface mode is enabled
JP8	Open: MII interface mode is selected	Close: RMII interface mode is selected
JP22	1-2: RS232 is enabled	

6.3 How to use the demonstration

6.3.1 SSL client demonstration

This demonstration consists of using the STM3241G-EVAL board as a client that connects to a secure server to provide the SSL Handshake protocol.

Demonstration architecture

The SSL client demonstration as shown in *Figure 8* contains four tasks:

LED task: Blink LED4 every 200 ms.

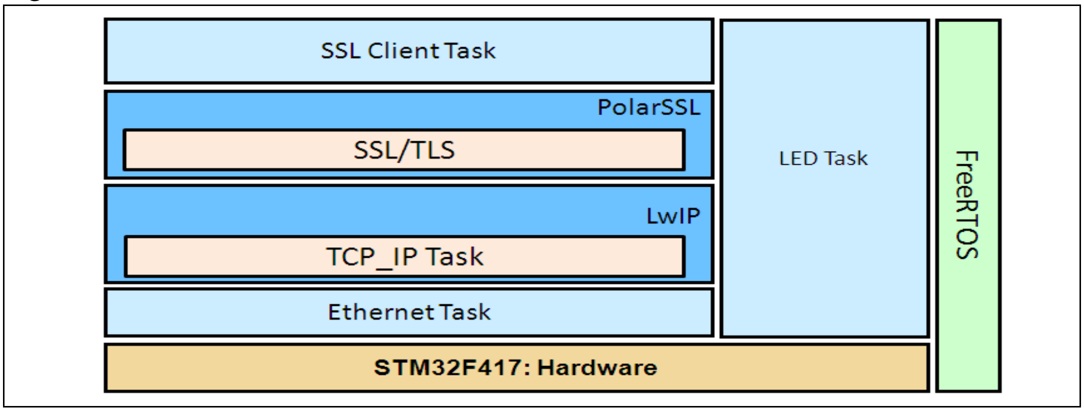
Ethernet task: The low-level layer was set to detect the reception of frames by interrupts. So, when the Ethernet controller receives a valid frame, it generates an interrupt. In the handling function of this interrupt, a binary semaphore is created to wake up the Ethernet task. This task transfers the input frames to the TCP/IP stack.

TCP/IP task: All packet processing (input and output) is done inside this thread. The application threads communicate with this thread using message boxes and semaphores.

SSL client task: This task handles the SSL Handshake protocol. It connects to an SSL server and performs the following:

- Initializes SSL structures (SSL context, SSL session, SSL RNG).
- Connects to a SSL server.
- Sets up the SSL session.
- Handles the SSL Handshake protocol.
- Writes a message to the server.
- Reads a message from the server.
- Sends these messages through USART.
- Closes the connection.
- Cleans all SSL structures.

Figure 8. SSL client demonstration architecture



How to use the demonstration

First, connect the STM3241G-EVAL board as follows:

- Ethernet link: Connect to a remote PC (through a crossover Ethernet cable) or to your local network (through a straight Ethernet cable).
- RS232 link (used with HyperTerminal like application to display debug messages): Connect a null-modem female/female RS232 cable between the DB9 connector CN16 (USART3) and PC serial port.

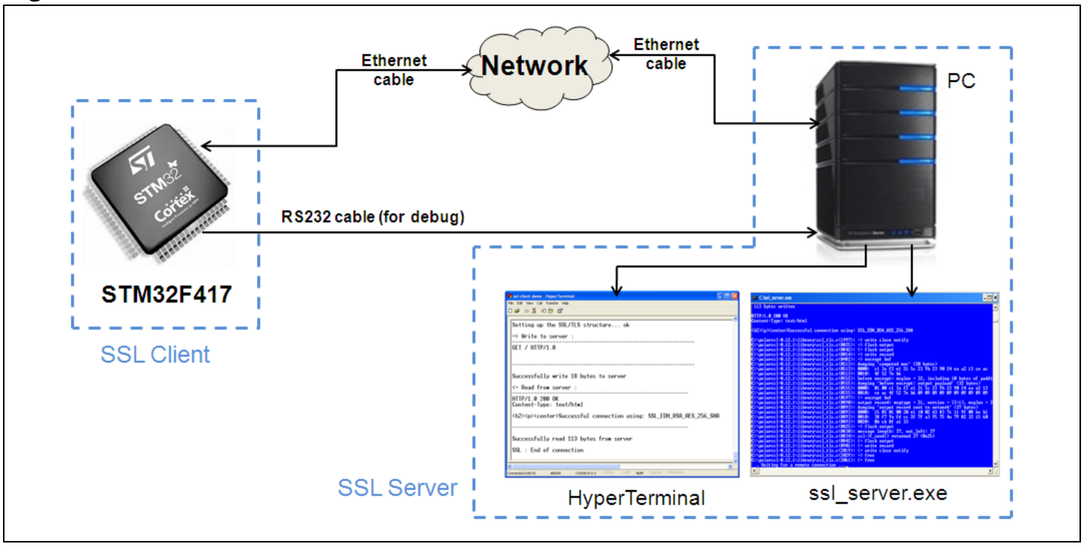
To run the SSL client example, please proceed as follows:

- Build and program the SSL client code in the STM32F417 Flash.
- Run the SSL server application on the remote PC, and run ssl_server.exe under Utilities\PC_Software\Server. This application then waits for a client connection on https port 443.
- Start the STM3241G-EVAL board.
- Monitor the connection status in the SSL server application window and HyperTerminal window.

Note: 1 Please ensure that the remote PC IP address is the same IP address as the one defined in ssl_client.c file (#define SSL_SERVER_NAME "192.168.0.1").

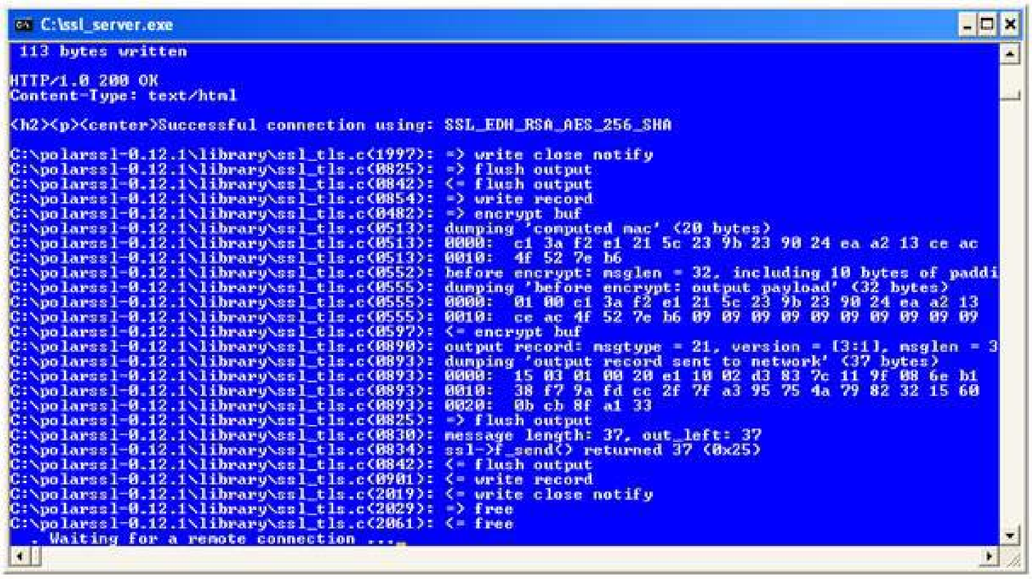
2 If you use a firewall, you must be sure that the ssl_server application accepts connection requests. If it does not, the firewall will reject the client requests.

Figure 9. SSL client demonstration



The **ssl_server.exe** application window is shown in *Figure 10*. The SSL server application displays the connection request status; all exchange messages between the server and the client are displayed.

Figure 10. ssl_server application window



HyperTerminal

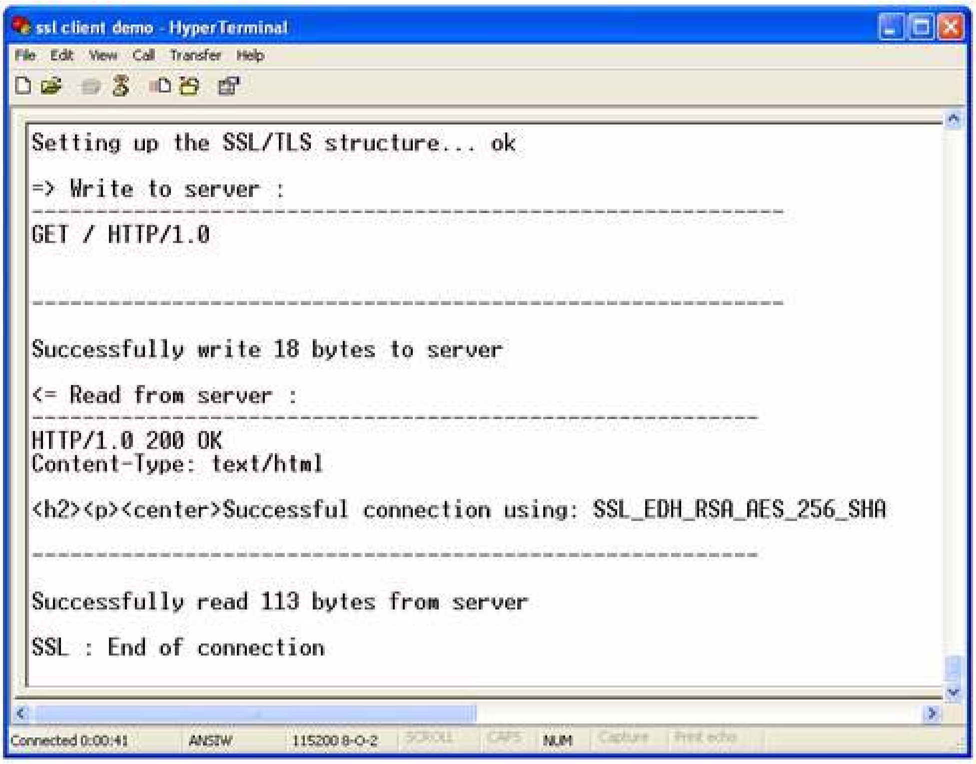
Figure 11: HyperTerminal window displays the status of the SSL client application running on the STM32F417xx device (write messages and read messages):

– Status of SSL structures (SSL context, SSL session, SSL RNG)

– Client request to the server: “GET”

– The received message contains the result of Handshake protocol: for example “Successful connection using: SSL_EDH_RSA_AES_256_SHA”.

Figure 11. HyperTerminal window



6.3.2 SSL server demonstration

This demonstration consists of setting up the STM3241G-EVAL board as an SSL server that waits for a SSL client request to make the connection.

Demonstration architecture

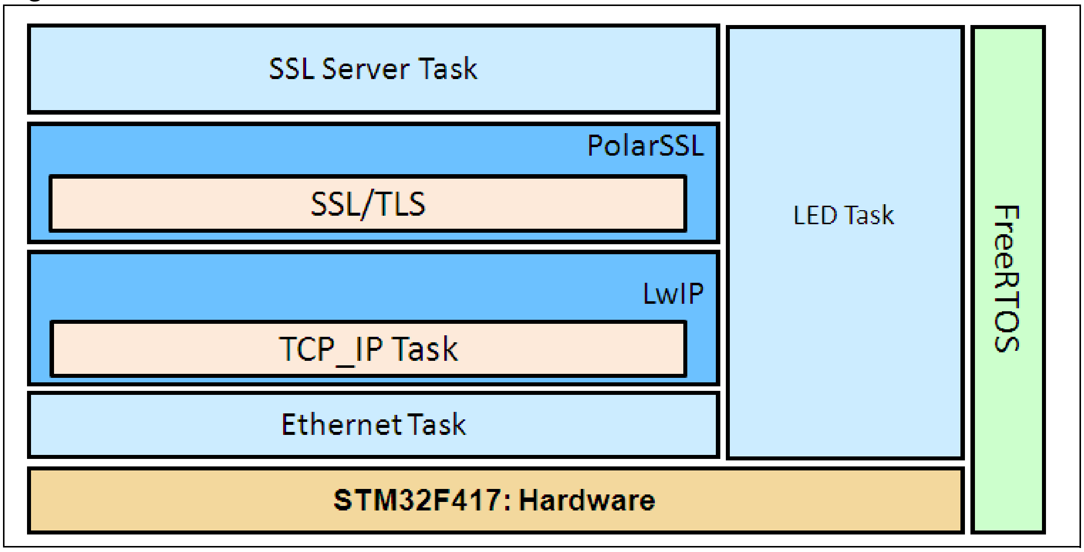
The SSL server demonstration contains five tasks:

The **LED**, **Ethernet**, and **TCP_IP** tasks are the same as the SSL client demonstration tasks.

SSL server task: This task creates an SSL connection and waits for the client's request to make the secure connection. When the connection is established, the client sends Get request to load the html page. This page contains information about the tasks running in this demonstration. The SSL server task also sends the status of the connection through USART.

DHCP_Client task: This task is used to configure the IP address by DHCP. To enable the DHCP client, uncomment the define USE_DHCP in main.h file.

Figure 12. SSL server demonstration architecture



How to use the demonstration

First, connect the STM3241G-EVAL board as follows:

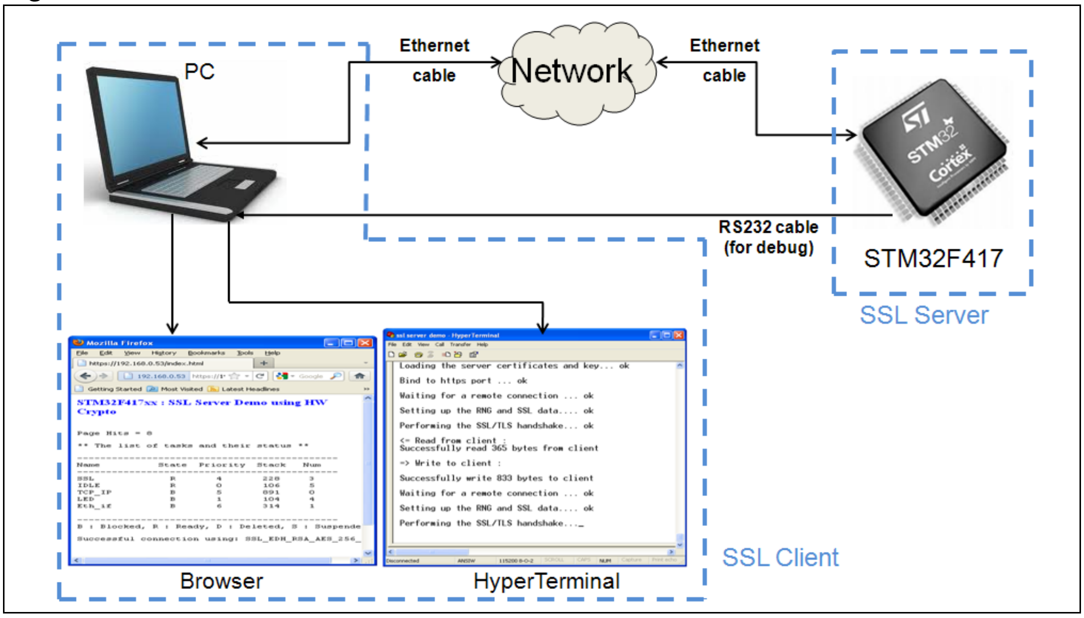
- Ethernet link: Connect to a remote PC (through a crossover Ethernet cable) or to your local network (through a straight Ethernet cable).
- RS232 link (used with HyperTerminal-like application to display debug messages): Connect a null-modem female/female RS232 cable between the DB9 connector CN16 (USART3) and the PC serial port.

To run the SSL server demonstration:

- Build and program the SSL server code in the STM32F417 Flash.
- Start the STM3241G-EVAL board.
- Open a web browser such as Internet Explorer or Firefox, and type the board's IP address in the browser, for example https//192.168.0.8.

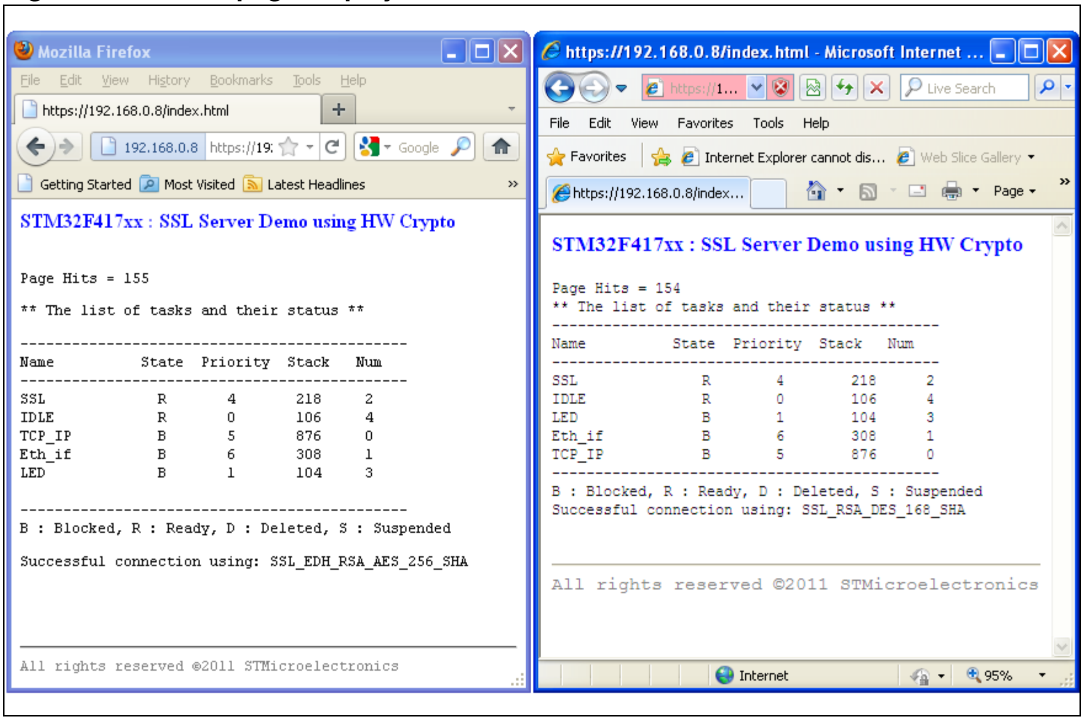
Note: If you use a firewall, you must be sure that the HTTPS port accepts the connection requests. If it does not, the firewall will reject the connection.

Figure 13. SSL server demonstration



On successful connection, a page is displayed showing the running tasks and their status. This page contains also the number of page hits and the list of cipher suites used in the connection.

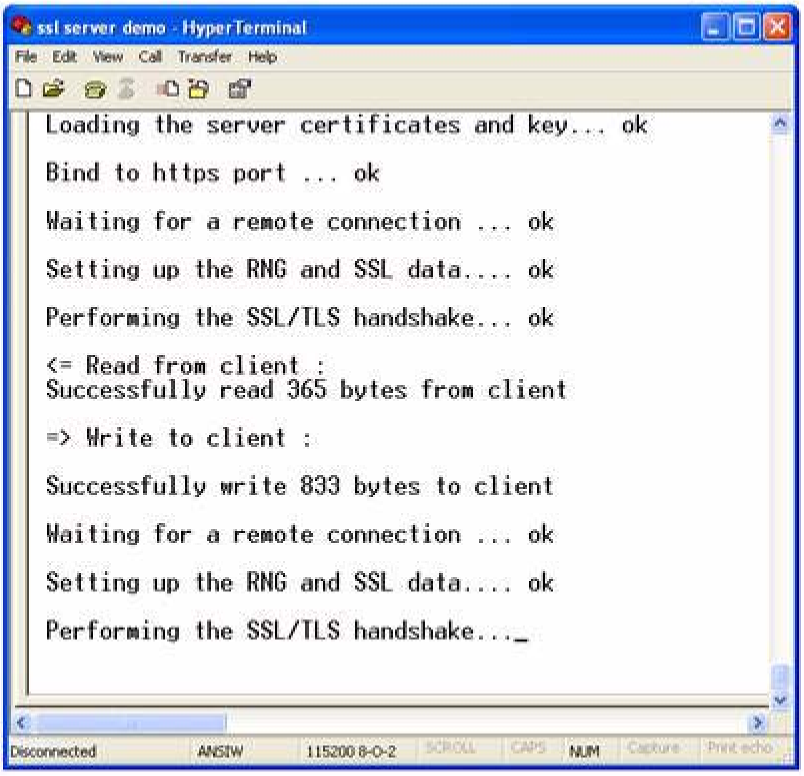
Figure 14. HTML page displayed on successful connection



You can monitor the connection status of the SSL server application running on an STM32F417xx device, using the HyperTerminal window. This window (*Figure 15*) shows:

- the status of connection, SSL structures and Handshake protocol,
- the size of the client's request message,
- the size of the server's response (html page).

Figure 15. HyperTerminal SSL server connection status



Note: *The first time you connect to the server, you receive a warning message from the browser about the certificate presented. This warning occurs when the certificate has been issued by a certification authority (CA) that is not recognized by the browser or when the certificate was issued to a different web address.*

This is due to the fact that the SSL server application uses a self-signed test certificate. It is safe to continue past this warning (see Appendix A on page 31).

6.4 Memory footprint of the SSL demonstrations

6.4.1 SSL client demonstration

Table 3: SSL client demonstration footprint provides the client demonstration footprint, calculated with the following configuration:

- 2 buffers of 1500 bytes constitute the lwIP pool of buffers. These parameters are defined in the lwipopts.h file by PBUF_POOL_SIZE and PBUF_POOL_BUFSIZE.
- 2 Kbytes dedicated to the lwIP's heap and defined in the lwipopts.h file by MEM_SIZE.
- 5 buffers of 1520 bytes dedicated to the Ethernet driver and defined in the stm32f4x7_eth_conf.h file.

These values are provided for demonstration purposes only. So, if you want to port the current package and use it for your application, the above parameters should be adjusted to your needs.

Table 3. SSL client demonstration footprint

Modules	Flash memory (bytes)		SRAM (bytes)
	Ro code	Ro data	Rw data
Ethernet driver and interface	2340	0	7816
lwIP memory management and IP modules	18894	16	7088
PolarSSL	63004	2755	748
FreeRTOS	3050	64	13636
Application modules: Main and system initialization	2736	0	2285
STM32F4xx Standard Peripherals Library Drivers	2750	6	16
STM324xG-EVAL board	1942	4576	44
Others (stack, heap, etc.)	21610	100	44732
Total	116326	7517	76365

Note: The software is compiled using IAR EWARM v6.21.3, with high optimization for code size.

6.4.2 SSL server demonstration

The table below provides the server demonstration footprint, calculated with the following configuration:

- 4 buffers of 1500 bytes that constitute the lwIP pool of buffers. These parameters are defined in the lwipopts.h file by PBUF_POOL_SIZE and PBUF_POOL_BUFSIZE.
- 5 Kbytes dedicated to the lwIP's heap and defined in the lwipopts.h file by MEM_SIZE.
- 6 buffers of 1520 bytes dedicated to the Ethernet driver and defined in the stm32f4x7_eth_conf.h file.

These values are provided for demonstration purposes only. So, if you want to port the current package and use it for your application, the above parameters should be adjusted to your needs.

Table 4. SSL server demonstration footprint

Modules	Flash memory (bytes)		SRAM (bytes)
	Ro code	Ro data	Rw data
Ethernet driver and interface	2340	0	9372
lwIP memory management and IP modules	21794	10	13888
PolarSSL	65674	7820	696
FreeRTOS	3310	13	14712
Application modules: Main and system initialization	4036	465	2953
STM32F4xx standard peripheral library drivers	2750	1	16
STM324xG-EVAL board	1982	4563	44
Others (stack, heap...)	21640	56	50620
Total	123526	12928	92301

Note: The software is compiled using IAR EWARM v6.21.3, with high optimization for code size.

7 Conclusion

This application note describes two STM32F417xx demonstration programs that implement the PolarSSL library.

The first one demonstrates the ability of the STM32F417xx device to exchange messages with a server through an SSL connection. This demonstration program allows you to connect the STM3241G-EVAL board to a secure web server.

The second one is a combination of HTTP with SSL protocol to provide encryption and secure identification of the server. This demonstration program allows you to connect to an STM3241G-EVAL board using the SSL protocol from a web browser.

8 References

[1]: RFC 2246: The TLS protocol version 1.0

[2]: RM0090: STM32F405xx, STM32F407xx, STM32F415xx and STM32F417xx microcontroller family reference manual

Appendix A Additional information

A.1 Flowcharts

Figure 16. SSL client task flowchart

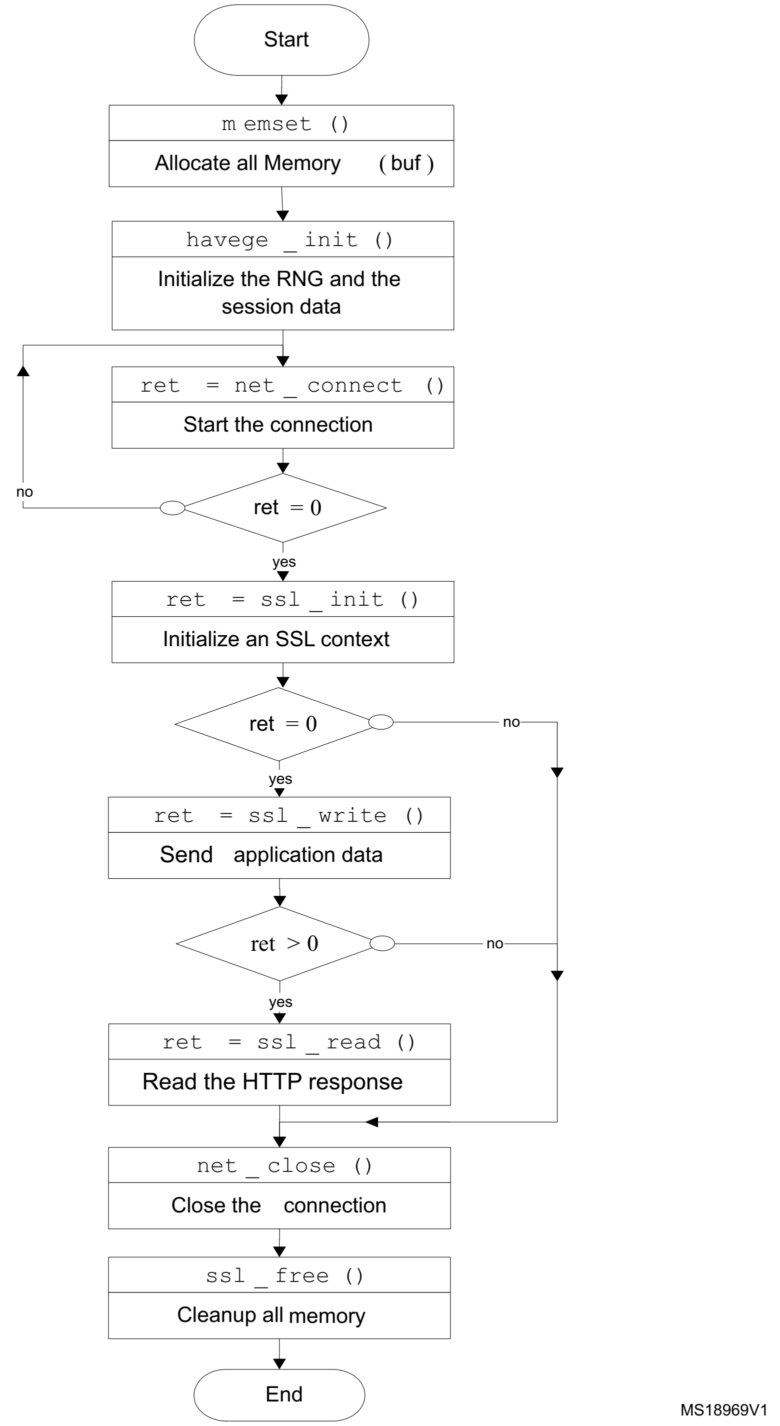
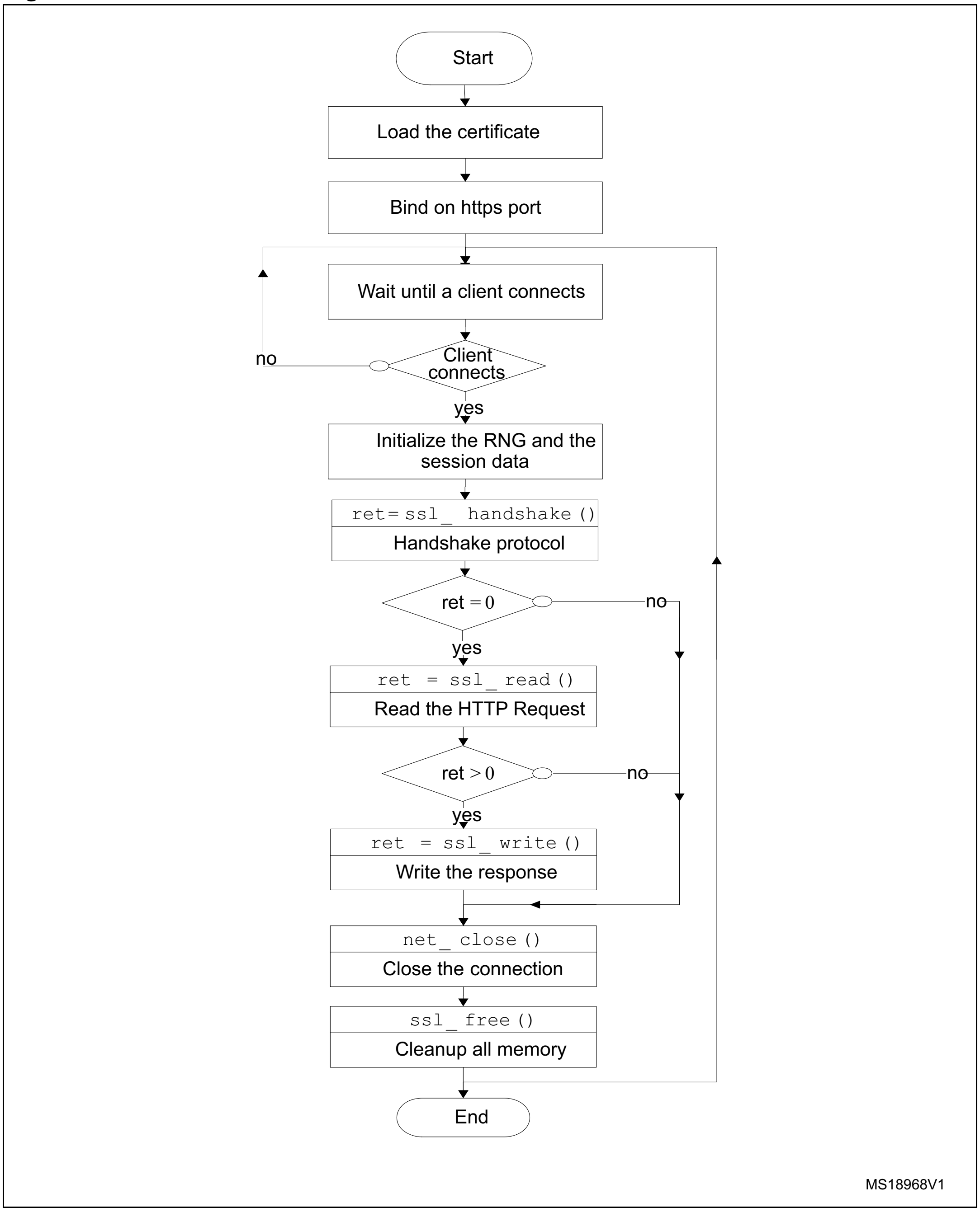


Figure 17. SSL server task flowchart



A.2 Project configuration

A.2.1 LwIP configuration

Table 5 lists the lwIP software component configuration. LwIP configuration can be done by modifying lwipopts.h:

Table 5. lwIP options for SSL server demonstration

Option	Value	Description
MEM_SIZE	5 * 1024	The size of the heap memory
MEMP_NUM_PBUF	5	The number of buffers sent without copying
MEMP_NUM_UDP_PCB	4	The number of simultaneously active UDP “connections”
MEMP_NUM_TCP_PCB	5	The number of simultaneously active TCP connections
MEMP_NUM_TCP_PCB_LISTEN	5	The number of listening TCP connections
PBUF_POOL_SIZE	4	The number of packet buffers
PBUF_POOL_BUFSIZE	1500	The size of each pbuf in the pbuf pool.
LWIP_ICMP	1	Enable ICMP protocol
LWIP_DHCP	1	Enable DCHP protocol
LWIP_UDP	1	Enable UDP protocol
LWIP_TCP	1	Enable TCP protocol
TCP_MSS	1460	TCP maximum segment size
TCP_WND	2 * TCP_MSS	TCP window size: receive buffer space in bytes
TCP_SND_BUF	2 * TCP_MSS	TCP sender buffer space

Table 6. lwIP options for SSL client demonstration

Option	Value	Description
MEM_SIZE	2 * 1024	The size of the heap memory
MEMP_NUM_PBUF	2	The number of buffers sent without copying
MEMP_NUM_UDP_PCB	2	The number of simultaneously active UDP “connections”
MEMP_NUM_TCP_PCB	2	The number of simultaneously active TCP connections
MEMP_NUM_TCP_PCB_LISTEN	6	The number of listening TCP connections
PBUF_POOL_SIZE	2	The number of packet buffers
PBUF_POOL_BUFSIZE	1500	The size of each pbuf in the pbuf pool.

Table 6. lwIP options for SSL client demonstration (continued)

Option	Value	Description
LWIP_ICMP	1	Enable ICMP protocol
LWIP_DHCP	1	Enable DCHP protocol
LWIP_UDP	1	Enable UDP protocol
LWIP_TCP	1	Enable TCP protocol
TCP_MSS	1460	TCP Maximum Segment Size
TCP_WND	2 * TCP_MSS	TCP window size: receive buffer space in bytes
TCP_SND_BUF	2 * TCP_MSS	TCP sender buffer space

A.2.2 PolarSSL configuration

PolarSSL configuration can be done by modifying config.h file; you can enable/disable the software component by commenting or uncommenting the specific line.

In order to decrease the memory size, unused modules should be commented.

Table 7. PolarSSL options: config.h file for SSL server demonstration

Option	Description
POLARSSL_DEBUG_MSG	Enable all SSL/TLS debugging messages.
POLARSSL_AES_C	Enable the following ciphersuites: SSL_RSA_AES_128_SHA SSL_RSA_AES_256_SHA SSL_EDH_RSA_AES_256_SHA
POLARSSL_ARC4_C	Enable the following ciphersuites: SSL_RSA_RC4_128_MD5 SSL_RSA_RC4_128_SHA
POLARSSL_CAMELLIA_C	Enable the following ciphersuites: SSL_RSA_CAMELLIA_128_SHA SSL_RSA_CAMELLIA_256_SHA SSL_EDH_RSA_CAMELLIA_256_SHA
POLARSSL_DES_C	Enable the following ciphersuites: SSL_RSA_DES_168_SHA SSL_EDH_RSA_DES_168_SHA
POLARSSL_DHM_C	Enable the following ciphersuites: SSL_EDH_RSA_DES_168_SHA SSL_EDH_RSA_AES_256_SHA SSL_EDH_RSA_CAMELLIA_256_SHA
POLARSSL_SSL_SRV_C	Enable SSL/TLS server mode

Table 8. PolarSSL options: config.h file for SSL client demonstration

Option	Description
POLARSSL_DEBUG_MSG	Enable all SSL/TLS debugging messages.
POLARSSL_AES_C	Enable the following ciphersuites: SSL_RSA_AES_128_SHA SSL_RSA_AES_256_SHA SSL_EDH_RSA_AES_256_SHA
POLARSSL_ARC4_C	Enable the following ciphersuites: SSL_RSA_RC4_128_MD5 SSL_RSA_RC4_128_SHA
POLARSSL_CAMELLIA_C	Enable the following ciphersuites: SSL_RSA_CAMELLIA_128_SHA SSL_RSA_CAMELLIA_256_SHA SSL_EDH_RSA_CAMELLIA_256_SHA
POLARSSL_DES_C	Enable the following ciphersuites: SSL_RSA_DES_168_SHA SSL_EDH_RSA_DES_168_SHA
POLARSSL_DHM_C	Enable the following ciphersuites: SSL_EDH_RSA_DES_168_SHA SSL_EDH_RSA_AES_256_SHA SSL_EDH_RSA_CAMELLIA_256_SHA
POLARSSL_SSL_CLI_C	Enable SSL/TLS client mode

A.2.3 FreeRTOS configuration

FreeRTOS configuration can be done by modifying FreeRTOSconfig.h file.

Table 9. FreeRTOS configuration for SSL client demonstration

Parameter	Value	Description
configMAX_PRIORITIES	7	The maximum value of priority
configMAX_TASK_NAME_LEN	16	The maximum length of task's name
configMINIMAL_STACK_SIZE	128	The size of stack allocated to the Idle task
configTOTAL_HEAP_SIZE	13 * 1024	Total FreeRTOS heap size

Table 10. FreeRTOS configuration for SSL server demonstration

Parameter	Value	Description
configMAX_PRIORITIES	7	The maximum value of priority
configMAX_TASK_NAME_LEN	16	The maximum length of task's name
configMINIMAL_STACK_SIZE	128	The size of stack allocated to the Idle task
configTOTAL_HEAP_SIZE	14 * 1024	Total FreeRTOS heap size

A.3 Running SSL server demo with Mozilla 7.0.1

The following is the procedure for Running SSL server demo with Mozilla 7.0.1.

1. Open the browser and type in the URL, for example, https://192.168.0.53. The browser displays a warning message as in *Figure 18*.

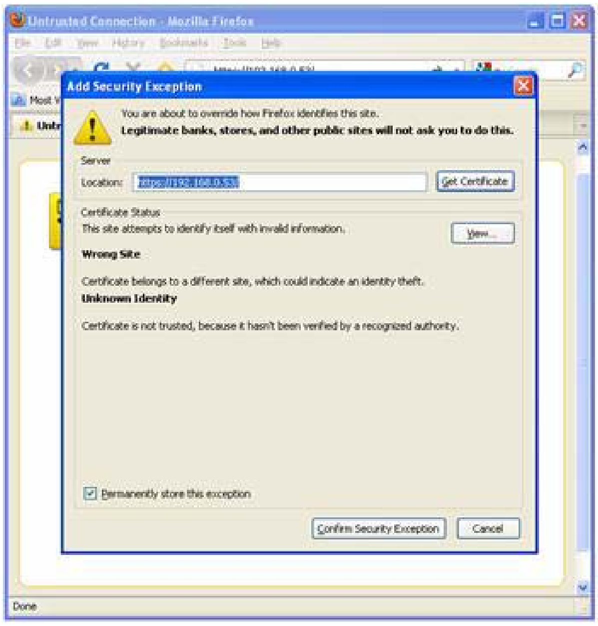
Figure 18. Untrusted connection dialog 1

2. Select **I Understand the Risks** and an another message will be displayed as in *Figure 19*.

Figure 19. Untrusted connection dialog 2

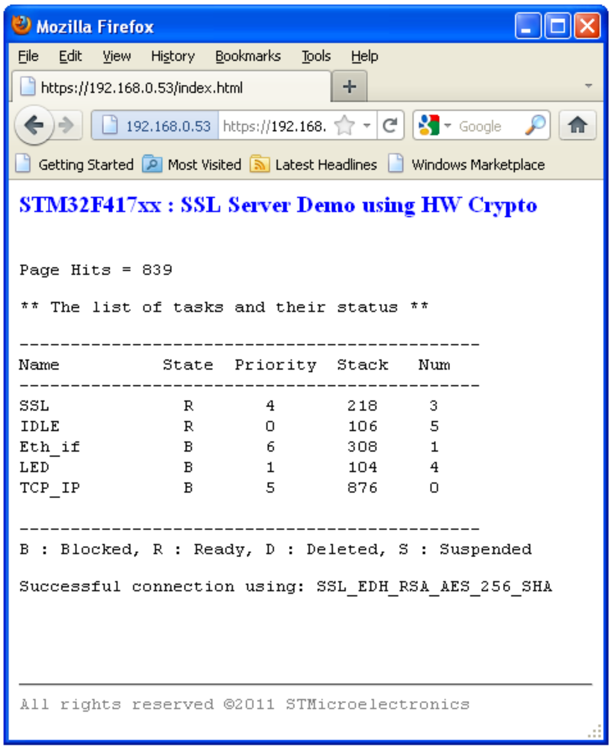
3. Click **Add Exception**. The browser downloads the (CA) certification authority certificate.

Figure 20. Add Security Exception dialog



4. Click **Confirm Security Exception** to start the secure connection as shown in *Figure 20*. On successful connection, *Figure 21: Task status page* is displayed showing the list of running tasks and their status. This window also contains the number of page hits.

Figure 21. Task status page

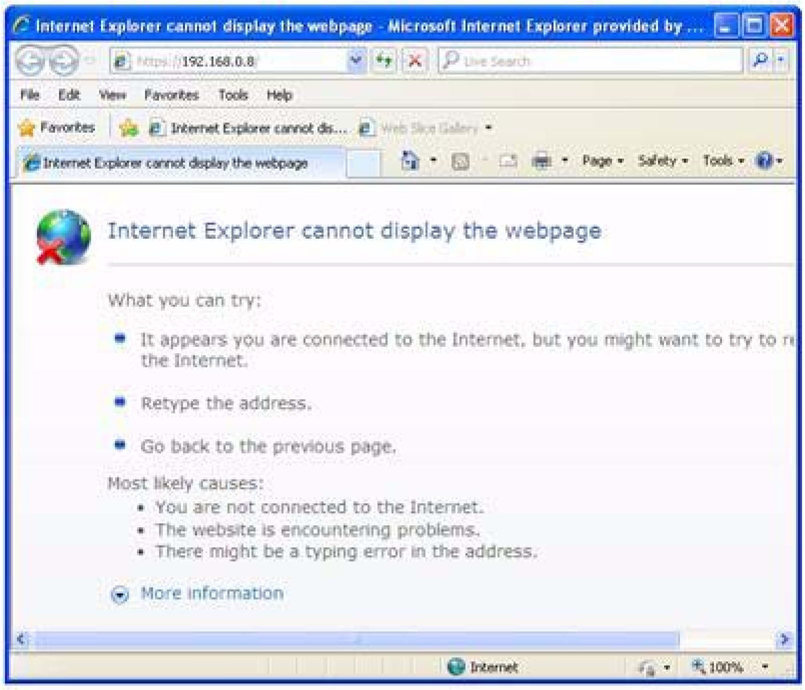


A.4 Running SSL server demo with IE8

The following is the procedure for running the SSL server demo with IE8 (Windows Internet Explorer 8).

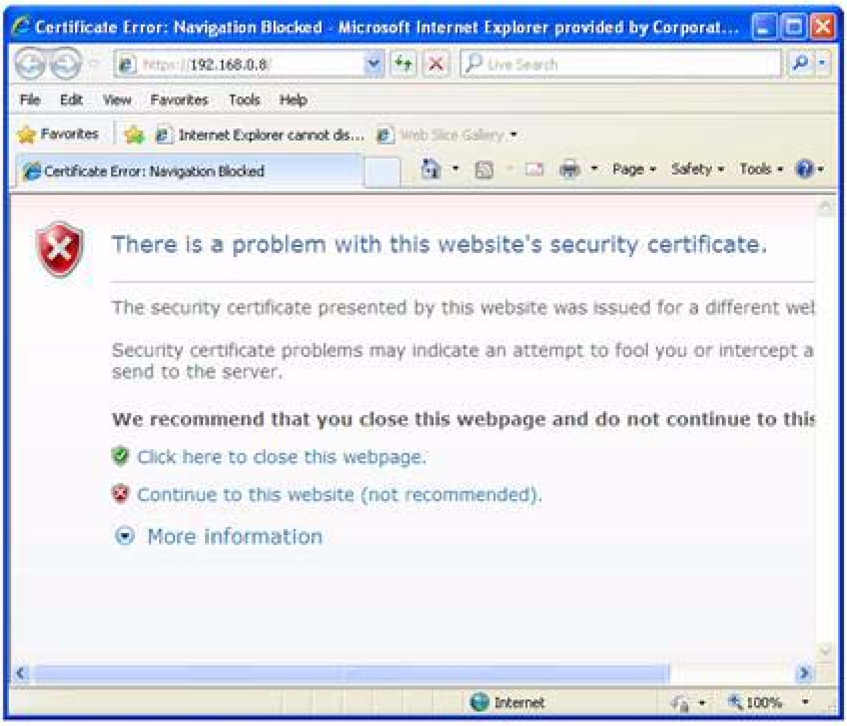
1. Open the browser and type in the URL, for example, https://192.168.0.8. The browser displays a warning message.

Figure 22. Cannot display webpage error message



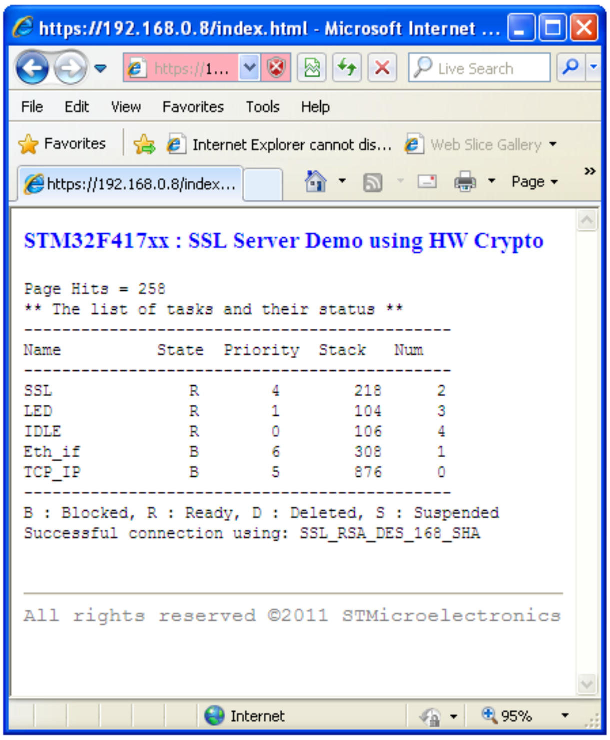
2. Refresh the current page.

Figure 23. Certificate error message



3. Select **Continue to this website (not recommended)**: If successful, you should see the following web page as shown in *Figure 24: Task status page*.

Figure 24. Task status page



9 Revision history

Table 11. Document revision history

Date	Revision	Changes
31-Oct-2011	1	Initial release