FreeRTOS

Porting Guide

FreeRTOS: Porting Guide

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FreeRTOS Porting

What is FreeRTOS?

Developed in partnership with the world's leading chip companies over a 15-year period, and now downloaded every 175 seconds, FreeRTOS is a market-leading real-time operating system (RTOS) for microcontrollers and small microprocessors. Distributed freely under the MIT open source license, FreeRTOS includes a kernel and a growing set of libraries suitable for use across all industry sectors. FreeRTOS is built with an emphasis on reliability and ease of use.

FreeRTOS includes libraries for connectivity, security, and over-the-air (OTA) updates. FreeRTOS also includes demo applications that show FreeRTOS features on qualified boards.

FreeRTOS is an open-source project. You can download the source code, contribute changes or enhancements, or report issues on the GitHub site at https://github.com/aws/amazon-freertos. We release FreeRTOS code under the MIT open source license, so you can use it in commercial and personal projects.

We also welcome contributions to the FreeRTOS documentation (*FreeRTOS User Guide*, *FreeRTOS Porting Guide*, and *FreeRTOS Qualification Guide*). The markdown source for the documentation is available at https://github.com/awsdocs/aws-freertos-docs. It is released under the Creative Commons (CC BY-ND) license.

The FreeRTOS kernel and components are released individually and use semantic versioning. Integrated FreeRTOS releases are made periodically. All releases use date-based versioning with the format YYYYMM.NN, where:

- Y represents the year.
- M represents the month.
- N represents the release order within the designated month (00 being the first release).

For example, a second release in July 2021 would be 202107.01.

Previously, FreeRTOS releases used semantic versioning for major releases. Although it has moved to date-based versioning (FreeRTOS 1.4.8 updated to FreeRTOS AWS Reference Integrations 201906.00), the FreeRTOS kernel and each individual FreeRTOS library still retain semantic versioning. In semantic versioning, the version number itself (X.Y.Z) indicates whether the release is a major, minor, or point release. You can use the semantic version of a library to assess the scope and impact of a new release on your application.

LTS releases are maintained differently than other release types. Major and minor releases are frequently updated with new features in addition to defect resolutions. LTS releases are only updated with changes to address critical defects and security vulnerabilities. No new features are introduced in a given LTS release after launch. They are maintained for at least three calendar years after release, and provide device manufacturers the option to use a stable baseline as opposed to a more dynamic baseline represented by major and minor releases.

Porting FreeRTOS to your IoT device

Before a microcontroller board can run FreeRTOS, some FreeRTOS code must be ported to the device's hardware. Basic kernel ports should refer to the FreeRTOS porting guide on www.freertos.org. For ports intending to include the FreeRTOS libraries for security, connectivity, etc., the following instructions build on the kernel port.

To port FreeRTOS to your device

1. Follow the instructions in Downloading FreeRTOS for Porting (p. 8) to download the latest version of FreeRTOS for porting.
2. Follow the instructions in Setting Up Your FreeRTOS Source Code for Porting (p. 9) to configure the files and folders in your FreeRTOS download for porting and testing.
3. Follow the instructions in Porting the FreeRTOS Libraries (p. 25) to port the FreeRTOS libraries to your device. Each porting topic includes instructions on testing the ports.

System requirements

The device that you port to FreeRTOS must be a microcontroller board that meets the following minimum requirements:

- 25MHz processing speed
- 64KB RAM
- 128KB program memory per executable image stored on the MCU
- (If Porting the AWS IoT over-the-air update library (p. 72)) Two executable images stored on the MCU

Porting older versions of FreeRTOS

If you are porting an older version of FreeRTOS, go to the FreeRTOS AWS Reference Integrations repository, and checkout the version of FreeRTOS that you are porting by its version tag. The qualification and testing documentation will be in PDF format, in the `tests` folder. See the table below for the qualification and testing documentation history.

Revision history of FreeRTOS porting and qualification documentation

Date	Documentation version for the Porting and Qualification guides	Change history	FreeRTOS version
July, 2021	202107.00 (Porting Guide) 202107.00 (Qualification Guide)	• Release 202107.00 • Changed Porting the AWS IoT over-the-air update library (p. 72) • Added Migrating from version 1 to version 3 for OTA applications (p. 105) • Added Migrating from version 1 to version 3 for OTA Pal port (p. 117)	202107.00
December, 2020	202012.00 (Porting Guide) 202012.00 (Qualification Guide)	• Release 202012.00 • Added Configuring the coreHTTP library for testing (p. 71)	202012.00

Date	Documentation version for the Porting and Qualification guides	Change history	FreeRTOS version
		• Added Porting the Cellular library (p. 102)	
November, 2020	202011.00 (Porting Guide) 202011.00 (Qualification Guide)	• Release 202011.00 • Added Configuring the coreMQTT library for testing (p. 70)	202011.00
July, 2020	202007.00 (Porting Guide) 202007.00 (Qualification Guide)	• Release 202007.00	202007.00
February 18, 2020	202002.00 (Porting Guide) 202002.00 (Qualification Guide)	• Release 202002.00 • Amazon FreeRTOS is now FreeRTOS	202002.00
December 17, 2019	201912.00 (Porting Guide) 201912.00 (Qualification Guide)	• Release 201912.00 • Added Porting the common I/O libraries (p. 93).	201912.00
October 29, 2019	201910.00 (Porting Guide) 201910.00 (Qualification Guide)	• Release 201910.00 • Updated random number generator porting information.	201910.00
August 26, 2019	201908.00 (Porting Guide) 201908.00 (Qualification Guide)	• Release 201908.00 • Added *Configuring the HTTPS client library for testing* Updated Porting the corePKCS11 library (p. 47)	201908.00
June 17, 2019	201906.00 (Porting Guide) 201906.00 (Qualification Guide)	• Release 201906.00 • Directory structured updated	201906.00 Major

Date	Documentation version for the Porting and Qualification guides	Change history	FreeRTOS version
May 21, 2019	1.4.8 (Porting Guide) 1.4.8 (Qualification Guide)	• Porting documentation moved to the FreeRTOS Porting Guide • Qualification documentation moved to the FreeRTOS Qualification Guide	1.4.8
February 25, 2019	1.1.6	• Removed download and configuration instructions from Getting Started Guide Template Appendix (page 84)	1.4.5 1.4.6 1.4.7
December 27, 2018	1.1.5	• Updated Checklist for Qualification appendix with CMake requirement (page 70)	1.4.5 1.4.6
December 12, 2018	1.1.4	• Added lwIP porting instructions to TCP/IP porting appendix (page 31)	1.4.5
November 26, 2018	1.1.3	• Added Bluetooth Low Energy porting appendix (page 52) • Added AWS IoT Device Tester for FreeRTOS testing information throughout document • Added CMake link to Information for listing on the FreeRTOS Console appendix (page 85)	1.4.4

Date	Documentation version for the Porting and Qualification guides	Change history	FreeRTOS version
November 7, 2018	1.1.2	• Updated PKCS #11 PAL interface porting instructions in PKCS #11 porting appendix (page 38) • Updated path to `CertificateConfigurator.html` (page 76) • Updated Getting Started Guide Template appendix (page 80)	1.4.3
October 8, 2018	1.1.1	• Added new "Required for AFQP" column to `aws_test_runner_config.h` test configuration table (page 16) • Updated Unity module directory path in Create the Test Project section (page 14) • Updated "Recommended Porting Order" chart (page 22) • Updated client certificate and key variable names in TLS appendix, Test Setup (page 40) • File paths changed in Secure Sockets porting appendix, Test Setup (page 34); TLS porting appendix, Test Setup (page 40); and TLS Server Setup appendix (page 57)	1.4.2
August 27, 2018	1.1.0	• Added OTA Updates porting appendix (page 47) • Added Bootloader porting appendix (page 51)	1.4.0 1.4.1

Date	Documentation version for the Porting and Qualification guides	Change history	FreeRTOS version
August 9, 2018	1.0.1	• Updated "Recommended Porting Order" chart (page 22) • Updated PKCS #11 porting appendix (page 36) • File paths changed in TLS porting appendix, Test Setup (page 40), and TLS Server Setup appendix, step 9 (page 51) • Fixed hyperlinks in MQTT porting appendix, Prerequisites (page 45) • Added AWS CLI config instructions to examples in Instructions to Create a BYOC appendix (page 57)	1.3.1 1.3.2
July 31, 2018	1.0.0	Initial version of the FreeRTOS Qualification Program Guide	1.3.0

Porting FAQs

What is a FreeRTOS port?

A FreeRTOS port is a board-specific implementation of APIs for the required FreeRTOS libraries and the FreeRTOS that your platform supports. The port enables the APIs to work on the board, and implements the required integration with the device drivers and BSPs that are provided by the platform vendor. Your port should also include any configuration adjustments (e.g. clock rate, stack size, heap size) that are required by the board.

My device does not support Wi-Fi, Bluetooth Low Energy, or over-the-air (OTA) updates. Are all libraries required to port FreeRTOS?

The primary requirement for porting FreeRTOS connectivity libraries is that your device can connect to the cloud. If, for example, you can connect to the cloud across a secure Ethernet connection, the Wi-Fi, Bluetooth Low Energy, and over-the-air (OTA) libraries are not required. Keep in mind that some test and demo applications will not work without porting all of the libraries.

Can I reach an "echo server" from two different networks (for example, from two subnets across 2 different access points)?

An echo server is required to pass the TCP/IP and TLS port tests. The echo server must be reachable from the network that a board is connected to. Please consult your IT support to enable routing across subnets if you need devices on different subnets to communicate with a single echo server.

What network ports need to be open to run the FreeRTOS port tests?

The following network connections are required to run the FreeRTOS port tests:

Port	Protocol
443, 8883	MQTT
8443	Greengrass Discovery

If you have questions about porting that are not answered on this page or in the rest of the FreeRTOS Porting Guide, please contact the FreeRTOS engineering team.

Downloading FreeRTOS for Porting

Before you begin porting FreeRTOS to your platform, you need to download FreeRTOS or clone the FreeRTOS repository from GitHub. See the README.md file for instructions.

> **Note**
> We recommend that you clone the repository. Cloning makes it easier for you to pick up updates to the master branch as they are pushed to the repository.

After you download or clone FreeRTOS, you can start porting FreeRTOS code to your platform. For instructions, see Setting Up Your FreeRTOS Source Code for Porting (p. 9), and then see Porting the FreeRTOS Libraries (p. 25).

> **Note**
> Throughout FreeRTOS documentation, the FreeRTOS download is referred to as *`freertos`*.

Setting Up Your FreeRTOS Source Code for Porting

After you download FreeRTOS, you need to configure some of the files and folders in the FreeRTOS download before you can begin porting.

To prepare your FreeRTOS download for porting, you need to follow the instructions in Configuring the FreeRTOS download (p. 9) to configure the directory structure of your FreeRTOS download to fit your device.

If you plan to test the ported libraries as you implement them for debugging purposes, you also need to configure some files for testing before you begin porting. For instructions on test set up, see Setting up your FreeRTOS source code for testing (p. 11).

> **Note**
> You must use the AWS IoT Device Tester for FreeRTOS to officially validate your ports for qualification. For more information about AWS IoT Device Tester for FreeRTOS, see Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide.
> For information about qualifying your device for FreeRTOS, see the FreeRTOS Qualification Guide.

After you configure your FreeRTOS download and set up your testing environment, you can beginning porting FreeRTOS. For porting and testing instructions, see Porting the FreeRTOS Libraries (p. 25).

Configuring the FreeRTOS download

Follow the instructions below to configure the FreeRTOS download for porting FreeRTOS code to your device.

Configuring directories for vendor-supplied, board-specific libraries

Under the download's root directory (*freertos*), the `vendors` folder is structured as follows:

```
vendors
+ - vendor    (Template, to be renamed to the name of the MCU vendor)
    + - boards
    |   + - board    (Template, to be renamed to the name of the development board)
    |       + - aws_demos
    |       + - aws_tests
    |       + - CMakeLists.txt
    |       + - ports
    + - driver_library    (Template, to be renamed to the library name)
        + - driver_library_version    (Template, to be renamed to the library version)
```

The *vendor* and *board* folders are template folders that we provide to make it easier to create demo and test projects. Their directory structure ensures that all demo and test projects have a consistent organization.

The *aws_tests* folder has the following structure:

```
vendors/vendor/boards/board/aws_tests
+ - application_code    (Contains main.c, which contains main())
|   + - vendor_code    (Contains vendor-supplied, board-specific files)
|   + - main.c    (Contains main())
+ - config_files    (Contains FreeRTOS config files)
```

All test projects require vendor-supplied driver libraries. Some vendor-supplied files, such as a header file that maps GPIO output to an LED light, are specific to a target development board. These files belong in the *vendor*_code folder.

Other vendor-supplied files, such as a GPIO library, are common across a board's MCU family. These files belong in the *driver_library* folder.

To set up the directories for vendor-supplied libraries that are common across an MCU family

1. Save all required vendor-supplied libraries that are common across a target board's MCU family in the *driver_library_version* folder.
2. Rename the *vendor* folder to the name of the vendor, and rename the *driver_library* and *driver_library_version* folders to the name of the driver library and its version.

   Important
   Do not save vendor-supplied libraries that are common across a target board's MCU family to any subdirectories of *freertos*/test or *freertos*/demos.

Configuring directories for project files

Under *freertos*, the projects folder is structured as follows:

```
projects
+ - vendor    (Template, to be renamed to the name of the MCU vendor)
    + - board    (Template, to be renamed to the name of the development board)
        + - ide    (Contains an IDE-specific project)
        + - visual_studio    (contains project files for Visual Studio)
```

To set up the project directories

1. Rename the *ide* folder to the name of the IDE that you are using to build the test project.
2. Rename the *vendor* folder to the name of the vendor, and rename the *board* folder to the name of the development board.

Configuring FreeRTOSConfig.h

After you have configured the directory structure of your FreeRTOS download, configure your board name in the FreeRTOSConfig.h configuration header file.

To configure your board name in FreeRTOSConfig.h

1. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/FreeRTOSConfig.h.
2. In the line #define configPLATFORM_NAME "*Unknown*", change *Unknown* to match the name of your board.

Setting up your FreeRTOS source code for testing

FreeRTOS includes tests for each ported library. The `aws_test_runner.c` file defines a `RunTests` function that runs each test that you have specified in the `aws_test_runner_config.h` header file. As you port each FreeRTOS library, you can test the ports by building the ported FreeRTOS source code, flashing the compiled code to your board, and running it on the board.

To build the FreeRTOS source code for testing, you can use either of the following:

- A supported IDE.

  If you're using an IDE to build FreeRTOS source code, you need to set up an IDE test project. Follow the instructions in Creating an IDE project (p. 11) to create a test project in your IDE. Each library-specific porting section under Porting the FreeRTOS Libraries (p. 25) includes additional instructions for setting up a library's ported source files in the IDE test project.
- The CMake build system.

  If you are using CMake, you need to create a `CMakeLists.txt` CMake list file. Follow the instructions in Creating a CMake list file (p. 12) to create a `CMakeLists.txt` CMake list file.

  Important
  A `CMakeLists.txt` file is required for listing a qualified device on the FreeRTOS console, regardless of the testing method that you use.

After you build the code, use your platform's flash utility to flash the compiled code to your device.

Note
You specify your build and flash tools in the `userdata.json` file for Device Tester, so if you are validating your ports with Device Tester, you do not need to flash your code manually.

Creating an IDE project

After you configure your FreeRTOS download, you can create an IDE project and import the code into the project.

Follow the instructions below to create an IDE project with the required IDE project structure for testing.

Important
If you are using an Eclipse-based IDE, do not configure the project to build all the files in any given folder. Instead, add source files to a project by linking to each source file individually.

1. Open your IDE, and create a project named `aws_tests` in the *`freertos`*`/projects/`*`vendor`*`/`*`board`*`/`*`ide`* directory.
2. In the IDE, create two virtual folders under the `aws_tests` project:

   - `application_code`
   - `config_files`

   Under `aws_tests`, there should now be two virtual folders in the IDE project: `application_code` and `config_files`.

   Note
   Eclipse generates an additional `includes` folder. This folder is not a part of the required structure.
3. Import all of the files under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/application_code` and its subdirectories into the `aws_tests/application_code` virtual folder in your IDE.

4. Import all of the files under *freertos*/tests and its subdirectories into the aws_tests/application_code virtual directory in your IDE.
5. Import all of the header files in the *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files directory into the aws_tests/config_files virtual folder in your IDE.

   Note
   If you are not porting a specific library, you do not need to import the files for that library into your project. For example, if you are not porting the OTA library, you can leave out the aws_ota_agent_config.h and aws_test_ota_config.h files. If you are not porting the Wi-Fi library, you can leave out the aws_test_wifi_config.h and aws_wifi_config.h files.
6. Import the required libraries in *freertos*/libraries and its subdirectories into the aws_tests IDE project, including any required third-party libraries. For information on the required libraries please follow the FreeRTOS porting flowchart. Information about which FreeRTOS libraries depend on third-party libraries that need to be included in addition to the test project is provided in the specific library's porting section.

   Finally, import the unity files from the following directories into your project.

   - *freertos*/libraries/3rdparty/unity/src/
   - *freertos*/libraries/3rdparty/unity/extras/fixture/src/

   Note
   If you are not porting a specific library, you do not need to import the files for that library into your project.
7. Import all of the source files in the *freertos*/freertos_kernel and *freertos*/freertos_kernel/include directories into the aws_tests IDE project.
8. Import the subdirectory of *freertos*/freertos_kernel/portable that corresponds to your compiler and platform architecture into the aws_tests IDE project.
9. Import the FreeRTOS memory management implementation that you are using for your device into the aws_tests IDE project.

   The *freertos*/freertos_kernel/portable/MemMang directory contains FreeRTOS memory management implementations. We highly recommend that you use heap_4.c or heap_5.c.

   For more information about FreeRTOS memory management, see Memory Management.
10. Open your project's IDE properties, and add the following paths to your compiler's include path:

    - *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files
    - *freertos*/freertos_kernel/include
    - *freertos*/freertos_kernel/portable/*compiler*/*architecture*
    - Any paths required for vendor-supplied driver libraries
11. Define UNITY_INCLUDE_CONFIG_H and AMAZON_FREERTOS_ENABLE_UNIT_TESTS as project-level macros in the project properties.

After you finish setting up your IDE project, you are ready to port the FreeRTOS libraries to your device. For instructions, see Porting the FreeRTOS Libraries (p. 25).

Creating a CMake list file

After you configure your FreeRTOS download for porting, you can set up a CMake list file for your project and platform.

Topics

Prerequisites

Make sure that your host machine meets the following prerequisites before you continue:

- Your device's compilation toolchain must support the machine's operating system. CMake supports all versions of Windows, macOS, and Linux.

  Windows subsystem for Linux (WSL) is not supported. Use native CMake on Windows machines.
- You must have CMake version 3.13 or later installed.

  You can download the binary distribution of CMake from CMake.org.

  Note
  If you download the binary distribution of CMake, make sure that you add the CMake executable to the PATH environment variable before you use CMake from command line.

  You can also download and install CMake using a package manager, like homebrew on macOS, and scoop or chocolatey on Windows.

  Note
  The CMake package versions in the package managers for many Linux distributions are out-of-date. If your distribution's package manager does not include the latest version of CMake, you can try `linuxbrew` or `nix`.
- You must have a compatible native build system.

  CMake can target many native build systems, including GNU Make or Ninja. Both Make and Ninja can be installed with package managers on Linux, macOS, and Windows. If you are using Make on Windows, you can install a standalone version from Equation, or you can install MinGW, which bundles Make.

  Note
  The Make executable in MinGW is called `mingw32-make.exe`, instead of `make.exe`.

  We recommend that you use Ninja, because it is faster than Make and also provides native support to all desktop operating systems.

Creating a list file for your platform from the CMakeLists.txt template

A `CMakeLists.txt` template file is provided with FreeRTOS, under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt`.

The `CMakeLists.txt` template file consists of four sections:

Follow the instructions to edit these four sections of the list file to match your platform. You can refer to the `CMakeLists.txt` files for other qualified vendor boards under *`freertos`*`/vendors` as examples.

Two primary functions are called throughout the file:

`afr_set_board_metadata(name value)`

This function defines metadata for the FreeRTOS console. The function is defined in *freertos*/tools/cmake/afr_metadata.cmake.

`afr_mcu_port(module_name [<DEPENDS> [targets...]])`

This function defines the portable-layer target associated with a FreeRTOS module (that is, library). It creates a CMake `GLOBAL INTERFACE IMPORTED` target with a name of the form `AFR:`*module_name*`::mcu_port`. If `DEPENDS` is used, additional targets are linked with `target_link_libraries`. The function is defined in *freertos*/tools/cmake/afr_module.cmake.

FreeRTOS console metadata

The first section of the template file defines the metadata that is used to display a board's information in the FreeRTOS console. Use the function `afr_set_board_metadata(`*name value*`)` to define each field listed in the template. This table provides descriptions of each field.

Field Name	Value Description
`ID`	A unique ID for the board.
`DISPLAY_NAME`	The name of the board as you want it displayed on the FreeRTOS console.
`DESCRIPTION`	A short description of the board for the FreeRTOS console.
`VENDOR_NAME`	The name of the vendor of the board.
`FAMILY_NAME`	The name of the board's MCU family.
`DATA_RAM_MEMORY`	The size of the board's RAM, followed by abbreviated units. For example, use KB for kilobytes.
`PROGRAM_MEMORY`	The size of the board's program memory, followed by abbreviated units. For example, use "MB" for megabytes.
`CODE_SIGNER`	The code-signing platform used for OTA updates. Use AmazonFreeRTOS-Default for SHA256 hash algorithm and ECDSA encryption algorithm. If you want to use a different code-signing platform, contact us.
`SUPPORTED_IDE`	A semicolon-delimited list of IDs for the IDEs that the board supports.
`IDE_`*ID*`_NAME`	The name of the supported IDE. Replace *ID* with the ID listed for the IDE in the `SUPPORTED_IDE` field.
`IDE_`*ID*`_COMPILER`	A semicolon-delimited list of names of supported compilers for the supported IDE. Replace *ID* with the ID listed for the IDE in the `SUPPORTED_IDE` field.

Field Name	Value Description
KEY_IMPORT_PROVISIONING	Set to TRUE if the board demo project imports the credentials from the pre-provisioned aws_clientcredential_keys.h header file; in this case, **Quick Connect** will be enabled in the FreeRTOS console. Set to FALSE if the intended board provisioning mechanism is JITR/JITP or multi-account registration; in this case, **Quick Connect** will be disabled in the FreeRTOS console.

Compiler settings

The second section of the template file defines the compiler settings for your board. To create a target that holds the compiler settings, call the afr_mcu_port function with compiler in place of the *module_name* to create an INTERFACE target with the name AFR::compiler::mcu_port. The kernel publicly links to this INTERFACE target so that the compiler settings are transitively populated to all modules.

Use the standard, built-in CMake functions to define the compiler settings in this section of the list file. As you define the compiler settings, follow these best practices:

- Use target_compile_definitions to provide compile definitions and macros.
- Use target_compile_options to provide compiler flags.
- Use target_include_directories to provide include directories.
- Use target_link_options to provide linker flags.
- Use target_link_directories to provide linker-search directories.
- Use target_link_libraries to provide libraries to link against.

Note
If you define the compiler settings somewhere else, you don't need to duplicate the information in this section of the file. Instead, call afr_mcu_port with DEPENDS to bring in the target definition from another location.
For example:

```
# your_target is defined somewhere else. It does not have to be in the same file.
afr_mcu_port(compiler DEPENDS your_target)
```

When you call afr_mcu_port with DEPENDS, it calls target_link_libraries(AFR::*module_name*::mcu_port INTERFACE *your_targets*), which populates the compiler settings for the required AFR::compiler::mcu_port target.

Using multiple compilers

If your board supports multiple compilers, you can use the AFR_TOOLCHAIN variable to dynamically select the compiler settings. This variable is set to the name of the compiler you are using, which should be same as the name of the toolchain file found under *freertos*/tools/cmake/toolchains.

For example:

```
if("${AFR_TOOLCHAIN}" STREQUAL "arm-gcc")
    afr_mcu_port(compiler DEPENDS my_gcc_settings).
```

```
elseif("${AFR_TOOLCHAIN}" STREQUAL "arm-iar")
    afr_mcu_port(compiler DEPENDS my_iar_settings).
else()
    message(FATAL_ERROR "Compiler ${AFR_TOOLCHAIN} not supported.")
endif()
```

Advanced compiler settings

If you want to set more advanced compiler settings, such as setting compiler flags based on programming language, or changing settings for different release and debug configurations, you can use CMake generator expressions.

For example:

```
set(common_flags "-foo")
set(c_flags "-foo-c")
set(asm_flags "-foo-asm")
target_compile_options(
    my_compiler_settings INTERFACE
    $<$<COMPILE_LANGUAGE:C>:${common_flags} ${c_flags}> # This only have effect on C files.
    $<$<COMPILE_LANGUAGE:ASM>:${common_flags} ${asm_flags}> # This only have effect on ASM
 files.
)
```

CMake generator expressions are not evaluated at the configuration stage, when CMake reads list files. They are evaluated at the generation stage, when CMake finishes reading list files and generates build files for the target build system.

FreeRTOS portable layers

The third section of the template file defines all of the portable layer targets for FreeRTOS (that is, libraries).

You must use the `afr_mcu_port(`*`module_name`*`)` function to define a portable layer target for each FreeRTOS module that you plan to implement.

You can use any CMake functions you want, as long as the `afr_mcu_port` call creates a target with a name that provides the information required to build the corresponding FreeRTOS module.

The `afr_mcu_port` function creates a GLOBAL INTERFACE IMPORTED library target with a name of the form `AFR::`*`module_name`*`::mcu_port`. As a `GLOBAL` target, it can be referenced in CMake list files. As an `INTERFACE` target, it is not built as a standalone target or library, but compiled into the corresponding FreeRTOS module. As an `IMPORTED` target, its name includes a namespace (`::`) in the target name (for example, `AFR::kernel::mcu_port`).

Modules without corresponding portable layer targets are disabled by default. If you run CMake to configure FreeRTOS, without defining any portable layer targets, you should see the following output:

```
FreeRTOS modules:
  Modules to build:
  Disabled by user:
  Disabled by dependency:  kernel, posix, pkcs11, secure_sockets, mqtt, ...

  Available demos:
  Available tests:
```

As you update the `CMakeLists.txt` file with porting layer targets, the corresponding FreeRTOS modules are enabled. You should also be able to build any FreeRTOS module whose dependency

requirements are subsequently satisfied. For example, if the coreMQTT library is enabled, the Device Shadow library is also enabled, because its only dependency is the coreMQTT library.

Note
The FreeRTOS kernel dependency is a minimum requirement. The CMake configuration fails if the FreeRTOS kernel dependency is not satisfied.

Setting up the kernel porting target

To create the kernel porting target (`AFR::kernel::mcu_port`), call `afr_mcu_port` with the module name `kernel`. When you call `afr_mcu_port`, specify the targets for the FreeRTOS portable layer and driver code. After you create the target, you can provide the dependency information and the FreeRTOS portable layer and driver code information for the target to use.

Follow these instructions to set up the kernel porting target.

To set up the kernel porting target

1. Create a target for the driver code.

   For example, you can create a `STATIC` library target for the driver code:

   ```
   add_library(my_board_driver STATIC ${driver_sources})

   # Use your compiler settings
   target_link_libraries(
       my_board_driver
       PRIVATE AFR::compiler::mcu_port
   # Or use your own target if you already have it.
   #   PRIVATE ${compiler_settings_target}
   )

   target_include_directories(
       my_board_driver
       PRIVATE "include_dirs_for_private_usage"
       PUBLIC "include_dirs_for_public_interface"
   )
   ```

   Or you can create an `INTERFACE` library target for the driver code:

   ```
   # No need to specify compiler settings since kernel target has them.
   add_library(my_board_driver INTERFACE ${driver_sources})
   ```

   Note
   An `INTERFACE` library target does not have build output. If you use an `INTERFACE` library target, the driver code is compiled into the kernel library.

2. Configure the FreeRTOS portable layer:

   ```
   add_library(freertos_port INTERFACE)
   target_sources(
       freertos_port
       INTERFACE
           "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F/port.c"
           "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F/portmacro.h"
           "${AFR_MODULES_DIR}/freertos_kernel/portable/MemMang/heap_4.c"
   )
   target_include_directories(
       freertos_port
       INTERFACE
           "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F"
           "${include_path_to_FreeRTOSConfig_h}
   ```

```
)
```

Note
You can also configure the FreeRTOS portable layer by specifying these source files and their include directories directly in the `AFR::kernel::mcu_port` target.

3. Create the kernel portable layer target:

```
# Bring in driver code and freertos portable layer dependency.
afr_mcu_port(kernel DEPENDS my_board_driver freertos_port)

# If you need to specify additional configurations, use standard CMake functions with
# AFR::kernel::mcu_port as the target name.
target_include_directories(
    AFR::kernel::mcu_port
    INTERFACE
        "${additional_includes}" # e.g. board configuration files
)
target_link_libraries(
    AFR::kernel::mcu_port
    INTERFACE
        "${additional_dependencies}"
)
```

4. To test your list file and configuration, you can write a simple application that uses the FreeRTOS kernel port. For more information about developing and building FreeRTOS applications with CMake, see Building FreeRTOS with CMake (p. 20).
5. After you create the demo, add `add_executable` and `target_link_libraries` calls to the list file, and compile the kernel as a static library to verify that the kernel portable layer is correctly configured.

```
add_executable(
    my_demo
    main.c
)
target_link_libraries(
    my_demo
    PRIVATE AFR::kernel
)
```

Setting up the porting targets for FreeRTOS modules

After you add the portable layer target for the kernel, you can add portable layer targets for other FreeRTOS modules.

For example, to add the portable layer for the Wi-Fi module:

```
afr_mcu_port(wifi)
target_sources(
    AFR::wifi::mcu_port
    INTERFACE "${AFR_MODULES_DIR}/vendors/vendor/boards/board/ports/wifi/iot_wifi.c"
)
```

This example Wi-Fi module portable layer has only one implementation file, which is based on the driver code.

If you want to add the portable layer for the FreeRTOS Secure Sockets module, the module depends on TLS. This makes its portable layer target slightly more complicated than that of the Wi-Fi module. FreeRTOS provides a default TLS implementation based on mbedTLS that you can link to:

```
afr_mcu_port(secure_sockets)
target_sources(
    AFR::secure_sockets::mcu_port
    INTERFACE ${portable_layer_sources}
)
target_link_libraries(
    AFR::secure_sockets::mcu_port
    AFR::tls
)
```

In this example code, the standard CMake function `target_link_libraries` states that the Secure Sockets portable layer depends on `AFR::tls`.

You can reference all FreeRTOS modules by using their target name `AFR::`*`module_name`*. For example, you can use the same syntax to also state a dependency on FreeRTOS-Plus-TCP:

```
target_link_libraries(
    AFR::secure_sockets::mcu_port
    AFR::freertos_plus_tcp
    AFR::tls
)
```

Note
If your platform handles TLS by itself, you can use your driver code directly. If you use your driver code directly for TLS, you don't need to call `target_link_libraries`, because all FreeRTOS modules implicitly depend on the kernel that includes your driver code.
Because all non-kernel FreeRTOS modules implicitly depend on the kernel, their porting layers don't require you to specify the kernel as a dependency. The POSIX module, however, is defined as an optional kernel module. If you want to use POSIX, you must explicitly include it in your kernel portable layer. For example:

```
# By default, AFR::posix target does not expose standard POSIX headers in its
 public
# interface, i.e., You need to use "freertos_plus_posix/source/
FreeRTOS_POSIX_pthread.c"  instead of "pthread.h".
# Link to AFR::use_posix instead if you need to use those headers directly.
target_link_libraries(
    AFR::kernel::mcu_port
    INTERFACE AFR::use_posix
)
```

FreeRTOS demos and tests

The final section of the template file defines the demo and test targets for FreeRTOS. CMake targets are created automatically for each demo and test that satisfies the dependency requirements.

In this section, define an executable target with the `add_executable` function. Use `aws_tests` as the target name if you're compiling tests, or `aws_demos` if you're compiling demos. You might need to provide other project settings, such as linker scripts and post-build commands. For example:

```
if(AFR_IS_TESTING)
    set(exe_target aws_tests)
else()
    set(exe_target aws_demos)
endif()

set(CMAKE_EXECUTABLE_SUFFIX ".elf")
add_executable(${exe_target} "${board_dir}/application_code/main.c")
```

`target_link_libraries` is then called to link available CMake demo or test targets to your executable target.

Note
You still need to modify `aws_demos/config_files/aws_demo_config.h` and `aws_tests/config_files/aws_test_runner_config.h` to enable demos and tests.

Running post-build commands

For information about running post-build commands, see add_custom_command. Use the second signature. For example:

```
# This should run an external command "command --arg1 --arg2".
add_custom_command(
    TARGET ${exe_target} POST_BUILD COMMAND "command" "--arg1" "--arg2"
)
```

Note
CMake supports many common, platform-independent operations for creating directories, copying files, and so on. For more information about CMake command-line operations, see the CMake command-line tool reference. You can reference the CMake command-line tool from a CMake list file with the built-in variable `${CMAKE_COMMAND}`.

Building FreeRTOS with CMake

CMake targets your host operating system as the target system by default. To use CMake for cross compiling, you must provide a toolchain file that specifies the compiler that you want to use. FreeRTOS provides some default toolchain files in *`freertos`*`/tools/cmake/toolchains`. The instructions for using the toolchain file differ depending on whether you are using the CMake command-line interface or the GUI. Generating build files (CMake command-line tool) (p. 20) has more details. To learn more about cross-compiling in CMake, visit the Cross Compiling on the official CMake Wiki.

To build a CMake-based project

1. Run CMake to generate the build files for a native build system, like Make or Ninja.

   You can use either the CMake command-line tool or the CMake GUI to generate the build files for your native build system.

   For information about generating FreeRTOS build files, see Generating build files (CMake command-line tool) (p. 20) and Generating build files (CMake GUI) (p. 21).
2. Invoke the native build system to make the project into an executable.

   For information about making FreeRTOS build files, see Building FreeRTOS from generated build files (p. 24).

Generating build files (CMake command-line tool)

You can use the CMake command-line tool (`cmake`) to generate build files for FreeRTOS from the command line.

To generate the build files, you must specify the target board, compiler and the locations of your source code and build directory. Specify the target board with the `-DVENDOR` option. Specify the compiler with the `-DCOMPILER` option. Specify the location of your source code with the `-S` switch and the location of the generated build files with the `-B` switch.

Note
The compiler must be in the system's `PATH` variable, otherwise you must specify the location of the compiler.

For example, if the vendor is Texas Instruments, and the board is the CC3220 Launchpad, and the compiler is GCC for ARM, you can issue the following command to build from the source files located in the current directory to a directory named *build-directory*:

```
cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-directory
```

Note
If you are using Windows, you must specify the native build system because CMake uses Visual Studio by default. For example:

```
cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-
directory -G Ninja
```

Or:

```
cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-
directory -G "MinGW Makefiles"
```

The regular expressions `${VENDOR}.*` and `${BOARD}.*` are used to search for a matching board, so you don't have to use the full names of the vendor and board for the `VENDOR` and `BOARD` options. Partial names work, provided there is a single match. For example, the following commands generate the same build files from the same source:

```
cmake -DVENDOR=ti -DCOMPILER=arm-ti -S . -B build-directory
```

```
cmake -DBOARD=cc3220 -DCOMPILER=arm-ti -S . -B build-directory
```

```
cmake -DVENDOR=t -DBOARD=cc -DCOMPILER=arm-ti -S . -B build-directory
```

You can use the `CMAKE_TOOLCHAIN_FILE` option if you want to use a toolchain file that is not located in the default directory `cmake/toolchains`. For example:

```
cmake -DBOARD=cc3220 -DCMAKE_TOOLCHAIN_FILE='/path/to/toolchain_file.cmake' -S . -B build-
directory
```

If the toolchain file does not use absolute paths for your compiler, and you didn't add your compiler to the `PATH` environment variable, CMake might not be able to find it. To make sure that CMake finds your toolchain file, you can use the `AFR_TOOLCHAIN_PATH` option. This option searches the specified toolchain directory path and the toolchain's subfolder under `bin`. For example:

```
cmake -DBOARD=cc3220 -DCMAKE_TOOLCHAIN_FILE='/path/to/toolchain_file.cmake' -
DAFR_TOOLCHAIN_PATH='/path/to/toolchain/' -S . -B build-directory
```

To enable debugging, set the `CMAKE_BUILD_TYPE` to `debug`. With this option enabled, CMake adds debug flags to the compile options, and builds FreeRTOS with debug symbols.

```
# Build with debug symbols
cmake -DBOARD=cc3220 -DCOMPILER=arm-ti -DCMAKE_BUILD_TYPE=debug -S . -B build-directory
```

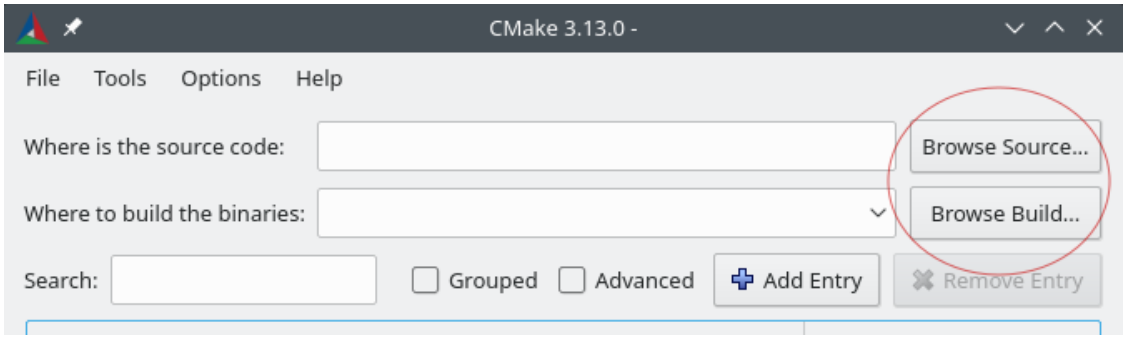
You can also set the `CMAKE_BUILD_TYPE` to `release` to add optimization flags to the compile options.

Generating build files (CMake GUI)

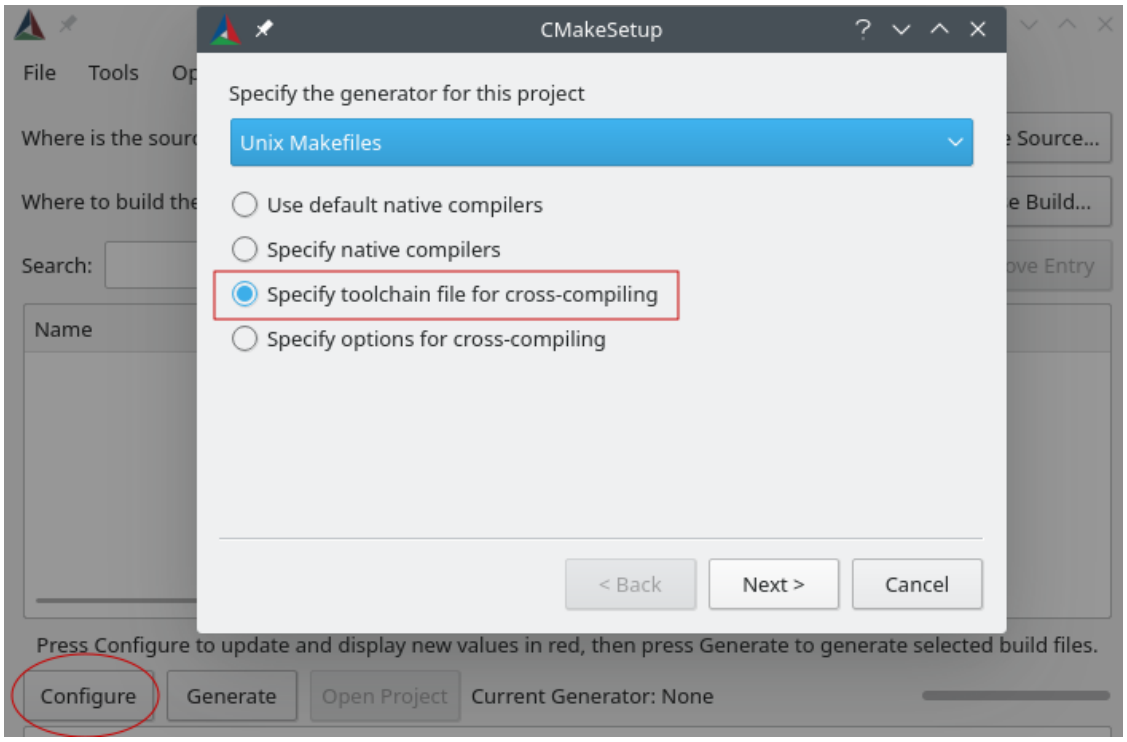
You can use the CMake GUI to generate FreeRTOS build files.

To generate build files with the CMake GUI

1. From the command line, issue `cmake-gui` to start the GUI.
2. Choose **Browse Source** and specify the source input, and then choose **Browse Build** and specify the build output.



3. Choose **Configure**, and under **Specify the build generator for this project**, find and choose the build system that you want to use to build the generated build files.



   Note
   If you do not see the pop up window, you might be reusing an existing build directory. In this case, delete the CMake cache first by clicking **File->Delete** Cache in the menu.

4. Choose **Specify toolchain file for cross-compiling**, and then choose **Next**.
5. Choose the toolchain file (for example, *`freertos`*`/tools/cmake/toolchains/arm-ti.cmake`), and then choose **Finish**.

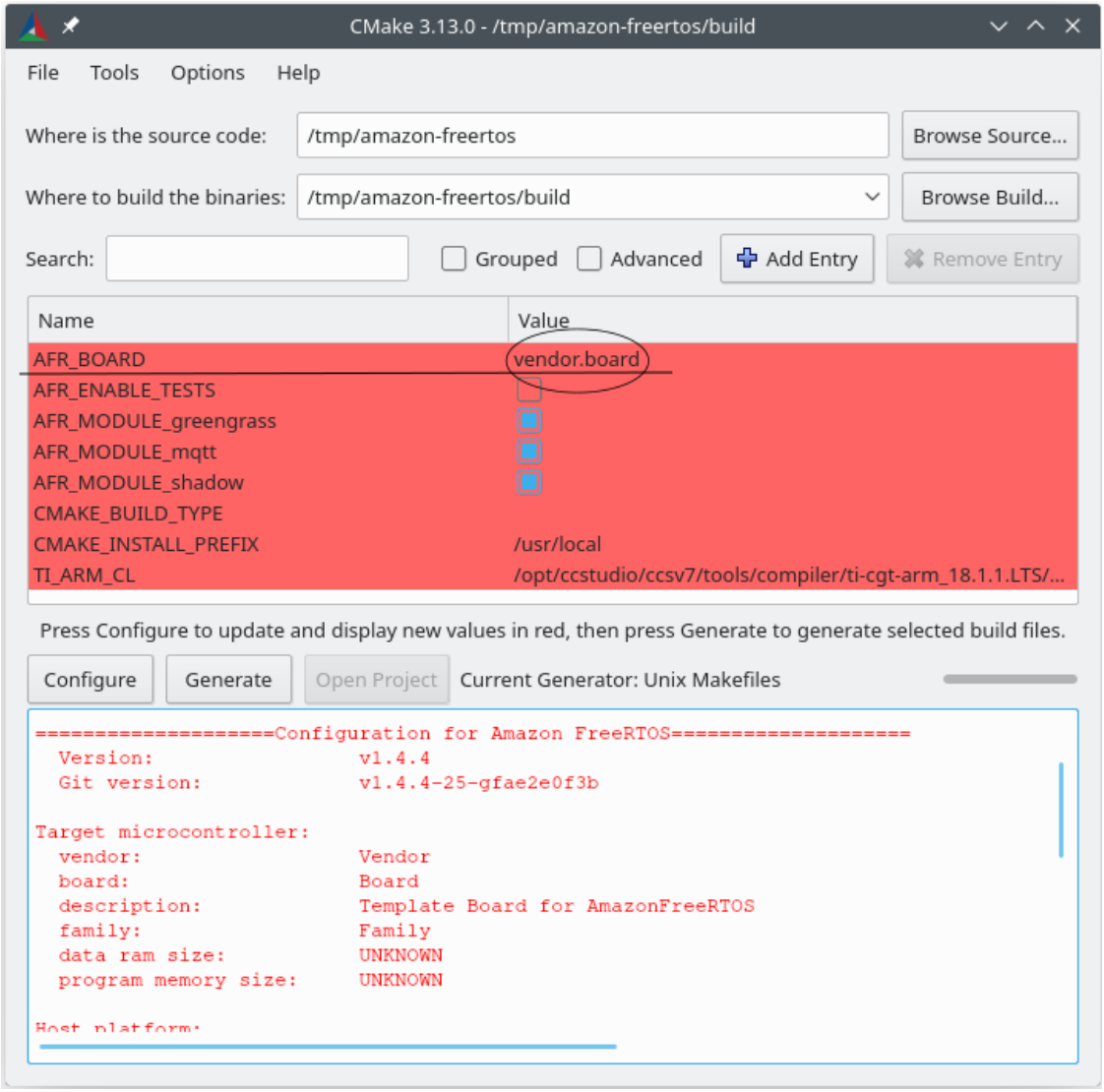
   The default configuration for FreeRTOS is the template board, which does not provide any portable layer targets. As a result, a window appears with the message **Error in configuration process**.

   Note
   If you see the following error message:

```
CMake Error at tools/cmake/toolchains/find_compiler.cmake:23 (message):
Compiler not found, you can specify search path with "AFR_TOOLCHAIN_PATH".
```

It means the compiler is not in your environment variable PATH. You can set the AFR_TOOLCHAIN_PATH variable in the GUI to tell CMake where you installed your compiler. If you do not see the AFR_TOOLCHAIN_PATH variable, click the **Add Entry** button in the pop up window, enter AFR_TOOLCHAIN_PATH as the **name**, select PATH as the **type**, and enter the compiler path in the **value**, for example, "C:/toolchains/arm-none-eabi-gcc".

6. The GUI should now look like this:



Choose **AFR_BOARD**, choose your board, and then choose **Configure** again.

7. Choose **Generate**. CMake generates the build system files (for example, makefiles or ninja files), and these files appear in the build directory you specified in the first step. Follow the instructions in the next section to generate the binary image.

Building FreeRTOS from generated build files

You can build FreeRTOS with a native build system by calling the build system command from the output binaries directory. For example, if your build file output directory is *build-directory*, and you are using Make as your native build system, run the following commands:

```
cd build-directory
make -j4
```

You can also use the CMake command-line tool to build FreeRTOS. CMake provides an abstraction layer for calling native build systems. For example:

```
cmake --build build-directory
```

Here are some other common uses of the CMake command-line tool's build mode:

```
# Take advantage of CPU cores.
cmake --build build-directory --parallel 8
```

```
# Build specific targets.
cmake --build build-directory --target afr_kernel
```

```
# Clean first, then build.
cmake --build build-directory --clean-first
```

For more information about the CMake build mode, see the CMake documentation.

Porting the FreeRTOS Libraries

Before you start porting, follow the instructions in Setting Up Your FreeRTOS Source Code for Porting (p. 9).

To port FreeRTOS to your device, follow the instructions in the topics below.

1. Implementing the `configPRINT_STRING()` macro (p. 28)
2. Configuring a FreeRTOS kernel port (p. 29)
3. Porting the Wi-Fi library (p. 30)

   Note
   If your device does not support Wi-Fi, you can use an ethernet connection to connect to the AWS Cloud instead. A port of the FreeRTOS Wi-Fi library is not necessarily required.
4. Porting a TCP/IP stack (p. 36)
5. Porting the Secure Sockets library (p. 40)
6. Porting the corePKCS11 library (p. 47)
7. Porting the TLS library (p. 52)
8. Configuring the coreMQTT library for testing (p. 70)
9. Configuring the coreHTTP library for testing (p. 71)
10. Porting the AWS IoT over-the-air update library (p. 72)

    Note
    Currently, a port of the FreeRTOS OTA update library is not required for qualification.
11. Porting the Bluetooth Low Energy library (p. 81)

    Note
    Currently, a port of the FreeRTOS Bluetooth Low Energy library is not required for qualification.
12. Perform Over the Air Updates using Bluetooth Low Energy (p. 85)

    Note
    Currently AWS IoT Device Tester does not support qualification of Over the Air updates using Bluetooth Low Energy library. A partner interested in this qualification should contact AWS through the APN (AWS Partner Network) team.
13. Porting the common I/O libraries (p. 93)

    Note
    Currently, a port of the FreeRTOS common I/O library is not required for qualification.
14. Porting the Cellular library (p. 102)

    Note
    Currently, a port of the FreeRTOS Cellular library is not required for qualification.

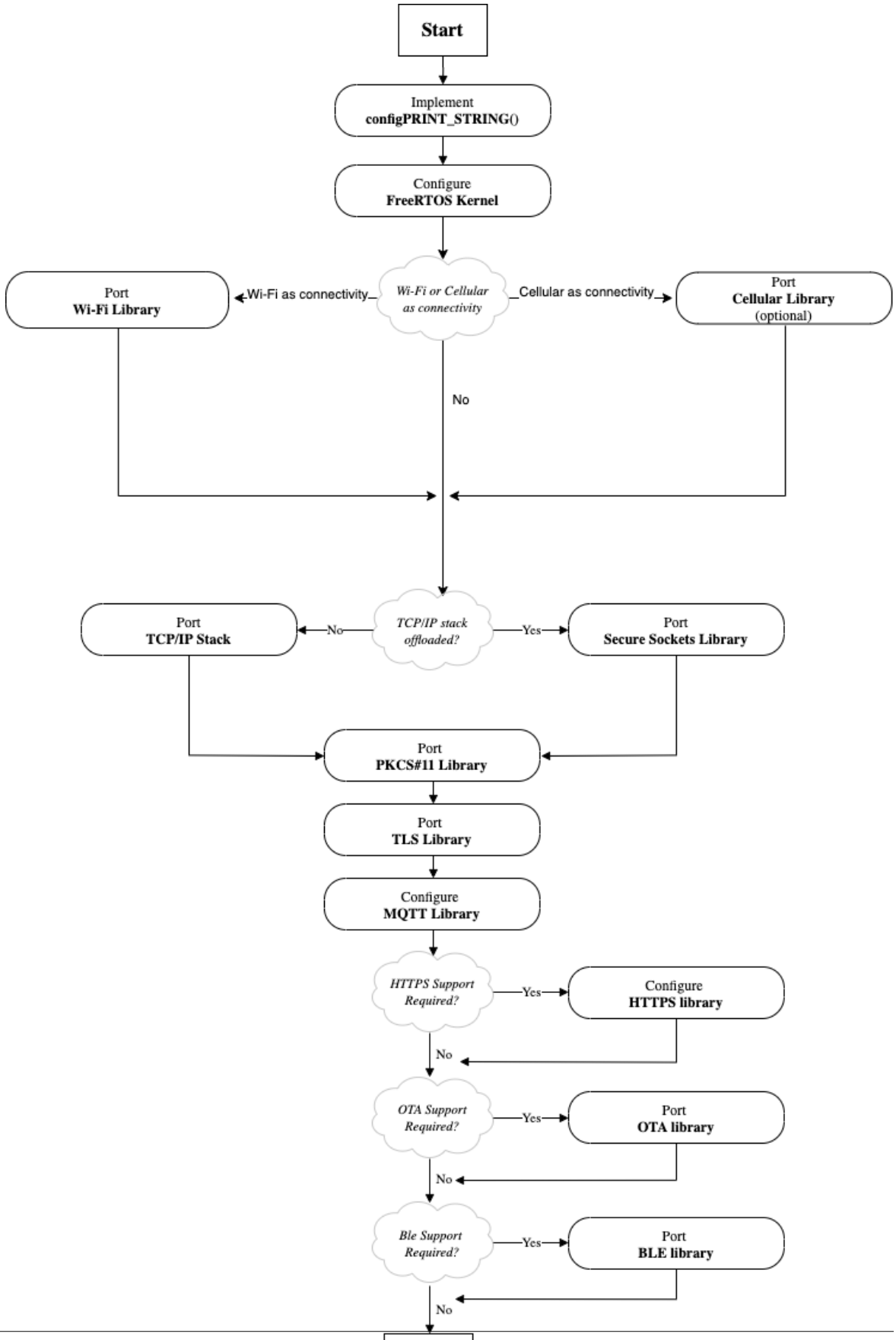
After you port FreeRTOS to your board, you can officially validate the ports for FreeRTOS qualification with AWS IoT Device Tester for FreeRTOS. For more information about AWS IoT Device Tester for FreeRTOS, see Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide.

Note
Before you validate your port of FreeRTOS using the AWS IoT Device Tester for FreeRTOS you must remove any logging messages that you might have inserted in your code for testing purposes, otherwise the validation may fail.

For information about qualifying your device for FreeRTOS, see the FreeRTOS Qualification Guide.

FreeRTOS porting flowchart

Use the flowchart below as a visual aid as you port FreeRTOS to your device.


Start
Implement
configPRINT_STRING()
Configure
FreeRTOS Kernel
Wi-Fi or Cellular as connectivity
Wi-Fi as connectivity
Port
Wi-Fi Library
Cellular as connectivity
Port
Cellular Library
(optional)
No
TCP/IP stack offloaded?
No
Port
TCP/IP Stack
Yes
Port
Secure Sockets Library
Port
PKCS#11 Library
Port
TLS Library
Configure
MQTT Library
HTTPS Support Required?
Yes
Configure
HTTPS library
No
OTA Support Required?
Yes
Port
OTA library
No
Ble Support Required?
Yes
Port
BLE library
No
END

Implementing the configPRINT_STRING() macro

You must implement the configPRINT_STRING() macro before you port the FreeRTOS libraries. FreeRTOS uses configPRINT_STRING() to output test results as human-readable ASCII strings.

Prerequisites

To implement the configPRINT_STRING() macro, you need the following:

- A development board that supports UART or virtual COM port output.
- A FreeRTOS project configured for your platform, and a porting-test IDE project.

  For information, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).

Implementation

To implement configPRINT_STRING()

1. Connect your device to a terminal emulator to output test results.
2. Open the file *freertos*/vendors/*vendor*/boards/*board*/aws_tests/application_code/main.c, and locate the call to configPRINT_STRING("Test Message") in the prvMiscInitialization() function.
3. Immediately before the call to configPRINT_STRING("Test Message"), add code that uses the vendor-supplied UART driver to initialize the UART baud rate level to 115200.
4. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/FreeRTOSConfig.h, and locate the empty definition of configPRINT_STRING(). The macro takes a NULL-terminated ASCII C string as its only parameter.
5. Update the empty definition of configPRINT_STRING() so that it calls the vendor-supplied UART output function.

   For example, suppose the UART output function has the following prototype:

   ```
   void MyUARTOutput( char *DataToOutput, size_t LengthToOutput );
   ```

   You would implement configPRINT_STRING() as:

   ```
   #define configPRINT_STRING( X ) MyUARTOutput( (X), strlen( (X) ) )
   ```

Testing

Build and execute the test demo project. If Test Message appears in the UART console, then the console is connected and configured correctly, configPRINT_STRING() is behaving properly, and testing is complete. You can remove the call to configPRINT_STRING("Test Message") from prvMiscInitialization().

After you implement the configPRINT_STRING() macro, you can start configuring a FreeRTOS kernel port for your device. See Configuring a FreeRTOS kernel port (p. 29) for instructions.

Configuring a FreeRTOS kernel port

This section provides instructions for integrating a port of the FreeRTOS kernel into a FreeRTOS port-testing project. For a list of available kernel ports, see FreeRTOS Kernel Ports.

FreeRTOS uses the FreeRTOS kernel for multitasking and inter-task communications. For more information, see the FreeRTOS Kernel Fundamentals in the FreeRTOS User Guide and FreeRTOS.org.

> **Note**
> Porting the FreeRTOS kernel to a new architecture is out of the scope of this documentation. If you are interested in porting the FreeRTOS kernel to a new architecture, contact the FreeRTOS engineering team.
> For the FreeRTOS Qualification program, only existing ports are supported. Modifications to these ports are not accepted within the Qualification program. Only the official ports that can be downloaded from Github are accepted.

Prerequisites

To set up the FreeRTOS kernel for porting, you need the following:

- An official FreeRTOS kernel port for the target platform.
- An IDE project or `CMakeLists.txt` list file that includes the correct FreeRTOS kernel port files for the target platform and compiler.

  For information about setting up a test project, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- An implementation of the `configPRINT_STRING()` macro for your device.

  For information about implementing `configPRINT_STRING()`, see Implementing the `configPRINT_STRING()` macro (p. 28).

Configuring the FreeRTOS kernel

The header file *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/FreeRTOSConfig.h` specifies application-specific configuration settings for the FreeRTOS kernel. For a description of each configuration option, see Customisation on FreeRTOS.org.

To configure the FreeRTOS kernel to work with your device, open `FreeRTOSConfig.h`, and verify that the configuration options in the following table are correctly specified for your platform.

Configuration option	Description
`configCPU_CLOCK_HZ`	Specifies the frequency of the clock used to generate the tick interrupt.
`configMINIMAL_STACK_SIZE`	Specifies the minimum stack size. As a starting point, this can be set to the value used in the official FreeRTOS demo for the FreeRTOS kernel port in use. Official FreeRTOS demos are those distributed from the FreeRTOS.org website. Make sure that stack overflow checking is set to 2, and increase `configMINIMAL_STACK_SIZE` if overflows occur. To save RAM, set stack sizes to the minimum value that does not result in a stack overflow.

Configuration option	Description
`configTOTAL_HEAP_SIZE`	Sets the size of the FreeRTOS heap. Like task stack sizes, the heap size can be tuned to ensure unused heap space does not consume RAM.

Note
If you are porting ARM Cortex-M3, M4, or M7 devices, you must also specify `configPRIO_BITS` and `configMAX_SYSCALL_INTERRUPT_PRIORITY` correctly.

Testing

1. Open `/libraries/freertos_plus/standard/utils/src/iot_system_init.c`, and comment out the line that calls `SOCKETS_Init()` from within function `SYSTEM_Init()`. This initialization function belongs to a library that you haven't ported yet. The porting section for this library includes instructions to uncomment this function.
2. Build the test project, and then flash it to your device for execution.
3. If "`.`" appears in the UART console every 5 seconds, then the FreeRTOS kernel is configured correctly, and testing is complete.

   Open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/FreeRTOSConfig.h`, and set `configUSE_IDLE_HOOK` to 0 to stop the kernel from executing `vApplicationIdleHook()` and outputting "`.`".
4. If "`.`" appears at any frequency other than 5 seconds, open `FreeRTOSConfig.h` and verify that `configCPU_CLOCK_HZ` is set to the correct value for your board.

After you have configured the FreeRTOS kernel port for your device, you can start porting the Wi-Fi library. See Porting the Wi-Fi library (p. 30) for instructions.

Porting the Wi-Fi library

The FreeRTOS Wi-Fi library interfaces with vendor-supplied Wi-Fi drivers. For more information about the FreeRTOS Wi-Fi library, see FreeRTOS Wi-Fi Library in the FreeRTOS User Guide.

If your device does not support Wi-Fi networking, you can skip porting the FreeRTOS Wi-Fi library and start Porting a TCP/IP stack (p. 36).

Note
For qualification, your device must connect to the AWS Cloud. If your device does not support Wi-Fi, you can use an Ethernet connection instead. A port of the FreeRTOS Wi-Fi library is not necessarily required.

Prerequisites

To port the Wi-Fi library, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes the vendor-supplied Wi-Fi drivers.

  For information about setting up a test project, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- A validated configuration of the FreeRTOS kernel.

For information about configuring the FreeRTOS kernel for your platform, see Configuring a FreeRTOS kernel port (p. 29).

- Two wireless access points.

Porting

freertos/vendors/*vendor*/boards/*board*/ports/wifi/iot_wifi.c contains empty definitions of a set of Wi-Fi management functions. Use the vendor-supplied Wi-Fi driver library to implement at least the set of functions listed in the following table.

Function	Description
WIFI_On	Turns on Wi-Fi module and initializes the drivers.
WIFI_ConnectAP	Connects to a Wi-Fi access point (AP).
WIFI_Disconnect	Disconnects from an AP.
WIFI_Scan	Performs a Wi-Fi network scan.
WIFI_GetIP	Retrieves the Wi-Fi interface's IP address.
WIFI_GetMAC	Retrieves the Wi-Fi interface's MAC address.
WIFI_GetHostIP	Retrieves the host IP address from a hostname using DNS.

freertos/libraries/abstractions/wifi/include/iot_wifi.h provides the information required to implement these functions.

Testing

If you're using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you're using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

Important
In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Don't create duplicate copies of source files.

To set up the Wi-Fi library in the IDE project

1. Add the source file *freertos*/vendors/*vendor*/boards/*board*/ports/wifi/iot_wifi.c to your aws_tests IDE project.
2. Add the source file aws_test_wifi.c to the aws_tests IDE project.

Configuring the CMakeLists.txt file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

See below for an example portable layer target definition for the Wi-Fi library.

```
# WiFi
afr_mcu_port(wifi)
target_sources(
    AFR::wifi::mcu_port
    INTERFACE "freertos/vendors/vendor/boards/board/ports/wifi/iot_wifi.c"
)
```

Setting up your local testing environment

After you set up the library in the IDE project, you need to configure some other files for testing.

To configure the source and header files for the Wi-Fi tests

1. Open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/application_code/main.c`, and delete the `#if 0` and `#endif` compiler directives in the function definitions of `vApplicationDaemonTaskStartupHook(void)` and `prvWifiConnect(void)`.
2. If you have not ported the Secure Sockets library, open *`freertos`*`/libraries/freertos_plus/standard/utils/src/iot_system_init.c`, and comment out the line that calls `SOCKETS_Init()`. When you reach the Porting the Secure Sockets library (p. 40) section, you will be instructed to uncomment this initialization function call.
3. Open *`freertos`*`/tests/include/aws_clientcredential.h`, and set the macros in the following table for the first AP.

Macro	Value
`clientcredentialWIFI_SSID`	The Wi-Fi SSID as a C string (in quotation marks).
`clientcredentialWIFI_PASSWORD`	The Wi-Fi password as a C string (in quotation marks).
`clientcredentialWIFI_SECURITY`	One of the following: • `eWiFiSecurityOpen` • `eWiFiSecurityWEP` • `eWiFiSecurityWPA` • `eWiFiSecurityWPA2` `eWiFiSecurityWPA2` is recommended.

4. Open *`freertos`*`/libraries/abstractions/wifi/test/aws_test_wifi.h`, and set the macros in the following table for the second AP.

Macro	Value
`testWIFI_SSID`	The Wi-Fi SSID as a C string (in quotation marks).
`testWIFI_PASSWORD`	The Wi-Fi password as a C string (in quotation marks).
`testWIFI_SECURITY`	One of the following: • `eWiFiSecurityOpen` • `eWiFiSecurityWEP` • `eWiFiSecurityWPA` • `eWiFiSecurityWPA2` `eWiFiSecurityWPA2` is recommended.

5. To enable the Wi-Fi tests, open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/aws_test_runner_config.h`, and set the `testrunnerFULL_WIFI_ENABLED` to `1`.

   Important
   The following tests require a port of the Secure Sockets library and a running echo server:

   - `WiFiConnectionLoop`
   - `WiFiIsConnected`
   - `WiFiConnectMultipleAP`

   You won't be able to pass these tests until you port the Secure Sockets library and start an echo server. After you port the Secure Sockets library and start an echo server, rerun the Wi-Fi tests to be sure that all tests pass. For information about porting the Secure Sockets library, see Porting the Secure Sockets library (p. 40). For information about setting up an echo server, see Setting up an echo server (p. 45).

Running the tests

To execute the Wi-Fi tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console.

```
.......--------STARTING TESTS--------
UUID: _uuid_d46442f6f32f4759bbfbefc66296069e
.4 29881 [TestRunner] WiFi Networks and strength:
5 29885 [TestRunner]    MikroTik-11AA97: -51
6 29889 [TestRunner]    afrlab-test-ubi_IoT: -41
7 29894 [TestRunner]    afrlab-test-ubi-mtk_IoT: -55
8 29899 [TestRunner]    afrlab-guest-mtk: -55
9 29903 [TestRunner]    afrlab-guest: -41
10 29907 [TestRunner]    afrlab-test: -41
11 29911 [TestRunner]    ConfigureMe: -52
12 29915 [TestRunner]    afrlab-test-mtk: -57
13 29919 [TestRunner]    : -39
14 29922 [TestRunner]    wpa2: -78
15 29926 [TestRunner] End of WiFi Networks
.TEST(Full_WiFi, AFQP_WiFiOnOff) PASS
..16 34778 [TestRunner] WiFi Networks and strength:
17 34782 [TestRunner]    ConfigureMe: -51
18 34786 [TestRunner]    afrlab-test-ubi-mtk_IoT: -52
19 34791 [TestRunner]    afrlab-guest-mtk: -52
20 34796 [TestRunner]    afrlab-test-ubi_IoT: -40
21 34800 [TestRunner]    afrlab-test-mtk: -51
22 34805 [TestRunner]    afrlab-guest: -40
23 34809 [TestRunner]    afrlab-test: -40
24 34813 [TestRunner]    MikroTik-11AA97: -51
25 34817 [TestRunner]    WifiSensorL16: -84
26 34821 [TestRunner]    : -41
27 34824 [TestRunner] End of WiFi Networks
.TEST(Full_WiFi, AFQP_WiFiMode) PASS
```

. . .

```
513 603362 [TestRunner] End of WiFi Networks
.TEST(Full_WiFi, AFQP_WIFI_NetworkAdd_AddManyNetworks) PASS
.514 608223 [TestRunner] WiFi Networks and strength:
515 608228 [TestRunner]    ConfigureMe: -49
516 608232 [TestRunner]    afrlab-test-ubi-mtk_IoT: -49
517 608237 [TestRunner]    afrlab-test-mtk: -49
518 608241 [TestRunner]    afrlab-guest-mtk: -49
519 608246 [TestRunner]    afrlab-guest: -40
520 608250 [TestRunner]    afrlab-test-ubi_IoT: -40
521 608255 [TestRunner]    afrlab-test: -40
522 608259 [TestRunner]    : -41
523 608262 [TestRunner]    IoTDeviceServicesLab: -46
524 608267 [TestRunner]    IoTDeviceServicesLab100: -45
525 608273 [TestRunner] End of WiFi Networks
.TEST(Full_WiFi, AFQP_WIFI_NetworkDelete_DeleteManyNetworks) PASS
..526 613134 [TestRunner] WiFi Networks and strength:
527 613139 [TestRunner]    ConfigureMe: -49
528 613143 [TestRunner]    afrlab-test-ubi_IoT: -40
529 613148 [TestRunner]    afrlab-test-mtk: -49
530 613152 [TestRunner]    afrlab-guest: -40
531 613156 [TestRunner]    afrlab-test: -40
532 613161 [TestRunner]    WifiSensorL16: -85
533 613165 [TestRunner]    afrlab-test-ubi-mtk_IoT: -51
534 613170 [TestRunner]    afrlab-guest-mtk: -49
535 613175 [TestRunner]    : -39
536 613178 [TestRunner]    wpa2: -68
537 613182 [TestRunner] End of WiFi Networks
.....TEST(Full_WiFi, AFQP_WIFI_ConnectAP_ConnectAllChannels) PASS
....538 666067 [TestRunner] Wi-Fi reconnected following tests finished.


-------------------
43 Tests 0 Failures 0 Ignored
```

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you finish porting the FreeRTOS Wi-Fi library to your device, you can start porting a TCP/IP stack. See Porting a TCP/IP stack (p. 36) for instructions.

Porting a TCP/IP stack

FreeRTOS provides a TCP/IP stack for boards that do not have on-chip TCP/IP functionality. If your platform offloads TCP/IP functionality to a separate network processor or module, you can skip this porting section and start Porting the Secure Sockets library (p. 40).

FreeRTOS+TCP is a native TCP/IP stack for the FreeRTOS kernel. FreeRTOS+TCP is maintained by the FreeRTOS engineering team and is the recommended TCP/IP stack to use with FreeRTOS. For more information, see Porting FreeRTOS+TCP (p. 36).

The lightweight IP (lwIP) TCP/IP stack is an open source third-party TCP/IP stack, ported to the FreeRTOS kernel. The lwIP port layer currently supports lwIP version 2.1.2. For more information, see Porting lwIP (p. 39).

> **Note**
> These porting sections only provide instructions for porting to a platform's Ethernet or Wi-Fi driver. The tests only ensure that the Ethernet or Wi-Fi driver can connect to a network. You cannot test sending and receiving data across a network until you have ported the Secure Sockets library.

Porting FreeRTOS+TCP

FreeRTOS+TCP is a native TCP/IP stack for the FreeRTOS kernel. For more information, see FreeRTOS.org.

Prerequisites

To port the FreeRTOS+TCP library, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes the vendor-supplied Ethernet or Wi-Fi drivers.

  For information about setting up a test project, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- A validated configuration of the FreeRTOS kernel.

  For information about configuring the FreeRTOS kernel for your platform, see Configuring a FreeRTOS kernel port (p. 29).

Porting

Before you start porting the FreeRTOS-TCP library, check the *`freertos`*`/libraries/freertos_plus/standard/freertos_plus_tcp/portable/NetworkInterface` directory to see if a port to your device already exists.

If a port does not exist, do the following:

1. Follow the Porting FreeRTOS+TCP to a Different Microcontroller instructions on FreeRTOS.org to port FreeRTOS+TCP to your device.
2. If necessary, follow the Porting FreeRTOS+TCP to a New Embedded C Compiler instructions on FreeRTOS.org to port FreeRTOS+TCP to a new compiler.

3. Implement a new port that uses the vendor-supplied Ethernet or Wi-Fi drivers in a file called `NetworkInterface.c`, and save the file to *`freertos`*`/libraries/freertos_plus/standard/freertos_plus_tcp/portable/NetworkInterface/`*`board_family`*.

   Note
   The files in the *`freertos`*`/libraries/freertos_plus/standard/freertos_plus_tcp/portable/BufferManagement` directory are used by multiple ports. Do not edit the files in this directory.

After you create a port, or if a port already exists, open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/FreeRTOSIPConfig.h`, and edit the configuration options so they are correct for your platform. For more information about the configuration options, see FreeRTOS+TCP Configuration on FreeRTOS.org.

Testing

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

Important
In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the FreeRTOS+TCP library in the IDE project

1. Add all of the source and header files in *`freertos`*`/libraries/freertos_plus/standard/freertos_plus_tcp` and its subdirectories to the `aws_tests` IDE project.

   Note
   FreeRTOS includes five example heap management implementations under *`freertos`*`/freertos_kernel/portable/MemMang`. FreeRTOS+TCP and `BufferAllocation_2.c` require the `heap_4.c` or `heap_5.c` implementations. You must use `heap_4.c` or `heap_5.c` to ensure that the FreeRTOS demo applications run properly. Do not use a custom heap implementation.

2. Add *`freertos`*`/libraries/freertos_plus/standard/freertos_plus_tcp/include` to your compiler's include path.

Configuring the `CMakeLists.txt` file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

Setting up your local testing environment

After you set up the library in the IDE project, you need to configure some other files for testing.

To configure the source and header files for the TCP tests

1. If you have not ported the Secure Sockets library, open *freertos*/libraries/freertos_plus/standard/utils/src/iot_system_init.c, and in the function SYSTEM_Init(), comment out the line that calls SOCKETS_Init(). When you reach the Porting the Secure Sockets library (p. 40) section, you will be instructed to uncomment this initialization function call.
2. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/application_code/main.c, and uncomment the call to FreeRTOS_IPInit().
3. Fill the following arrays with valid values for your network:

Variable	Description
uint8_t ucMACAddress[6]	Default MAC address configuration.
uint8_t ucIPAddress[4]	Default IP address configuration. **Note** By default, the IP address is acquired by DHCP. If DHCP fails or if you do not want to use DHCP, the static IP address that is defined here is used. To disable DHCP, open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/FreeRTOSIPConfig.h, and set ipconfigUSE_DHCP to 0. For demos, ipconfigUSE_DHCP is defined in *freertos*/vendors/*vendor*/boards/*board*/aws_demos/config_files/FreeRTOSIPConfig.h.
uint8_t ucNetMask[4]	Default net mask configuration.
uint8_t ucGatewayAddress[4]	Default gateway address configuration.
uint8_t ucDNSServerAddress[4]	Default DNS server address configuration.

4. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/FreeRTOSIPConfig.h, and set the ipconfigUSE_NETWORK_EVENT_HOOK macro to 1.
5. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/application_code/main.c, and add the following code to the beginning of the function definition for vApplicationIPNetworkEventHook():

```
if (eNetworkEvent == eNetworkUp)
{
    configPRINT("Network connection successful. \n\r");
}
```

Running the tests

To execute the FreeRTOS+TCP tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console. If Network connection successful appears, the Ethernet or Wi-Fi driver successfully connected to the network, and the test is complete.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

Porting lwIP

lwIP is an alternative, open source TCP/IP stack. For more information, see lwIP - A Lightweight TCP/IP Stack - Summary. FreeRTOS currently supports version 2.1.2.

Prerequisites

To port the lwIP stack, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes vendor-supplied network drivers.
- A validated configuration of the FreeRTOS kernel.

  For information about configuring the FreeRTOS kernel for your platform, see Configuring a FreeRTOS kernel port (p. 29).

Porting

Before you port the lwIP TCP/IP stack to your device, check the *freertos*`/libraries/3rdparty/lwip/src/portable` directory to see if a port to your platform already exists.

1. If a port does not exist, do the following:

   Under *freertos*`/libraries/3rdparty/lwip/src/portable`, create a directory named *vendor*`/`*board*`/netif`, where the *vendor* and *board* directories match your platform.
2. Port the *freertos*`/libraries/3rdparty/lwip/src/netif/ethernetif.c` stub file according to the comments in the stub file.
3. After you have created a port, or if a port already exists, in the test project's `main.c` file, add a call to `tcpip_init()`.
4. In *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files`, create a configuration file named `lwipopts.h`. This file must contain the following line:

   ```
   #include "arch/lwipopts_freertos.h"
   ```

   The file should also contain any platform-specific configuration options.

Testing

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Note
There are no TCP/IP porting tests specific to lwIP.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

Important
In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the lwIP source files in the IDE project

1. Add all of the source and header files in `lwip/src` and its subdirectories to the `aws_tests` IDE project.

   Note
   If you added a `.c` file to the IDE project, and then edited that `.c` file for a port, you must replace the original `.c` file with the edited one in the IDE project.
2. Add the following paths to your compiler's include path:

   - *freertos*`/libraries/3rdparty/lwip/src/include`
   - *freertos*`/libraries/3rdparty/lwip/src/portable`
   - *freertos*`/libraries/3rdparty/lwip/src/portable/`*vendor*`/`*board*`/include`

Configuring the `CMakeLists.txt` file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *freertos*`/vendors/`*vendor*`/boards/`*board*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

A Secure Sockets library implementation already exists for the FreeRTOS+TCP TCP/IP stack and the lwIP stack. If you are using FreeRTOS+TCP or lwIP, you do not need to port the Secure Sockets library. After you finish porting the FreeRTOS+TCP stack or the lwIP stack to your device, you can start Porting the corePKCS11 library (p. 47). Even if you do not need to create a port for the Secure Sockets library, your platform still needs to pass the AWS IoT Device Tester tests for the Secure Sockets library for qualification.

Porting the Secure Sockets library

You can use the FreeRTOS Secure Sockets library to create and configure a TCP socket, connect to an MQTT broker, and send and receive TCP data. The Secure Sockets library also encapsulates TLS functionality. Only a standard TCP socket is required to create a TLS-protected socket. For more information, see FreeRTOS Secure Sockets Library in the FreeRTOS User Guide.

FreeRTOS includes a Secure Sockets implementation for the FreeRTOS+TCP and lightweight IP (lwIP) TCP/IP stacks, which are used in conjunction with mbedTLS. If you are using either the FreeRTOS+TCP or the lwIP TCP/IP stack, you do not need to port the Secure Sockets library.

Note

- Even if you do not need to create a port of the Secure Sockets library, your platform must still pass the qualification tests for the Secure Sockets library. Qualification is based on results from AWS IoT Device Tester.
- Your TLS implementation should support the TLS cipher suites that are supported by AWS IoT.
- If you modify the TLS configuration of the Secure Sockets library, this may cause a failure when you attempt to connect to the echo server. Not all cipher suites supported by the echo

server are supported by the Secure Sockets library, and if you enable a cipher suite that the library does not currently support (for example, SHA384) you may be unable to connect.
- If your platform offloads TCP/IP functionality to a separate network chip, you need to port the FreeRTOS Secure Sockets library to your device.

Prerequisites

To port the Secure Sockets library, you need the following:

- A port of the Wi-Fi library (required only if you are using Wi-Fi for network connectivity).

  For information about porting the Wi-Fi library, see Porting the Wi-Fi library (p. 30).
- If your board has cellular connectivity, you must provide a Secure Sockets library that uses the cellular modem as transport. You can implement the Secure Sockets library in two ways:
  - Implement the Secure Sockets API by using the AT commands of your modem directly.
  - Use the Cellular library provided by FreeRTOS, which hides the AT commands and provides a socket-like API. For more information, see Porting the Cellular library (p. 102).
- A port of a TCP/IP stack.

  For information about porting a TCP/IP stack, see Porting a TCP/IP stack (p. 36).
- An echo server.

  FreeRTOS includes an echo server, written in Go, in the *freertos*`/tools/echo_server` directory. For more information, see Setting up an echo server (p. 45).

Porting

If your platform offloads TCP/IP functionality to a separate network chip, you need to implement all the functions for which stubs exist in *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/secure_sockets/iot_secure_sockets.c`.

Testing

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

Important
In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the Secure Sockets library in the IDE project

1. If you are using the FreeRTOS+TCP TCP/IP stack, add *freertos*`/libraries/abstractions/secure_sockets/freertos_plus_tcp/iot_secure_sockets.c` to the `aws_tests` IDE project.

   If you are using the lwIP TCP/IP stack, add *freertos*`/libraries/abstractions/secure_sockets/lwip/iot_secure_sockets.c` to the `aws_tests` IDE project.

   If you are using your own TCP/IP port, add *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/secure_sockets/iot_secure_sockets.c` to the `aws_tests` IDE project.

2. Add `secure_sockets/test/aws_test_tcp.c` to the `aws_tests` IDE project.

Configuring the `CMakeLists.txt` file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

See below for an example portable layer target definition for the Secure Sockets library.

```
# Secure sockets
afr_mcu_port(secure_sockets)
# Link to AFR::secure_sockets_freertos_tcp if you want use default implementation based on
# FreeRTOS-Plus-TCP.
target_link_libraries(
AFR::pkcs11::mcu_port
INTERFACE AFR::secure_sockets_freertos_tcp
)
# Or provide your own implementation.
target_sources(
AFR::secure_sockets::mcu_port
INTERFACE "$path/iot_secure_sockets.c"
)
```

Setting up your local testing environment

After you set up the library in the IDE project, you need to configure some other files for testing.

To configure the source and header files for the Secure Sockets tests

1. Open *`freertos`*`/libraries/freertos_plus/standard/utils/src/iot_system_init.c`, and in the function `SYSTEM_Init()`, make sure that the line that calls `SOCKETS_Init()` is not commented out.
2. Start an echo server.

   If you have not ported the TLS library to your platform, you can only test your Secure Sockets port using an unsecured echo server (*`freertos`*`/tools/echo_server/echo_server.go`). For instructions on setting up and running an unsecured echo server, see Setting up an echo server (p. 45).
3. In `aws_test_tcp.h`, set the IP address to the correct values for your server. For example, if your server's IP address is `192.168.2.6`, set the following values in `aws_test_tcp.h`:

Macro	Value
`tcptestECHO_SERVER_ADDR0`	`192`
`tcptestECHO_SERVER_ADDR1`	`168`
`tcptestECHO_SERVER_ADDR2`	`2`

Macro	Value
`tcptestECHO_SERVER_ADDR3`	`6`

4. Open `aws_test_tcp.h`, and set the `tcptestSECURE_SERVER` macro to `0` to run the Secure Sockets tests without TLS.
5. Open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/aws_test_runner.config.h`, and set the `testrunnerFULL_TCP_ENABLED` macro to `1` to enable the sockets tests.
6. Open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/application_code/main.c`, and and delete the `#if 0` and `#endif` compiler directives in the `vApplicationIPNetworkEventHook ( void )` definition to enable the testing task.

   Note
   This change is required to port the remaining libraries.

   Important
   For qualification, you must pass the Secure Sockets tests with TLS. After you port the TLS library, rerun the Secure Sockets tests with TLS tests enabled, using a TLS-capable echo server. To port the TLS library, see Porting the TLS library (p. 52).

To set up testing for Secure Sockets after porting the TLS library

1. Start a secure echo server.

   For information, see Setting up an echo server (p. 45).
2. Set the IP address and port in *`freertos`*`/tests/include/aws_test_tcp.h` to correct values for your server. For example, if your server's IP address is `192.168.2.6`, and the server is listening on `9000`, set the following values in *`freertos`*`/tests/include/aws_test_tcp.h`:

Macro	Value
`tcptestECHO_SERVER_TLS_ADDR0`	`192`
`tcptestECHO_SERVER_TLS_ADDR1`	`168`
`tcptestECHO_SERVER_TLS_ADDR2`	`2`
`tcptestECHO_SERVER_TLS_ADDR3`	`6`
`tcptestECHO_PORT_TLS`	`9000`

3. Open *`freertos`*`/tests/include/aws_test_tcp.h`, and set the `tcptestSECURE_SERVER` macro to `1` to enable TLS tests.
4. Download a trusted root certificate. For information about accepted root certificates and download links, see Server Authentication in the AWS IoT Developer Guide. We recommend that you use Amazon Trust Services certificates.
5. In a browser window, open *`freertos`*`/tools/certificate_configuration/PEMfileToCString.html`.
6. Under **PEM Certificate or Key**, choose the root CA file that you downloaded.
7. Choose **Display formatted PEM string to be copied into aws_clientcredential_keys.h**, and then copy the certificate string.
8. Open `aws_test_tcp.h`, and paste the formatted certificate string into the definition for `tcptestECHO_HOST_ROOT_CA`.
9. Use the second set of OpenSSL commands in *`freertos`*`/tools/echo_server/readme-gencert.txt` to generate a client certificate and private key that is signed by the certificate

authority. The certificate and key allow the custom echo server to trust the client certificate that your device presents during TLS authentication.

10. Format the certificate and key with the *freertos*`/tools/certificate_configuration/PEMfileToCString.html` formatting tool.
11. Before you build and run the test project on your device, open `aws_clientcredential_keys.h`, and copy the client certificate and private key, in PEM format, into the definitions for `keyCLIENT_CERTIFICATE_PEM` and `keyCLIENT_PRIVATE_KEY_PEM`.

Running the tests

To execute the Secure Sockets tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console.

```
Starting Tests...

TEST(Full_TCP, SOCKETS_CloseInvalidParams) PASS
```

...

```
TEST(Full_TCP, SECURE_SOCKETS_NonBlockingConnect) PASS

TEST(Full_TCP, SECURE_SOCKETS_TwoSecureConnections) PASS

TEST(Full_TCP, SECURE_SOCKETS_SetSecureOptionsAfterConnect) PASS



-----------------------

47 Tests 3 Failures 0 Ignored

FAIL

----All tests finished----
```

If all tests pass, then testing is complete.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you finish porting the FreeRTOS Secure Sockets library to your device, you can start porting the corePKCS11 library. See Porting the corePKCS11 library (p. 47) for instructions.

Setting up an echo server

The *freertos*/tools/echo_server/ directory has the source code for a Go-based echo server that you can use to test TCP on FreeRTOS. You can find the TCP tests in the *freertos*/libraries/abstractions/secure_sockets/test/iot_test_tcp.c file. Follow the instructions in this section to set up and run the echo server.

Prerequisites

To run the TLS echo server, you must install the following:

- Go – You can download the latest version from golang.org.
- OpenSSL – For a Linux source code download, see OpenSSL.org. You can also use a package manager to install OpenSSL for Linux and macOS.

Create credentials

After you finish the prerequisites, you must enter the following commands to create your credentials.

Server

The following openssl command generates a self-signed server certificate.

RSA

```
openssl req -newkey rsa:2048 -nodes -x509 -sha256 -out certs/server.pem -keyout
 certs/server.key -days 365 -subj "/C=US/ST=WA/L=Place/O=YourCompany/OU=IT/
CN=www.your-company-website.com/emailAddress=yourEmail@your-company-website.com"
```

EC

```
openssl req -new -x509 -nodes -newkey ec:<(openssl ecparam -name prime256v1) -
keyout certs/server.key -out certs/server.pem -days 365 -subj "/C=US/ST=WA/L=Place/
O=YourCompany/OU=IT/CN=www.your-company-website.com/emailAddress=yourEmail@your-
company-website.com"
```

Client

The following openssl commands generate a client certificate.

RSA

```
openssl genrsa -out certs/client.key 2048
openssl req -new -key certs/client.key -out certs/client.csr -subj "/
C=US/ST=WA/L=Place/O=YourCompany/OU=IT/CN=www.your-company-website.com/
emailAddress=yourEmail@your-company-website.com"
openssl x509 -req -in certs/client.csr -CA certs/server.pem -CAkey certs/server.key
 -CAcreateserial -out certs/client.pem -days 365 -sha256
```

EC

```
ecparam -genkey -name prime256v1 -out certs/client.key
openssl req -new -key certs/client.key -out certs/client.csr -subj "/
C=US/ST=WA/L=Place/O=YourCompany/OU=IT/CN=www.your-company-website.com/
emailAddress=yourEmail@your-company-website.com"
```

```
openssl x509 -req -in certs/client.csr -CA certs/server.pem -CAkey certs/server.key
 -CAcreateserial -out certs/client.pem -days 365 -sha256
```

Directory structure

By default, certificates and keys are stored in a directory named `certs` that is located on a relative path specified in the configuration file, `config.json`. If you want to move your credentials to a different directory, you can update this directory location in the configuration file.

You can find the source code for the echo server in the `echo_server.go` file.

Server configuration

The echo server reads a JSON based configuration file. The default location for this JSON file is `./config.json`. To override this, specify the location of the JSON with the `-config` flag.

The JSON file contains the following options:

server-port

Specify the port on which to open a socket.

server-certificate-location

The relative or absolute path to the server certificate generated in Create credentials (p. 45).

secure-connection

Enable this option to have the echo server use TLS. You must first Create credentials (p. 45).

logging

Enable this option to output all log messages received to a file.

verbose

Enable this option to output the contents of the message sent to the echo server.

server-key-location

The relative or absolute path to the server key generated in Create credentials (p. 45).

Example configuration

```
{
    "verbose": false,
    "logging": false,
    "secure-connection": false,
    "server-port": "9000",
    "server-certificate-location": "./certs/server.pem",
    "server-key-location": "./certs/server.pem"
}
```

Run the echo server from the command line

Enter the following commands to run the echo server.

```
go run echo_server.go
```

Enter the following command to run with a custom config location.

```
go run echo_server.go -config=config_file_path
```

If you want to run the unsecure and secure TCP tests at the same time, you must start both a secure and an unsecure echo server. To do this, create a second, secure configuration file, and pass its location to the second instance of the echo server using the `-config` flag. Remember to also specify a different TCP port in the second configuration file.

Client device configuration

Before you run the TCP tests on your device, we recommend that you read Getting Started with FreeRTOS in the *FreeRTOS User Guide*.

After you complete the steps in Create credentials (p. 45), you should have the following files:

- `certs/server.pem`
- `certs/server.key`
- `certs/server.srl`
- `certs/client.pem`
- `certs/client.key`
- `certs/client.csr`

Make the following changes to these files:

freertos`/tests/include/aws_clientcredential.h`
- Define the broker endpoint.
- Define the thing name.
- Define access to Wi-Fi (if not on Ethernet).

freertos`/tests/include/aws_clientcredential_keys.h`
- Set `keyCLIENT_CERTIFICATE_PEM` to the contents of `certs/client.pem`.
- Leave `keyJITR_DEVICE_CERTIFICATE_AUTHORITY_PEM` as `NULL`.
- Set `keyCLIENT_PRIVATE_KEY_PEM` to the contents of `certs/client.key`.
- For more information, see Configuring the FreeRTOS demos.

freertos`/tests/include/aws_test_tcp.h`
- Set `tcptestECHO_HOST_ROOT_CA` to the contents of `certs/server.pem`.
- Set the IP address and the port of the echo server:
  - `tcptestECHO_SERVER_ADDR[0-3]`
  - `tcptestECHO_PORT`
- Set the IP address and the port of the secure echo server:
  - `tcptestECHO_SERVER_TLS_ADDR0[0-3]`
  - `tcptestECHO_PORT_TLS`

Porting the corePKCS11 library

The corePKCS11 library contains a software-based mock implementation of the PKCS #11 interface (API) that uses the cryptographic functionality provided by Mbed TLS. Storing private keys in general-purpose flash memory can be convenient in evaluation and rapid prototyping scenarios. In production scenarios, to reduce the threats of data theft and device duplication, we recommend that you use dedicated cryptographic hardware. Cryptographic hardware includes components with features that prevent cryptographic secret keys from being exported.

To use dedicated cryptographic hardware with FreeRTOS, port the PKCS #11 API for the hardware you are using. Generally, vendors for secure cryptoprocessors, such as Trusted Platform Module (TPM), Hardware Security Module (HSM), Secure Element, or any other type of secure hardware enclave, distribute a PKCS #11 implementation with the hardware. You can add the library to CMake and your IDE project, compile it and run the PKCS #11 test suite.

This section describes how to use the FreeRTOS corePKCS11 library as the basis of your own port of the PKCS #11 API. Only a subset of the PKCS #11 standard is implemented, with a focus on operations involving asymmetric keys, random number generation, and hashing. PKCS #11 API calls are made by the TLS helper interface in order to perform TLS client authentication during `SOCKETS_Connect`. PKCS #11 API calls are also made by our one-time developer provisioning workflow to import a TLS client certificate and private key for authentication to the AWS IoT MQTT broker. Those two use cases, provisioning and TLS client authentication, require implementation of only a small subset of the PKCS #11 interface standard.

For information about the FreeRTOS corePKCS11 library, see FreeRTOS corePKCS11 Library in the *FreeRTOS User Guide*.

Prerequisites

To port the corePKCS11 library, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes vendor-supplied drivers that are suitable for sensitive data.

  For information about setting up a test project, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- A validated configuration of the FreeRTOS kernel.

  For information about configuring the FreeRTOS kernel for your platform, see Configuring a FreeRTOS kernel port (p. 29).

Porting

To port the corePKCS11 library

1. Port the PKCS #11 API functions implemented by corePKCS11.

   The PKCS #11 API is dependent on the implementation of cryptographic primitives, such as SHA256 hashing and Elliptic Curve Digital Signature Algorithm (ECDSA) signing.

   The FreeRTOS implementation of PKCS #11 uses the cryptographic primitives implemented in the mbedTLS library. FreeRTOS includes a port for mbedTLS. If your target hardware offloads crypto to a separate module, or if you want to use a software implementation of the cryptographic primitives other than mbedTLS, you need to modify the existing PKCS #11 implementation.
2. Port the corePKCS11 Platform Abstraction Layer (PAL) for device-specific certificate and key storage.

   If you decide to use the FreeRTOS implementation of PKCS #11, little customization is required to read and write cryptographic objects to non-volatile memory (NVM), such as onboard flash memory.

   Cryptographic objects should be stored in a section of NVM that is not initialized and is not erased on device reprogramming. Users of the corePKCS11 library should be able to provision devices with credentials, and then reprogram the device with a new application that accesses these credentials through the corePKCS11 interface.

   corePKCS11 PAL ports must provide a location to store:

- The device client certificate.
- The device client private key.
- The device client public key.
- A trusted root CA.
- A code-verification public key (or a certificate that contains the code-verification public key) for secure bootloader and over-the-air (OTA) updates.
- A Just-In-Time provisioning certificate.

freertos/vendors/*vendor*/boards/*board*/ports/pkcs11/core_pkcs11_pal.c contains empty definitions for the PAL functions. You must provide ports for, at minimum, the functions listed in this table:

Function	Description
PKCS11_PAL_Initialize	Initializes the PAL layer. Called by the corePKCS11 library at the start of it's initialization sequence.
PKCS11_PAL_SaveObject	Writes data to non-volatile storage.
PKCS11_PAL_FindObject	Uses a PKCS #11 CKA_LABEL to search for a corresponding PKCS #11 object in non-volatile storage, and returns that object's handle, if it exists.
PKCS11_PAL_GetObjectValue	Retrieves the value of an object, given the handle.
PKCS11_PAL_GetObjectValueCleanup	Cleanup for the PKCS11_PAL_GetObjectValue call. Can be used to free memory allocated in a PKCS11_PAL_GetObjectValue call.

3. Add support for a cryptographically random entropy source to your port:

   - If your ports use the mbedTLS library for underlying cryptographic and TLS support, and your device has a true random number generator (TRNG):

     1. Implement the mbedtls_hardware_poll() function to seed the deterministic random bit generator (DRBG) that mbedTLS uses to produce a cryptographically random bit stream. The mbedtls_hardware_poll() function is located in *freertos*/vendors/*vendor*/boards/*board*/ports/pkcs11/core_pkcs11_pal.c.

   - If your ports use the mbedTLS library for underlying cryptographic and TLS support, but your device does not have a TRNG:

     1. Make a copy of *freertos*/libraries/3rdparty/mbedtls/include/mbedtls/config.h, and in that copy, uncomment MBEDTLS_ENTROPY_NV_SEED, and comment out MBEDTLS_ENTROPY_HARDWARE_ALT.

        Save the modified version of config.h to *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/config.h. Do not overwrite the original file.

     2. Implement the functions mbedtls_nv_seed_poll(), nv_seed_read_func(), and nv_seed_write_func().

For information about implementing these functions, see the comments in the mbedtls/include/mbedtls/entropy_poll.h and mbedtls/include/mbedtls/config.h mbedTLS header files.

Important
A seed file with an NIST-approved entropy source must be supplied to the device at manufacturing time.

Note
If you are interested in the FreeRTOS Qualification Program, please read our requirements for RNG.

For more information about NIST-approved DRBGs and entropy sources, see the following NIST publications:

- Recommendation for Random Number Generation Using Deterministic Random Bit Generators
- Recommendation for Random Bit Generator (RBG) Constructions

Testing

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

Important
In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the corePKCS11 library in the IDE project

1. Add the source file *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/pkcs11/core_pkcs11_pal.c` to the `aws_tests` IDE project.
2. Add all of the files in the *freertos*`/libraries/abstractions/pkcs11` directory and its subdirectories to the `aws_tests` IDE project.
3. Add all of the files in the *freertos*`/libraries/freertos_plus/standard/pkcs11` directory and its subdirectories to the `aws_tests` IDE project. These files implement wrappers for commonly grouped PKCS #11 function sets.
4. Add the source file *freertos*`/libraries/freertos_plus/standard/crypto/src/iot_crypto.c` to the `aws_tests` IDE project. This file implements the CRYPTO abstraction wrapper for mbedTLS.
5. Add all of the source and header files from *freertos*`/libraries/3rdparty/mbedtls` and its subdirectories to the `aws_tests` IDE project.
6. Add *freertos*`/libraries/3rdparty/mbedtls/include` and *freertos*`/libraries/abstractions/pkcs11` to the compiler's include path.

Configuring the `CMakeLists.txt` file

If you're using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

See the following example portable layer target definition for the corePKCS11 library that uses the mbedTLS-based software implementation of PKCS #11 and supplies a port-specific corePKCS11 PAL file.

```
# PKCS11
afr_mcu_port(pkcs11_implementation DEPENDS AFR::pkcs11_mbedtls)
target_sources(
    AFR::pkcs11_implementation::mcu_port
    INTERFACE
    "${afr_ports_dir}/pkcs11/core_pkcs11_pal.c"
)
```

Setting up your local testing environment

After you set up the library in the IDE project, you need to configure some other files for testing.

To configure the source and header files for the PKCS #11 tests

1. If you have ported the Secure Sockets library, open *`freertos`*`/libraries/freertos_plus/standard/utils/src/iot_system_init.c`, and in the function `SYSTEM_Init()`, uncomment calls to `SOCKETS_Init()`.
2. Open *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/aws_test_runner_config.h`, and set the `testrunnerFULL_PKCS11_ENABLED` macro to `1` to enable the PKCS #11 test.

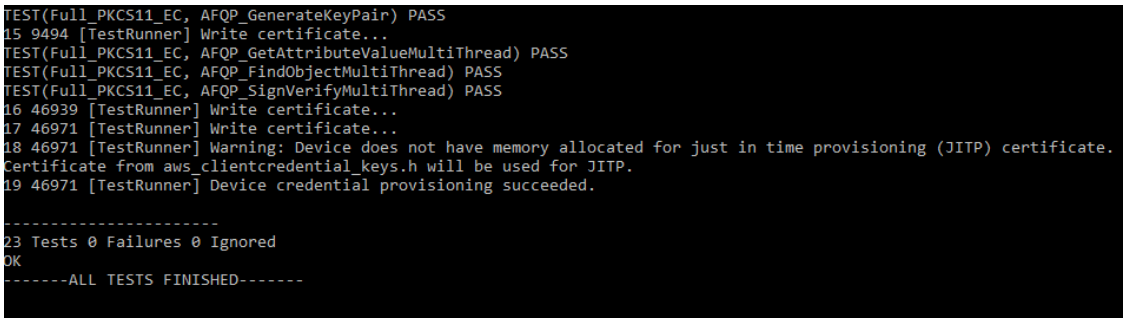
Running the tests

To execute the PKCS #11 tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console.

```
---------STARTING TESTS---------
TEST(Full_PKCS11_StartFinish, AFQP_StartFinish_FirstTest) PASS
TEST(Full_PKCS11_StartFinish, AFQP_GetFunctionList) PASS
TEST(Full_PKCS11_StartFinish, AFQP_InitializeFinalize) PASS
TEST(Full_PKCS11_StartFinish, AFQP_GetSlotList) PASS
TEST(Full_PKCS11_StartFinish, AFQP_OpenSessionCloseSession) PASS
TEST(Full_PKCS11_NoObject, AFQP_Digest) PASS
TEST(Full_PKCS11_NoObject, AFQP_Digest_ErrorConditions) PASS
TEST(Full_PKCS11_NoObject, AFQP_GenerateRandom) PASS
```

...



Testing is complete when all tests pass.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you finish porting the corePKCS11 library to your device, you can start porting the TLS library. See Porting the TLS library (p. 52) for instructions.

Porting the TLS library

For Transport Layer Security (TLS) authentication, FreeRTOS uses either mbedTLS or an off-chip TLS implementation, such as those found on some network co-processors. FreeRTOS includes a port of mbedTLS. If you use mbedTLS for TLS, TLS porting is not required. To allow different TLS implementations, third-party TLS libraries are accessed through a TLS abstraction layer.

> **Note**
> No matter which TLS implementation is used by your device's port of FreeRTOS, the port must pass the qualification tests for TLS. Qualification is based on results from AWS IoT Device Tester. Also, your TLS implementation should support the TLS cipher suites that are supported by AWS IoT.

To prepare your platform for testing TLS, you need to configure your device in the AWS Cloud, and you need certificate and key provisioning on the device.

Prerequisites

To port the FreeRTOS TLS library, you need the following:

- A port of the FreeRTOS Secure Sockets library.

  For information about porting the Secure Sockets library to your platform, see Porting the Secure Sockets library (p. 40).
- A port of the corePKCS11 library.

  For information about porting the corePKCS11 library to your platform, see Porting the corePKCS11 library (p. 47).
- An AWS account.

  For information about setting up an AWS account, see How do I create and activate a new Amazon Web Services account? on the AWS Knowledge Center.

- OpenSSL.

  You can download a version of OpenSSL for Windows from Shining Light. For a Linux source code download, see OpenSSL.org. You can also use a package manager to install OpenSSL for Linux and macOS.

Porting

If your target hardware offloads TLS functionality to a separate network chip, you need to implement the TLS abstraction layer functions in the following table.

Function	Description
`TLS_Init`	Initialize the TLS context.
`TLS_Connect`	Negotiate TLS and connect to the server.
`TLS_Recv`	Read the requested number of bytes from the TLS connection.
`TLS_Send`	Write the requested number of bytes to the TLS connection.
`TLS_Cleanup`	Free resources consumed by the TLS context.

`iot_tls.h` contains the information required to implement these functions. Save the file in which you implement the functions as `iot_tls.c`.

Connecting your device to AWS IoT

Your device must be registered with AWS IoT to communicate with the AWS Cloud. To register your board with AWS IoT, you need the following:

An AWS IoT policy

The AWS IoT policy grants your device permissions to access AWS IoT resources. It is stored in the AWS Cloud.

An AWS IoT thing

An AWS IoT thing allows you to manage your devices in AWS IoT. It is stored in the AWS Cloud.

A private key and X.509 certificate

The private key and certificate allow your device to authenticate with AWS IoT.

Follow these procedures to create a policy, thing, and key and certificate.

To create an AWS IoT policy

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Secure**, choose **Policies**, and then choose **Create**.
3. Enter a name to identify your policy.
4. In the **Add statements** section, choose **Advanced mode**. Copy and paste the following JSON into the policy editor window:

```
{
```

```
    "Version": "2012-10-17",
    "Statement": [
    {
"Effect": "Allow",
"Action": "iot:*",
"Resource": "*"
}
    ]
}
```

Important
This policy grants all AWS IoT resources access to all AWS IoT actions. This policy is convenient for development and testing purposes, but it is not recommended for production.

5. Choose **Create**.

To create an IoT thing, private key, and certificate for your device

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Manage**, and then choose **Things**.
3. If you do not have any things registered in your account, the **You don't have any things yet** page is displayed. If you see this page, choose **Register a thing**. Otherwise, choose **Create**.
4. On the **Creating AWS IoT things** page, choose **Create a single thing**.
5. On the **Add your device to the thing registry** page, enter a name for your thing, and then choose **Next**.
6. On the **Add a certificate for your thing** page, under **One-click certificate creation**, choose **Create certificate**.
7. Download your private key and certificate by choosing the **Download** links for each.
8. Choose **Activate** to activate your certificate. Certificates must be activated prior to use.
9. Choose **Attach a policy** to attach a policy to your certificate that grants your device access to AWS IoT operations.
10. Choose the policy you just created, and then choose **Register thing**.

After you obtain your certificates and keys from the AWS IoT console, you need to configure the *freertos*`/tests/include/aws_clientcredential.h` header file so your device can connect to AWS IoT.

To configure *freertos*`/tests/include/aws_clientcredential.h`

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Settings**.

   Your AWS IoT endpoint is displayed in **Endpoint**. It should look like *123456789012*`-ats.iot.`*us-east-1*`.amazonaws.com`. Make a note of this endpoint.
3. In the navigation pane, choose **Manage**, and then choose **Things**.

   Your device should have an AWS IoT thing name. Make a note of this name.
4. On the computer where you build the FreeRTOS source code, open the *freertos*`/test/include/aws_clientcredential.h` file in your IDE and specify values for the following constants:

   - `static const char clientcredentialMQTT_BROKER_ENDPOINT[] = "`*Your AWS IoT endpoint*`";`
   - `#define clientcredentialIOT_THING_NAME "`*The AWS IoT thing name of your board*`"`

Setting up certificates and keys for the TLS tests

TLS_ConnectRSA()

This section provides instructions on setting up certificates and keys for testing your TLS port.

For RSA device authentication, you can use the private key and the certificate that you downloaded from the AWS IoT console when you registered your device.

> **Note**
> After you have registered your device as an AWS IoT thing, you can retrieve device certificates from the AWS IoT console, but you cannot retrieve private keys.

FreeRTOS is a C language project. You must format certificates and keys before you add them to the *freertos*`/tests/include/aws_clientcredential_keys.h` header file.

To format the certificate and key for *freertos*`/tests/include/aws_clientcredential_keys.h`

1. In a browser window, open *freertos*`/tools/certificate_configuration/CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the *ID*`-certificate.pem.crt` file that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *ID*`-private.pem.key` file that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in *freertos*`/tests/include`. This overwrites the existing file in the directory.

   > **Note**
   > The certificate and private key are hard-coded for demonstration purposes only. Production-level applications should store these files in a secure location.

TLS_ConnectEC()

For Elliptic Curve Digital Signature Algorithm (ECDSA) authentication, you need to generate a private key, a certificate signing request (CSR), and a certificate. You can use OpenSSL to generate the private key and CSR, and you can use the CSR to generate the certificate in the AWS IoT console.

To generate a private key and a CSR

1. Use the following command to create a private key file named *p256_privatekey*`.pem` in the current working directory:

   ```
   openssl ecparam -name prime256v1 -genkey -noout -out p256_privatekey.pem
   ```

2. Use the following command to create a CSR file named *csr*`.csr` in the current working directory.

   ```
   openssl req -new -key p256_privatekey.pem -out csr.csr
   ```

To create a certificate in the AWS IoT console with a CSR

1. Open the AWS IoT console.
2. In the navigation pane, choose **Secure**, choose **Certificates**, and then choose **Create**.

3. Choose **Create with CSR**, and then find and upload the *csr*.csr file that you created with OpenSSL.
4. Choose **Activate** to activate the certificate, and then choose **Download** to download the certificate as a .cert.pem file.
5. Choose **Attach a policy**, and then find and select the AWS IoT policy that you created and attached to your RSA certificate in the Connecting your device to AWS IoT (p. 53) instructions, and choose **Done**.
6. Attach the certificate to the AWS IoT thing that you created when you registered your device.
7. From the **Certificates** page, find and select the certificate that you just created. From the upper right of the page, choose **Actions**, and then choose **Attach thing**.
8. Find and select the thing that you created for your device, and then choose **Attach**.

You must format the certificate and private key for your device before you add them to the *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h header file.

To format the certificate and key for *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h

1. In a browser window, open *freertos*/tools/certificate_configuration/PEMfileToCString.html.
2. Under **PEM Certificate or Key**, choose the *ID*-certificate.pem.crt that you downloaded from the AWS IoT console.
3. Choose **Display formatted PEM string to be copied into aws_clientcredential_keys.h**, and then copy the certificate string.
4. Open *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h, and paste the formatted certificate string into the definition for tlstestCLIENT_CERTIFICATE_PEM_EC.

   Note
   The certificate and private key are hard-coded for demonstration purposes only. Production-level applications should store these files in a secure location.
5. Follow the same steps to get the formatted string for the private key file that you created using OpenSSL (*p256_privatekey*.pem). Copy and paste the formatted private key string into the definition for tlstestCLIENT_PRIVATE_KEY_PEM_EC in *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h.

In *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h, define the tlstestMQTT_BROKER_ENDPOINT_EC with the same AWS IoT MQTT broker endpoint address that you used in Connecting your device to AWS IoT (p. 53).

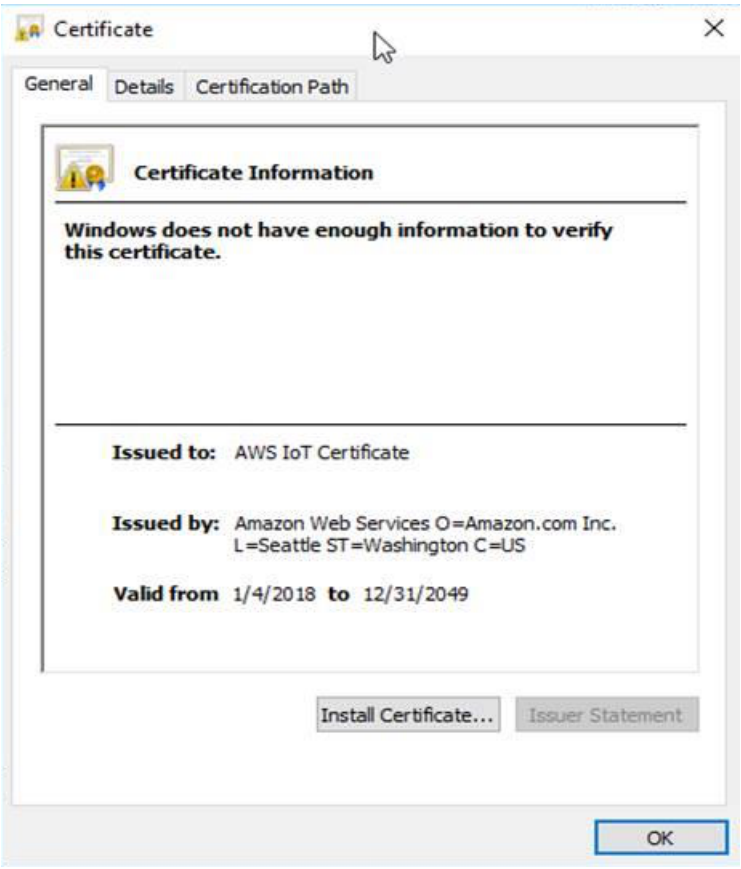
TLS_ConnectMalformedCert()

This test verifies that you can use a malformed certificate to authenticate with the server. Random modification of a certificate is likely to be rejected by X.509 certificate verification before the connection request is sent out. To set up a malformed certificate, we suggest that you modify the issuer of the certificate.

To modify the issuer of a certificate

1. Take the valid client certificate that you have been using, *ID*-certificate.pem.crt.

   In the Windows Certificate Manager, the certificate properties appear as follows:



2. Using the following command, convert the certificate from PEM to DER:

```
openssl x509 -outform der -in ID-certificate.pem.crt -out ID-certificate.der.crt
```

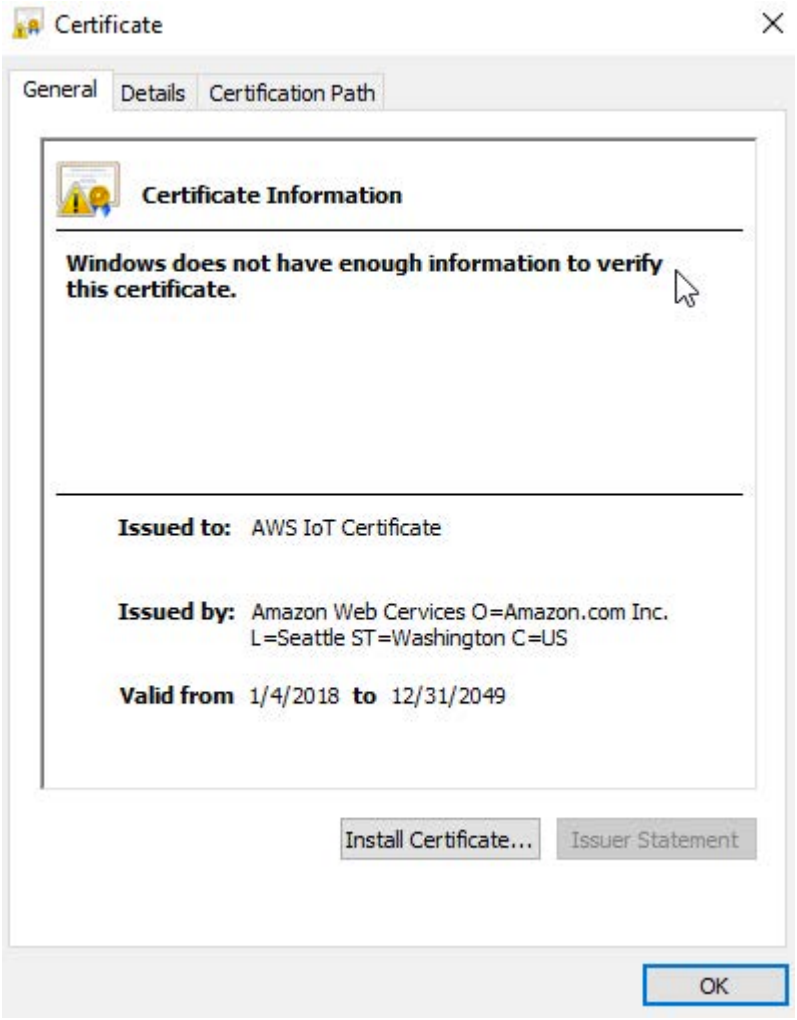
3. Open the DER certificate, and search for the following hexadecimal sequence:

```
41 6d 61 7a 6f 6e 20 57 65 62 20 53 65 72 76 69 63 65 73
```

   This sequence, translated to plain text, reads "Amazon Web Services."

4. Change the `53` to `43`, so that the sequence becomes "Amazon Web Cervices" in plain text, and save the file.

   In the Windows Certificate Manager, the certificate properties now appear as follows:



5. Use the following command to convert the certificate back to PEM:

```
openssl x509 -inform der -in ID-certificate.der.crt -out ID-cert-modified.pem.crt
```

You must format the malformed certificate for your device before you add it to the *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h header file.

To format the certificate for *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h

1. In a browser window, open *freertos*/tools/certificate_configuration/PEMfileToCString.html.
2. Under **PEM Certificate or Key**, choose the *ID*-certificate.pem.crt that you created and then modified.
3. Choose **Display formatted PEM string to be copied into aws_clientcredential_keys.h**, and then copy the certificate string.
4. Open *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h, and paste the formatted certificate string into the definition for tlstestCLIENT_CERTIFICATE_PEM_MALFORMED.

Note
The certificate is hard-coded for demonstration purposes only. Production-level applications should store these files in a secure location.

TLS_ConnectBYOCCredentials()

You can use your own certificate for authentication. To create and register a certificate with a valid rootCA/CA chain, follow the instructions in Creating a BYOC (ECDSA) (p. 60). After you create the certificate, you need to attach some policies to your device certificate, and then you need to attach your device's thing to the certificate.

To attach a policy to your device certificate

1. Open the AWS IoT console.
2. In the navigation pane, choose **Secure**, choose **Certificates**, and then choose the device certificate that you created and registered in Creating a BYOC (ECDSA) (p. 60).
3. Choose **Actions**, and then choose **Attach policy**.
4. Find and choose the AWS IoT policy that you created and attached to your RSA certificate in the Connecting your device to AWS IoT (p. 53) instructions, and then choose **Attach**.

To attach a thing to your device certificate

1. From the **Certificates** page, find and choose the same device certificate, choose **Actions**, and then choose **Attach thing**.
2. Find and choose the thing that you created for your device, and then choose **Attach**.

To format the certificate for *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h

1. In a browser window, open *freertos*/tools/certificate_configuration/PEMfileToCString.html.
2. Under **PEM Certificate or Key**, choose the *ID*-certificate.pem.crt that you created and then modified.
3. Choose **Display formatted PEM string to be copied into aws_clientcredential_keys.h**, and then copy the certificate string.
4. Open *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h, and paste the formatted certificate string into the definition for `tlstestCLIENT_BYOC_CERTIFICATE_PEM`.

   Note
   The certificate is hard-coded for demonstration purposes only. Production-level applications should store these files in a secure location.
5. Follow the same steps to get the formatted string for the private key file that you created. Copy and paste the formatted private key string into the definition for `tlstestCLIENT_BYOC_PRIVATE_KEY_PEM` in *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h.

TLS_ConnectUntrustedCert()

You can use your own certificate for authentication, without registering your certificate with AWS IoT. To create a certificate with a valid rootCA/CA chain, follow the instructions in Creating a BYOC (ECDSA) (p. 60), but skip the final instructions for registering your device with AWS IoT.

To format the certificate for *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h

1. In a browser window, open *freertos*/tools/certificate_configuration/PEMfileToCString.html.
2. Under **PEM Certificate or Key**, choose the *ID*-certificate.pem.crt that you created and then modified.
3. Choose **Display formatted PEM string to be copied into aws_clientcredential_keys.h**, and then copy the certificate string.
4. Open *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h, and paste the formatted certificate string into the definition for tlstestCLIENT_UNTRUSTED_CERTIFICATE_PEM.

   Note
   The certificate is hard-coded for demonstration purposes only. Production-level applications should store these files in a secure location.
5. Follow the same steps to get the formatted string for the private key file that you created. Copy and paste the formatted private key string into the definition for tlstestCLIENT_UNTRUSTED_PRIVATE_KEY_PEM in *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h.

Creating a BYOC (ECDSA)

In these procedures, you use the AWS IoT console, the AWS Command Line Interface, and OpenSSL to create and register certificates and keys for a device on the AWS Cloud. Make sure that you have installed and configured the AWS CLI on your machine before you run the AWS CLI commands.

Note
When you create CA certificates, use valid, consistent values for the Distinguished Name (DN) fields, when prompted. For the Common Name field, you can use any value, unless otherwise instructed.

To generate a root CA

1. Use the following command to generate a root CA private key:

```
openssl ecparam -name prime256v1 -genkey -noout -out rootCA.key
```

2. Use the following command to generate a root CA certificate:

```
openssl req -x509 -new -nodes -key rootCA.key -sha256 -days 1024 -out rootCA.crt
```

To generate an intermediate CA

1. Create required files:

```
touch index.txt
```

```
echo 1000 > serial
```

2. Save the ca.config (p. 62) file in the current working directory.
3. Use the following command to generate the intermediate CA's private key:

```
openssl ecparam -name prime256v1 -genkey -noout -out intermediateCA.key
```

4. Use the following command to generate the intermediate CA's CSR:

```
openssl req -new -sha256 -key intermediateCA.key -out intermediateCA.csr
```

5. Use the following command to sign the intermediate CA's CSR with the root CA:

```
openssl ca -config ca.config -notext -cert rootCA.crt -keyfile rootCA.key -days 500 -in
 intermediateCA.csr -out intermediateCA.crt
```

To generate a device certificate

Note
An ECDSA certificate is used here as an example.

1. Use the following command to generate a private key:

```
openssl ecparam -name prime256v1 -genkey -noout -out deviceCert.key
```

2. Use the following command to generate a CSR for a device certificate:

```
openssl req -new -key deviceCert.key -out deviceCert.csr
```

3. Use the following command to sign the device certificate with the intermediate CA:

```
openssl x509 -req -in deviceCert.csr -CA intermediateCA.crt -CAkey intermediateCA.key -
CAcreateserial -out deviceCert.crt -days 500 -sha256
```

To register both CA certificates

1. Use the following AWS CLI command to get the registration code:

```
aws iot get-registration-code
```

2. Use the following command to generate a private key for verification certificates:

```
openssl ecparam -name prime256v1 -genkey -noout -out verificationCert.key
```

3. Use the following command to create CSR for verification certificates:

```
openssl req -new -key verificationCert.key -out verificationCert.csr
```

When prompted, for `Common Name`, enter the registration code that you obtained in the first step.

4. Use the following command to sign a verification certificate using the root CA:

```
openssl x509 -req -in verificationCert.csr -CA rootCA.crt -CAkey rootCA.key -
CAcreateserial -out rootCAverificationCert.crt -days 500 -sha256
```

5. Use the following command to sign a verification certificate using the intermediate CA:

```
openssl x509 -req -in verificationCert.csr -CA intermediateCA.crt -CAkey
 intermediateCA.key -CAcreateserial -out intermediateCAverificationCert.crt -days 500 -
sha256
```

6. Use the following AWS CLI commands to register both CA certificates with AWS IoT:

```
aws iot register-ca-certificate --ca-certificate file://rootCA.crt --verification-cert
 file://rootCAverificationCert.crt
```

```
aws iot register-ca-certificate --ca-certificate file://intermediateCA.crt --
verification-cert file://intermediateCAverificationCert.crt
```

7. Use the following AWS CLI command to activate both CA certificates:

```
aws iot update-ca-certificate --certificate-id ID --new-status ACTIVE
```

   Where *ID* is the certificate ID of one of the certificates.

To register the device certificate

1. Use the following AWS CLI command to register the device certificate with AWS IoT:

```
aws iot register-certificate --certificate-pem file://deviceCert.crt --ca-certificate-
pem file://intermediateCA.crt
```

2. Use the following AWS CLI command to activate the device certificate:

```
aws iot update-certificate --certificate-id ID --new-status ACTIVE
```

   Where *ID* is the certificate ID of the certificate.

ca.config

Save the following text to a file named `ca.config` in your current working directory.

This file is a modified version of the `openssl.cnf` OpenSSL example configuration file.

```
#
# OpenSSL example configuration file.
# This is mostly being used for generation of certificate requests.
#


# This definition stops the following lines choking if HOME isn't
# defined.
HOME            = .
RANDFILE        = $ENV::HOME/.rnd


# Extra OBJECT IDENTIFIER info:
#oid_file        = $ENV::HOME/.oid
oid_section        = new_oids

# To use this configuration file with the "-extfile" option of the
# "openssl x509" utility, name here the section containing the
# X.509v3 extensions to use:
```

```
# extensions        =
# (Alternatively, use a configuration file that has only
# X.509v3 extensions in its main [= default] section.)

[ new_oids ]

# We can add new OIDs in here for use by 'ca', 'req' and 'ts'.
# Add a simple OID like this:
# testoid1=1.2.3.4
# Or use config file substitution like this:
# testoid2=${testoid1}.5.6

# Policies used by the TSA examples.
tsa_policy1 = 1.2.3.4.1
tsa_policy2 = 1.2.3.4.5.6
tsa_policy3 = 1.2.3.4.5.7

####################################################################
[ ca ]
default_ca    = CA_default        # The default ca section

####################################################################
[ CA_default ]

dir        = .                     # Where everything is kept
certs        = $dir             # Where the issued certs are kept
crl_dir        = $dir             # Where the issued crl are kept
database    = $dir/index.txt    # database index file.
#unique_subject    = no            # Set to 'no' to allow creation of
                    # several ctificates with same subject.
new_certs_dir    = $dir             # default place for new certs.

certificate    = $dir/cacert.pem     # The CA certificate
serial        = $dir/serial         # The current serial number
crlnumber    = $dir/crlnumber    # the current crl number
                    # must be commented out to leave a V1 CRL
crl        = $dir/crl.pem         # The current CRL
private_key    = $dir/private/cakey.pem# The private key
RANDFILE    = $dir/private/.rand    # private random number file


x509_extensions    = usr_cert        # The extentions to add to the cert

# Comment out the following two lines for the "traditional"
# (and highly broken) format.
name_opt     = ca_default        # Subject Name options
cert_opt     = ca_default        # Certificate field options

# Extension copying option: use with caution.
# copy_extensions = copy

# Extensions to add to a CRL. Note: Netscape communicator chokes on V2 CRLs
# so this is commented out by default to leave a V1 CRL.
# crlnumber must also be commented out to leave a V1 CRL.
# crl_extensions    = crl_ext

default_days    = 365            # how long to certify for
default_crl_days= 30            # how long before next CRL
default_md    = default        # use public key default MD
preserve    = no            # keep passed DN ordering

# A few difference way of specifying how similar the request should look
# For type CA, the listed attributes must be the same, and the optional
# and supplied fields are just that :-)
policy        = policy_match
```

```
# For the CA policy
[ policy_match ]
countryName         = match
stateOrProvinceName     = match
organizationName    = match
organizationalUnitName      = optional
commonName          = supplied
emailAddress        = optional

# For the 'anything' policy
# At this point in time, you must list all acceptable 'object'
# types.
[ policy_anything ]
countryName         = optional
stateOrProvinceName     = optional
localityName        = optional
organizationName    = optional
organizationalUnitName      = optional
commonName          = supplied
emailAddress        = optional

####################################################################
[ req ]
default_bits        = 2048
default_keyfile     = privkey.pem
distinguished_name      = req_distinguished_name
attributes          = req_attributes
x509_extensions     = v3_ca     # The extentions to add to the self signed cert

# Passwords for private keys if not present they will be prompted for
# input_password = secret
# output_password = secret

# This sets a mask for permitted string types. There are several options.
# default: PrintableString, T61String, BMPString.
# pkix     : PrintableString, BMPString (PKIX recommendation before 2004)
# utf8only: only UTF8Strings (PKIX recommendation after 2004).
# nombstr : PrintableString, T61String (no BMPStrings or UTF8Strings).
# MASK:XXXX a literal mask value.
# WARNING: ancient versions of Netscape crash on BMPStrings or UTF8Strings.
string_mask = utf8only

# req_extensions = v3_req # The extensions to add to a certificate request

[ req_distinguished_name ]
countryName             = Country Name (2 letter code)
countryName_default         = AU
countryName_min             = 2
countryName_max             = 2

stateOrProvinceName         = State or Province Name (full name)
stateOrProvinceName_default     = Some-State

localityName            = Locality Name (eg, city)

0.organizationName          = Organization Name (eg, company)
0.organizationName_default      = Internet Widgits Pty Ltd

# we can do this but it is not needed normally :-)
#1.organizationName         = Second Organization Name (eg, company)
#1.organizationName_default     = World Wide Web Pty Ltd

organizationalUnitName          = Organizational Unit Name (eg, section)
#organizationalUnitName_default     =

commonName              = Common Name (e.g. server FQDN or YOUR name)
```

```
commonName_max            = 64

emailAddress            = Email Address
emailAddress_max        = 64

# SET-ex3            = SET extension number 3

[ req_attributes ]
challengePassword        = A challenge password
challengePassword_min        = 4
challengePassword_max        = 20

unstructuredName        = An optional company name

[ usr_cert ]

# These extensions are added when 'ca' signs a request.

# This goes against PKIX guidelines but some CAs do it and some software
# requires this to avoid interpreting an end user certificate as a CA.

basicConstraints=CA:TRUE

# Here are some examples of the usage of nsCertType. If it is omitted
# the certificate can be used for anything *except* object signing.

# This is OK for an SSL server.
# nsCertType            = server

# For an object signing certificate this would be used.
# nsCertType = objsign

# For normal client use this is typical
# nsCertType = client, email

# and for everything including object signing:
# nsCertType = client, email, objsign

# This is typical in keyUsage for a client certificate.
# keyUsage = nonRepudiation, digitalSignature, keyEncipherment

# This will be displayed in Netscape's comment listbox.
nsComment            = "OpenSSL Generated Certificate"

# PKIX recommendations harmless if included in all certificates.
subjectKeyIdentifier=hash
authorityKeyIdentifier=keyid,issuer

# This stuff is for subjectAltName and issuerAltname.
# Import the email address.
# subjectAltName=email:copy
# An alternative to produce certificates that aren't
# deprecated according to PKIX.
# subjectAltName=email:move

# Copy subject details
# issuerAltName=issuer:copy

#nsCaRevocationUrl        = http://www.domain.dom/ca-crl.pem
#nsBaseUrl
#nsRevocationUrl
#nsRenewalUrl
#nsCaPolicyUrl
#nsSslServerName

# This is required for TSA certificates.
```

```
# extendedKeyUsage = critical,timeStamping

[ v3_req ]

# Extensions to add to a certificate request

basicConstraints = CA:FALSE
keyUsage = nonRepudiation, digitalSignature, keyEncipherment

[ v3_ca ]


# Extensions for a typical CA


# PKIX recommendation.

subjectKeyIdentifier=hash

authorityKeyIdentifier=keyid:always,issuer

# This is what PKIX recommends but some broken software chokes on critical
# extensions.


#basicConstraints = critical,CA:true
# So we do this instead.
basicConstraints = CA:true



# Key usage: this is typical for a CA certificate. However since it will
# prevent it being used as a test self-signed certificate it is best
# left out by default.
# keyUsage = cRLSign, keyCertSign

# Some might want this also
# nsCertType = sslCA, emailCA

# Include email address in subject alt name: another PKIX recommendation
# subjectAltName=email:copy
# Copy issuer details
# issuerAltName=issuer:copy

# DER hex encoding of an extension: beware experts only!
# obj=DER:02:03
# Where 'obj' is a standard or added object
# You can even override a supported extension:
# basicConstraints= critical, DER:30:03:01:01:FF

[ crl_ext ]

# CRL extensions.
# Only issuerAltName and authorityKeyIdentifier make any sense in a CRL.

# issuerAltName=issuer:copy
authorityKeyIdentifier=keyid:always

[ proxy_cert_ext ]
# These extensions should be added when creating a proxy certificate

# This goes against PKIX guidelines but some CAs do it and some software
# requires this to avoid interpreting an end user certificate as a CA.

basicConstraints=CA:FALSE
```

```
# Here are some examples of the usage of nsCertType. If it is omitted
# the certificate can be used for anything *except* object signing.

# This is OK for an SSL server.
# nsCertType            = server

# For an object signing certificate this would be used.
# nsCertType = objsign

# For normal client use this is typical
# nsCertType = client, email

# and for everything including object signing:
# nsCertType = client, email, objsign

# This is typical in keyUsage for a client certificate.
# keyUsage = nonRepudiation, digitalSignature, keyEncipherment

# This will be displayed in Netscape's comment listbox.
nsComment            = "OpenSSL Generated Certificate"

# PKIX recommendations harmless if included in all certificates.
subjectKeyIdentifier=hash
authorityKeyIdentifier=keyid,issuer

# This stuff is for subjectAltName and issuerAltname.
# Import the email address.
# subjectAltName=email:copy
# An alternative to produce certificates that aren't
# deprecated according to PKIX.
# subjectAltName=email:move

# Copy subject details
# issuerAltName=issuer:copy

#nsCaRevocationUrl        = http://www.domain.dom/ca-crl.pem
#nsBaseUrl
#nsRevocationUrl
#nsRenewalUrl
#nsCaPolicyUrl
#nsSslServerName

# This really needs to be in place for it to be a proxy certificate.
proxyCertInfo=critical,language:id-ppl-anyLanguage,pathlen:3,policy:foo

####################################################################
[ tsa ]

default_tsa = tsa_config1    # the default TSA section

[ tsa_config1 ]

# These are used by the TSA reply generation only.
dir        = ./demoCA        # TSA root directory
serial        = $dir/tsaserial    # The current serial number (mandatory)
crypto_device    = builtin        # OpenSSL engine to use for signing
signer_cert    = $dir/tsacert.pem     # The TSA signing certificate
                  # (optional)
certs        = $dir/cacert.pem    # Certificate chain to include in reply
                  # (optional)
signer_key    = $dir/private/tsakey.pem # The TSA private key (optional)



default_policy    = tsa_policy1        # Policy if request did not specify it
                    # (optional)
```

```
other_policies    = tsa_policy2, tsa_policy3    # acceptable policies (optional)
digests        = md5, sha1        # Acceptable message digests (mandatory)
accuracy    = secs:1, millisecs:500, microsecs:100    # (optional)
clock_precision_digits  = 0    # number of digits after dot. (optional)
ordering        = yes    # Is ordering defined for timestamps?
                # (optional, default: no)
tsa_name        = yes    # Must the TSA name be included in the reply?
                # (optional, default: no)
ess_cert_id_chain    = no    # Must the ESS cert id chain be included?
                # (optional, default: no)
```

Testing

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

> **Important**
> In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the TLS library in the IDE project

1. Add `iot_tls.c` to the `aws_tests` IDE project.
2. Add the source file `iot_test_tls.c` to the virtual folder `aws_tests/application_code/common_tests/tls`. This file includes the TLS tests.

Configuring the `CMakeLists.txt` file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

Setting up your local testing environment

There are five separate tests for the TLS port, one for each type of authentication supported by the FreeRTOS TLS library:

- `TLS_ConnectRSA()`
- `TLS_ConnectEC()`
- `TLS_ConnectMalformedCert()`
- `TLS_ConnectBYOCCredentials()`
- `TLS_ConnectUntrustedCert()`

To run these tests, your board must use the MQTT protocol to communicate with the AWS Cloud. AWS IoT hosts an MQTT broker that sends and receives messages to and from connected devices at the edge. The AWS IoT MQTT broker accepts mutually authenticated TLS connections only.

Follow the instructions in Connecting your device to AWS IoT (p. 53) to connect your device to AWS IoT.

Each TLS test requires a different certificate/key combination, formatted and defined in either *freertos*/tests/include/aws_clientcredential_keys.h or *freertos*/libraries/freertos_plus/standard/tls/test/iot_test_tls.h.

Follow the instructions in Setting up certificates and keys for the TLS tests (p. 55) to obtain the certificates and keys that you need for testing.

After you set up the library in the IDE project, you need to configure some other files for testing.

To configure the source and header files for the TLS tests

1. To enable the TLS tests, open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/aws_test_runner_config.h, and set the testrunnerFULL_TLS_ENABLED macro to 1.
2. Open *freertos*/libraries/freertos_plus/standard/utils/src/iot_system_init.c, and in the function SYSTEM_Init(), make sure that the line that calls SOCKETS_Init() is uncommented.

Running the tests

To execute the TLS tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console.

```
Starting Tests...

TEST(Full_TLS, AFQP_TLS_ConnectEC) PASS

TEST(Full_TLS, TLS_ConnectRSA) PASS

TEST(Full_TLS, TLS_ConnectMalformedCert) PASS

TEST(Full_TLS, TLS_ConnectUntrustedCert) PASS

TEST(Full_TLS, AFQP_TLS_ConnectBYOCCredentials) PASS

-----------------------
5 Tests 0 Failures 0 Ignored
OK
-------ALL TESTS FINISHED-------
```

If all tests pass, then testing is complete.

Important
After you have ported the TLS library and tested your ports, you must run the Secure Socket tests that depend on TLS functionality. For more information, see Testing (p. 41) in the Secure Sockets porting documentation.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you finish porting the FreeRTOS TLS library to your device, you can start setting up the coreMQTT library for testing. See Configuring the coreMQTT library for testing (p. 70) for instructions.

Configuring the coreMQTT library for testing

Devices on the edge can use the MQTT protocol to communicate with the AWS Cloud. AWS IoT hosts an MQTT broker that sends and receives messages to and from connected devices at the edge.

The coreMQTT library implements the MQTT protocol for devices running FreeRTOS. The coreMQTT library doesn't need to be ported, but your device's test project must pass all MQTT tests for qualification. For more information, see coreMQTT Library in the *FreeRTOS User Guide*.

Prerequisites

To set up the coreMQTT library tests, you need the following:

- A port of the TLS library.

  For information about porting the TLS library to your platform, see Porting the TLS library (p. 52).

If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

To set up the coreMQTT library in the IDE project

1. Add all the library source files in the *`freertos`*`/libraries/coreMQTT/source` directory and its subdirectories to the `aws_tests` IDE project.
2. Add all the source files for the network layer (used in the tests) in the *`freertos`*`/libraries/abstractions/transport` directory and `secure_sockets` subdirectory to the `aws_tests` IDE project.
3. Add a `core_mqtt_config.h` file, required for building the coreMQTT library, to the config files directory at *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files`.
4. Add the test source file at *`freertos`*`/tests/integration_test/core_mqtt_system.c` to the `aws_tests` IDE project.

Setting up your local testing environment

After you set up the library in the IDE project, you need to configure other files for testing.

To configure the source and header files for the MQTT tests

- To enable the MQTT tests, open *`freertos`*`/vendors/`*`vendor-name`*`/boards/`*`board-name`*`/aws_tests/config_files/aws_test_runner_config.h`, and set the `testrunnerFULL_CORE_MQTT_AWS_IOT_ENABLED` macro to `1`.

Running the tests

To execute the MQTT tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console. If all tests pass, then testing is complete.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you set up the coreMQTT library for your device, you can start porting the OTA agent library. See Porting the AWS IoT over-the-air update library (p. 72) for instructions.

If your device doesn't support OTA functionality, you can start porting the Bluetooth Low Energy library. See Porting the Bluetooth Low Energy library (p. 81) for instructions.

If your device doesn't support OTA and Bluetooth Low Energy functionality, then you are finished porting and can start the FreeRTOS qualification process. See the FreeRTOS Qualification Guide for more information.

Configuring the coreHTTP library for testing

Devices on the edge can use the HTTP protocol to communicate with the AWS Cloud. AWS IoT services host an HTTP server that sends and receives messages to and from connected devices at the edge.

Prerequisites

To set up the coreHTTP library tests, you need the following:

- A port of the TLS library.

  For information about porting the TLS library to your platform, see Porting the TLS library (p. 52).

If you're using an IDE to build test projects, you must set up your library port in the IDE project.

Setting up the IDE test project

To set up the coreHTTP library in the IDE project

1. Add all of the test source files in the *freertos*`/libraries/coreHTTP/source` directory and its subdirectories to the `aws_tests` IDE project.
2. Add all the source files for the network layer (used in the tests) in the *freertos*`/libraries/abstractions/transport` directory and the `secure_sockets` subdirectory to the `aws_tests` IDE project.
3. Add a `core_http_config.h` file to the config files directory at *freertos*`/vendors/vendor/boards/board/aws_tests/config_files`. This file is required to build the coreHTTP library.
4. Add the test source file at *freertos*`/tests/integration_test/core_http_system.c` to the `aws_tests` IDE project.

Setting up your local testing environment

After you set up the library in the IDE project, you must configure other files for testing.

To configure the source and header files for the HTTP tests

- To enable the HTTP tests, open the *freertos*/vendors/*vendor-name*/boards/*board-name*/aws_tests/config_files/aws_test_runner_config.h file and set the testrunnerFULL_CORE_HTTP_AWS_IOT_ENABLED macro to 1.

Running the tests

To run the HTTP tests

1. Build the test project, and then flash it to your device so that you can run it.
2. Check the test results in the UART console. If all tests pass, then testing is complete.

Porting the AWS IoT over-the-air update library

With FreeRTOS over-the-air (OTA) updates, you can do the following:

- Deploy new firmware images to a single device, a group of devices, or your entire fleet.
- Deploy firmware to devices as they are added to groups, are reset, or are reprovisioned.
- Verify the authenticity and integrity of new firmware after it has been deployed to devices.
- Monitor the progress of a deployment.
- Debug a failed deployment.
- Digitally sign firmware using Code Signing for AWS IoT.

For more information, see FreeRTOS Over-the-Air Updates in the *FreeRTOS User Guide* along with the AWS IoT Over-the-air Update Documentation.

You can use the OTA update library to integrate OTA functionality into your FreeRTOS applications. For more information, see FreeRTOS OTA update Library in the *FreeRTOS User Guide*.

FreeRTOS devices must enforce cryptographic code-signing verification on the OTA firmware images that they receive. We recommend the following algorithms:

- Elliptic-Curve Digital Signature Algorithm (ECDSA)
- NIST P256 curve
- SHA-256 hash

> **Note**
> A port of the FreeRTOS OTA update library is currently not required for device qualification.

Prerequisites

- Complete the instructions in Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- Create a port of the TLS library.

For information, see Porting the TLS library (p. 52).

- Create a bootloader that can support OTA updates.

  For more information about porting a bootloader demo application, see Porting the bootloader demo (p. 74).

Platform porting

You must provide an implementation of the OTA portable abstraction layer (PAL) to port the OTA library to a new device. The *freertos*/vendors/*vendor*/boards/*board*/ports/ota_pal_for_aws/ directory contains the `ota_pal.h` and `ota_pal.c` template files. The `ota_pal.c` file contains empty definitions of a set of platform abstraction layer (PAL) functions. At a minimum, you must implement the set of functions listed in the following table. For an example, see the Windows Simulator OTA PAL implementation.

Function name	Description
`otaPal_Abort`	Stops an OTA update.
`otaPal_CreateFileForRx`	Creates a file to store the received data chunks.
`otaPal_CloseFile`	Closes the specified file. This might authenticate the file if you use storage that implements cryptographic protection.
`otaPal_WriteBlock`	Writes a block of data to the specified file at the given offset. On success, the function returns the number of bytes written. Otherwise, the function returns a negative error code. The block size will always be a power of two and so will be aligned. For more information, see the OTA library configuration documentation.
`otaPal_ActivateNewImage`	Activates or launches the new firmware image. For some ports, if the device is programmatically reset synchronously, this function might not return.
`otaPal_SetPlatformImageState`	Does what is required by the platform to accept or reject the most recent OTA firmware image (or bundle). To determine how to implement this function, see the documentation for your board (platform) details and architecture.
`otaPal_GetPlatformImageState`	Gets the state of the OTA update image.

Implement the functions in this table if your device has built-in support for them.

Function name	Description
`otaPal_CheckFileSignature`	Verifies the signature of the specified file.
`otaPal_ReadAndAssumeCertificate`	Reads the specified signer certificate from the file system and returns it to the caller.
`otaPal_ResetDevice`	Resets the device.

Note
Make sure that you have a bootloader that can support OTA updates. For instructions about how to port the bootloader demo application provided with FreeRTOS or create your IoT device bootloader, see IoT device bootloader (p. 74).

Additional Information

The portable abstraction layer (PAL) enables the OTA update library to be independent of any specific hardware platform. The OTA library depends on interfaces to remain independent of the operating system and MQTT protocol implementation. If your application performs OTA over HTTP, then there is also an interface for the HTTP protocol implementation. The example applications in FreeRTOS use ports for these interfaces that are common to all of the platforms. Because of this, the PAL is the only interface that must be ported before a new platform can use the OTA library. Information on these interfaces can be found in the FreeRTOS documentation for the OTA update library.

IoT device bootloader

Porting the bootloader demo

The v202012.00 release of FreeRTOS includes a demo bootloader application for the Microchip Curiosity PIC32MZEF platform. For more information, see Demo Bootloader for the Microchip Curiosity PIC32MZEF in the *FreeRTOS User Guide*. You can port this demo to other platforms. If you don't port the demo to your platform, you can use your own bootloader application. For more information about how to write your own secure bootloader application, see Threat modeling for the IoT device bootloader (p. 74).

Threat modeling for the IoT device bootloader

Background

As a working definition, the embedded IoT devices referenced by this threat model are microcontroller-based products that interact with cloud services. They may be deployed in consumer, commercial, or industrial settings. IoT devices may gather data about a user, a patient, a machine, or an environment, and may control anything from light bulbs and door locks to factory machinery.

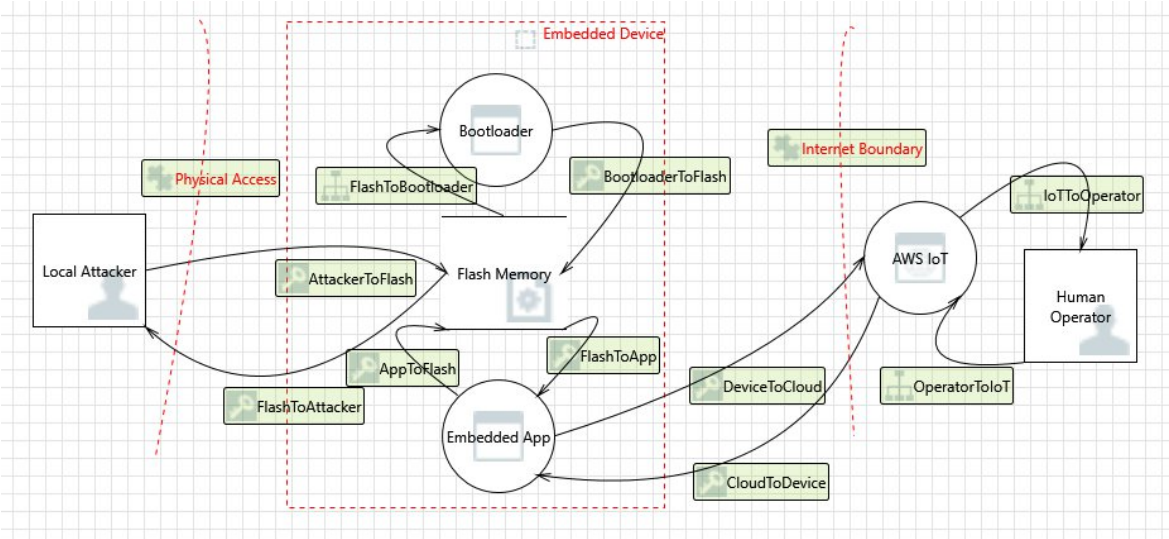
Threat modeling is an approach to security from the point of view of a hypothetical adversary. By considering the adversary's goals and methods, a list of threats is created. Threats are attacks against a resource or asset performed by an adversary. The list is prioritized and used to identify or create mitigations. When choosing mitigations, the cost of implementing and maintaining them should be balanced with the real security value they provide. There are multiple threat model methodologies. Each is capable of supporting the development of a secure and successful IoT product.

FreeRTOS offers OTA ("over-the-air") software updates to IoT devices. The update facility combines cloud services with on-device software libraries and a partner-supplied bootloader. This threat model focuses specifically on threats against the bootloader.

Bootloader use cases

- Digitally sign and encrypt firmware before deployment.
- Deploy new firmware images to a single device, a group of devices, or an entire fleet.
- Verify the authenticity and integrity of new firmware after it's deployed to devices.
- Devices only run unmodified software from a trusted source.
- Devices are resilient to faulty software received through OTA.

Data Flow Diagram



Threats

Some attacks will have multiple mitigations; for example, a network man-in-the-middle intended to deliver a malicious firmware image is mitigated by verifying trust in both the certificate offered by the TLS server and the code-signer certificate of the new firmware image. To maximize the security of the bootloader, any non-bootloader mitigations are considered unreliable. The bootloader should have intrinsic mitigations for each attack. Having layered mitigations is known as defense-in-depth.

Threats:

- An attacker hijacks the device's connection to the server to deliver a malicious firmware image.

  Mitigation example

  - Upon boot, the bootloader verifies the cryptographic signature of the image using a known certificate. If the verification fails, the bootloader rolls back to the previous image.
- An attacker exploits a buffer overflow to introduce malicious behavior to the existing firmware image stored in flash.

  Mitigation examples

  - Upon boot, the bootloader verifies, as previously described. When verification fails with no previous image available, the bootloader halts.
  - Upon boot, the bootloader verifies, as previously described. When verification fails with no previous image available, the bootloader enters a fail safe OTA only mode.
- An attacker boots the device to a previously stored image, which is exploitable.

  Mitigation examples

  - Flash sectors storing the last image are erased upon successful installation and test of a new image.
  - A fuse is burned with each successful upgrade, and each image refuses to run unless the correct number of fuses have been burned.
- An OTA update delivers a faulty or malicious image that bricks the device.

  Mitigation example

  - The bootloader starts a hardware watchdog timer that triggers rollback to the previous image.

- An attacker patches the bootloader to bypass image verification so the device will accept unsigned images.

  Mitigation examples

  - The bootloader is in ROM (read-only memory), and cannot be modified.
  - The bootloader is in OTP (one-time-programmable memory), and cannot be modified.
  - The bootloader is in the secure zone of ARM TrustZone, and cannot be modified.
- An attacker replaces the verification certificate so the device will accept malicious images.

  Mitigation examples

  - The certificate is in a cryptographic co-processor, and cannot be modified.
  - The certificate is in ROM (or OTP, or secure zone), and cannot be modified.

Further threat modeling

This threat model considers only the bootloader. Further threat modeling could improve overall security. A recommended method is to list the adversary's goals, the assets targeted by those goals, and points of entry to the assets. A list of threats can be made by considering attacks on the points of entry to gain control of the assets. The following are lists of examples of goals, assets, and entry points for an IoT device. These lists are not exhaustive, and are intended to spur further thought.

Adversary's goals

- Extort money
- Ruin reputations
- Falsify data
- Divert resources
- Remotely spy on a target
- Gain physical access to a site
- Wreak havoc
- Instill terror

Key assets

- Private keys
- Client certificate
- CA root certificates
- Security credentials and tokens
- Customer's personally identifiable information
- Implementations of trade secrets
- Sensor data
- Cloud analytics data store
- Cloud infrastructure

Entry points

- DHCP response
- DNS response
- MQTT over TLS

- HTTPS response
- OTA software image
- Other, as dictated by application, for example, USB
- Physical access to bus
- Decapped IC

Testing

If you're using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you're using an IDE for porting and testing, you must add some source files to the IDE test project before you can test your ported code. This includes code for the OTA library, PAL port, and OTA test code.

> **Important**
> In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Don't create duplicate copies of source files.

In this procedure, you add files for the OTA library, OTA port, and OTA test code to your test IDE project.

To set up your IDE test project

1. Add the OTA library code to your project:
   a. In a text editor, open the *freertos*`/libraries/ota_for_aws/otaFilePaths.cmake` file to see various CMake variables related to building the OTA library.
   b. Add the files listed in the variables `OTA_SOURCES`, `OTA_OS_FREERTOS_SOURCES`, `OTA_HTTP_SOURCES` (for the OTA over HTTP demo), and `OTA_MQTT_SOURCES` to your IDE project.
   c. Add the include paths listed in the variables `OTA_INCLUDE_PUBLIC_DIRS`, `OTA_INCLUDE_PRIVATE_DIRS`, and `OTA_INCLUDE_OS_FREERTOS_DIRS` to your IDE project.
2. Add the OTA PAL code to the project:
   a. Add *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/ota_pal_for_aws/` to your include path.
   b. Add the `ota_pal.c` and `ota_pal.h` files located in the *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/ota_pal_for_aws/` directory to your project.
   c. Add any platform specific files or include paths to your project.
3. Add the OTA test source file to the project:
   a. Add all source files located in *freertos*`\tests\integration_test\ota_pal` and its subdirectories to your project.
   b. Add *freertos*`\tests\integration_test\ota_pal` and *freertos*`\tests\integration_test\ota_pal\test_files` to the include path of your test project.
4. Add the OTA related config files to the test project:
   - Add the `ota_config.h` file (for the aws_demo project) and the `aws_test_ota_config.h` file (for the aws_test project) to the config files directory at *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files`.

     You can find examples in the *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files` directory.

For an example of an IDE test project for OTA, see the GitHub website.

Configuring the `CMakeLists.txt` file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in `CMakeLists.txt`, follow the instructions in FreeRTOS portable layers (p. 16).

The `CMakeLists.txt` template list file under *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/CMakeLists.txt` includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

The following is an example of a portable layer target definition for the OTA library.

```
# Over-the-air Updates
afr_mcu_port(ota)
target_sources(
    AFR::ota::mcu_port
    INTERFACE
        "${afr_ports_dir}/ota_pal_for_aws/ota_pal.c"
        "${afr_ports_dir}/ota_pal_for_aws/ota_pal.h"
        # Add platform specific files that are required to build ota_pal.c.
)

target_include_directories(
    AFR::ota::mcu_port
    INTERFACE "${afr_ports_dir}/ota_pal_for_aws"
    # Add platform specific include paths that are required to build ota_pal.c.
)

target_link_libraries(
    AFR::ota::mcu_port
    INTERFACE
        AFR::crypto
        AFR::ota
        # Add platform specific target dependencies that are required to build ota_pal.c.
)

# The qualification tests for the OTA PAL port requires this include path to run.
if(AFR_ENABLE_TESTS)
    target_include_directories(
        AFR::ota::mcu_port
        INTERFACE "${PROJECT_SOURCE_DIR}/tests/integration_test/ota_pal"
    )
endif()
```

You can find an example `CMakeLists.txt` file for the Windows Simulator platform on GitHub.

OTA PAL tests

Setting up the local testing environment

To configure the source and header files for the OTA PAL tests

1. In a text editor, open the *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/aws_test_runner_config.h` file, and set the `testrunnerFULL_OTA_PAL_ENABLED` macro to **1** to enable the PAL tests.

2. Open the *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/aws_test_ota_config.h file, and configure it for your platform. You can find the specific details on what configurations exist and how to set them in the configuration file.
3. Choose a signing certificate for your device from *freertos*/tests/integration_test/ota_pal/test_files. The certificates are used in the OTA tests for verification.

   Three types of signing certificates are available in the test code:

   - RSA/SHA1
   - RSA/SHA256
   - ECDSA/SHA256

   RSA/SHA1 and RSA/SHA256 are available for existing platforms only. ECDSA/SHA256 is recommended for OTA updates. If you have a different scheme, contact the FreeRTOS engineering team.

Running the tests

To run the OTA PAL tests

1. Build the test project, and then flash it to your device to run the tests.
2. Check the test results in the UART console.

```
---------STARTING TESTS---------

TEST(Full_OTA_PAL, otaPal_CloseFile_ValidSignature) PASS

TEST(Full_OTA_PAL, otaPal_CloseFile_InvalidSignatureBlockWritten) PASS

TEST(Full_OTA_PAL, otaPal_CloseFile_InvalidSignatureNoBlockWritten) PASS

TEST(Full_OTA_PAL, otaPal_CloseFile_NonexistingCodeSignerCertificate) PASS

TEST(Full_OTA_PAL, otaPal_CreateFileForRx_CreateAnyFile) PASS

TEST(Full_OTA_PAL, otaPal_Abort_OpenFile) PASS

TEST(Full_OTA_PAL, otaPal_Abort_FileWithBlockWritten) PASS

TEST(Full_OTA_PAL, otaPal_Abort_NullFileHandle) PASS

TEST(Full_OTA_PAL, otaPal_Abort_NonExistentFile) PASS

TEST(Full_OTA_PAL, otaPal_WriteBlock_WriteSingleByte) PASS

TEST(Full_OTA_PAL, otaPal_WriteBlock_WriteManyBlocks) PASS

TEST(Full_OTA_PAL, otaPal_ActivateNewImage_HappyPath) PASS

TEST(Full_OTA_PAL, otaPal_SetPlatformImageState_SelfTestImageState) PASS

TEST(Full_OTA_PAL, otaPal_SetPlatformImageState_InvalidImageState) PASS

TEST(Full_OTA_PAL, otaPal_SetPlatformImageState_UnknownImageState) PASS

TEST(Full_OTA_PAL, otaPal_SetPlatformImageState_RejectImageState) PASS

TEST(Full_OTA_PAL, otaPal_SetPlatformImageState_AcceptedImageStateButImageNotClosed) PASS

TEST(Full_OTA_PAL, otaPal_GetPlatformImageState_InvalidImageStateFromFileCloseFailure) PASS

TEST(Full_OTA_PAL, otaPal_ReadAndAssumeCertificate_ExistingFile) PASS

TEST(Full_OTA_PAL, otaPal_ReadAndAssumeCertificate_NonexistentFile) PASS

TEST(Full_OTA_PAL, prvPAL_CheckFileSignature_ValidSignature) PASS

TEST(Full_OTA_PAL, prvPAL_CheckFileSignature_InvalidSignatureBlockWritten) PASS

TEST(Full_OTA_PAL, prvPAL_CheckFileSignature_InvalidSignatureNoBlockWritten) PASS

TEST(Full_OTA_PAL, prvPAL_CheckFileSignature_NonexistingCodeSignerCertificate) PASS

TEST(Full_OTA_PAL, otaPal_CloseFile_ValidSignatureKeyInFlash) PASS


-----------------------

25 Tests 0 Failures 0 Ignored

OK

-------ALL TESTS FINISHED-------
```

Your platform passes the OTA PAL tests if there are 25 tests that ran with 0 failures and 0 ignores. At this point your platform can be used to run the OTA demo if you have configured your demo project.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you have ported the FreeRTOS OTA library and the bootloader demo, you can start porting the Bluetooth Low Energy library. For instructions, see Porting the Bluetooth Low Energy library (p. 81).

If your device does not support Bluetooth Low Energy functionality, then you are finished and can start the FreeRTOS qualification process. For more information, see the FreeRTOS Qualification Guide.

Porting the Bluetooth Low Energy library

You can use the FreeRTOS Bluetooth Low Energy library to provision Wi-Fi and send MQTT messages over Bluetooth Low Energy. The Bluetooth Low Energy library also includes higher-level APIs that you can use to communicate directly with the Bluetooth Low Energy stack. For more information, see FreeRTOS Bluetooth Low Energy Library in the FreeRTOS User Guide.

> **Note**
> A port of the FreeRTOS Bluetooth Low Energy library is currently not required for qualification.

Prerequisites

To port the Bluetooth Low Energy library, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes the vendor-supplied Bluetooth Low Energy drivers.

  For information about setting up a test project, see Setting Up Your FreeRTOS Source Code for Porting (p. 9).
- A validated configuration of the FreeRTOS kernel.

  For information about configuring the FreeRTOS kernel for your platform, see Configuring a FreeRTOS kernel port (p. 29).
- A Raspberry Pi 3 Model B+, with a memory card.

Porting

Three files in the *`freertos`*`/libraries/abstractions/ble_hal/include` folder define the FreeRTOS Bluetooth Low Energy APIs:

- `bt_hal_manager.h`
- `bt_hal_manager_adapter_ble.h`
- `bt_hal_gatt_server.h`

Each file includes comments that describe the APIs. You must implement the following APIs:

`bt_hal_manager.h`

- `pxBtManagerInit`

- `pxEnable`
- `pxDisable`
- `pxGetDeviceProperty`
- `pxSetDeviceProperty` (All options are mandatory except `eBTpropertyRemoteRssi` and `eBTpropertyRemoteVersionInfo`)
- `pxPair`
- `pxRemoveBond`
- `pxGetConnectionState`
- `pxPinReply`
- `pxSspReply`
- `pxGetTxpower`
- `pxGetLeAdapter`
- `pxDeviceStateChangedCb`
- `pxAdapterPropertiesCb`
- `pxSspRequestCb`
- `pxPairingStateChangedCb`
- `pxTxPowerCb`

`bt_hal_manager_adapter_ble.h`

- `pxRegisterBleApp`
- `pxUnregisterBleApp`
- `pxBleAdapterInit`
- `pxStartAdv`
- `pxStopAdv`
- `pxSetAdvData`
- `pxConnParameterUpdateRequest`
- `pxRegisterBleAdapterCb`
- `pxAdvStartCb`
- `pxSetAdvDataCb`
- `pxConnParameterUpdateRequestCb`
- `pxCongestionCb`

`bt_hal_gatt_server.h`

- `pxRegisterServer`
- `pxUnregisterServer`
- `pxGattServerInit`
- `pxAddService`
- `pxAddIncludedService`
- `pxAddCharacteristic`
- `pxSetVal`
- `pxAddDescriptor`

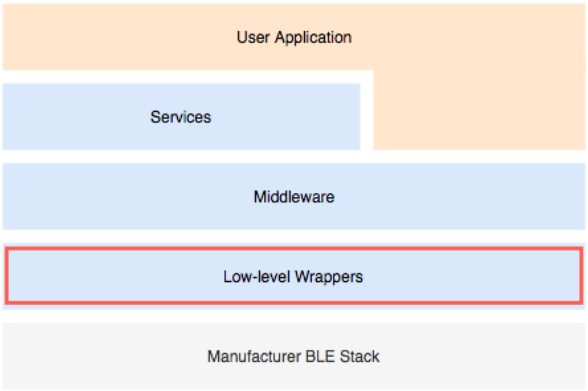
- `pxStartService`
- `pxStopService`
- `pxDeleteService`
- `pxSendIndication`
- `pxSendResponse`
- `pxMtuChangedCb`
- `pxCongestionCb`
- `pxIndicationSentCb`
- `pxRequestExecWriteCb`
- `pxRequestWriteCb`
- `pxRequestReadCb`
- `pxServiceDeletedCb`
- `pxServiceStoppedCb`
- `pxServiceStartedCb`
- `pxDescriptorAddedCb`
- `pxSetValCallbackCb`
- `pxCharacteristicAddedCb`
- `pxIncludedServiceAddedCb`
- `pxServiceAddedCb`
- `pxConnectionCb`
- `pxUnregisterServerCb`
- `pxRegisterServerCb`

Testing

This diagram shows the Bluetooth Low Energy testing framework.

To test your Bluetooth Low Energy ports, your computer communicates with an external, Bluetooth-enabled device (a Raspberry Pi 3 Model B+) over SSH, and with your device over Bluetooth Low Energy.

The Bluetooth Low Energy porting and qualification tests target the low-level wrapper layer that lies just above the manufacturer's hardware stack in the FreeRTOS Bluetooth Low Energy architecture:



If you are using an IDE to build test projects, you need to set up your library port in the IDE project.

Setting up the IDE test project

If you are using an IDE for porting and testing, you need to add some source files to the IDE test project before you can test your ported code.

> **Important**
> In the following steps, make sure that you add the source files to your IDE project from their on-disk location. Do not create duplicate copies of source files.

To set up the Bluetooth Low Energy library in the IDE project

1. Add all of the files in *freertos*/vendors/*vendor*/boards/*board*/ports/ble to your aws_tests IDE project.
2. Add all of the files in *freertos*/libraries/abstractions/ble_hal/include to your aws_tests IDE project.
3. Add all of the files in *freertos*/libraries/c_sdk/standard/ble to your aws_tests IDE project.
4. Open *freertos*/vendors/*vendor*/boards/*board*/aws_tests/application_code/main.c, and enable the required Bluetooth Low Energy drivers.

Configuring the CMakeLists.txt file

If you are using CMake to build your test project, you need to define a portable layer target for the library in your CMake list file.

To define a library's portable layer target in CMakeLists.txt, follow the instructions in FreeRTOS portable layers (p. 16).

The CMakeLists.txt template list file under *freertos*/vendors/*vendor*/boards/*board*/CMakeLists.txt includes example portable layer target definitions. You can uncomment the definition for the library that you are porting, and modify it to fit your platform.

Setting up your local testing environment

To set up the Raspberry Pi for testing

1. Follow the instructions in Setting up your Raspberry Pi to set up your Raspberry Pi with Raspbian OS.
2. Download bluez 5.50 from the kernel.org repository.
3. Follow the instructions in the README on the kernel.org repository to install bluez 5.50 on the Raspberry Pi.
4. Enable SSH on the Raspberry Pi. For instructions, see the Raspberry Pi documentation.
5. On your computer, open the *freertos*/libraries/abstractions/ble_hal/test/ble_test_scripts/runPI.sh script, and change the IP addresses in the first two lines to the IP address of your Raspberry Pi:

```
#!/bin/sh

scp * root@192.168.1.4:
ssh -t -t 192.168.1.4 -l root << 'ENDSSH'
rm -rf "/var/lib/bluetooth/*"
hciconfig hci0 reset
python test1.py
sleep 1
ENDSSH
```

Running the tests

To execute the Bluetooth Low Energy tests

1. Execute the `runPI.sh` script.
2. Clear any existing BLE bonds stored in the device.
3. Build the test project, and then flash it to your device for execution.
4. Check the test results in the UART console.

Validation

To officially qualify a device for FreeRTOS, you need to validate the device's ported source code with AWS IoT Device Tester. Follow the instructions in Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide to set up Device Tester for port validation. To test a specific library's port, the correct test group must be enabled in the `device.json` file in the Device Tester `configs` folder.

After you have ported the Bluetooth Low Energy library, you can start the FreeRTOS qualification process. For more information, see the FreeRTOS Qualification Guide.

If the device supports Over the Air Updates, then you should also validate Over the Air Updates over Bluetooth Low Energy using a companion device. For more details, see the next topic, Perform Over the Air Updates using Bluetooth Low Energy (p. 85).

Perform Over the Air Updates using Bluetooth Low Energy

Introduction

You can use the FreeRTOS Bluetooth Low Energy (BLE) and Over the Air Updates (OTA) libraries to perform a firmware update to a microcontroller device over Bluetooth Low Energy via an MQTT proxy running on a companion device. The update is performed using AWS IoT OTA jobs. The companion device connects to AWS IoT using Amazon Cognito credentials entered in a demo app. An authorized operator initiates the OTA update from the cloud. When the device connects through the demo app, the OTA update is initiated and the firmware is updated on the device.

Prerequisites

1. Port the Over The Air Updates agent to each microcontroller device:
   - Follow the steps in Platform porting (p. 73) and IoT device bootloader (p. 74).
   - After porting, follow the steps in Testing (p. 77) to verify that the OTA PAL tests pass.
2. Port the Bluetooth Low Energy library to each microcontroller:
   - Follow the steps in Porting the Bluetooth Low Energy library (p. 81).
3. Set up an AWS account if you don't already have one (the Free Tier is sufficient).
4. You must have access to an Android phone as the companion device with Android v 6.0 or later and Bluetooth version 4.2 or later.
5. Set up your development platform with:
   - Android Studio.

- The AWS CLI installed.
- Python3 installed.
- The boto3 AWS Software Developer Kit (SDK) for Python.

Setup

The following is an overview of the steps required for setup. You can skip steps 1 and 2 if you have already done these to test Over The Air Updates over WiFi or Ethernet.

1. Configure storage— Create an S3 bucket and policies and configure an IAM user that can perform updates.
2. Create a code-signing certificate— Create a signing certificate and allow the IAM user to sign firmware updates.
3. Configure Amazon Cognito authentication— Create a credential provider, user pool, and application access to the user pool.
4. Configure Amazon FreeRTOS— Set up Bluetooth Low Energy, client credentials, and the code-signing public certificate.
5. Configure an Android app— Set up the credential provider and user pool, then deploy the application to an Android device.

Step 1: Configure storage

You can skip these steps by launching the AWS CloudFormation template.

1. Create an S3 bucket with versioning enabled to hold the firmware images.
2. Create an OTA update service role and add the following managed policies to the role:
   - AWSIotLogging
   - AWSIotRuleActions
   - AWSIotThingsRegistration
   - AWSFreeRTOSOTAUpdate
3. Add an inline policy to the role to allow it to perform AWS IoT actions and allow access to the S3 bucket that you created.
4. Create an IAM user that can perform OTA updates. This user can sign and deploy firmware updates to AWS IoT devices in the account, and has access to do OTA updates on all devices. Access should be limited to trusted entities.
5. Attach permissions with an OTA user policy.
6. Create an inline policy that allows the IAM user you created to sign the firmware.

Step 2: Create the code-signing certificate

Create a code-signing certificate that can be used to sign the firmware. Note the certificate ARN when the certificate is imported.

```
aws acm import-certificate --profile=ota-update-user --certificate file://ecdsasigner.crt
 --private-key file://ecdsasigner.key
{
"CertificateArn": "arn:aws:acm:region:account:certificate/certid"
}
```

The ARN will be used later to create a signing profile. If desired, the profile can be created using the following command at this point:

```
aws signer put-signing-profile --profile=ota-update-user --profile-name myOTAProfile --
signing-material certificateArn=arn:aws:acm:region:account:certificate/certid --platform
 AmazonFreeRTOS-Default --signing-parameters certname=/cert.pem
{
"arn": "arn:aws:signer::account:/signing-profiles/myOTAProfile"
}
```

Step 3: Configure the Amazon Cognito Authentication

AWS IoT configuration

First, set up the AWS IoT thing and policy. Because we are using the MQTT proxy on the Android phone which will be authenticated using Amazon Cognito, the device does not need the AWS IoT certificates.

Before you create the AWS IoT Policy, you need to know your AWS region and AWS account number.

Step 3a: Create an AWS IoT Policy

1. Sign in to the AWS IoT console.
2. In the upper-right corner, choose your account and under **My Account** make a note of your 12-digit account ID.
3. In the left navigation pane, choose **Settings**. Under **Custom endpoint**, make a note of the endpoint value. The endpoint should be something like "*xxxxxxxxxxxxxx*.iot.*us-west-2*.amazonaws.com". In this example, the AWS region is "us-west-2".
4. In the left navigation pane, choose **Secure**, choose **Policies**, and then choose **Create**.
5. If you do not have a policy created in your account, you will see the message "You don't have any policies yet" and you should choose **Create a policy**.
6. Enter a name for your policy (for example, "mqtt_proxy_iot_policy").
7. In the **Add statements** section, choose **Advanced mode**. Copy and paste the following JSON into the policy editor window. Replace "aws-account-id" with your account ID (step 2). Replace "aws-region" with your region, for example "us-west-2" (step 3).

```
{
  "Version": "2012-10-17",
  "Statement": [
      {
          "Effect": "Allow",
          "Action": "iot:Connect",
          "Resource": "arn:aws:iot:region:account-id:*"
      },
      {
          "Effect": "Allow",
          "Action": "iot:Publish",
          "Resource": "arn:aws:iot:region:account-id:*"
      },
      {
          "Effect": "Allow",
          "Action": "iot:Subscribe",
          "Resource": "arn:aws:iot:region:account-id:*"
      },
      {
          "Effect": "Allow",
          "Action": "iot:Receive",
          "Resource": "arn:aws:iot:region:account-id:*"
```

```
        }
    ]
}
```

8. Choose **Create**.

Step 3b: Create an AWS IoT thing

1. Sign in to the AWS IoT console.
2. In the left navigation pane, choose **Manage**, and then choose **Things**. In the top-right corner, choose **Create**.
3. If you do not have any IoT things registered in your account, the message "You don't have any things yet" is displayed and you should choose **Register a thing**.
4. On the **Creating AWS IoT things** page, choose **Create a single thing**.
5. On the **Add your device to the thing registry** page, enter a name for your thing (for example, "my_thing"). Only alphanumeric characters, hyphen ("-") and underscore ("_") are allowed. Choose **Next**.
6. On the **Add a certificate for your thing** page, under **Skip certificate and create thing**, choose **Create thing without certificate**.

   Because we are using the BLE proxy mobile app that uses an Amazon Cognito credential for authentication and authorization, no device certificate is required.

Amazon Cognito configuration

Amazon Cognito is required for authentication of the MQTT proxy mobile app. An IAM policy is attached to the authenticated identity to allow the principal to attach the AWS IoT policy to the credential.

Step 3c: Set up an Amazon Cognito user pool

1. Sign in to the Amazon Cognito console.
2. In the right top navigation area, choose **Create a user pool**.
3. Enter the pool name (for example, "mqtt_proxy_user_pool").
4. Choose **Review defaults**.
5. Next to **App Clients**, click **Add app client...**, and then choose **Add an app client**.
6. Enter the app client name (for example "mqtt_app_client").
7. Make sure **Generate client secret** is selected.
8. Choose **Create app client**.
9. Choose **Return to pool details**.
10. On the **Review** page of the user pool, choose **Create pool**.
11. You should see a message that says "Your user pool was created successfully."
12. Make a note of the "Pool ID".
13. In the left navigation pane, choose **App clients**.
14. Click **Show Details**.
15. Make a note of the "App client ID" and the "App client secret".

Step 3d: Amazon Cognito Identity Pool

1. Sign in to the Amazon Cognito console.
2. Choose **Create new identity pool**.

3. Enter a name for the identity pool (for example, "mqtt_proxy_identity_pool").
4. Expand **Authentication providers**.
5. Choose the **Cognito** tab.
6. Enter the **User pool ID** and **App client ID** that you saved from "Step 3c: Set up an Amazon Cognito user pool".
7. Choose **Create Pool**.
8. On the next page, choose **Allow** to create new roles for authenticated and unauthenticated identities.
9. Make a note of the **Identity pool ID**, which has the format "us-east-1:xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx".

Next, we attach an IAM policy to the authenticated identity so that the credential can attach the IoT policy to it.

Step 3e: Attach IAM policy to the authenticated identity

1. Open the Amazon Cognito console.
2. Choose the identity pool that you just created (for example, "mqtt_proxy_identity_pool").
3. Choose **Edit identity pool**.
4. Make a note of the IAM Role assigned to the Authenticated role (for example, "Cognito_mqtt_proxy_identity_poolAuth_Role").
5. Open the IAM console.
6. In the navigation pane, choose **Roles**.
7. Search for the role (for example, "Cognito_mqtt_proxy_identity_poolAuth_Role"), and then choose it.
8. Choose **Add inline policy**, and then choose **JSON**.
9. Enter the following policy:

```
{
  "Version": "2012-10-17",
  "Statement": [
      {
          "Effect": "Allow",
          "Action": [
              "iot:AttachPolicy",
              "iot:AttachPrincipalPolicy",
              "iot:Connect",
              "iot:Publish",
              "iot:Subscribe",
              "iot:Receive"
          ],
          "Resource": "*"
      }
  ]
}
```

10. Choose **Review Policy**.
11. Enter a policy name (for example, "mqttProxyCognitoPolicy").
12. Choose **Create policy**.

Step 4: Configure FreeRTOS

Enable the OTA update demo as follows:

Note
Only one demo can be enabled at a time in the Demo Runner.

1. Open `vendors/vendor/boards/board/aws_demos/config_files/aws_demo_config.h`.
   - Define `CONFIG_OTA_UPDATE_DEMO_ENABLED`.
   - Change `democonfigNETWORK_TYPES` to `AWSIOT_NETWORK_TYPE_BLE`.
2. Open `demos/include/aws_clientcredential.h`:
   - Change the endpoint URL in `clientcredentialMQTT_BROKER_ENDPOINT[]`.
   - Change the thing name to the name of your thing (for example, "my_thing") in `clientcredentialIOT_THING_NAME`.

     Note
     Certificates don't have to be added when you use Amazon Cognito credentials.
3. Open `vendors/vendor/boards/board/aws_demos/common/config_files/aws_iot_network_config.h`.
   - Change `configSUPPORTED_NETWORKS` and `configENABLED_NETWORKS` to only include `AWSIOT_NETWORK_TYPE_BLE`.
4. Open `ota_demo_config.h`:
   - Change `otapalconfigCODE_SIGNING_CERTIFICATE` to refer to the certificate to be used to sign the firmware binary file.

The application should start up and print the demo version:

```
11 13498 [iot_thread] [INFO ][DEMO][134980] Successfully initialized the demo. Network
 type for the demo: 2
12 13498 [iot_thread] [INFO ][MQTT][134980] MQTT library successfully initialized.
13 13498 [iot_thread] OTA demo version 0.9.20
14 13498 [iot_thread] Creating MQTT Client...
```

Step 5: Configure the Android app

Download the Android Bluetooth Low Energy SDK and a sample app from the amazon-freertos-ble-android-sdk GitHub repo.

Make the following changes:

1. Modify the file `app/src/main/res/raw/awsconfiguration.json`:

   Fill in the "PoolId", "Region", "AppClientId", and "AppClientSecret" fields using the instructions in the following sample JSON.

```
{
  "UserAgent": "MobileHub/1.0",
  "Version": "1.0",
  "CredentialsProvider": {
      "CognitoIdentity": {
          "Default": {
              "PoolId": "Cognito->Manage Identity Pools->Federated Identities-
>mqtt_proxy_identity_pool->Edit Identity Pool->Identity Pool ID",
              "Region": "Your region (for example us-east-1)"
```

```
          }
      }
  },

  "IdentityManager": {
      "Default": {}
  },

  "CognitoUserPool": {
      "Default": {
          "PoolId": "Cognito-> Manage User Pools -> mqtt_proxy_user_pool -> General
 Settings -> PoolId",
          "AppClientId": "Cognito-> Manage User Pools -> mqtt_proxy_user_pool ->
 General Settings -> App clients ->Show Details",
          "AppClientSecret": "Cognito-> Manage User Pools -> mqtt_proxy_user_pool ->
 General Settings -> App clients ->Show Details",
          "Region": "Your region (for example us-east-1)"
      }
  }
}
```

2. Modify the file `app/src/main/java/software/amazon/freertos/DemoConstants.java`:
   - Specify the policy name (for example, "mqtt_proxy_iot_policy") that you created earlier.
   - Set the Region (for example, "us-east-1").
3. Build and install the demo app:
   a. In Android Studio, choose **Build**, **Make Module app**.
   b. Choose **Run**, **Run app**. You can go to the logcat window pane in Android Studio to monitor log messages.
   c. On the Android device, create an account from the login screen.
   d. Create a user. If a user already exists, enter the user's credentials.
   e. Allow the FreeRTOS Demo to access the device's location.
   f. Scan for Bluetooth Low Energy devices.
   g. Move the slider for the device found to **On**.
   h. Press **'y'** on the serial port debug console.
   i. Choose **Pair & Connect**.

The **More...** link becomes active after the connection. You should see the connection state change to **BLE_CONNECTED** in the Android device logcat when the connection is complete:

```
2019-06-06 20:11:32.160 23484-23497/software.amazon.freertos.demo I/FRD: BLE connection
 state changed: 0; new state: BLE_CONNECTED
```

Before the messages can be transmitted, the FreeRTOS device and the Android device must negotiate the MTU. You should see the following printout in logcat:

```
2019-06-06 20:11:46.720 23484-23497/software.amazon.freertos.demo I/FRD: onMTUChanged : 512
 status: Success
```

The device connects to the app and starts sending MQTT messages using the MQTT proxy. To confirm that the device can communicate, make sure that you can see the MQTT_CONTROL characteristic data value change to 01:

```
2019-06-06 20:12:28.752 23484-23496/software.amazon.freertos.demo D/FRD: <-<-<- Writing to
 characteristic: MQTT_CONTROL with data: 01
2019-06-06 20:12:28.839 23484-23496/software.amazon.freertos.demo D/FRD:
 onCharacteristicWrite for:
```

Complete pairing on microcontroller console

You will be prompted to press 'y' on the console when the device is paired with the Android device. The demo will not function until this step is performed.

```
E (135538) BT_GATT: GATT_INSUF_AUTHENTICATION: MITM Required
W (135638) BT_L2CAP: l2cble_start_conn_update, the last connection update command still
 pending.
E (135908) BT_SMP: Value for numeric comparison = 391840
15 13588 [InputTask] Numeric comparison:391840
16 13589 [InputTask] Press 'y' to confirm
17 14078 [InputTask] Key accepted
W (146348) BT_SMP: FOR LE SC LTK IS USED INSTEAD OF STK
18 16298 [iot_thread] Connecting to broker...
19 16298 [iot_thread] [INFO ][MQTT][162980] Establishing new MQTT connection.
20 16298 [iot_thread] [INFO ][MQTT][162980] (MQTT connection 0x3ffd5754, CONNECT operation
 0x3ffd586c) Waiting for operation completion.
21 16446 [iot_thread] [INFO ][MQTT][164450] (MQTT connection 0x3ffd5754, CONNECT operation
 0x3ffd586c) Wait complete with result SUCCESS.
22 16446 [iot_thread] [INFO ][MQTT][164460] New MQTT connection 0x3ffc0ccc established.
23 16446 [iot_thread] Connected to broker.
```

Testing

1. To install the prerequisites, run the following commands:

   ```
   pip3 install boto3
   pip3 install pathlib
   ```

2. Download the python script.
3. Bump up the FreeRTOS application version in `demos/include/aws_application_version.h` and build a new binary file.
4. To get help, run the following command in a terminal window:

   ```
   python3 start_ota.py -h
   ```

   ```
   usage: start_ota.py [-h] --profile PROFILE [--region REGION]
                       [--account ACCOUNT] [--devicetype DEVICETYPE] --name NAME
                       --role ROLE --s3bucket S3BUCKET --otasigningprofile
                       OTASIGNINGPROFILE --signingcertificateid
                       SIGNINGCERTIFICATEID [--codelocation CODELOCATION]
   Script to start OTA update
   optional arguments:
   -h, --help            show this help message and exit
   --profile PROFILE     Profile name created using aws configure
   --region REGION       Region
   --account ACCOUNT     Account ID
   --devicetype DEVICETYPE thing|group
   --name NAME           Name of thing/group
   --role ROLE           Role for OTA updates
   --s3bucket S3BUCKET   S3 bucket to store firmware updates
   --otasigningprofile OTASIGNINGPROFILE
                         Signing profile to be created or used
   ```

```
--signingcertificateid SIGNINGCERTIFICATEID
                      certificate id (not arn) to be used
--codelocation CODELOCATION
                      base folder location (can be relative)
```

5. If you used the provided AWS CloudFormation template to create resources, here's an example run:

```
python3 start_ota_stream.py --profile otausercf --name my_thing --role
 ota_ble_iot_role-sample --s3bucket afr-ble-ota-update-bucket-sample --
otasigningprofile abcd --signingcertificateid certificateid
```

Validation

1. From the console, the logs show that the OTA update has started and the file block download is in progress:

```
38 2462 [OTA Task] [prvParseJobDoc] Job was accepted. Attempting to start transfer.
---
49 2867 [OTA Task] [prvIngestDataBlock] Received file block 1, size 1024
50 2867 [OTA Task] [prvIngestDataBlock] Remaining: 1290
51 2894 [OTA Task] [prvIngestDataBlock] Received file block 2, size 1024
52 2894 [OTA Task] [prvIngestDataBlock] Remaining: 1289
53 2921 [OTA Task] [prvIngestDataBlock] Received file block 3, size 1024
54 2921 [OTA Task] [prvIngestDataBlock] Remaining: 1288
55 2952 [OTA Task] [prvIngestDataBlock] Received file block 4, size 1024
56 2953 [OTA Task] [prvIngestDataBlock] Remaining: 1287
57 2959 [iot_thread] State: Active  Received: 5   Queued: 5   Processed: 5   Dropped: 0
```

2. When the OTA update is complete, the device restarts with the updated firmware, connects again to the Android app, and then performs a self test.
3. If the self test succeeds, the updated firmware is marked as active and you should see the updated version in the console:

```
13 13498 [iot_thread] OTA demo version 0.9.21
```

References

1. AWS Blog on OTA updates over Bluetooth Low Energy.

Porting the common I/O libraries

In general, device drivers are independent of the underlying operating system and are specific to a given hardware configuration. A hardware abstraction layer (HAL) is a wrapper that provides common interfaces between drivers and higher-level application code. The HAL abstracts away the details of how a specific driver works and provides a uniform API to control similar devices. In this way, you can use the same APIs to control various devices across multiple microcontroller (MCU) based reference boards.

FreeRTOS common I/O acts as a hardware abstraction layer. It provides a set of standard APIs for accessing common serial devices across supported reference boards. These APIs communicate and interact with some common peripherals and enable your application code to function across platforms. Without common I/O, the code that is required to work with low-level devices is silicon vendor specific.

Supported peripherals

- UART
- SPI
- I2C

Supported features

- Synchronous read/write – The function doesn't return until the requested amount of data has been transferred.
- Asynchronous read/write – The function returns immediately and the data transfer happens asynchronously. When function execution completes, a registered user callback is invoked.

Peripheral specific

- I2C – Combine multiple operations into one transaction, typically to do write then read operations in one transaction.
- SPI – Transfer data between primary and secondary, which means the write and read operations happen simultaneously.

Porting

See the FreeRTOS Porting Guide.

Topics

Prerequisites

To port the common I/O Libraries, you need the following:

- An IDE project or `CMakeLists.txt` list file that includes the vendor-supplied I/O drivers.
- A validated configuration of the FreeRTOS kernel.

Testing

First, either set up an IDE project or configure CMake.

Set Up Your Local Testing Environment

No changes are required in the test file *`freertos`*`/libraries/abstractions/common_io/test/test_iot_`*`peripheral`*`.c`.

Device-specific code is in the following files

- *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_tests/config_files/test_iot_config.h`
- *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/ports/common_io/test_iot_internal.c`

To set up your local testing environment

1. Create a test configuration header file named *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/test_iot_config.h. For its content, refer to the "Test Setup" section for each peripheral.
2. Create a test setup file named *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/test_iot_internal.c. For its content, refer to the "Test Setup" section for each peripheral.
3. To enable the common I/O tests, open the file *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/aws_test_runner_config.h.
4. Set testrunnerFULL_COMMON_IO_ENABLED to **1**

Set Up the IDE Test Project

If you're using an IDE for porting and testing, you must add the source files to the IDE test project before you can test your ported code.

> **Important**
> In the following steps, make sure that you add the source files to your IDE project from their current on-disk location. Don't create duplicate copies of the source files.

To set up the common I/O libraries in IDE project

1. Add all implementation source files *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/iot_*peripheral*.c to your aws_tests IDE project (one file per peripheral).
2. Add all test source files *freertos*/libraries/abstractions/common_io/test/test_iot_*peripheral*.c to your aws_tests IDE project (one file per peripheral).
3. Add the test configuration file *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/test_iot_config.h to your aws_tests IDE project (just this one file for all peripherals).
4. Add the test setup file *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/test_iot_internal.c to your aws_tests IDE project (just this one file for all peripherals).

Configure the CMakeLists.txt File

If you're using CMake to build your test project, you must define a portable layer target for the library in your CMake list file.

The CMakeLists.txt template list file at *freertos*/vendors/*vendor*/boards/*board*/CMakeLists.txt includes examples of portable layer target definitions. Uncomment the definition of each library that you're porting, and modify it to fit your platform.

Example

The following is portable layer target definition for the common I/O library.

```
# Common I/O
afr_mcu_port(common_io)
target_sources(
    AFR::common_io::mcu_port
    INTERFACE
        # peripheral implementations
        freertos/vendors/vendor/boards/board/ports/common_io/iot_peripheral_1.c
        freertos/vendors/vendor/boards/board/ports/common_io/iot_peripheral_2.c
        freertos/vendors/vendor/boards/board/ports/common_io/iot_peripheral_3.c
        ...
        # test configuration and pre-steps
```

```
        freertos/vendors/vendor/boards/board/ports/common_io/test_iot_internal.c
)

#
 ----------------------------------------------------------------------------------------------------
# FreeRTOS demos and tests
#
 ----------------------------------------------------------------------------------------------------

...

if(AFR_IS_TESTING)
    set(exe_target aws_tests)
else()
    set(exe_target aws_demos)
endif()

...

# link common io library along with others
target_link_libraries(
    ${exe_target}
    PRIVATE
        AFR::wifi
        AFR::utils
        AFR::common_io
)
```

Run the Tests

To execute the common I/O tests

1. Build the test project, and then flash it to your device for execution.
2. Check the test results in the UART console.

Porting the I2C library

I2C library interfaces with vendor-supplied I2C drivers. If the device doesn't have an I2C peripheral, you can skip porting I2C interfaces. The I2C library can only use the I2C peripheral that is on the device as the primary.

Prerequisites

To port the I2C library, you need an I2C secondary device. It can be one of the following:

- An onboard I2C sensor.
- An external device, such as a Raspberry PI.

Porting

Use the vendor-supplied I2C driver library to implement all the functions in *freertos*`/libraries/abstractions/common_io/include/iot_i2c.h`. The header file provides the required API behavior information. An implementation source file should be created and named *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/common_io/iot_i2c.c`.

If any of the I2C features are not supported on a target device, make the corresponding functions return `IOT_I2C_FUNCTION_NOT_SUPPORTED`. For the list of functions that can return `IOT_I2C_FUNCTION_NOT_SUPPORTED`, see the API as documented in *freertos*`/libraries/abstractions/common_io/include/iot_i2c.h`.

Anonymous Handle "struct IotI2CDescriptor"

This usually encapsulates the driver's handle and variety of states. See the following example.

```
/* Suppose the data type of driver handle for I2C is Driver_I2C_Handle */
struct IotI2CDescriptor
{
    Driver_I2C_Handle xHandle;     /* Driver Handle. */
    IotI2CConfig_t xConfig;        /* Bus Configuration. */
    IotI2CCallback_t xCallback;    /* Callback function. */
    void * pvUserContext;          /* User context passed in callback. */
    uint16_t usSlaveAddr;          /* Slave Address. */
    uint16_t usTransmittedTxBytes; /* Number of Transmitted Bytes */
    uint16_t usReceivedRxBytes;    /* Number of Received Bytes */
    SemaphoreHandle_t xSemphr;     /* Optional, useful when there is a synchronization
 situation. */
    /* State: if already opened. */
    /* State: if send no stop. */
};
```

Test setup

Hardware Setup

If you're using an onboard sensor as a slave device, you can skip this step.

If you use an external device, you need to wire the SDA (data) lines and SCL (clock) lines of the two devices.

You can find the I2C test file in the following directory: *freertos*`/libraries/abstractions/common_io/test/test_iot_i2c.c`

To test the set up configurations

1. Add the I2C configurations to *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files/test_iot_config.h`.

   `IOT_TEST_COMMON_IO_I2C_SUPPORTED`

   If this device has I2C peripheral, set to **1**. Otherwise, set it to **0**.

   `IOT_TEST_COMMON_IO_I2C_SUPPORTED_SEND_NO_STOP`

   If the I2C doesn't explicitly support sending stop condition, set to **1**. Otherwise, set to **0**.

   `IOT_TEST_COMMON_IO_I2C_SUPPORTED_CANCEL`

   If the I2C supports cancelling the asynchronous transaction with interrupt or DMA, set to **1**. Otherwise, set to **0**.

   `I2C_TEST_SET`

   Specify the number of I2C instances to test.
2. Define test data in the *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files/test_iot_config.h` file.

   `i2cTestInstanceIdx`

   The I2C instance IDs.

   `i2cTestInstanceNum`

   The total number of I2C instances.

`i2cTestSlaveAddr`

Device address.

`i2cTestDeviceRegister`

Register address on the test device.

`i2cTestWriteVal`

A byte value to be written to the test device.

`gIotI2cHandle`

Not used. Define it as an array of null to compile.

Example

```
/* I2C includes */
#include "iot_i2c.h"

#define IOT_TEST_COMMON_IO_I2C_SUPPORTED                    1

#if ( IOT_TEST_COMMON_IO_I2C_SUPPORTED == 1 )
    #define IOT_TEST_COMMON_IO_I2C_SUPPORTED_SEND_NO_STOP    1
    #define IOT_TEST_COMMON_IO_I2C_SUPPORTED_CANCEL          1
#endif

#define I2C_TEST_SET                                        1

/* Slave address. */
const uint8_t i2cTestSlaveAddr[ I2C_TEST_SET ] = { 0xD4 };
/* Register address. */
const uint8_t i2cTestDeviceRegister[ I2C_TEST_SET ] = { 0x73 };
/* A value that is written to slave device during test. */
const uint8_t i2cTestWriteVal[ I2C_TEST_SET ] = { 0b01101010 };
/* I2C instance ID. */
const uint8_t i2cTestInstanceIdx[ I2C_TEST_SET ] = { 1 };
/* Total number of I2C instances. */
const uint8_t i2cTestInstanceNum[ I2C_TEST_SET ] = { 3 };

/* Unused, but this needs to be defined. */
IotI2CHandle_t gIotI2cHandle[ 4 ] = { NULL, NULL, NULL, NULL };
```

3. Add I2C test setup code to the *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/test_iot_internal.c file.

```
#include "test_iot_internal.h"

/* These global variables are defined in test_iot_i2c.c. */
extern uint8_t uctestIotI2CSlaveAddr;
extern uint8_t xtestIotI2CDeviceRegister;
extern uint8_t uctestIotI2CWriteVal;
extern uint8_t uctestIotI2CInstanceIdx;
extern uint8_t uctestIotI2CInstanceNum;

void SET_TEST_IOT_I2C_CONFIG(int testSet)
{
    uctestIotI2CSlaveAddr = i2cTestSlaveAddr[testSet];
    xtestIotI2CDeviceRegister = i2cTestDeviceRegister[testSet];
    uctestIotI2CWriteVal = i2cTestWriteVal[testSet];
    uctestIotI2CInstanceIdx = i2cTestInstanceIdx[testSet];
    uctestIotI2CInstanceNum = i2cTestInstanceNum[testSet];
```

```
}
```

Porting the UART library

The UART library interfaces with vendor-supplied UART drivers. If the device doesn't have any UART peripherals, you can skip porting the UART interface.

Prerequisites

- Use a jump wire to connect the RX and TX of the UART for loopback testing.

Porting

Use the vendor-supplied UART driver library to implement all the functions in *freertos*`/libraries/abstractions/common_io/include/iot_uart.h`. The header file provides information about the required API behavior. An implementation source file should be created and named *freertos*`/vendors/`*vendor*`/boards/`*board*`/ports/common_io/iot_uart.c`.

If the target device doesn't support any UART features, make the corresponding functions return `IOT_UART_FUNCTION_NOT_SUPPORTED`. For the list of functions that can return `IOT_UART_FUNCTION_NOT_SUPPORTED`, refer to the API as documented in *freertos*`/libraries/abstractions/common_io/include/iot_uart.h`.

Anonymous Handle "struct IotUARTDescriptor"

This usually encapsulates driver's handle and variety of states. See the following example.

```
/* Suppose the data type of the driver handle for UART is UART_Handle */
struct IotUARTDescriptor
{
    IotUARTCallback_t xUartCallback; /* Application Specified callback. */
    UART_Handle * pxUartContext;     /* UART handle to be passed to driver functions. */
    void * pvUserCallbackContext;    /
    uint8_t sOpened;
};
```

Test setup

Hardware Setup

On the UART port to test, connect the TX and RX for loopback by using a jump wire.

You can find the UART test file in the following directory: *freertos*`/libraries/abstractions/common_io/test/test_iot_uart.c`

To test the setup configurations

1. Add the UART configuration to the *freertos*`/vendors/`*vendor*`/boards/`*board*`/aws_tests/config_files/test_iot_config.h` file.

   `IOT_TEST_COMMON_IO_UART_SUPPORTED`

   If this device has UART peripheral, set to **1**. Otherwise, set **0**.

   `UART_TEST_SET`

   The number of UART instances to test.

2. Define test data in the *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/test_iot_config.h file.

   `uartTestPort`

   The UART instance IDs.

   `uartIotUartFlowControl`

   The UART flow control configuration.

   `uartIotUartParity`

   The UART parity bit configuration.

   `uartIotUartWordLength`

   The UART word length configuration.

   `uartIotUartStopBits`

   The UART stop bit configuration.

   Example

```
/* UART */
#define UART_TEST_SET    1
const uint8_t uartTestPort[ UART_TEST_SET ] = { 1 };
const uint32_t uartIotUartFlowControl[ UART_TEST_SET ] = { UART_FLOW_CONTROL };
const uint32_t uartIotUartParity[ UART_TEST_SET ] = { UART_PARITY };
const uint32_t uartIotUartWordLength[ UART_TEST_SET ] = { UART_WORD_LENGTH };
const uint32_t uartIotUartStopBits[ UART_TEST_SET ] = { UART_STOP_BITS };
```

3. Add the UART test setup code to the *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/test_iot_internal.c file.

```
#include "test_iot_internal.h"

/* UART */
extern uint8_t ustestIotUartPort;
extern uint32_t ultestIotUartFlowControl;
extern uint32_t ultestIotUartParity;
extern uint32_t ultestIotUartWordLength;
extern uint32_t ultestIotUartStopBits;

void SET_TEST_IOT_UART_CONFIG( int testSet )
{
    ustestIotUartPort = uartTestPort[ testSet ];
    ultestIotUartFlowControl = uartIotUartFlowControl[ testSet ];
    ultestIotUartParity = uartIotUartParity[ testSet ];
    ultestIotUartWordLength = uartIotUartWordLength[ testSet ];
    ultestIotUartStopBits = uartIotUartStopBits[ testSet ];
}
```

Porting the SPI library

The SPI library interfaces with vendor-supplied SPI drivers. If the device doesn't have an SPI peripheral, you can skip porting the SPI interfaces. The SPI library can only use the SPI peripheral on the device as controller.

Porting

Use the vendor-supplied SPI driver library to implement all the functions in *freertos*/libraries/abstractions/common_io/include/iot_spi.h. The header file provides the required API behavior information. The implementation source file should be created as *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/iot_spi.c.

It's possible that a target device doesn't support some SPI features. In that case, make the corresponding functions return IOT_SPI_FUNCTION_NOT_SUPPORTED. For the list of functions that can return IOT_SPI_FUNCTION_NOT_SUPPORTED, refer to the API as documented in *freertos*/libraries/abstractions/common_io/include/iot_spi.h.

Anonymous Handle "struct IotSPIDescriptor"

This usually encapsulates the driver's handle and variety of states. See the following example.

```
/* Suppose the data type of driver handle for SPI is Driver_SPI_Handle */
struct IotSPIDescriptor
{
    Driver_SPI_Handle xHandle;     /* Driver Handle. */
    IotSPIConfig_t xConfig;        /* Bus Configuration. */
    IotSPICallback_t xCallback;    /* Callback function. */
    void * pvUserContext;          /* User context passed in callback. */
    /* State: if already opened. */
};
```

Test setup

You can find the SPI test file in the following directory: *freertos*/libraries/abstractions/common_io/test/test_iot_spi.c

To test the setup configurations

1. Add the SPI configurations to the *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/test_iot_config.h file.

   IOT_TEST_COMMON_IO_SPI_SUPPORTED

   If the device has an SPI peripheral, set this to **1**. Otherwise, set to **0**.

   SPI_TEST_SET

   The number of SPI instances to test.
2. Define test data in the *freertos*/vendors/*vendor*/boards/*board*/aws_tests/config_files/test_iot_config.h file.

   spiTestPort

   The SPI instance IDs.

   spiIotMode

   The SPI mode.

   spiIotSpitBitOrder

   The SPI bit order.

   spiIotFrequency

   The SPI frequency.

   spiIotDummyValue

   The dummy value.

Example

```
/* SPI includes */
#include "iot_spi.h"

#define IOT_TEST_COMMON_IO_SPI_SUPPORTED                    1
#define I2C_TEST_SET                                        1

const uint8_t spiTestPort[ SPI_TEST_SET ] = { 1 };
const uint32_t spiIotMode[ SPI_TEST_SET ] = { eSPIMode0 };
const uint32_t spiIotSpitBitOrder[ SPI_TEST_SET ] = { eSPIMSBFirst };
const uint32_t spiIotFrequency[ SPI_TEST_SET ] = { 500000U };
const uint32_t spiIotDummyValue[ SPI_TEST_SET ] = { 0 };
```

3. Add SPI test setup code in the *freertos*/vendors/*vendor*/boards/*board*/ports/common_io/test_iot_internal.c file.

```
#include "test_iot_internal.h"

/* SPI */
extern uint8_t ultestIotSpiInstance;
extern IotSPIMode_t xtestIotSPIDefaultConfigMode;
extern IotSPIBitOrder_t xtestIotSPIDefaultconfigBitOrder;
extern uint32_t ultestIotSPIFrequency;
extern uint32_t ultestIotSPIDummyValue;

void SET_TEST_IOT_SPI_CONFIG(int testSet)
{
    ultestIotSpiInstance = spiTestPort[ testSet ] ;
    xtestIotSPIDefaultConfigMode = spiIotMode[ testSet ];
    xtestIotSPIDefaultconfigBitOrder = spiIotSpitBitOrder[ testSet ];
    ultestIotSPIFrequency = spiIotFrequency[ testSet ];
    ultestIotSPIDummyValue = spiIotDummyValue[ testSet ];
}
```

Porting the Cellular library

FreeRTOS Labs now supports AT commands, TCP offloaded cellular abstraction Layer. For more information, see FreeRTOS Labs - Cellular Libraries and the Porting Guide for more information.

Note
The Cellular Library is in FreeRTOS Labs. The libraries in the FreeRTOS Labs download are fully functional, but undergoing improvements to their implementation, documentation, and coding style.

Prerequisites

There is no direct dependency for the Cellular Library, however, in the FreeRTOS network stack, Ethernet, Wi-Fi and cellular cannot co-exist, so developers must choose one of them to integrate with the Secure Sockets library.

Note
If the cellular module is able to support TLS offload, or does not support AT commands, developers can implement their own cellular abstraction to integrate with the Secure Sockets library.

Migrating from Version 1.4.x to Version 201906.00 (and newer)

For a list of FreeRTOS releases, see https://github.com/aws/amazon-freertos/releases.

Migrating applications

FreeRTOS version 201906.00 introduced some changes to the FreeRTOS directory structure that break project files built on previous versions of FreeRTOS. In order for applications built on previous versions of FreeRTOS to work with FreeRTOS version 201906.00 or newer, you must move the application code to new projects and include the 201906.00 header files in the application.

Version 201906.00 introduced new APIs for the MQTT, Device Shadow, and Device Defender libraries. The APIs for previous versions of these libraries are accessible through header files of the 201906.00 implementations of these libraries, making FreeRTOS version 201906.00 backward-compatible.

Note
If you are migrating from previous versions to version 201906.00 or newer, you might need to reconfigure your `iot_config.h` and `FreeRTOSConfig.h` files to accommodate the new library implementations. For information about global configuration settings, see the Global Configuration File Reference.

Migrating ports

If you have ported a version of FreeRTOS released prior to the 201906.00 release, you need to migrate your ported code to be compatible with versions 201906.00 and later. For information about porting, see the FreeRTOS Porting Guide.

FreeRTOS code directory structure

In versions released prior to 201906.00, the *`freertos`*`/lib/third_party/mcu_vendor/`*`vendor`* folder held the vendor-ported code. One or more project files under the same *`vendor`* folder compiled the code. In versions 201906.00 and later, vendor code is located under the *`freertos`*`/vendors/`*`vendor`* folder, and project files are located under the *`freertos`*`/projects/`*`vendor`* folder.

Note
The code for ports did not change with version 201906.00. Only the location of the code changed. Move any existing ports to the new folder structure.

CMake build system

Version 201906.00 introduced support for using CMake to generate project files. For information about using CMake with FreeRTOS, see Building FreeRTOS with CMake (p. 20).

A CMake list file is required for qualification. For information about creating a CMake list file, see Creating a CMake list file (p. 12).

Migrating the Wi-Fi library port

The FreeRTOS Wi-Fi library features four new APIs to add, remove, and retrieve a Wi-Fi network, and to receive notifications for Wi-Fi network state changes. All of these new APIs are optional, and are intended to support Wi-Fi credentials provisioning over Bluetooth Low Energy. If your device does not support Bluetooth Low Energy, you do not need to implement these APIs.

- `WIFI_NetworkAdd`

```
WIFIReturnCode_t WIFI_NetworkAdd(
    const WIFINetworkProfile_t * const pxNetworkProfile,
    uint16_t * pusIndex );
```

- `WIFI_NetworkGet`

```
WIFIReturnCode_t WIFI_NetworkGet(
WIFINetworkProfile_t * pxNetworkProfile,
    uint16_t usIndex );
```

- `WIFI_NetworkDelete`

```
WIFIReturnCode_t WIFI_NetworkDelete( uint16_t usIndex );
```

- `WIFI_RegisterNetworkStateChangeEventCallback`

```
WIFIReturnCode_t WIFI_RegisterNetworkStateChangeEventCallback(
    IotNetworkStateChangeEventCallback_t xCallback );
```

With the following `typedef` statements:

```
typedef void ( *IotNetworkStateChangeEventCallback_t ) (
    uint32_t ulNetworkType,
    AwsIotNetworkState_t xState );
```

```
typedef enum AwsIotNetworkState
{
    eNetworkStateUnknown = 0,
    eNetworkStateDisabled,
    eNetworkStateEnabled
} AwsIotNetworkState_t;
```

For information about porting the Wi-Fi library, see Porting the Wi-Fi Library in the FreeRTOS Porting Guide.

Migrating from version 1 to version 3 for OTA applications

This guide will help you migrate your application from OTA library version 1 to version 3.

Note
The OTA version 2 APIs are the same as OTA v3 APIs, so if your application is using version 2 of the APIs then changes are not required for API calls but we recommend that you integrate version 3 of the library.

Demos for OTA version 3 are available here:

- ota_demo_core_mqtt.
- ota_demo_core_http.
- ota_ble.

Summary of API changes

Summary of API changes between OTA Library version 1 and version 3

OTA version 1 API	OTA version 3 API	Description of changes
OTA_AgentInit	OTA_Init	The input paramerts are changed as well as the value returned from the function due to changes in the implementation in OTA v3. Please refer to the section for OTA_Init below for details.
OTA_AgentShutdown	OTA_Shutdown	Change in the input parameters including an additional parameter for an optional unsubscribe from MQTT topics. Please refer to the section for OTA_Shutdown below for details.
OTA_GetAgentState	OTA_GetState	The API name is changed with no changes to the input parameter. The return value is the same but the enum and members are renamed. Please refer to the section for OTA_GetState below for details.
n/a	OTA_GetStatistics	New API added that replaces the APIs OTA_GetPacketsReceived, OTA_GetPacketsQueued, OTA_GetPacketsProcessed, OTA_GetPacketsDropped. Please refer to the section for

OTA version 1 API	OTA version 3 API	Description of changes
		OTA_GetStatistics below for details.
OTA_GetPacketsReceived	n/a	This API is removed from version 3 and replaced by OTA_GetStatistics.
OTA_GetPacketsQueued	n/a	This API is removed from version 3 and replaced by OTA_GetStatistics.
OTA_GetPacketsProcessed	n/a	This API is removed from version 3 and replaced by OTA_GetStatistics.
OTA_GetPacketsDropped	n/a	This API is removed from version 3 and replaced by OTA_GetStatistics.
OTA_ActivateNewImage	OTA_ActivateNewImage	The input parameters are the same but the return OTA error code is renamed and new error codes are added in version 3 of the OTA library. Please see the section for OTA_ActivateNewImage for details.
OTA_SetImageState	OTA_SetImageState	The input parameters are the same and renamed, the return OTA error code is renamed and new error codes are added in version 3 of the OTA library. Please see the section for OTA_SetImageState for details.
OTA_GetImageState	OTA_GetImageState	The input parameters are the same, the return enum is renamed in version 3 of the OTA library. Please see the section for OTA_GetImageState for details.
OTA_Suspend	OTA_Suspend	The input parameters are the same, the return OTA error code is renamed and new error codes are added in version 3 of the OTA library. Please see the section for OTA_Suspend for details.

OTA version 1 API	OTA version 3 API	Description of changes
OTA_Resume	OTA_Resume	The input parameter for connection is removed as the connection is handled in the OTA demo/application, the return OTA error code is renamed and new error codes are added in version 3 of the OTA library. Please see the section for OTA_Resume for details.
OTA_CheckForUpdate	OTA_CheckForUpdate	The input parameters are the same, the return OTA error code is renamed and new error codes are added in version 3 of the OTA library. Please see the section for OTA_CheckForUpdate for details.
n/a	OTA_EventProcessingTask	New API added and it is the main event loop to handle events for OTA update and must be called by the application task. Please see the section for OTA_EventProcessingTask for details.
n/a	OTA_SignalEvent	New API added and it adds the event to the back of OTA event queue and is used by internal OTA modules to signal the agent task. Please see the section for OTA_SignalEvent for details.
n/a	OTA_Err_strerror	New API for error code to string conversion for OTA errors.
n/a	OTA_JobParse_strerror	New API for error code to string conversion for Job Parsing errors.
n/a	OTA_OsStatus_strerror	New API for status code to string conversion for OTA OS port status.
n/a	OTA_PalStatus_strerror	New API for status code to string conversion for OTA PAL port status.

Description of changes required

OTA_Init

When initializing the OTA Agent in v1 the `OTA_AgentInit` API is used which takes parameters for connection context, thing name, complete callback and timeout as input.

```
OTA_State_t OTA_AgentInit( void * pvConnectionContext,
                           const uint8_t * pucThingName,
                           pxOTACompleteCallback_t xFunc,
                           TickType_t xTicksToWait );
```

This API is now changed to `OTA_Init` with parameters for the buffers required for ota, ota interfaces, thing name and application callback.

```
OtaErr_t OTA_Init( OtaAppBuffer_t * pOtaBuffer,
                   OtaInterfaces_t * pOtaInterfaces,
                   const uint8_t * pThingName,
                   OtaAppCallback OtaAppCallback );
```

Removed input parameters -

pvConnectionContext -

The connection context is removed because the OTA Library Version 3 does not require the connection context to be passed to it and the MQTT/HTTP operations are handled by their respective interfaces in the OTA demo/application.

xTicksToWait -

The ticks to wait parameter is also removed as the task is created in the OTA demo/application before calling OTA_Init.

Renamed input parameters -

xFunc -

The parameter is renamed to OtaAppCallback and its type is changed to OtaAppCallback_t.

New input parameters -

pOtaBuffer

The application must allocate the buffers and pass them to the OTA library using the OtaAppBuffer_t structure during initialization. The buffers required differ slightly depending on the protocol used for downloading the file. For the MQTT protocol the buffers for stream name are required and for the HTTP protocol the buffers for pre-signed url and authorization scheme are required.

Buffers required when using MQTT for file download -

```
static OtaAppBuffer_t otaBuffer =
{
    .pUpdateFilePath    = updateFilePath,
    .updateFilePathsize = otaexampleMAX_FILE_PATH_SIZE,
    .pCertFilePath      = certFilePath,
    .certFilePathSize   = otaexampleMAX_FILE_PATH_SIZE,
    .pStreamName        = streamName,
    .streamNameSize     = otaexampleMAX_STREAM_NAME_SIZE,
    .pDecodeMemory      = decodeMem,
    .decodeMemorySize   = ( 1U << otaconfigLOG2_FILE_BLOCK_SIZE ),
```

```
    .pFileBitmap        = bitmap,
    .fileBitmapSize     = OTA_MAX_BLOCK_BITMAP_SIZE
};
```

Buffers required when using HTTP for file download -

```
static OtaAppBuffer_t otaBuffer =
{
    .pUpdateFilePath    = updateFilePath,
    .updateFilePathsize = otaexampleMAX_FILE_PATH_SIZE,
    .pCertFilePath      = certFilePath,
    .certFilePathSize   = otaexampleMAX_FILE_PATH_SIZE,
    .pDecodeMemory      = decodeMem,
    .decodeMemorySize   = ( 1U << otaconfigLOG2_FILE_BLOCK_SIZE ),
    .pFileBitmap        = bitmap,
    .fileBitmapSize     = OTA_MAX_BLOCK_BITMAP_SIZE,
    .pUrl               = updateUrl,
    .urlSize            = OTA_MAX_URL_SIZE,
    .pAuthScheme        = authScheme,
    .authSchemeSize     = OTA_MAX_AUTH_SCHEME_SIZE
};
```

Where -

```
    pUpdateFilePath    Path to store the files.
    updateFilePathsize Maximum size of the file path.
    pCertFilePath      Path to certificate file.
    certFilePathSize   Maximum size of the certificate file path.
    pStreamName        Name of stream to download the files.
    streamNameSize     Maximum size of the stream name.
    pDecodeMemory      Place to store the decoded files.
    decodeMemorySize   Maximum size of the decoded files buffer.
    pFileBitmap        Bitmap of the parameters received.
    fileBitmapSize     Maximum size of the bitmap.
    pUrl               Presigned url to download files from S3.
    urlSize            Maximum size of the URL.
    pAuthScheme        Authentication scheme used to validate download.
    authSchemeSize     Maximum size of the auth scheme.
```

pOtaInterfaces

The second input parameter to OTA_Init is a reference to the OTA interfaces for type OtaInterfaces_t. This set of interfaces must be passed to the OTA Library and includes in the operating system interface the MQTT interface, HTTP interface and platform abstraction layer interface.

OTA OS Interface

The OTA OS Functional interface is a set of APIs that must be implemented for the device to use the OTA library. The function implementations for this interface are provided to the OTA library in the user application. The OTA library calls the function implementations to perform functionalities that are typically provided by an operating system. This includes managing events, timers, and memory allocation. The implementations for FreeRTOS and POSIX are provided with the OTA library.

Example for FreeRTOS using the provided FreeRTOS port -

```
    OtaInterfaces_t otaInterfaces;
    otaInterfaces.os.event.init   = OtaInitEvent_FreeRTOS;
    otaInterfaces.os.event.send   = OtaSendEvent_FreeRTOS;
    otaInterfaces.os.event.recv   = OtaReceiveEvent_FreeRTOS;
```

```
    otaInterfaces.os.event.deinit = OtaDeinitEvent_FreeRTOS;
    otaInterfaces.os.timer.start  = OtaStartTimer_FreeRTOS;
    otaInterfaces.os.timer.stop   = OtaStopTimer_FreeRTOS;
    otaInterfaces.os.timer.delete = OtaDeleteTimer_FreeRTOS;
    otaInterfaces.os.mem.malloc   = Malloc_FreeRTOS;
    otaInterfaces.os.mem.free     = Free_FreeRTOS;
```

Example for Linux using the provided POSIX port -

```
OtaInterfaces_t otaInterfaces;
otaInterfaces.os.event.init    = Posix_OtaInitEvent;
otaInterfaces.os.event.send    = Posix_OtaSendEvent;
otaInterfaces.os.event.recv    = Posix_OtaReceiveEvent;
otaInterfaces.os.event.deinit  = Posix_OtaDeinitEvent;
otaInterfaces.os.timer.start   = Posix_OtaStartTimer;
otaInterfaces.os.timer.stop    = Posix_OtaStopTimer;
otaInterfaces.os.timer.delete  = Posix_OtaDeleteTimer;
otaInterfaces.os.mem.malloc    = STDC_Malloc;
otaInterfaces.os.mem.free      = STDC_Free;
```

MQTT Interface

The OTA MQTT interface is a set of APIs that must be implemented in a library to enable the OTA library to download a file block from streaming service.

Example using the coreMQTT Agent APIs from the OTA over MQTT demo-

```
OtaInterfaces_t otaInterfaces;
otaInterfaces.mqtt.subscribe = prvMqttSubscribe;
otaInterfaces.mqtt.publish = prvMqttPublish;
otaInterfaces.mqtt.unsubscribe = prvMqttUnSubscribe;
```

HTTP Interface

The OTA HTTP interface is a set of APIs that must be implemented in a library to enable the OTA library to download a file block by connecting to a pre-signed url and fetching data blocks. It is optional unless you configure the OTA library to download from a pre-signed URL instead of a streaming service.

Example using the coreHTTP APIs from the OTA over HTTP demo-

```
OtaInterfaces_t otaInterfaces;
otaInterfaces.http.init = httpInit;
otaInterfaces.http.request = httpRequest;
otaInterfaces.http.deinit = httpDeinit;
```

OTA PAL Interface

The OTA PAL interface is a set of APIs that must be implemented for the device to use the OTA library. The device specific implementation for the OTA PAL is provided to the library in the user application. These functions are used by the library to store, manage, and authenticate downloads.

```
    OtaInterfaces_t otaInterfaces;
    otaInterfaces.pal.getPlatformImageState = otaPal_GetPlatformImageState;
    otaInterfaces.pal.setPlatformImageState = otaPal_SetPlatformImageState;
    otaInterfaces.pal.writeBlock = otaPal_WriteBlock;
    otaInterfaces.pal.activate = otaPal_ActivateNewImage;
    otaInterfaces.pal.closeFile = otaPal_CloseFile;
    otaInterfaces.pal.reset = otaPal_ResetDevice;
```

```
    otaInterfaces.pal.abort = otaPal_Abort;
    otaInterfaces.pal.createFile = otaPal_CreateFileForRx;
```

Changes in return -

The return is changed from OTA agent state to OTA error code. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaErr_t.

OTA_Shutdown

In the OTA Library version 1 the API used to shutdown the OTA Agent was OTA_AgentShutdown which is now changed to OTA_Shutdown along with changes in input parameters.

OTA Agent Shutdown (version 1)

```
OTA_State_t OTA_AgentShutdown( TickType_t xTicksToWait );
```

OTA Agent Shutdown (version 3)

```
OtaState_t OTA_Shutdown( uint32_t ticksToWait,
                         uint8_t unsubscribeFlag );
```

ticksToWait -

The number of ticks to wait for the OTA Agent to complete the shutdown process. If this is set to zero, the function will return immediately without waiting. The actual state is returned to the caller. The agent does not sleep for this while but used for busy looping.

New input parameter -

unsubscribeFlag -

Flag to indicate if unsubscribe operations should be performed from the job topics when shutdown is called. If the flag is 0 then unsubscribe operations are not called for job topics. If the application must be unsubscribed from the job topics then this flag must be set to 1 when calling OTA_Shutdown.

Changes in return -

OtaState_t -

The enum for OTA Agent state and its members are renamed. Please refer to AWS IoT Over-the-air Update v3.0.0.

OTA_GetState

The API name is changed from OTA_AgentGetState to OTA_GetState.

OTA Agent Shutdown (version 1)

```
OTA_State_t OTA_GetAgentState( void );
```

OTA Agent Shutdown (version 3)

```
OtaState_t OTA_GetState( void );
```

Changes in return -

OtaState_t -

The enum for OTA Agent state and its members are renamed. Please refer to AWS IoT Over-the-air Update v3.0.0.

OTA_GetStatistics

New single API added for statistics. It replaces the APIs OTA_GetPacketsReceived, OTA_GetPacketsQueued, OTA_GetPacketsProcessed, OTA_GetPacketsDropped. Also, in the OTA Library version 3, the statistics numbers are related to the current job only.

OTA Library version 1

```
uint32_t OTA_GetPacketsReceived( void );
uint32_t OTA_GetPacketsQueued( void );
uint32_t OTA_GetPacketsProcessed( void );
uint32_t OTA_GetPacketsDropped( void );
```

OTA Library version 3

```
OtaErr_t OTA_GetStatistics( OtaAgentStatistics_t * pStatistics );
```

pStatistics -

Input/output parameter for statistics data like packets received, dropped, queued and processed for current job.

Output parameter -

OTA error code.

Example usage -

```
OtaAgentStatistics_t otaStatistics = { 0 };
OTA_GetStatistics( &otaStatistics );
LogInfo( ( " Received: %u   Queued: %u   Processed: %u   Dropped: %u",
                           otaStatistics.otaPacketsReceived,
                           otaStatistics.otaPacketsQueued,
                           otaStatistics.otaPacketsProcessed,
                           otaStatistics.otaPacketsDropped ) );
```

OTA_ActivateNewImage

The input parameters are the same but the return OTA error code is renamed and new error codes are added in the version 3 of the OTA library.

OTA Library version 1

```
OTA_Err_t OTA_ActivateNewImage( void );
```

OTA Library version 3

```
OtaErr_t OTA_ActivateNewImage( void );
```

The return OTA error code enum is changed and new error codes are added. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaErr_t.

Example usage -

```
OtaErr_t otaErr = OtaErrNone;
otaErr = OTA_ActivateNewImage();
/* Handle error */
```

OTA_SetImageState

The input parameters are the same and renamed, the return OTA error code is renamed and new error codes are added in the version 3 of the OTA library.

OTA Library version 1

```
OTA_Err_t OTA_SetImageState( OTA_ImageState_t eState );
```

OTA Library version 3

```
OtaErr_t OTA_SetImageState( OtaImageState_t state );
```

The input parameter is renamed to OtaImageState_t. Please refer to AWS IoT Over-the-air Update v3.0.0.

The return OTA error code enum is changed and new error codes are added. Please refer to AWS IoT Over-the-air Update v3.0.0 / OtaErr_t.

Example usage -

```
 OtaErr_t otaErr = OtaErrNone;
 otaErr = OTA_SetImageState( OtaImageStateAccepted );
 /* Handle error */
```

OTA_GetImageState

The input parameters are same, the return enum is renamed in the version 3 of the OTA library.

OTA Library version 1

```
OTA_ImageState_t OTA_GetImageState( void );
```

OTA Library version 3

```
OtaImageState_t OTA_GetImageState( void );
```

The return enum is renamed to OtaImageState_t. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaImageState_t .

Example usage -

```
OtaImageState_t imageState;
imageState = OTA_GetImageState();
```

OTA_Suspend

The input parameters are the same, the return OTA error code is renamed and new error codes are added in the version 3 of the OTA library.

OTA Library version 1

```
OTA_Err_t OTA_Suspend( void );
```

OTA Library version 3

```
OtaErr_t OTA_Suspend( void );
```

The return OTA error code enum is changed and new error codes are added. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaErr_t.

Example usage -

```
OtaErr_t xOtaError = OtaErrUninitialized;
xOtaError = OTA_Suspend();
/* Handle error */
```

OTA_Resume

The input parameter for connection is removed as the connection is handled in the OTA demo/application, the return OTA error code is renamed and new error codes are added in the version 3 of the OTA library.

OTA Library version 1

```
OTA_Err_t OTA_Resume( void * pxConnection );
```

OTA Library version 3

```
OtaErr_t OTA_Resume( void );
```

The return OTA error code enum is changed and new error codes are added. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaErr_t.

Example usage -

```
OtaErr_t xOtaError = OtaErrUninitialized;
xOtaError = OTA_Resume();
/* Handle error */
```

OTA_CheckForUpdate

The input parameters are the same, the return OTA error code is renamed and new error codes are added in the version 3 of the OTA library.

OTA Library version 1

```
OTA_Err_t OTA_CheckForUpdate( void );
```

OTA Library version 3

```
OtaErr_t OTA_CheckForUpdate( void )
```

The return OTA error code enum is changed and new error codes are added. Please refer to AWS IoT Over-the-air Update v3.0.0 : OtaErr_t.

OTA_EventProcessingTask

This is a new API and is the main event loop to handle events for OTA updates. It must be called by the application task. This loop will continue to handle and execute events received for OTA Update until this task is terminated by the application.

OTA Library version 3

```
void OTA_EventProcessingTask( void * pUnused );
```

Example for FreeRTOS -

```
/* Create FreeRTOS task*/
xTaskCreate( prvOTAAgentTask,
             "OTA Agent Task",
             otaexampleAGENT_TASK_STACK_SIZE,
             NULL,
             otaexampleAGENT_TASK_PRIORITY,
             NULL );

/* Call OTA_EventProcessingTask from the task */
static void prvOTAAgentTask( void * pParam )
{
    /* Calling OTA agent task. */
    OTA_EventProcessingTask( pParam );
    LogInfo( ( "OTA Agent stopped." ) );

    /* Delete the task as it is no longer required. */
    vTaskDelete( NULL );
}
```

Example for POSIX -

```
/* Create posix thread.*/
if( pthread_create( &threadHandle, NULL, otaThread, NULL ) != 0 )
{
    LogError( ( "Failed to create OTA thread: "
                ",errno=%s",
                strerror( errno ) ) );

   /* Handle error. */
}

/* Call OTA_EventProcessingTask from the thread.*/
static void * otaThread( void * pParam )
{
    /* Calling OTA agent task. */
    OTA_EventProcessingTask( pParam );
    LogInfo( ( "OTA Agent stopped." ) );

    return NULL;
}
```

OTA_SignalEvent

This is a new API that adds the event to the back of the event queue and is also used by internal OTA modules to signal agent task.

OTA Library version 3

```
bool OTA_SignalEvent( const OtaEventMsg_t * const pEventMsg );
```

Example usage -

```
OtaEventMsg_t xEventMsg = { 0 };
xEventMsg.eventId = OtaAgentEventStart;
( void ) OTA_SignalEvent( &xEventMsg );
```

Integrating the OTA Library as a submodule in your application

If you want to integrate the OTA library in your own application you can use the git submodule command. Git submodules allow you to keep a Git repository as a subdirectory of another Git repository. The OTA library version 3 is maintained in the ota-for-aws-iot-embedded-sdk repository.

```
git submodule add https://github.com/aws/ota-for-aws-iot-embedded-
sdk.git destination_folder
```

```
git commit -m "Added the OTA Library as submodule to the project."
```

```
git push
```

For more information, see Integrating the OTA Agent into your application in the *FreeRTOS User Guide*.

References

- OTAv1.
- OTAv3.

Migrating from version 1 to version 3 for OTA Pal port

The Over-the-air Updates Library introduced some changes in the folder structure and the placement of configurations required by the library and the demo applications. For OTA applications designed to work with v1.2.0 to migrate to v3.0.0 of the library, you must update the PAL port function signatures and include additional configuration files as described in this migration guide.

Changes to OTA PAL

- The OTA PAL port directory name has been updated from `ota` to `ota_pal_for_aws`. This folder must contain 2 files: `ota_pal.c` and `ota_pal.h`. The PAL header file `libraries/freertos_plus/aws/ota/src/aws_iot_ota_pal.h` has been deleted from the OTA library and must be defined inside the port.
- The return codes (`OTA_Err_t`) are translated into an enum `OTAMainStatus_t`. Refer to ota_platform_interface.h for translated return codes. Helper macros are also provided to combine `OtaPalMainStatus` and `OtaPalSubStatus` codes and extract `OtaMainStatus` from `OtaPalStatus` and similar.
- Logging in the PAL
  - Removed the `DEFINE_OTA_METHOD_NAME` macro.
  - Earlier: `OTA_LOG_L1( "[%s] Receive file created.\r\n", OTA_METHOD_NAME );`.
  - Updated: `LogInfo(( "Receive file created."));` Use `LogDebug`, `LogWarn` and `LogError` for the appropriate log.
- Variable `cOTA_JSON_FileSignatureKey` changed to `OTA_JsonFileSignatureKey`.

Functions

The function signatures are defined in `ota_pal.h` and start with the prefix `otaPal` instead of `prvPAL`.

> **Note**
> The exact name of the PAL is technically open ended, but to be compatible with the qualification tests, the name should conform to the ones specified below.

- Version 1: `OTA_Err_t prvPAL_CreateFileForRx( OTA_FileContext_t * const *C* );`

  Version 3: `OtaPalStatus_t otaPal_CreateFileForRx( OtaFileContext_t * const *pFileContext* );`

  Notes: Create a new receive file for the data chunks as they come in.
- Version 1: `int16_t prvPAL_WriteBlock( OTA_FileContext_t * const C, uint32_t ulOffset, uint8_t * const pcData, uint32_t ulBlockSize );`

  Version 3: `int16_t otaPal_WriteBlock( OtaFileContext_t * const pFileContext, uint32_t ulOffset, uint8_t * const pData, uint32_t ulBlockSize );`

Notes: Write a block of data to the specified file at the given offset.

- Version 1: `OTA_Err_t prvPAL_ActivateNewImage( void );`

  Version 3: `OtaPalStatus_t otaPal_ActivateNewImage( OtaFileContext_t * const *pFileContext* );`

  Notes: Activate the newest MCU image received via OTA.

- Version 1: `OTA_Err_t prvPAL_ResetDevice( void );`

  Version 3: `OtaPalStatus_t otaPal_ResetDevice( OtaFileContext_t * const *pFileContext* );`

  Notes: Reset the device.

- Version 1: `OTA_Err_t prvPAL_CloseFile( OTA_FileContext_t * const *C* );`

  Version 3: `OtaPalStatus_t otaPal_CloseFile( OtaFileContext_t * const *pFileContext* );`

  Notes: Authenticate and close the underlying receive file in the specified OTA context.

- Version 1: `OTA_Err_t prvPAL_Abort( OTA_FileContext_t * const *C* );`

  Version 3: `OtaPalStatus_t otaPal_Abort( OtaFileContext_t * const *pFileContext* );`

  Notes: Abort an OTA transfer.

- Version 1: `OTA_Err_t prvPAL_SetPlatformImageState( OTA_ImageState_t *eState* );`

  Version 3: `OtaPalStatus_t otaPal_SetPlatformImageState( OtaFileContext_t * const pFileContext, OtaImageState_t eState );`

  Notes: Attempt to set the state of the OTA update image.

- Version 1: `OTA_PAL_ImageState_t prvPAL_GetPlatformImageState( void );`

  Version 3: `OtaPalImageState_t otaPal_GetPlatformImageState( OtaFileContext_t * const *pFileContext* );`

  Notes: Get the state of the OTA update image.

Data Types

- Version 1: `OTA_PAL_ImageState_t`

  File: `aws_iot_ota_agent.h`

  Version 3: `OtaPalImageState_t`

  File: `ota_private.h`

  Notes: *The image state set by platform implementation.*

- Version 1: `OTA_Err_t`

  File: `aws_iot_ota_agent.h`

  Version 3: `OtaErr_t OtaPalStatus_t (combination of OtaPalMainStatus_t and OtaPalSubStatus_t)`

File: `ota.h`, `ota_platform_interface.h`

Notes: v1: These were macros defining a 32 unsigned integer. v3: Specialized enum representing the type of error and associated with an error code.

- Version 1: `OTA_FileContext_t`

  File: `aws_iot_ota_agent.h`

  Version 3: `OtaFileContext_t`

  File: `ota_private.h`

  Notes: v1: Contains an enum and buffers for the data. v3: Contains additional data-length variables.

- Version 1: `OTA_ImageState_t`

  File: `aws_iot_ota_agent.h`

  Version 3: `OtaImageState_t`

  File: `ota_private.h`

  Notes: *OTA Image states*

Configuration changes

The file `aws_ota_agent_config.h` was renamed to `ota_config.h` which changes the include guards from `_AWS_OTA_AGENT_CONFIG_H_` to `OTA_CONFIG_H_`.

- The file `aws_ota_codesigner_certificate.h` has been deleted.
- Included the new logging stack to print debug messages:

```
/************************************************/
/******* DO NOT CHANGE the following order ********/
/************************************************/

/* Logging related header files are required to be included in the following order:
 * 1. Include the header file "logging_levels.h".
 * 2. Define LIBRARY_LOG_NAME and  LIBRARY_LOG_LEVEL.
 * 3. Include the header file "logging_stack.h".
 */

/* Include header that defines log levels. */
#include "logging_levels.h"

/* Configure name and log level for the OTA library. */
#ifndef LIBRARY_LOG_NAME
    #define LIBRARY_LOG_NAME     "OTA"
#endif
#ifndef LIBRARY_LOG_LEVEL
    #define LIBRARY_LOG_LEVEL    LOG_INFO
#endif

#include "logging_stack.h"

/************ End of logging configuration ***************/
```

- Added the constant config:

```
/** * @brief Size of the file data block message (excluding the header). */
#define otaconfigFILE_BLOCK_SIZE ( 1UL << otaconfigLOG2_FILE_BLOCK_SIZE )
```

New File: `ota_demo_config.h` contains the configs that are required by the OTA demo such as the code signing certificate and application version.

- `signingcredentialSIGNING_CERTIFICATE_PEM` which was defined in `demos/include/aws_ota_codesigner_certificate.h` has been moved to `ota_demo_config.h` as `otapalconfigCODE_SIGNING_CERTIFICATE` and can can be accessed from the PAL files as:

```
static const char codeSigningCertificatePEM[] = otapalconfigCODE_SIGNING_CERTIFICATE;
```

  The file `aws_ota_codesigner_certificate.h` has been deleted.
- The macros `APP_VERSION_BUILD`, `APP_VERSION_MINOR`, `APP_VERSION_MAJOR` have been added to `ota_demo_config.h`. The old files containing the version information have been removed, for example `tests/include/aws_application_version.h`, `libraries/c_sdk/standard/common/include/iot_appversion32.h`, `demos/demo_runner/aws_demo_version.c`.

Changes to the OTA PAL tests

- Removed the "Full_OTA_AGENT" test group along with all related files. This test group was previously required for qualification. These tests were for the OTA library and not specific to the OTA PAL port. The OTA library now has full test coverage that is hosted in the OTA repository so this test group is no longer required.
- Removed the "Full_OTA_CBOR" and "Quarantine_OTA_CBOR" test groups as well as all related files. These tests were not part of the qualification tests. The functionalities these tests covered are now being tested in the OTA repository.
- Moved the testing files from the library directory to the `tests/integration_tests/ota_pal` directory.
- Updated the OTA PAL qualification tests to use v3.0.0 of the OTA library API.
- Updated how the OTA PAL tests access the code signing certificate for tests. Previously there was a dedicated header file for the code signing credential. This is no longer the case for the new version of the library. The test code expects this variable to be defined in `ota_pal.c`. The value is assigned to a macro that is defined in the platform specific OTA config file.

Checklist

Use this checklist to make sure you follow the steps required for migration:

- Update the name of the ota pal port folder from `ota` to `ota_pal_for_aws`.
- Add the file `ota_pal.h` with the functions mentioned above. For an example `ota_pal.h` file, see GitHub.
- Add the configuration files:
  - Change the name of the file from `aws_ota_agent_config.h` to (or create) `ota_config.h`.
    - Add:

```
otaconfigFILE_BLOCK_SIZE ( 1UL << otaconfigLOG2_FILE_BLOCK_SIZE )
```

    - Include:

      ```
      #include "ota_demo_config.h"
      ```

    - Copy the above files to the `aws_test config` folder and substitute any includes of `ota_demo_config.h` with `aws_test_ota_config.h`.
    - Add an `ota_demo_config.h` file.
    - Add an `aws_test_ota_config.h` file.
- Make the following changes to `ota_pal.c`:
    - Update the includes with the latest OTA library file names.
    - Remove the `DEFINE_OTA_METHOD_NAME` macro.
    - Update the signatures of the OTA PAL functions.
    - Update the name of the file context variable from `C` to `pFileContext`.
    - Update the `OTA_FileContext_t` struct and all related variables.
    - Update `cOTA_JSON_FileSignatureKey` to `OTA_JsonFileSignatureKey`.
    - Update the `OTA_PAL_ImageState_t` and `Ota_ImageState_t` types.
    - Update the error type and values.
    - Update the printing macros to use the logging stack.
    - Update the `signingcredentialSIGNING_CERTIFICATE_PEM` to be `otapalconfigCODE_SIGNING_CERTIFICATE`.
    - Update `otaPal_CheckFileSignature` and `otaPal_ReadAndAssumeCertificate` function comments.
- Update the `CMakeLists.txt` file.
- Update the IDE projects.