Amazon FreeRTOS

User Guide

Amazon FreeRTOS: User Guide

Table of Contents

What Is Amazon FreeRTOS?

Amazon FreeRTOS consists of the following components:

- A microcontroller operating system based on the FreeRTOS kernel
- Amazon FreeRTOS libraries for connectivity, security, and over-the-air (OTA) updates.
- A console that allows you to download a zip file that contains everything you need to get started with Amazon FreeRTOS.
- Over-the-air (OTA) Updates.
- The Amazon FreeRTOS Qualification Program.

The FreeRTOS Kernel

The FreeRTOS kernel is a real-time operating system kernel that supports numerous architectures and is ideal for building embedded microcontroller applications. The kernel provides:

- A multitasking scheduler.
- Multiple memory allocation options (including the ability to create statically allocated systems).
- Inter-task coordination primitives, including task notifications, message queues, multiple types of semaphores, and stream and message buffers.

Amazon FreeRTOS Libraries

Amazon FreeRTOS includes libraries that enable you to:

- Securely connect devices to the AWS IoT cloud using MQTT and device shadows.
- Discover and connect to AWS IoT Greengrass cores.
- Manage Wi-Fi connections.
- Audit the configuration of your devices, monitor connected devices to detect abnormal behavior, and to mitigate security risks. For more information, see AWS IoT Device Defender. Amazon FreeRTOS provides a library that enables your Amazon FreeRTOS-based devices to write metrics to AWS IoT Device Defender. For more information, see Amazon FreeRTOS Device Defender Library.

  Note
  The Device Defender library currently works on the Microchip Curiosity PIC32MZEF development board and the Windows simulator.
- Listen for and process over-the-air (OTA) updates.

Amazon FreeRTOS Console

The Amazon FreeRTOS console enables you to configure and download a package that contains everything you need to write an application for your microcontroller-based devices:

- The FreeRTOS kernel
- Amazon FreeRTOS libraries
- Platform support libraries

- Hardware drivers

You can download a package with a predefined configuration or create your own configuration by selecting your hardware platform and the libraries required for your application. These configurations are saved in AWS and are available for download at any time.

The Amazon FreeRTOS console is part of the AWS IoT console. You can find it by choosing the link above or by browsing to the AWS IoT console.

To open the Amazon FreeRTOS console

1. Browse to the AWS IoT console.
2. From the navigation pane choose **Software**.
3. Under **Amazon FreeRTOS Device Software** choose **Configure Download**.

Downloading Amazon FreeRTOS Source Code

You can download the RTOS kernel and software libraries from the Amazon FreeRTOS console or from GitHub.

Over-the-Air Updates

Internet-connected devices can be in use for a long time, and must be updated periodically to fix bugs and improve functionality. Often these devices must be updated in the field and need to be updated remotely or "over-the-air". The Amazon FreeRTOS Over-the-Air (OTA) Update service enables you to:

- Digitally sign firmware prior to deployment.
- Securely 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, reset, or reprovisioned.
- Once deployed to devices, verify the authenticity and integrity of the new firmware.
- Monitor the progress of a deployment.
- Debug a failed deployment.

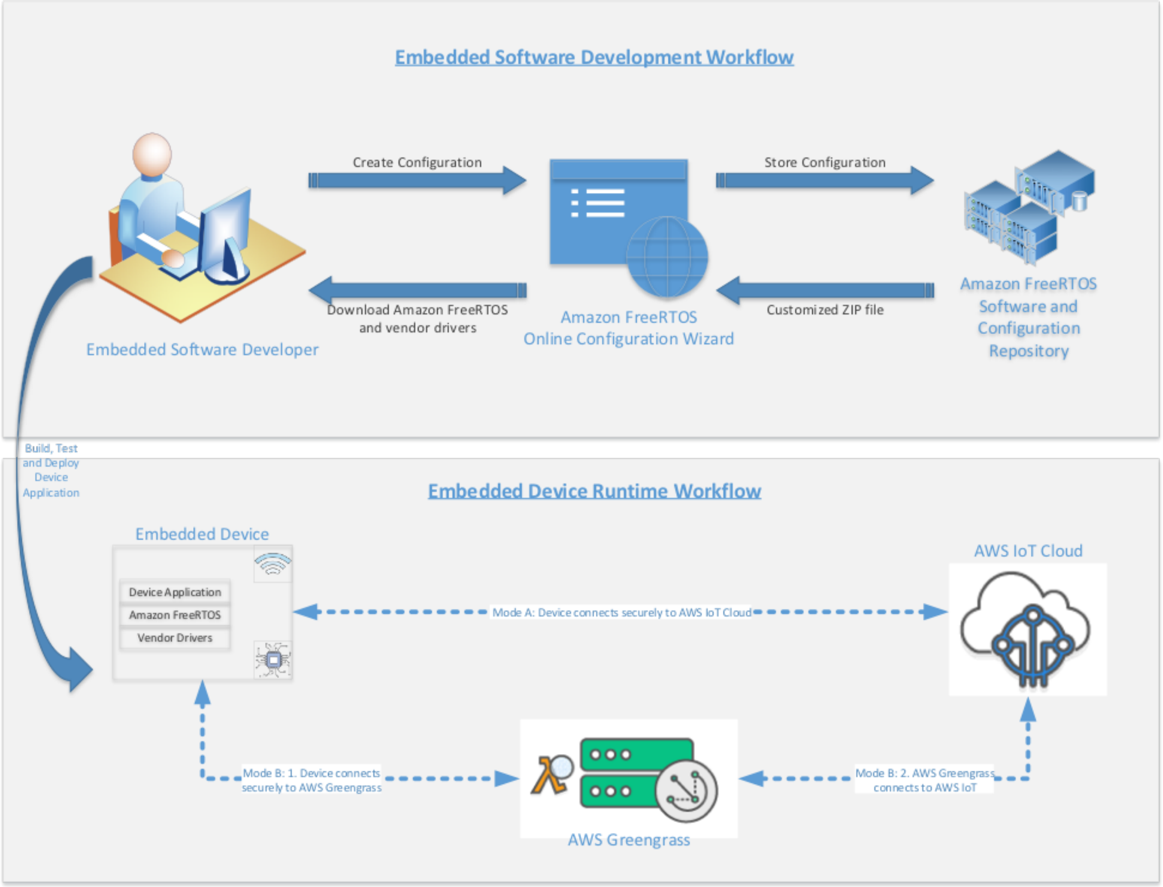
When you send files over the air, it is a best practice to digitally sign them so that the devices that receive the files can verify they have not been tampered with en route. You can use Code Signing for Amazon FreeRTOS to sign and encrypt your files or you can sign your files with your own code-signing tools. For more information about Code Signing for Amazon FreeRTOS, see the Code Signing for Amazon FreeRTOS Developer Guide.

For more information about OTA updates, see:

- Amazon FreeRTOS Over-the-Air Updates (p. 108)
- OTA Demo Application (p. 168)

Development Workflow

You start development by configuring and downloading a package from the Amazon FreeRTOS console in the AWS IoT console. You unzip the package and import it into your IDE. You can then develop your embedded application on your selected hardware platform and manufacture and deploy these devices using the development process appropriate for your device. Deployed devices can connect to the AWS IoT service or AWS IoT Greengrass as part of a complete IoT solution. The following diagram shows the development workflow and the subsequent connectivity from Amazon FreeRTOS-based devices.


Embedded Software Development Workflow
Create Configuration
Store Configuration
Download Amazon FreeRTOS and vendor drivers
Customized ZIP file
Embedded Software Developer
Amazon FreeRTOS Online Configuration Wizard
Amazon FreeRTOS Software and Configuration Repository
Build, Test and Deploy Device Application
Embedded Device Runtime Workflow
Embedded Device
Device Application
Amazon FreeRTOS
Vendor Drivers
AWS IoT Cloud
Mode A: Device connects securely to AWS IoT Cloud
Mode B: 1. Device connects securely to AWS Greengrass
Mode B: 2. AWS Greengrass connects to AWS IoT
AWS Greengrass

You can also download the Amazon FreeRTOS source code from GitHub.

Getting Started with Amazon FreeRTOS

This section shows you how to download and configure Amazon FreeRTOS and run a demo application on one of the qualified microcontroller boards. In this tutorial, we assume you are familiar with AWS IoT and the AWS IoT console. If not, we recommend that you start with the AWS IoT Getting Started tutorial.

Prerequisites

To follow along with this tutorial, you need an AWS account, an IAM user with permission to access AWS IoT and Amazon FreeRTOS, and one of the supported hardware platforms.

AWS Account and Permissions

To create an AWS account, see Create and Activate an AWS Account.

To add an IAM user to your AWS account, see IAM User Guide. To grant your IAM user account access to AWS IoT and Amazon FreeRTOS, attach the following IAM policies to your IAM user account:

- `AmazonFreeRTOSFullAccess`
- `AWSIoTFullAccess`

To attach the AmazonFreeRTOSFullAccess policy to your IAM user

1. Browse to the IAM console, and from the navigation pane, choose **Users**.
2. Enter your user name in the search text box, and then choose it from the list.
3. Choose **Add permissions**.
4. Choose **Attach existing policies directly**.
5. In the search box, enter **`AmazonFreeRTOSFullAccess`**, choose it from the list, and then choose **Next: Review**.
6. Choose **Add permissions**.

To attach the AWSIoTFullAccess policy to your IAM user

1. Browse to the IAM console, and from the navigation pane, choose **Users**.
2. Enter your user name in the search text box, and then choose it from the list.
3. Choose **Add permissions**.
4. Choose **Attach existing policies directly**.
5. In the search box, enter **`AWSIoTFullAccess`**, choose it from the list, and then choose **Next: Review**.
6. Choose **Add permissions**.

For more information about IAM and user accounts, see IAM User Guide.

For more information about policies, see IAM Permissions and Policies.

Amazon FreeRTOS Supported Hardware Platforms

You need one of the supported MCU boards:

- STMicroelectronicsSTM32L4 Discovery Kit IoT Node
- Texas Instruments CC3220SF-LAUNCHXL
- NXP LPC54018 IoT Module
- Microchip Curiosity PIC32MZEF Bundle
- Espressif ESP32-DevKitC
- Espressif ESP-WROVER-KIT
- Infineon XMC4800 IoT Connectivity Kit
- Xilinx Avnet MicroZed Industrial IoT Kit
- Microsoft Windows 7 or later, with at least a dual core and a hard-wired Ethernet connection
- Nordic nRF52840-DK [BETA]

Registering Your MCU Board with AWS IoT

You must register your MCU board so it can communicate with AWS IoT. To register your device, you must create:

- An IoT thing.

  An IoT thing allows you to manage your devices in AWS IoT.
- A private key and X.509 certificate.

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

  The AWS IoT policy grants your device permissions to access AWS IoT resources.

To create an AWS IoT policy

1. To create an IAM policy, you need to know your AWS Region and AWS account number.

   To find your AWS account number, in the upper-right corner of the AWS Management Console, choose **My Account**. Your account ID is displayed under **Account Settings**.

   To find the AWS Region for your AWS account, open a command prompt window and enter the following command:

   ```
   AWS IoT describe-endpoint
   ```

   The output should look like this:

   ```
   {
       "endpointAddress": "xxxxxxxxxxxxxx.iot.us-west-2.amazonaws.com"
   }
   ```

   In this example, the region is `us-west-2`.

2. Browse to the AWS IoT console.
3. In the navigation pane, choose **Secure**, choose **Policies**, and then choose **Create**.
4. Enter a name to identify your policy.
5. In the **Add statements** section, choose **Advanced mode**. Copy and paste the following JSON into the policy editor window. Replace *aws-region* and *aws-account* with your region and account ID .

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

    This policy grants the following permissions:

    `iot:Connect`

    Grants your device the permission to connect to the AWS IoT message broker.

    `iot:Publish`

    Grants your device the permission to publish an MQTT message on the `freertos/demos/echo` MQTT topic.

    `iot:Subscribe`

    Grants your device the permission to subscribe to the `freertos/demos/echo` MQTT topic filter.

    `iot:Receive`

    Grants your device the permission to receive messages from the AWS IoT message broker.
6. 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 IoT 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. Make a note of the certificate ID. You need it later to attach a policy to your certificate.
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 choose **Register thing**.

Install a Terminal Emulator

A terminal emulator can help you diagnose problems or verify your device code is running properly. There are a variety of terminal emulators available for Windows, macOS, and Linux. You must connect your device to your computer before you attempt to connect a terminal emulator to your device.

Use these settings in your terminal emulator:

Terminal Setting	Value
Port	Depends on platform and other devices you have connected to your computer.
BAUD rate	115200
Data	8 bit
Parity	none
Stop	1 bit
Flow control	none

Getting Started with the Texas Instruments CC3220SF-LAUNCHXL

Before you begin, see Prerequisites (p. 4).

If you do not have the Texas Instruments (TI) CC3220SF-LAUNCHXL Development Kit, you can purchase one from Texas Instruments.

Setting Up Your Environment

Amazon FreeRTOS supports two IDEs for the TI CC3220SF-LAUNCHXL development kit: Code Composer Studio and IAR Embedded Workbench.

For information about installing Code Composer Studio, see Install Code Composer Studio (p. 8).

For information about installing IAR Embedded Workbench, see Install IAR Embedded Workbench (p. 8).

You also need to Install the SimpleLink CC3220 SDK (p. 8), Install Uniflash (p. 9), Configure Wi-Fi Provisioning (p. 9), and Install the Latest Service Pack (p. 9).

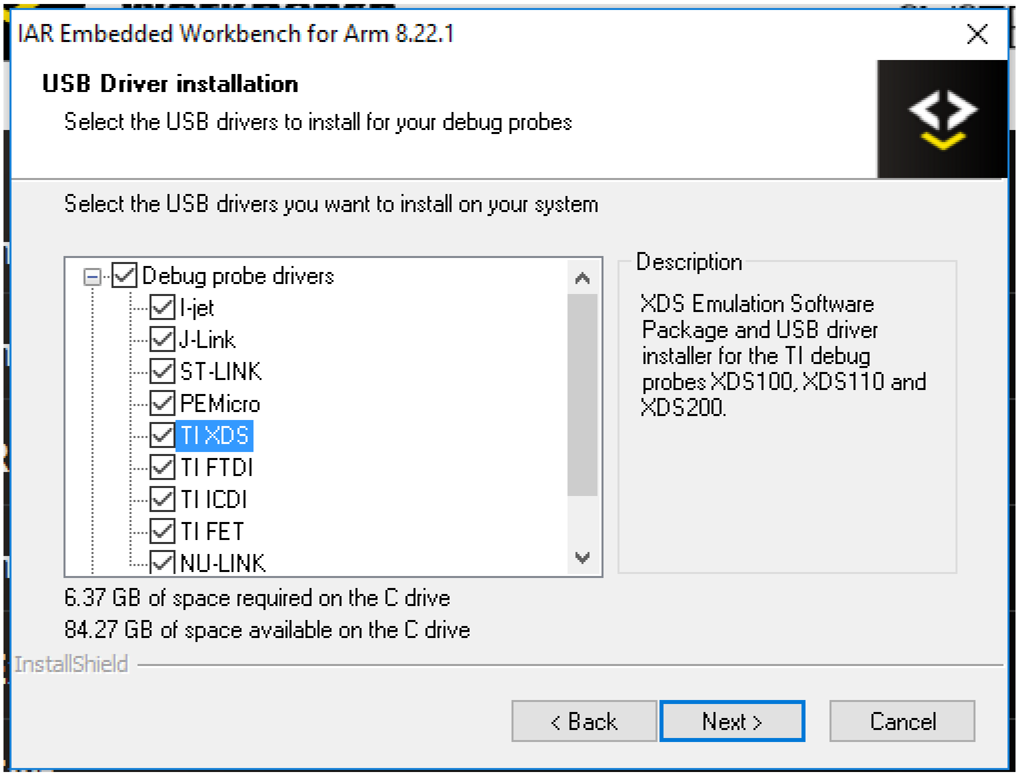
Install Code Composer Studio

1. Browse to TI Code Composer Studio.
2. Download the offline installer for version 7.3.0 for the platform of your host machine (Windows, macOS, or Linux 64-bit).
3. Unzip and run the offline installer. Follow the prompts.
4. For **Product Families to Install**, choose **SimpleLink Wi-Fi CC32xx Wireless MCUs**.
5. On the next page, accept the default settings for debugging probes, and then choose **Finish**.

If you experience issues when you are installing Code Composer Studio, see TI Development Tools Support, Code Composer Studio FAQs, and Troubleshooting Code Composer Studio.

Install IAR Embedded Workbench

1. Browse to IAR Embedded Workbench for ARM.
2. Download and run the Windows installer. In **Debug probe drivers**, make sure that **TI XDS** is selected:



IAR Embedded Workbench for Arm 8.22.1

USB Driver installation

Select the USB drivers to install for your debug probes

Select the USB drivers you want to install on your system

- ☑ Debug probe drivers
  - ☑ I-jet
  - ☑ J-Link
  - ☑ ST-LINK
  - ☑ PEMicro
  - ☑ TI XDS
  - ☑ TI FTDI
  - ☑ TI ICDI
  - ☑ TI FET
  - ☑ NU-LINK

Description

XDS Emulation Software Package and USB driver installer for the TI debug probes XDS100, XDS110 and XDS200.

6.37 GB of space required on the C drive
84.27 GB of space available on the C drive

3. Complete the installation and launch the program. On the **License Wizard** page, choose **Register with IAR Systems to get an evaluation license**, or use your own IAR license.

Install the SimpleLink CC3220 SDK

Install the SimpleLink CC3200 SDK. The SimpleLink Wi-Fi CC3200 SDK contains drivers for the CC3200 programmable MCU, more than 40 sample applications, and documentation required to use the samples.

Install Uniflash

Install Uniflash. CCS Uniflash is a standalone tool used to program on-chip flash memory on TI MCUs. Uniflash has a GUI, command line, and scripting interface.

Configure Wi-Fi Provisioning

To configure the Wi-Fi settings for your board, do one of the following:

- Complete the Amazon FreeRTOS demo application described in Configure Your Project (p. 10).
- Use SmartConfig from Texas Instruments.

Install the Latest Service Pack

1. On your TI CC3220SF-LAUNCHXL, place the SOP jumper on the middle set of pins (position = 1) and reset the board.
2. Start Uniflash, and from the list of configurations, choose **CC3200SF-LAUNCHXL**. Choose **Start Image Creator**.
3. Choose **New Project**.
4. On the **Start new project** page, enter a name for your project. For **Device Type**, choose **CC3220SF**. For **Device Mode**, choose **Develop**, and then choose **Create Project**.
5. Disconnect your serial terminal (if previously connected) and on the right side of the Uniflash application window, choose **Connect**.
6. From the left column, choose **Service Pack**.
7. Choose **Browse**, and then navigate to where you installed the CC3220SF SimpleLink SDK. The service pack is located at `ti\simplelink_cc32xx_sdk_VERSION\tools\cc32xx_tools\servicepack-cc3x20\sp_VERSION.bin`.
8. Choose the button and then choose **Program Image (Create & Program)** to install the service pack. Remember to switch the SOP jumper back to position 0 and reset the board.

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Under **Software Configurations**, find **Connect to AWS IoT- TI**, and then:

   If you are using Code Composer Studio, choose **Download**.

   If you are using IAR Embedded Workbench, choose **Connect to AWS IoT-TI**. Under **Hardware platform**, choose **Edit**. Under **Integrated Development Environment (IDE)**, choose **IAR Embedded Workbench**. Make sure the compiler is set to IAR, and then choose **Create and Download**.
5. Unzip the downloaded file to your hard drive. When unzipped, you have a directory named `AmazonFreeRTOS`. You can place this directory anywhere you want, but be aware of path length limitations on Windows.

Note

The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.

In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. Registering Your MCU Board with AWS IoT (p. 5) is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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 `<1234567890123>-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. In your IDE, open `<BASE_FOLDER>\demos\common\include\aws_clientcredential.h` and specify values for the following `#define` constants:
   - `clientcredentialMQTT_BROKER_ENDPOINT` *Your AWS IoT endpoint*
   - `clientcredentialIOT_THING_NAME` *The AWS IoT thing name of your board*

To configure your Wi-Fi

1. Open the `aws_clientcredential.h` file.
2. Specify values for the following `#define` constants:
   - `clientcredentialWIFI_SSID` *The SSID for your Wi-Fi network*
   - `clientcredentialWIFI_PASSWORD` *The password for your Wi-Fi network*
   - `clientcredentialWIFI_SECURITY` *The security type of your Wi-Fi network*

     Valid security types are:
     - `eWiFiSecurityOpen` (Open, no security)
     - `eWiFiSecurityWEP` (WEP security)
     - `eWiFiSecurityWPA` (WPA security)
     - `eWiFiSecurityWPA2` (WPA2 security)

To configure your AWS IoT credentials

Note

To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You must format the certificate and private key for your device.

1. In a browser window, open *<BASE_FOLDER>*`\tools\certificate_configuration\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the *<ID>*`-certificate.pem.crt` that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *<ID>*`-private.pem.key` that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in *<BASE_FOLDER>*`\demos\common\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.

Build and Run Amazon FreeRTOS Samples

Build and Run Amazon FreeRTOS Samples in TI Code Composer

Import the Amazon FreeRTOS Sample Code into TI Code Composer

1. Open TI Code Composer, and choose **OK** to accept the default workspace name.
2. On the **Getting Started** page, choose **Import Project**.
3. In **Select search-directory**, enter *<BASE_FOLDER>*`\demos\ti\cc3220_launchpad\ccs`. The project `aws_demos` should be selected by default. To import the project into TI Code Composer, choose **Finish**.
4. In **Project Explorer**, double-click **aws_demos** to make the project active.
5. From **Project**, choose **Build Project** to make sure the project compiles without errors or warnings.

Subscribe to MQTT topic

Note
Before you run the Amazon FreeRTOS samples, do the following:

1. Make sure the Sense On Power (SOP) jumper on your Texas Instruments CC3220SF-LAUNCHXL is in position 0. For more information, see CC3200 SimpleLink User's Guide.
2. Use a USB cable to connect your Texas Instruments CC3220SF-LAUNCHXL to your computer.
3. Sign in to the AWS IoT console.
4. In the navigation pane, choose **Test** to open the MQTT client.
5. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.

Run the Amazon FreeRTOS samples in TI Code Composer

1. Rebuild your project.
2. In TI Code Composer,from **Run**, choose **Debug**.
3. When the debugger stops at the breakpoint in `main()`, go to the **Run** menu, and choose **Resume**.

In the MQTT client in the AWS IoT console, you should see the MQTT messages sent by your device.

Build and Run Amazon FreeRTOS Samples in IAR Embedded Workbench

Import the Amazon FreeRTOS Sample Code into IAR Embedded Workbench

1. Open IAR Embedded Workbench, choose **File**, and then choose **Open Workspace**.
2. Navigate to `<BASE_FOLDER>\demos\ti\cc3220_launchpad\iar`, choose **aws_demos.eww**, and then choose **OK**.
3. Right-click the project name (`aws_demos`), and then choose **Make**.

Subscribe to MQTT topic

1. Make sure the Sense On Power (SOP) jumper on your Texas Instruments CC3220SF-LAUNCHXL is in position 0. For more information, see CC3200 SimpleLink User's Guide.
2. Use a USB cable to connect your Texas Instruments CC3220SF-LAUNCHXL to your computer.
3. Sign in to the AWS IoT console.
4. In the navigation pane, choose **Test** to open the MQTT client.
5. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.

Run the Amazon FreeRTOS samples in IAR Embedded Workbench

1. Rebuild your project.

   To rebuild the project, from the **Project** menu, choose **Make**.
2. From the **Project** menu, choose **Download and Debug**. You can ignore "Warning: Failed to initialize EnergyTrace," if it's displayed. For more information about EnergyTrace, see MSP EnergyTrace Technology.
3. When the debugger stops at the breakpoint in `main()`, go to the **Debug** menu, and choose **Go**.

You should see MQTT messages sent by your device in the MQTT client of the AWS IoT console.

Troubleshooting

If you don’t see messages in the MQTT client of the AWS IoT console, you might need to configure debug settings for the board.

1. In Code Composer, on **Project Explorer**, choose **aws_demos**.
2. From the **Run** menu, choose **Debug Configurations**.
3. In the navigation pane, choose **aws_demos**.
4. On the **Target** tab, under **Connection Options**, choose **Reset the target on a connect**.
5. Choose **Apply**, and then choose **Close**.

If these steps don’t work, look at the program's output in the serial terminal. You should see some text that indicates the source of the problem.

Getting Started with the STMicroelectronics STM32L4 Discovery Kit IoT Node

Before you begin, see Prerequisites (p. 4).

If you do not already have the STMicroelectronics STM32L4 Discovery Kit IoT Node, you can purchase one from STMicroelectronics.

Make sure you have installed the latest Wi-Fi firmware. To download the latest Wi-Fi firmware, see STM32L4 Discovery kit IoT node, low-power wireless, BLE, NFC, SubGHz, Wi-Fi. Under **Binary Resources**, choose **Inventek ISM 43362 Wi-Fi module firmware update (read the readme file for instructions)** .

Setting Up Your Environment

Install System Workbench for STM32

1. Browse to OpenSTM32.org.
2. Register on the OpenSTM32 webpage. You need to sign in to download System Workbench.
3. Browse to the System Workbench for STM32 installer to download and install System Workbench.

If you experience issues during installation, see the FAQs on the System Workbench website.

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. In the AWS IoT console, browse to the Amazon FreeRTOS page.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose **Download FreeRTOS Software**.
5. Under **Software Configurations**, find **Connect to AWS IoT- ST**, and then choose **Download**.
6. Unzip the downloaded file to the AmazonFreeRTOS folder, and make a note of the folder's path.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. Registering Your MCU Board with AWS IoT (p. 5) is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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 `*<1234567890123>*-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. In your IDE, open `*<BASE_FOLDER>*\demos\common\include\aws_clientcredential.h` and specify values for the following `#define` constants:

   - `clientcredentialMQTT_BROKER_ENDPOINT` *`Your AWS IoT endpoint`*
   - `clientcredentialIOT_THING_NAME` *`The AWS IoT thing name of your board`*

To configure your Wi-Fi

1. Open the `aws_clientcredential.h` file.
2. Specify values for the following `#define` constants:

   - `clientcredentialWIFI_SSID` *`The SSID for your Wi-Fi network`*
   - `clientcredentialWIFI_PASSWORD` *`The password for your Wi-Fi network`*
   - `clientcredentialWIFI_SECURITY` *`The security type of your Wi-Fi network`*

     Valid security types are:
     - `eWiFiSecurityOpen` (Open, no security)
     - `eWiFiSecurityWEP` (WEP security)
     - `eWiFiSecurityWPA` (WPA security)
     - `eWiFiSecurityWPA2` (WPA2 security)

To configure your AWS IoT credentials

> **Note**
> To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You must format the certificate and private key for your device.

1. In a browser window, open `*<BASE_FOLDER>*\tools\certificate_configuration\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the `*<ID>*-certificate.pem.crt` that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the `*<ID>*-private.pem.key` that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in `*<BASE_FOLDER>*\demos\common\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.

Build and Run Amazon FreeRTOS Samples

Import the Amazon FreeRTOS Sample Code into the STM32 System Workbench

1. Open the STM32 System Workbench and enter a name for a new workspace.
2. From the **File** menu, choose **Import**. Expand **General**, choose **Existing Projects into Workspace**, and then choose **Next**.
3. In **Select Root Directory**, enter `<BASE_FOLDER>\demos\st\stm32l475_discovery\ac6`.
4. The project `aws_demos` should be selected by default.
5. Choose **Finish** to import the project into STM32 System Workbench.
6. From the **Project** menu, choose **Build All**. Confirm the project compiles without any errors or warnings.

Run the Amazon FreeRTOS Samples

1. Use a USB cable to connect your STMicroelectronics STM32L4 Discovery Kit IoT Node to your computer.
2. Rebuild your project.
3. Sign in to the AWS IoT console.
4. In the navigation pane, choose **Test** to open the MQTT client.
5. In **Subscription topic**, enter `freertos/demos/echo`, and then choose **Subscribe to topic**.
6. From **Project Explorer**, right-click `aws_demos`, choose **Debug As**, and then choose **Ac6 STM32 C/C++ Application**.

   If a debug error occurs the first time a debug session is launched, follow these steps:

   1. In STM32 System Workbench, from the **Run** menu, choose **Debug Configurations**.
   2. Choose **aws_demos Debug**. (You might need to expand **Ac6 STM32 Debugging**.)
   3. Choose the **Debugger** tab.
   4. In **Configuration Script**, choose **Show Generator Options**.
   5. In **Mode Setup**, set **Reset Mode** to **Software System Reset**. Choose **Apply**, and then choose **Debug**.
7. When the debugger stops at the breakpoint in `main()`, from the **Run** menu, choose **Resume**.

You should see MQTT messages sent by your device in the MQTT client in the AWS IoT console.

Run the Bluetooth Low-Energy Demo

Amazon FreeRTOS support for Bluetooth Low Energy is in public beta release. BLE demos are subject to change.

Note
To run the BLE demo, you need the SPBTLE-1S BLE module for the STM32L475 Discovery Kit.

Amazon FreeRTOS supports Bluetooth Low Energy (BLE) connectivity. You can download Amazon FreeRTOS with BLE from GitHub.

For instructions about how to run the MQTT over BLE demo on your board, see the MQTT over BLE demo application.

Troubleshooting

If you see the following in the UART output from the demo application, you need to update the Wi-Fi module’s firmware:

```
[Tmr Svc] WiFi firmware version is: xxxxxxxxxxxxx
[Tmr Svc] [WARN] WiFi firmware needs to be updated.
```

To download the latest Wi-Fi firmware, see STM32L4 Discovery kit IoT node, low-power wireless, BLE, NFC, SubGHz, Wi-Fi. In **Binary Resources**, choose the download link for **Inventek ISM 43362 Wi-Fi module firmware update**.

Getting Started with the NXP LPC54018 IoT Module

Before you begin, see Prerequisites (p. 4).

If you do not have an NXP LPC54018 IoT Module, you can order one from NXP. Use a USB cable to connect your NXP LPC54018 IoT Module to your computer.

Setting Up Your Environment

Amazon FreeRTOS supports two IDEs for the NXP LPC54018 IoT Module: IAR Embedded Workbench and MCUXpresso.

Before you begin, install one of these IDEs.

To install IAR Embedded Workbench for ARM

1. Browse to Software for NXP Kits and choose **Download Software**.

   Note
   IAR Embedded Workbench for ARM requires Microsoft Windows.
2. Unzip and run the installer. Follow the prompts.
3. In the **License Wizard**, choose **Register with IAR Systems to get an evaluation license**.

To install MCUXpresso from NXP

1. Download and run the MCUXpresso installer from NXP.
2. Browse to MCUXpresso SDK and choose **Build your SDK.**
3. Choose **Select Development Board**.
4. Under **Select Development Board**, in **Search by Name**, enter **`LPC54018-IoT-Module`**.
5. Under **Boards**, choose **LPC54018-IoT-Module**.
6. Verify the hardware details, and then choose **Build MCUXepresso SDK**.
7. The SDK for Windows using the MCUXpresso IDE is already built. Choose **Download SDK**. If you are using another operating system, under **Host OS**, choose your operating system, and then choose **Download SDK**.

8. Start the MCUXpresso IDE, and choose the **Installed SDKs** tab.
9. Drag and drop the downloaded SDK archive file into the **Installed SDKs** window.

If you experience issues during installation, see NXP Support or NXP Developer Resources.

Connecting a JTAG Debugger

You need a JTAG debugger to launch and debug your code running on the NXP LPC54018 board. Amazon FreeRTOS was tested using a Segger J-Link probe. For more information about supported debuggers, see the NXP LPC54018 User Guide.

> **Note**
> If you are using a Segger J-Link debugger, you need a converter cable to connect the 20-pin connector from the debugger to the 10-pin connector on the NXP IoT module.

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. Browse to the Amazon FreeRTOS page in the AWS IoT console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose **Download FreeRTOS Software**.
5. Under **Software Configurations**, find **Connect to AWS IoT- NXP**, and then:

   If you are using IAR Workbench, choose **Download**.

   If you are using MCUXpresso:

   a. In **Software Configurations**, find **Connect to AWS IoT- NXP**. Select **Connect to AWS IoT- NXP**, but do not choose **Download**.
   b. Under **Hardware Platform**, choose **Edit**.
   c. Under **Integrated Development Environment (IDE)**, choose **MCUXpresso**.
   d. Under **Compiler**, choose **GCC**.
   e. At the bottom of the page, choose **Create and Download**.
6. Unzip the downloaded file to the AmazonFreeRTOS folder and make a note of the folder's path.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. Registering Your MCU Board with AWS IoT (p. 5) is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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 `<1234567890123>-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. In your IDE, open `<BASE_FOLDER>\demos\common\include\aws_clientcredential.h` and specify values for the following `#define` constants:

   - `clientcredentialMQTT_BROKER_ENDPOINT` *`Your AWS IoT endpoint`*
   - `clientcredentialIOT_THING_NAME` *`The AWS IoT thing name of your board`*

To configure your Wi-Fi

1. Open the `aws_clientcredential.h` file.
2. Specify values for the following `#define` constants:

   - `clientcredentialWIFI_SSID` *`The SSID for your Wi-Fi network`*
   - `clientcredentialWIFI_PASSWORD` *`The password for your Wi-Fi network`*
   - `clientcredentialWIFI_SECURITY` *`The security type of your Wi-Fi network`*

     Valid security types are:
     - `eWiFiSecurityOpen` (Open, no security)
     - `eWiFiSecurityWEP` (WEP security)
     - `eWiFiSecurityWPA` (WPA security)
     - `eWiFiSecurityWPA2` (WPA2 security)

To configure your AWS IoT credentials

> **Note**
> To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You must format the certificate and private key for your device.

1. In a browser window, open `<BASE_FOLDER>\tools\certificate_configuration\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the `<ID>-certificate.pem.crt` that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the `<ID>-private.pem.key` that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in `<BASE_FOLDER>\demos\common\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.

Build and Run Amazon FreeRTOS Samples

Import the Amazon FreeRTOS Sample Code into Your IDE

To import the Amazon FreeRTOS sample code into the IAR Embedded Workbench IDE

1. Open IAR Embedded Workbench, and from the **File** menu, choose **Open Workspace**.
2. In the **search-directory** text box, enter `<BASE_FOLDER>\demos\nxp\lpc54018_iot_module\iar`, and choose **aws_demos.eww**.
3. From the **Project** menu, choose **Rebuild All**.

To import the Amazon FreeRTOS sample code into the MCUXpresso IDE

1. Open MCUXpresso, and from the **File** menu, choose **Open Projects From File System**.
2. In the **Directory** text box, enter `<BASE_FOLDER>\demos\nxp\lpc54018_iot_module\mcuxpresso`, and choose **Finish**
3. From the **Project** menu, choose **Build All**.

Run the FreeRTOS Samples

To run the Amazon FreeRTOS demos on the NXP LPC54018 IoT Module board, connect the USB port on the NXP IoT Module to your host computer, open a terminal program, and connect to the port identified as USB Serial Device.

1. Rebuild your project.
2. Sign in to the AWS IoT console.
3. In the navigation pane, choose **Test** to open the MQTT client.
4. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.
5. In your IDE, from the **Project** menu, choose **Build**.
6. Connect the NXP IoT Module and the Segger J-Link Debugger to the USB ports on your computer using mini-USB to USB cables.
7. If you are using IAR Embedded Workbench:

    a. From the **Project** menu, choose **Download and Debug**.

    b. From the **Debug** menu, choose **Start Debugging**.

    c. When the debugger stops at the breakpoint in `main`, from the **Debug** menu, choose **Go.**

    Note

    If a **J-Link Device Selection** dialog box opens, choose **OK** to continue. In the **Target Device Settings** dialog box, choose **Unspecified**, choose **Cortex-M4**, and then choose **OK**. You only need to be do this once.
8. If you are using MCUXpresso:

    a. If this is your first time debugging, choose the `aws_demos` project and from the **Debug** toolbar, choose the blue debug button.

    b. Any detected debug probes are displayed. Choose the probe you want to use, and then choose **OK** to start debugging.

> **Note**
> When the debugger stops at the breakpoint in `main()`, press the debug restart button once to reset the debugging session. (This is required due to a bug with MCUXpresso debugger for NXP54018-IoT-Module).

9. When the debugger stops at the breakpoint in `main()`, from the **Debug** menu, choose **Go**.

You should see MQTT messages sent by your device in the MQTT client of the AWS IoT console.

Troubleshooting

If no messages appear in the AWS IoT console, try the following:

1. Open a terminal window to view the logging output of the sample. This can help you determine what is going wrong.
2. Check that your network credentials are valid.

Getting Started with the Microchip Curiosity PIC32MZEF

Before you begin, see Prerequisites (p. 4).

If you do not have the Microchip Curiosity PIC32MZEF bundle, you can purchase one from Microchip. You need the following items:

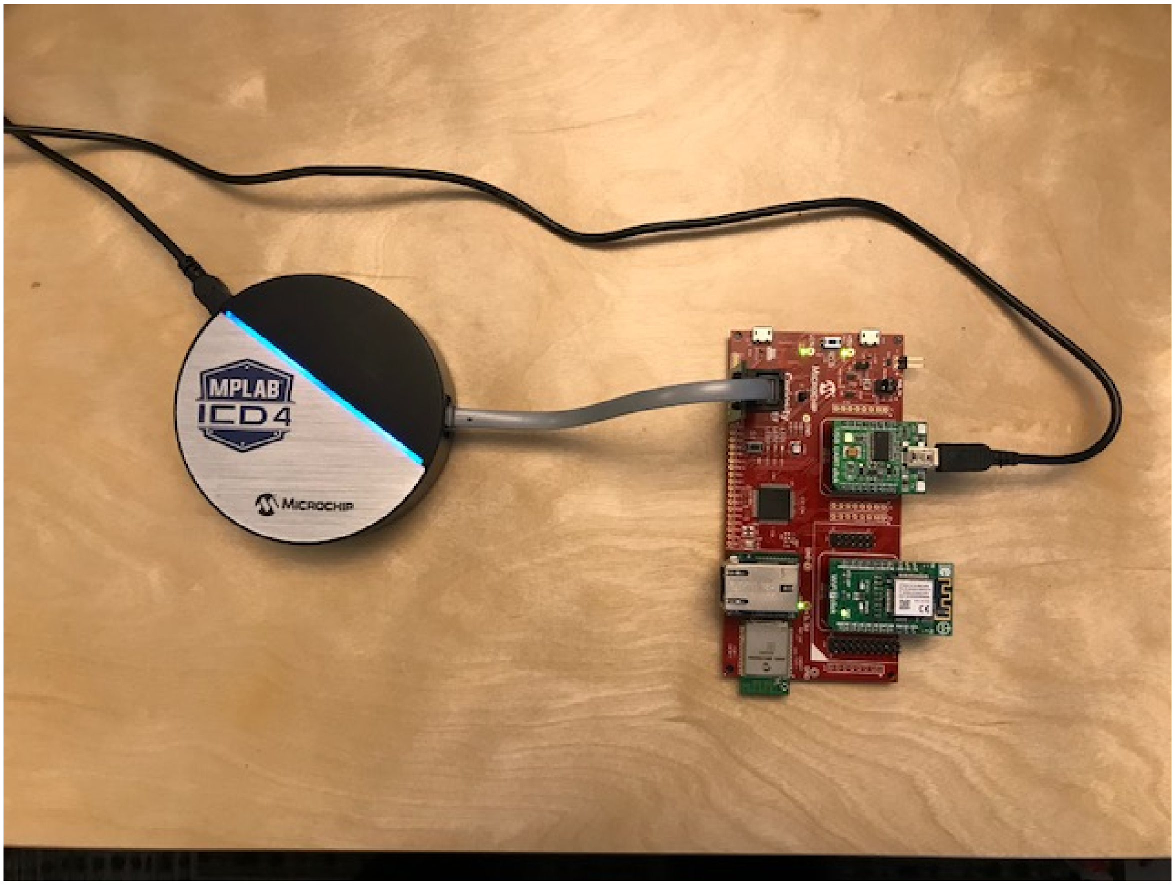
- MikroElectronika USB UART Click Board
- RJ-11 to ICSP Adapter
- MPLAB ICD 4 In-Circuit Debugger
- PIC32 LAN8720 PHY daughter board
- MikroElectronika WiFi 7 Click Board

Setting Up the Microchip Curiosity PIC32MZEF Hardware

1. Connect the MikroElectronika USB UART Click Board to the microBUS 1 connector on the Microchip Curiosity PIC32MZEF.
2. Connect the PIC32 LAN8720 PHY daughter board to the J18 header on the Microchip Curiosity PIC32MZEF.
3. Connect the MikroElectronika USB UART Click Board to your computer using a USB A to USB mini-B cable.
4. Connect the MikroElectronika WiFi 7 Click Board to the microBUS 2 connector on the Microchip Curiosity PIC32MZEF.
5. Connect the RJ-11 to ICSP Adapter to the Microchip Curiosity PIC32MZEF.
6. Connect the MPLAB ICD 4 In-Circuit Debugger to your Microchip Curiosity PIC32MZEF using an RJ-11 cable.

7. Connect the ICD 4 In-Circuit Debugger to your computer using a USB A to USB mini-B cable.
8. Insert the RJ-11 to ICSP Adaptor J2 into the ICSP header on the Microchip Curiosity PIC32MZEF at the J16.
9. Connect one end of an Ethernet cable to the LAN8720 PHY daughter board. Connect the other end to your router or other internet port.

The following image shows the Microchip Curiosity PIC32MZEF and all required peripherals assembled.



The LED on in-circuit debugger turns a solid blue when it is ready.

Setting Up Your Environment

1. Install the latest Java SE SDK.
2. Install Python version 3.x or later.
3. Install the latest version of the MPLAB X IDE:
   - MPLAB X Integrated Development Environment for Windows
   - MPLAB X Integrated Development Environment for macOS
   - MPLAB X Integrated Development Environment for Linux
4. Install the latest version of the MPLAB XC32 Compiler:
   - MPLAB XC32/32++ Compiler for Windows
   - MPLAB XC32/32++ Compiler for macOS
   - MPLAB XC32/32++ Compiler for Linux

5. Install the latest version of the MPLAB Harmony Integrated Software Framework (optional):
   - MPLAB Harmony Integrated Software Framework for Windows
   - MPLAB Harmony Integrated Software Framework for macOS
   - MPLAB Harmony Integrated Software Framework for Linux
6. Start up a UART terminal emulator and open a connection with the following settings:
   - Baud rate: 115200
   - Data: 8 bit
   - Parity: None
   - Stop bits: 1
   - Flow control: None

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. Browse to the Amazon FreeRTOS page in the AWS IoT console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose **Download FreeRTOS Software**.
5. In **Software Configurations**, find **Connect to AWS IoT- Microchip**, and then choose **Download**.
6. Unzip the downloaded file to the AmazonFreeRTOS folder, and make a note of the folder's path.

   Note
   The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
   In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. Registering Your MCU Board with AWS IoT (p. 5) is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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 `<1234567890123>-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. In your IDE, open *<BASE_FOLDER>*`\demos\common\include\aws_clientcredential.h` and specify values for the following `#define` constants:

   - `clientcredentialMQTT_BROKER_ENDPOINT` *Your AWS IoT endpoint*
   - `clientcredentialIOT_THING_NAME` *The AWS IoT thing name of your board*

To configure your Wi-Fi

1. Open the `aws_clientcredential.h` file.
2. Specify values for the following `#define` constants:

   - `clientcredentialWIFI_SSID` *The SSID for your Wi-Fi network*
   - `clientcredentialWIFI_PASSWORD` *The password for your Wi-Fi network*
   - `clientcredentialWIFI_SECURITY` *The security type of your Wi-Fi network*

     Valid security types are:
     - `eWiFiSecurityOpen` (Open, no security)
     - `eWiFiSecurityWEP` (WEP security)
     - `eWiFiSecurityWPA` (WPA security)
     - `eWiFiSecurityWPA2` (WPA2 security)

To configure your AWS IoT credentials

> **Note**
> To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You must format the certificate and private key for your device.

1. In a browser window, open *<BASE_FOLDER>*`\tools\certificate_configuration\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the *<ID>*`-certificate.pem.crt` that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *<ID>*`-private.pem.key` that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in *<BASE_FOLDER>*`\demos\common\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.

Build and Run Amazon FreeRTOS Samples

Open the Amazon FreeRTOS Demo Application in the MPLAB IDE

1. In the MPLAB IDE, from the **File** menu, choose **Open Project**.
2. Browse to and open *<BASE_FOLDER>*`\demos\microchip\curiosity_pic32mzef\mplab`.

3. Choose **Open project**.

   Note
   When you open the project for the first time, you can ignore warning messages like the following:

```
warning: Configuration "pic32mz_ef_curiosity" builds with "XC32", but indicates no
 toolchain directory.
warning: Configuration "pic32mz_ef_curiosity" refers to file "AmazonFreeRTOS/lib/
third_party/mcu_vendor/microchip/harmony/framework/bootloader/src/bootloader.h"
 which does not exist in the disk. The make process might not build correctly.
```

Run the Amazon FreeRTOS Samples

1. Rebuild your project.
2. Sign in to the AWS IoT console.
3. In the navigation pane, choose **Test** to open the MQTT client.
4. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.
5. On the **Projects** tab, right-click the `aws_demos` top-level folder, and then choose **Debug**.
6. The first time you debug the samples, an **ICD 4 not Found** dialog box is displayed. In the tree view, under the **ICD 4** node, choose the ICD4 serial number, and then choose **OK**.
7. When the debugger stops at the breakpoint in `main()`, from the **Run** menu, choose **Resume**.

The ICD 4 turns half yellow as it is programming the device, and then half green when it is running. The **ICD4** tab appears in the IDE. Successful programming looks like the following:

```


*****************************************************


Connecting to MPLAB ICD 4...

Currently loaded versions:
Application version............01.02.00
Boot version...................01.00.00
FPGA version...................01.00.00
Script version.................00.02.18
Script build number............fd44437f19
Application build number.......0123456789

Connecting to MPLAB ICD 4...

Currently loaded versions:
Boot version...................01.00.00
Updating firmware application...
Connecting to MPLAB ICD 4...

Currently loaded versions:
Application version............01.02.16
Boot version...................01.00.00
FPGA version...................01.00.00
Script version.................00.02.18
Script build number............fd44437f19
Application build number.......0123456789

Target voltage detected
Target device PIC32MZ2048EFM100 found.
```

```
Device Id Revision = 0xA1
Serial Number:
Num0 = ec4f6d3c
Num1 = 6b845410

Erasing...

The following memory area(s) will be programmed:
program memory: start address = 0x1d000000, end address = 0x1d07bfff
program memory: start address = 0x1d1fc000, end address = 0x1d1fffff
configuration memory
boot config memory

Programming/Verify complete

Running
```

> **Note**
> We recommend that you use the MPLAB In-Circuit Debugger instead of the USB port for debugging. The ICD 4 makes it possible for you to step through code more quickly and add breakpoints without restarting the debugger.

You should see MQTT messages sent by your device in the MQTT client of the AWS IoT console.

Troubleshooting

If no messages appear in the AWS IoT console, try the following:

1. Open a terminal window to view the logging output of the sample. This can help you determine what is going wrong.
2. Check that your network credentials are valid.

Getting Started with the Espressif ESP32-DevKitC and the ESP-WROVER-KIT

Both the ESP32-DevKitC and the ESP-WROVER KIT are supported on Amazon FreeRTOS. To check which development module you have, see ESP32 Modules and Boards.

> **Note**
> Currently, the Amazon FreeRTOS port for ESP32-WROVER-KIT and ESP DevKitC does not support the following:
>
> - Lightweight IP.
> - Symmetric multiprocessing (SMP).

Setting Up the Espressif Hardware

For the ESP32-DevKitC development board, see Getting Started with the ESP32-DevKitC development board.

For the ESP-WROVER-KIT development board, see Getting Started with the ESP-WROVER-KIT development board.

Setting Up Your Environment

Establishing a Serial Connection

To establish a serial connection with the ESP32-DevKitC, you must install CP210x USB to UART Bridge VCP drivers. If you are running Windows 10, install v6.7.5 of the CP210x USB to UART Bridge drivers. If you are running an older version of Windows, install the version indicated in the list of downloads.

To establish a serial connection with the ESP32-WROVER-KIT, you must install some FTDI virtual COM port drivers. For more information, see Establishing a Serial Connection with ESP32.

Make a note of the serial port you configure (based on host OS). You need it during the build process.

Setting Up the Toolchain

When following the links below, do not install the ESP-IDF library from Espressif, Amazon FreeRTOS already contains this library. In addition, make sure the `IDF_PATH` environment variable has not been set.

- Setting up the toolchain for Windows
- Setting up the toolchain for macOS
- Setting up the toolchain for Linux

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Downloading Amazon FreeRTOS

Clone the Amazon FreeRTOS repository from GitHub.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

1. If you are running macOS or Linux, open a terminal prompt. If you are running Windows, open mingw32.exe.
2. Install Python 2.7.10 or later.
3. If you are running Windows, use the **easy_install awscli** to install the AWS CLI in the mingw32 environment.

   If you are running macOS or Linux, make sure the AWS CLI is installed on your system. For more information, see Installing the AWS Command Line Interface.
4. Run **aws configure** to configure the AWS CLI. For more information, see Configuring the AWS CLI.
5. Use the following command to install the boto3 Python module:

- On Windows, in the mingw32 environment, use **easy_install boto3**
- On macOS or Linux, use **pip install boto3**

Amazon FreeRTOS includes scripts to make it easier to set up your Espressif board. To configure the Espressif scripts, open `<BASE_FOLDER>/tools/aws_config_quick_start/configure.json` and set the following attributes:

`afr_source_dir`

The complete path to the Amazon FreeRTOS download on your computer.

`thing_name`

The name of the IoT thing that represents your board.

`wifi_ssid`

The SSID of your Wi-Fi network.

`wifi_password`

The password for your Wi-Fi network.

`wifi_security`

The security type for your Wi-Fi network.

Valid security types are:

- `eWiFiSecurityOpen` (Open, no security)
- `eWiFiSecurityWEP` (WEP security)
- `eWiFiSecurityWPA` (WPA security)
- `eWiFiSecurityWPA2` (WPA2 security)

To run the configuration script

1. If you are running macOS or Linux, open a terminal prompt. If you are running Windows, open mingw32.exe.
2. Go to the `<BASE_FOLDER>/tools/aws_config_quick_start` directory and run the following command:

   python SetupAWS.py setup

This script creates an IoT thing, certificate, and policy. It attaches the IoT policy to the certificate and the certificate to the IoT thing. It also populates the `aws_clientcredential.h` file with your AWS IoT endpoint, Wi-Fi SSID, and credentials. Finally, it formats your certificate and private key and writes them to the `aws_clientcredential.h` header file. For more information about the script, see the README.md in the `<BASE_FOLDER>/tools/aws_config_quick_start` directory.

Build and Run Amazon FreeRTOS Samples

To flash the demo application onto your board

1. Connect your board to your computer.
2. In macOS or Linux, open a terminal. In Windows, open mingw32.exe (downloaded from mysys toolchain).

3. Navigate to `<BASE_FOLDER>/demos/espressif/esp32_devkitc_esp_wrover_kit/make` and enter following command:

   ```
   make menuconfig
   ```

   In the Espressif IoT Development Framework Configuration menu, navigate to **Serial flasher config**, and then to **Default serial port** to configure the serial port.

   On Windows, serial ports have names like `COM1`. On macOS, they start with `/dev/cu`. On Linux, they start with `/dev/tty`.

   The serial port you configure here is used to write the demo application to your board.

   Depending on your hardware, you can increase the default baud rate up to 921600. This can reduce the time required to flash your board. To increase the baud rate, choose **Serial flash config**, and then choose **Default baud rate**.

   To confirm your selection, choose ENTER. To save the configuration, choose **Save** and then choose **Exit**.

To build and flash firmware (including boot loader and partition table) and monitor serial console output, open a command prompt. Navigate to `<BASE_FOLDER>\demos\espressif\esp32_devkitc_esp_wrover_kit/make` and run the following command:

```
make flash monitor
```

At the end of the compilation output, you should see text like the following:

```

I (31) boot: ESP-IDF v3.1-dev-322-gf307f41-dirty 2nd stage bootloader
I (31) boot: compile time 11:30:50
I (34) boot: Enabling RNG early entropy source...
I (37) boot: SPI Speed      : 40MHz
I (41) boot: SPI Mode       : DIO
I (45) boot: SPI Flash Size : 4MB
I (49) boot: Partition Table:
I (53) boot: ## Label            Usage          Type ST Offset   Length
I (60) boot:  0 nvs              WiFi data        01 02 00009000 00006000
I (68) boot:  1 phy_init         RF data          01 01 0000f000 00001000
I (75) boot:  2 factory          factory app      00 00 00010000 00100000
I (82) boot:  3 storage          Unknown data     01 82 00110000 00010000
I (90) boot: End of partition table
I (94) esp_image: segment 0: paddr=0x00010020 vaddr=0x3f400020 size=0x12710 ( 75536) map
I (129) esp_image: segment 1: paddr=0x00022738 vaddr=0x3ffb0000 size=0x0240c (  9228) load
I (133) esp_image: segment 2: paddr=0x00024b4c vaddr=0x40080000 size=0x00400 (  1024) load
0x40080000: _iram_start at BASE_FOLDER/AmazonFreeRTOS-Espressif/lib/FreeRTOS/portable/GCC/
Xtensa_ESP32/xtensa_vectors.S:1685

I (136) esp_image: segment 3: paddr=0x00024f54 vaddr=0x40080400 size=0x0b0bc ( 45244) load
I (164) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x6d454 (447572) map
0x400d0018: _stext at ??:?

I (319) esp_image: segment 5: paddr=0x0009d474 vaddr=0x4008b4bc size=0x02d44 ( 11588) load
0x4008b4bc: xStreamBufferSend at BASE_FOLDER/AmazonFreeRTOS-Espressif/lib/FreeRTOS/
stream_buffer.c:636

I (324) esp_image: segment 6: paddr=0x000a01c0 vaddr=0x400c0000 size=0x00000 (     0) load
I (334) boot: Loaded app from partition at offset 0x10000
I (334) boot: Disabling RNG early entropy source...
I (338) cpu_start: Pro cpu up.
```

```
I (341) cpu_start: Single core mode
I (346) heap_init: Initializing. RAM available for dynamic allocation:
I (353) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (359) heap_init: At 3FFC0420 len 0001FBE0 (126 KiB): DRAM
I (365) heap_init: At 3FFE0440 len 00003BC0 (14 KiB): D/IRAM
I (371) heap_init: At 3FFE4350 len 0001BCB0 (111 KiB): D/IRAM
I (378) heap_init: At 4008E200 len 00011E00 (71 KiB): IRAM
I (384) cpu_start: Pro cpu start user code
I (66) cpu_start: Starting scheduler on PRO CPU.
I (96) wifi: wifi firmware version: f79168c
I (96) wifi: config NVS flash: enabled
I (96) wifi: config nano formating: disabled
I (106) system_api: Base MAC address is not set, read default base MAC address from BLK0 of
 EFUSE
I (106) system_api: Base MAC address is not set, read default base MAC address from BLK0 of
 EFUSE
I (136) wifi: Init dynamic tx buffer num: 32
I (136) wifi: Init data frame dynamic rx buffer num: 32
I (136) wifi: Init management frame dynamic rx buffer num: 32
I (136) wifi: wifi driver task: 3ffc5ec4, prio:23, stack:4096
I (146) wifi: Init static rx buffer num: 10
I (146) wifi: Init dynamic rx buffer num: 32
I (156) wifi: wifi power manager task: 0x3ffcc248 prio: 21 stack: 2560
0 7 [Tmr Svc] WiFi module initialized. Connecting to AP Guest...
W (166) phy_init: failed to load RF calibration data (0x1102), falling back to full
 calibration
I (396) phy: phy_version: 383.0, 79a622c, Jan 30 2018, 15:38:06, 0, 2
I (406) wifi: mode : sta (30:ae:a4:4b:3d:64)
I (406) WIFI: SYSTEM_EVENT_STA_START
I (526) wifi: n:1 0, o:1 0, ap:255 255, sta:1 0, prof:1
I (526) wifi: state: init -> auth (b0)
I (536) wifi: state: auth -> assoc (0)
I (536) wifi: state: assoc -> run (10)
I (536) wifi: connected with Guest, channel 1
I (536) WIFI: SYSTEM_EVENT_STA_CONNECTED
I (3536) wifi: pm start, type:0

1 826 [IP-task] vDHCPProcess: offer c0a8520bip
I (8356) event: sta ip: 192.168.82.11, mask: 255.255.224.0, gw: 192.168.64.1
I (8356) WIFI: SYSTEM_EVENT_STA_GOT_IP
2 827 [IP-task] vDHCPProcess: offer c0a8520bip
3 828 [Tmr Svc] WiFi Connected to AP. Creating tasks which use network...
4 828 [Tmr Svc] Creating MQTT Echo Task...
5 829 [MQTTEcho] MQTT echo attempting to connect to a14o5vz6c0ikzv.iot.us-
west-2.amazonaws.com.
6 829 [MQTTEcho] Sending command to MQTT task.
7 830 [MQTT] Received message 10000 from queue.
8 2030 [IP-task] Socket sending wakeup to MQTT task.
I (20416) PKCS11: Initializing SPIFFS
W (20416) SPIFFS: mount failed, -10025. formatting...
I (20956) PKCS11: Partition size: total: 52961, used: 0
9 2596 [MQTT] Received message 0 from queue.
10 2601 [IP-task] Socket sending wakeup to MQTT task.
11 2601 [MQTT] Received message 0 from queue.
12 2607 [IP-task] Socket sending wakeup to MQTT task.
13 2607 [MQTT] Received message 0 from queue.
14 2607 [MQTT] MQTT Connect was accepted. Connection established.
15 2607 [MQTT] Notifying task.
16 2608 [MQTTEcho] Command sent to MQTT task passed.
17 2608 [MQTTEcho] MQTT echo connected.
18 2608 [MQTTEcho] MQTT echo test echoing task created.
19 2608 [MQTTEcho] Sending command to MQTT task.
20 2609 [MQTT] Received message 20000 from queue.
21 2610 [IP-task] Socket sending wakeup to MQTT task.
22 2611 [MQTT] Received message 0 from queue.
23 2612 [IP-task] Socket sending wakeup to MQTT task.
```

```
24 2612 [MQTT] Received message 0 from queue.
25 2612 [MQTT] MQTT Subscribe was accepted. Subscribed.
26 2612 [MQTT] Notifying task.
27 2613 [MQTTEcho] Command sent to MQTT task passed.
28 2613 [MQTTEcho] MQTT Echo demo subscribed to freertos/demos/echo
29 2613 [MQTTEcho] Sending command to MQTT task.
30 2614 [MQTT] Received message 30000 from queue.
31 2619 [IP-task] Socket sending wakeup to MQTT task.
32 2619 [MQTT] Received message 0 from queue.
33 2620 [IP-task] Socket sending wakeup to MQTT task.
34 2620 [MQTT] Received message 0 from queue.
35 2620 [MQTT] MQTT Publish was successful.
36 2620 [MQTT] Notifying task.
37 2620 [MQTTEcho] Command sent to MQTT task passed.
38 2620 [MQTTEcho] Echo successfully published 'Hello World 0'
39 2624 [IP-task] Socket sending wakeup to MQTT task.
40 2624 [MQTT] Received message 0 from queue.
41 2624 [Echoing] Sending command to MQTT task.
42 2624 [MQTT] Received message 40000 from queue.
43 2625 [IP-task] Socket sending wakeup to MQTT task.
44 2625 [MQTT] Received message 0 from queue.
45 2626 [IP-task] Socket sending wakeup to MQTT task.
46 2626 [MQTT] Received message 0 from queue.
47 2628 [IP-task] Socket sending wakeup to MQTT task.
48 2628 [MQTT] Received message 0 from queue.
49 2628 [MQTT] MQTT Publish was successful.
50 2628 [MQTT] Notifying task.
51 2628 [Echoing] Command sent to MQTT task passed.
52 2630 [Echoing] Message returned with ACK: 'Hello World 0 ACK'

*** Similar output deleted for brevity ***

317 7692 [IP-task] Socket sending wakeup to MQTT task.
318 7692 [MQTT] Received message 0 from queue.
319 7698 [IP-task] Socket sending wakeup to MQTT task.
320 7698 [MQTT] Received message 0 from queue.
321 8162 [MQTTEcho] Sending command to MQTT task.
322 8162 [MQTT] Received message 190000 from queue.
323 8163 [IP-task] Socket sending wakeup to MQTT task.
324 8163 [MQTT] Received message 0 from queue.
325 8164 [IP-task] Socket sending wakeup to MQTT task.
326 8164 [MQTT] Received message 0 from queue.
327 8164 [MQTT] MQTT Publish was successful.
328 8164 [MQTT] Notifying task.
329 8165 [MQTTEcho] Command sent to MQTT task passed.
330 8165 [MQTTEcho] Echo successfully published 'Hello World 11'
331 8167 [IP-task] Socket sending wakeup to MQTT task.
332 8167 [MQTT] Received message 0 from queue.
333 8168 [Echoing] Sending command to MQTT task.
334 8169 [MQTT] Received message 1a0000 from queue.
335 8170 [IP-task] Socket sending wakeup to MQTT task.
336 8170 [MQTT] Received message 0 from queue.
337 8171 [IP-task] Socket sending wakeup to MQTT task.
338 8171 [MQTT] Received message 0 from queue.
339 8171 [MQTT] MQTT Publish was successful.
340 8171 [MQTT] Notifying task.
341 8172 [Echoing] Command sent to MQTT task passed.
342 8173 [Echoing] Message returned with ACK: 'Hello World 11 ACK'
343 8174 [IP-task] Socket sending wakeup to MQTT task.
344 8174 [MQTT] Received message 0 from queue.
345 8179 [IP-task] Socket sending wakeup to MQTT task.
346 8179 [MQTT] Received message 0 from queue.
347 8665 [MQTTEcho] Sending command to MQTT task.
348 8665 [MQTT] Received message 1b0000 from queue.
349 8665 [MQTT] About to close socket.
350 8666 [IP-task] Socket sending wakeup to MQTT task.
```

```
351 8667 [MQTT] Socket closed.
352 8667 [MQTT] Stack high watermark for MQTT task: 2792
353 8667 [MQTT] Notifying task.
354 8667 [MQTT] Received message 0 from queue.
355 8668 [MQTTEcho] Command sent to MQTT task passed.
356 8668 [MQTTEcho] MQTT echo demo finished.
```

Run the Bluetooth Low-Energy Demos

> Amazon FreeRTOS support for Bluetooth Low Energy is in public beta release. BLE demos are subject to change.

Amazon FreeRTOS supports Bluetooth Low Energy (BLE) connectivity. You can download Amazon FreeRTOS with BLE from GitHub.

For instructions about how to run the MQTT over BLE demo on your board, see the MQTT over BLE demo application.

For instructions about how to run the Wi-Fi Provisioning demo on your board, see the Wi-Fi Provisioning demo application.

Troubleshooting

- If you are using a Mac and it does not recognize your ESP-WROVER-KIT, make sure you do not have the D2XX drivers installed. To uninstall them, follow the instructions in the FTDI Drivers Installation Guide for macOS X.
- The monitor utility provided by ESP-IDF (and invoked using **make monitor**) helps you decode addresses. For this reason, it can help you get some meaningful backtraces in the event the application crashes. For more information, see Automatically Decoding Addresses on the Espressif website.
- It is also possible to enable GDBstub for communication with gdb without requiring any special JTAG hardware. For more information, see Launch GDB for GDBStub.
- For information about setting up an OpenOCD-based environment if JTAG hardware-based debugging is required, see JTAG Debugging.
- If `pyserial` cannot be installed using `pip` on macOS, download it from pyserial.
- If the board resets continuously, try erasing the flash by entering the following command on the terminal:

```
make erase_flash
```

- If you see errors when you run `idf_monitor.py`, use Python 2.7.

Other Notes

- Required libraries from ESP-IDF are included in Amazon FreeRTOS , so there is no need to download them externally. If `IDF_PATH` is set, we recommend that you remove it before you build Amazon FreeRTOS.
- On Window systems, it can take 3-4 minutes for the project to build. You can use the `-j4` switch on the **make** command to reduce the build time:

```
make flash monitor -j4
```

Debugging Code on Espressif ESP32-DevKitC and ESP-WROVER-KIT

You need a JTAG to USB cable. We use a USB to MPSSE cable (for example, the FTDI C232HM-DDHSL-0).

ESP-DevKitC JTAG Setup

For the FTDI C232HM-DDHSL-0 cable, these are the connections to the ESP32 DevkitC:

C232HM-DDHSL-0 Wire Color	ESP32 GPIO Pin	JTAG Signal Name
Brown (pin 5)	IO14	TMS
Yellow (pin 3)	IO12	TDI
Black (pin 10)	GND	GND
Orange (pin 2)	IO13	TCK
Green (pin 4)	IO15	TDO

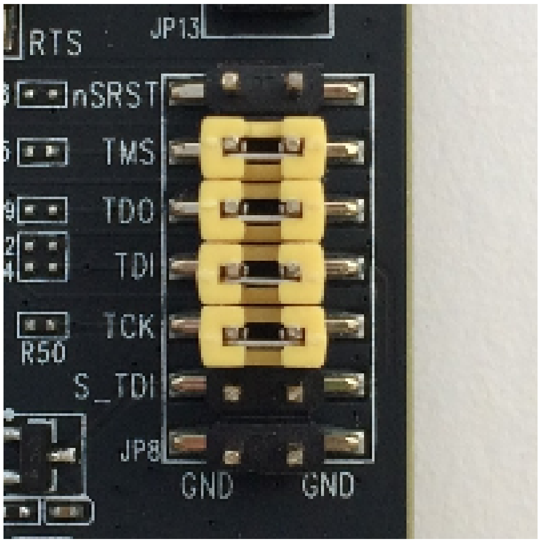
ESP-WROVER-KIT JTAG Setup

For the FTDI C232HM-DDHSL-0 cable, these are the connections to the ESP32-WROVER-KIT:

C232HM-DDHSL-0 Wire Color	ESP32 GPIO Pin	JTAG Signal Name
Brown (pin 5)	IO14	TMS
Yellow (pin 3)	IO12	TDI
Orange (pin 2)	IO13	TCK
Green (pin 4)	IO15	TDO

These tables were developed from the FTDI C232HM-DDHSL-0 datasheet. For more information, see C232HM MPSSE Cable Connection and Mechanical Details in the datasheet.

To enable JTAG on the ESP-WROVER-KIT, place jumpers on the TMS, TDO, TDI, TCK, and S_TDI pins as shown here:



Debugging on Windows

To set up for debugging on Windows

1. Connect the USB side of the FTDI C232HM-DDHSL-0 to your computer and the other side as described in Debugging Code on Espressif ESP32-DevKitC and ESP-WROVER-KIT (p. 32). The FTDI C232HM-DDHSL-0 device should appear in **Device Manager** under **Universal Serial Bus Controllers**.
2. From the list of USB controllers, right-click the FTDI C232HM-DDHSL-0 device (the manufacturer is FTDI), and choose **Properties**. In the properties window, choose the **Details** tab to see the properties of the device. If the device is not listed, install the Windows driver for FTDI C232HM-DDHSL-0.
3. Verify that the vendor ID and product ID displayed in **Device Manager** match the IDs in `demos\espressif\esp32_devkitc_esp_wrover_kit\esp32_devkitj_v1.cfg`. The IDs are specified in a line that begins with `ftdi_vid_pid` followed by a vendor ID and a product ID:

```
ftdi_vid_pid 0x0403 0x6014
```

4. Download OpenOCD for Windows.
5. Unzip the file to `C:\` and add `C:\openocd-esp32\bin` to your system path.
6. OpenOCD requires libusb, which is not installed by default on Windows. To install it:

   a. Download zadig.exe.
   b. Run `zadig.exe`. From the **Options** menu, choose **List All Devices**.
   c. From the drop-down menu, choose **C232HM-DDHSL-0**.
   d. In the target driver box, to the right of the green arrow, choose **WinUSB**.
   e. From the drop-down box under the target driver box, choose the arrow, and then choose **Install Driver**. Choose **Replace Driver**.
7. Open a command prompt, navigate to *`<BASE_FOLDER>\demos\espressif\esp32_devkitc_esp_wrover_kit\make`* and run:

```
openocd.exe -f esp32_devkitj_v1.cfg -f esp-wroom-32.cfg
```

   Leave this command prompt open.
8. Open a new command prompt, navigate to your `msys32` directory, and run `mingw32.exe`. In the mingw32 terminal, navigate to *`<BASE_FOLDER>`*`\demos\espressif\esp32_devkitc_esp_wrover_kit\make` and run **make flash monitor**.

9. Open another mingw32 terminal, navigate to *<BASE_FOLDER>*\demos\espressif\esp32_devkitc_esp_wrover_kit\make and run `xtensa-esp32-elf-gdb -x gdbinit build/aws_demos.elf`. The program should stop in the `main` function.

   Note
   The ESP32 supports a maximum of two break points.

Debugging on macOS

1. Download the FTDI driver for macOS.
2. Download OpenOCD.
3. Extract the downloaded .tar file and set the path in `.bash_profile` to *<OCD_INSTALL_DIR>*/openocd-esp32/bin.
4. Use the following command to install `libusb` on macOS:

   ```
   brew install libusb
   ```

5. Use the following command to unload the serial port driver:

   ```
   sudo kextunload -b com.FTDI.driver.FTDIUSBSerialDriver
   ```

6. If you are running a macOS version later than 10.9, use the following command to unload Apple's FTDI driver:

   ```
   sudo kextunload -b com.apple.driver.AppleUSBFTDI
   ```

7. Use the following command to get the product ID and vendor ID of the FTDI cable. It lists the attached USB devices:

   ```
   system_profiler SPUSBDataType
   ```

   The output from `system_profiler` should look like the following:

   ```
   C232HM-DDHSL-0:
   Product ID: 0x6014
   Vendor ID: 0x0403 (Future Technology Devices International Limited)
   ```

8. Verify the vendor and product IDs match the IDs in `demos/espressif/esp32_devkitc_esp_wrover_kit/esp32_devkitj_v1.cfg`. The IDs are specified on a line that begins with `ftdi_vid_pid` followed by a vendor ID and a product ID:

   ```
   ftdi_vid_pid 0x0403 0x6014
   ```

9. Open a terminal window, navigate to *<BASE_FOLDER>*/demos/espressif/esp32_devkitc_esp_wrover_kit/make, and use the following command to run OpenOCD:

   ```
   openocd -f esp32_devkitj_v1.cfg -f
           esp-wroom-32.cfg
   ```

10. Open a new terminal, and use the following command to load the FTDI serial port driver:

    ```
    sudo kextload -b com.FTDI.driver.FTDIUSBSerialDriver
    ```

11. Navigate to *<BASE_FOLDER>*>/demos/espressif/esp32_devkitc_esp_wrover_kit/make, and run the following command:

```
make flash monitor
```

12. Open another new terminal, navigate to `<BASE_FOLDER>/demos/espressif/esp32_devkitc_esp_wrover_kit/make`, and run the following command:

```
xtensa-esp32-elf-gdb -x gdbinit build/aws_demos.elf
```

The program should stop at `main()`.

Debugging on Linux

1. Download OpenOCD. Extract the tarball and follow the installation instructions in the readme file.
2. Use the following command to install libusb on Linux:

```
sudo apt-get install libusb-1.0
```

3. Open a terminal and enter **`ls -l /dev/ttyUSB*`**to list all USB devices connected to your computer. This helps you check if the board's USB ports are recognized by the operating system. You should see output similar to the following:

```
$ls -l /dev/ttyUSB*
crw-rw---- 1 root dialout 188, 0 Jul 10 19:04 /dev/ttyUSB0
crw-rw---- 1 root dialout 188, 1 Jul 10 19:04 /dev/ttyUSB1
```

4. Sign off and then sign in and cycle the power to the board to make the changes take effect. In a terminal prompt, list the USB devices. Make sure the group-owner has changed from `dialout` to `plugdev`:

```
$ls -l /dev/ttyUSB*
crw-rw---- 1 root plugdev 188, 0 Jul 10 19:04 /dev/ttyUSB0
crw-rw---- 1 root plugdev 188, 1 Jul 10 19:04 /dev/ttyUSB1
```

The `/dev/ttyUSBn` interface with the lower number is used for JTAG communication. The other interface is routed to the ESP32's serial port (UART) and is used for uploading code to the ESP32's flash memory.

5. In a terminal window, navigate to `<BASE_FOLDER>/demos/espressif/esp32_devkitc_esp_wrover_kit/make`, and use the following command to run OpenOCD:

```
openocd -f esp32_devkitj_v1.cfg -f esp-wroom-32.cfg
```

6. Open another terminal, navigate to `<BASE_FOLDER>/demos/espressif/esp32_devkitc_esp_wrover_kit/make`, and run the following command:

```
make flash monitor
```

7. Open another terminal, navigate to `<BASE_FOLDER>/demos/espressif/esp32_devkitc_esp_wrover_kit/make`, and run the following command:

```
xtensa-esp32-elf-gdb -x gdbinit build/aws_demos.elf
```

The program should stop in `main()`.

Getting Started with the Infineon XMC4800 IoT Connectivity Kit

Before you begin, see Prerequisites (p. 4).

If you do not have the Infineon XMC4800 IoT Connectivity Kit, you can purchase one from Infineon.

If you want to open a serial connection with the board to view logging and debugging information, you need a 3.3V USB/Serial converter, in addition to the XMC4800 IoT Connectivity Kit. The CP2104 is a common USB/Serial converter that is widely available in boards such as Adafruit's CP2104 Friend.

Setting Up Your Environment

Amazon FreeRTOS uses Infineon's DAVE development environment to program the XMC4800. Before you begin, you need to download and install DAVE and some J-Link drivers to communicate with the on-board debugger.

Install DAVE

1. Go to Infineon's DAVE software download page.
2. Choose the DAVE package for your operating system and submit your registration information. After registering with Infineon, you should receive a confirmation email with a link to download a .zip file.
3. Download the DAVE package .zip file (`DAVE_`*`version_os_date`*`.zip`), and unzip it to the location where you want to install DAVE (for example, `C:\DAVE4`).

    Note
    Some Windows users have reported problems using Windows Explorer to unzip the file. We recommend that you use a third-party program such as 7-Zip.
4. To launch DAVE, run the executable file found in the unzipped `DAVE_`*`version_os_date`*`.zip` folder.

For more information, see the DAVE Quick Start Guide.

Install Segger J-Link Drivers

To communicate with the XMC4800 Relax EtherCAT board's on-board debugging probe, you need the drivers included in the J-Link Software and Documentation pack. You can download the J-Link Software and Documentation pack from Segger's J-Link software download page.

Set Up a Serial Connection

Setting up a serial connection is optional, but recommended. A serial connection allows your board to send logging and debugging information in a form that you can view on your development machine.

The XMC4800 demo application uses a UART serial connection on pins P0.0 and P0.1, which are labeled on the XMC4800 Relax EtherCAT board's silkscreen. To set up a serial connection:

1. Connect the pin labeled “RX<P0.0” to your USB/Serial converter's “TX” pin.
2. Connect the pin labeled “TX>P0.1” to your USB/Serial converter's “RX” pin.
3. Connect your serial converter's Ground pin to one of the pins labeled “GND” on your board. The devices must share a common ground.

Power is supplied from the USB debugging port, so do not connect your serial adapter's positive voltage pin to the board.

> **Note**
> Some serial cables use a 5V signaling level. The XMC4800 board and the Wi-Fi Click module require a 3.3V. Do not use the board's IOREF jumper to change the board's signals to 5V.

With the cable connected, you can open a serial connection on a terminal emulator such as GNU Screen. The baud rate is set to 115200 by default with 8 data bits, no parity, and 1 stop bit.

Download and Configure Amazon FreeRTOS

After you set up your environment, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Under **Software Configurations**, find **Connect to AWS IoT- Infineon**, and then choose **Download**.
5. Unzip the downloaded file to the AmazonFreeRTOS folder, and make note of the folder path.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. Registering Your MCU Board with AWS IoT (p. 5) is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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 `*<1234567890123>*-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. In your IDE, open `*<BASE_FOLDER>*\demos\common\include\aws_clientcredential.h` and specify values for the following `#define` constants:
   - `clientcredentialMQTT_BROKER_ENDPOINT` *`Your AWS IoT endpoint`*
   - `clientcredentialIOT_THING_NAME` *`The AWS IoT thing name of your board`*

To configure your Wi-Fi

1. Open the `aws_clientcredential.h` file.
2. Specify values for the following `#define` constants:

   - `clientcredentialWIFI_SSID` *`The SSID for your Wi-Fi network`*
   - `clientcredentialWIFI_PASSWORD` *`The password for your Wi-Fi network`*
   - `clientcredentialWIFI_SECURITY` *`The security type of your Wi-Fi network`*

     Valid security types are:

     - `eWiFiSecurityOpen` (Open, no security)
     - `eWiFiSecurityWEP` (WEP security)
     - `eWiFiSecurityWPA` (WPA security)
     - `eWiFiSecurityWPA2` (WPA2 security)

To configure your AWS IoT credentials

> **Note**
> To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You must format the certificate and private key for your device.

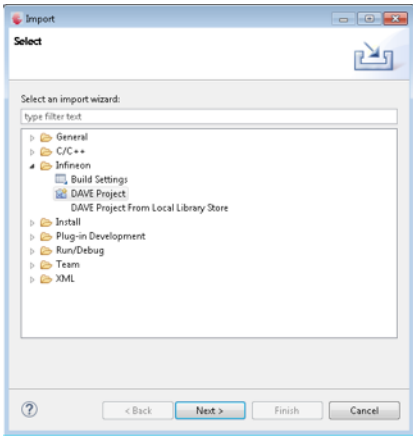
1. In a browser window, open *`<BASE_FOLDER>`*`\tools\certificate_configuration\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the *`<ID>`*`-certificate.pem.crt` that you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *`<ID>`*`-private.pem.key` that you downloaded from the AWS IoT console.
4. Choose **Generate and save aws_clientcredential_keys.h**, and then save the file in *`<BASE_FOLDER>`*`\demos\common\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.

Build and Run Amazon FreeRTOS Samples

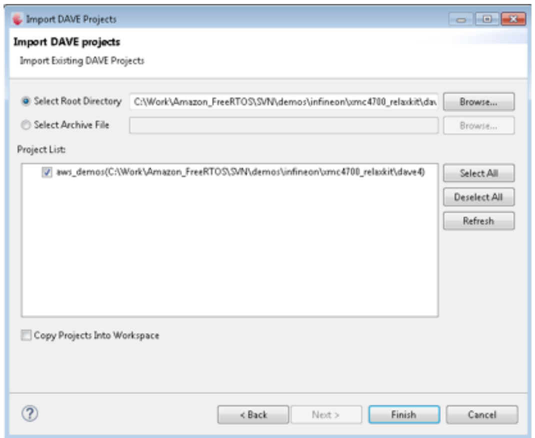
Import the Amazon FreeRTOS Sample Code into DAVE

1. Start DAVE.
2. In DAVE, choose **File**, **Import**. In the **Import** window, expand the **Infineon** folder, choose **DAVE Project**, and then choose **Next**.



3. In the **Import DAVE Projects** window, choose **Select Root Directory**, choose **Browse**, and then choose the XMC4800 demo project.

   In the directory where you unzipped your Amazon FreeRTOS download, the demo project is located in `<BASE_FOLDER>/demos/infineon/xmc4800_iotkit/dave`.



● Select Root Directory C:\Work\Amazon_FreeRTOS\SVN\demos\infineon\xmc4700_relaxkit\dav

○ Select Archive File

Project List:

☑ aws_demos(C:\Work\Amazon_FreeRTOS\SVN\demos\infineon\xmc4700_relaxkit\dave4)

□ Copy Projects Into Workspace

   Make sure that **Copy Projects Into Workspace** is unchecked.

4. Choose **Finish**.

   The `aws_demos` project should be imported into your workspace and activated.

5. From the **Project** menu, choose **Build Active Project**.

   Make sure that the project builds without errors.

Run the FreeRTOS Demo

After you have configured your project, you are ready to run the demo project on your board.

1. Use a USB cable to connect your XMC4800 IoT Connectivity Kit to your computer. The board has two microUSB connectors. Use the one labeled “X101”, where Debug appears next to it on the board's silkscreen.
2. From the **Project** menu, choose **Rebuild Active Project** to rebuild `aws_demos` and ensure that your configuration changes are picked up.
3. Sign in to the AWS IoT console.
4. In the navigation pane, choose **Test** to open the MQTT client.

5. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.
6. From **Project Explorer**, right-click `aws_demos`, choose **Debug As**, and then choose **DAVE C/C++ Application**.
7. Double-click **GDB SEGGER J-Link Debugging** to create a debug confirmation. Choose **Debug**.
8. When the debugger stops at the breakpoint in `main()`, from the **Run** menu, choose **Resume**.

In the AWS IoT console, the MQTT client from steps 4-5 should display the MQTT messages sent by your device. If you use the serial connection, you see something like this on the UART output:

```
0 0 [Tmr Svc] Starting key provisioning...
1 1 [Tmr Svc] Write root certificate...
2 4 [Tmr Svc] Write device private key...
3 82 [Tmr Svc] Write device certificate...
4 86 [Tmr Svc] Key provisioning done...
5 291 [Tmr Svc] Wi-Fi module initialized. Connecting to AP...
.6 8046 [Tmr Svc] Wi-Fi Connected to AP. Creating tasks which use network...
7 8058 [Tmr Svc] IP Address acquired [IP Address]
8 8058 [Tmr Svc] Creating MQTT Echo Task...
9 8059 [MQTTEcho] MQTT echo attempting to connect to [MQTT Broker].
...10 23010 [MQTTEcho] MQTT echo connected.
11 23010 [MQTTEcho] MQTT echo test echoing task created.
.12 26011 [MQTTEcho] MQTT Echo demo subscribed to freertos/demos/echo
13 29012 [MQTTEcho] Echo successfully published 'Hello World 0'
.14 32096 [Echoing] Message returned with ACK: 'Hello World 0 ACK'
.15 37013 [MQTTEcho] Echo successfully published 'Hello World 1'
16 40080 [Echoing] Message returned with ACK: 'Hello World 1 ACK'
.17 45014 [MQTTEcho] Echo successfully published 'Hello World 2'
.18 48091 [Echoing] Message returned with ACK: 'Hello World 2 ACK'
.19 53015 [MQTTEcho] Echo successfully published 'Hello World 3'
.20 56087 [Echoing] Message returned with ACK: 'Hello World 3 ACK'
.21 61016 [MQTTEcho] Echo successfully published 'Hello World 4'
22 64083 [Echoing] Message returned with ACK: 'Hello World 4 ACK'
.23 69017 [MQTTEcho] Echo successfully published 'Hello World 5'
.24 72091 [Echoing] Message returned with ACK: 'Hello World 5 ACK'
.25 77018 [MQTTEcho] Echo successfully published 'Hello World 6'
26 80085 [Echoing] Message returned with ACK: 'Hello World 6 ACK'
.27 85019 [MQTTEcho] Echo successfully published 'Hello World 7'
.28 88086 [Echoing] Message returned with ACK: 'Hello World 7 ACK'
.29 93020 [MQTTEcho] Echo successfully published 'Hello World 8'
.30 96088 [Echoing] Message returned with ACK: 'Hello World 8 ACK'
.31 101021 [MQTTEcho] Echo successfully published 'Hello World 9'
32 104102 [Echoing] Message returned with ACK: 'Hello World 9 ACK'
.33 109022 [MQTTEcho] Echo successfully published 'Hello World 10'
.34 112047 [Echoing] Message returned with ACK: 'Hello World 10 ACK'
.35 117023 [MQTTEcho] Echo successfully published 'Hello World 11'
36 120089 [Echoing] Message returned with ACK: 'Hello World 11 ACK'
.37 122068 [MQTTEcho] MQTT echo demo finished.
38 122068 [MQTTEcho] ----Demo finished----
```

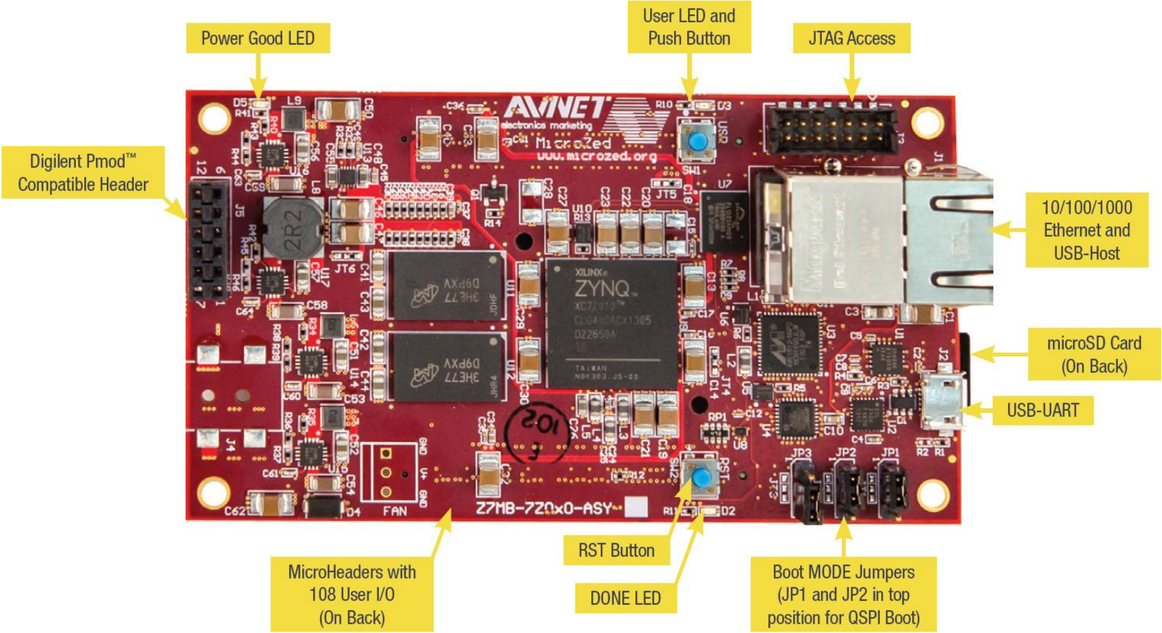
Getting Started with the Xilinx Avnet MicroZed Industrial IoT Kit

Before you begin, see Prerequisites (p. 4).

If you do not have the Xilinx Avnet MicroZed Industrial IoT Kit, you can purchase one from Avnet.

Setting Up the MicroZed Hardware

The following diagram might be helpful when you set up the MicroZed hardware:


Power Good LED
User LED and Push Button
JTAG Access
Digilent Pmod™ Compatible Header
10/100/1000 Ethernet and USB-Host
microSD Card (On Back)
USB-UART
MicroHeaders with 108 User I/O (On Back)
RST Button
DONE LED
Boot MODE Jumpers (JP1 and JP2 in top position for QSPI Boot)

To set up the MicroZed board

1. Connect your computer to the USB-UART port on your MicroZed board.
2. Connect your computer to the JTAG Access port on your MicroZed board.
3. Connect a router or internet-connected Ethernet port to the Ethernet and USB-Host port on your MicroZed board.

Setting Up Your Environment

To set up Amazon FreeRTOS configurations for the MicroZed kit, you must use the Xilinx Software Development Kit (XSDK). XSDK is supported on Windows and Linux.

Download and Install XSDK

To install Xilinx software, you need a free Xilinx account.

To download the XSDK

1. Go to the Software Development Kit Standalone WebInstall Client download page.
2. Choose the option appropriate for your operating system.
3. You are directed to a Xilinx sign-in page.

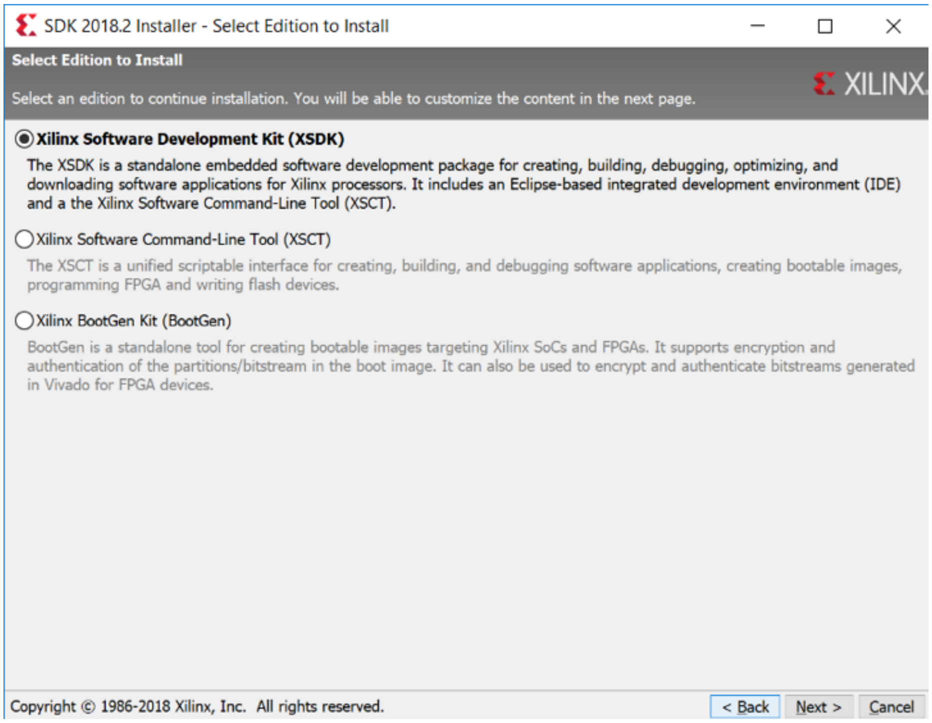
   If you have an account with Xilinx, enter your user name and password and then choose **Sign in**.

   If you do not have an account, choose **Create your account**. After you register, you should receive an email with a link to activate your Xilinx account.
4. On the **Name and Address Verification** page, enter your information and then choose **Next**. The download should be ready to start.

5. Save the `Xilinx_SDK_`*`version`*`_`*`os`* file.

To install the XSDK

1. Open the `Xilinx_SDK_`*`version`*`_`*`os`* file.
2. In **Select Edition to Install**, choose **Xilinx Software Development Kit (XSDK)** and then choose **Next**.



SDK 2018.2 Installer - Select Edition to Install

Select Edition to Install

Select an edition to continue installation. You will be able to customize the content in the next page.

● **Xilinx Software Development Kit (XSDK)**

The XSDK is a standalone embedded software development package for creating, building, debugging, optimizing, and downloading software applications for Xilinx processors. It includes an Eclipse-based integrated development environment (IDE) and a the Xilinx Software Command-Line Tool (XSCT).

○ Xilinx Software Command-Line Tool (XSCT)

The XSCT is a unified scriptable interface for creating, building, and debugging software applications, creating bootable images, programming FPGA and writing flash devices.

○ Xilinx BootGen Kit (BootGen)

BootGen is a standalone tool for creating bootable images targeting Xilinx SoCs and FPGAs. It supports encryption and authentication of the partitions/bitstream in the boot image. It can also be used to encrypt and authenticate bitstreams generated in Vivado for FPGA devices.

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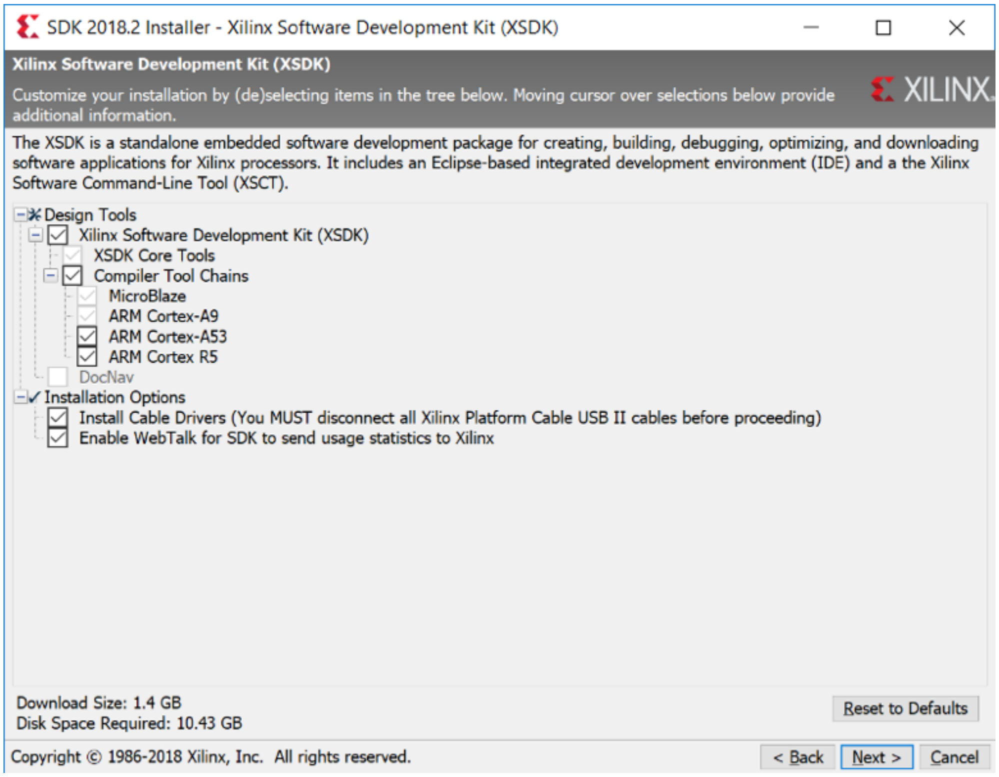
3. On the following page of the installation wizard, under **Installation Options**, select **Install Cable Drivers** and then choose **Next**.



SDK 2018.2 Installer - Xilinx Software Development Kit (XSDK)

Xilinx Software Development Kit (XSDK)

Customize your installation by (de)selecting items in the tree below. Moving cursor over selections below provide additional information.

The XSDK is a standalone embedded software development package for creating, building, debugging, optimizing, and downloading software applications for Xilinx processors. It includes an Eclipse-based integrated development environment (IDE) and a the Xilinx Software Command-Line Tool (XSCT).

- Design Tools
  - ☑ Xilinx Software Development Kit (XSDK)
    - ☑ XSDK Core Tools
    - ☑ Compiler Tool Chains
      - ☑ MicroBlaze
      - ☑ ARM Cortex-A9
      - ☑ ARM Cortex-A53
      - ☑ ARM Cortex R5
  - □ DocNav
- ✓ Installation Options
  - ☑ Install Cable Drivers (You MUST disconnect all Xilinx Platform Cable USB II cables before proceeding)
  - ☑ Enable WebTalk for SDK to send usage statistics to Xilinx

Download Size: 1.4 GB
Disk Space Required: 10.43 GB

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If your computer does not detect the MicroZed's USB-UART connection, install the CP210x USB-to-UART Bridge VCP drivers manually. For instructions, see the Silicon Labs CP210x USB-to-UART Installation Guide.

For more information about XSDK, see the Getting Started with Xilinx SDK on the Xilink website.

Download and Configure Amazon FreeRTOS

After you set up your environment, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. Browse to the AWS IoT console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Under **Software Configurations**, find **Connect to AWS IoT- Xilinx**, and then choose **Download**.
5. Unzip the downloaded file to the `AmazonFreeRTOS` folder, and make a note of the folder's path.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. This is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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

   Your AWS IoT endpoint appears in the **Endpoint** text box. It should look like `<1234567890123>-ats.iot.<us-east-1>.amazonaws.com`. Make a note of this endpoint.
3. In the navigation pane, choose **Manage**, and then choose **Things**. Make a note of the AWS IoT thing name for your device.
4. With your AWS IoT endpoint and your AWS IoT thing name on hand, open `<BASE_FOLDER>\demos\common\include\aws_clientcredential.h` in your IDE, and specify values for the following `#define` constants:

   - `clientcredentialMQTT_BROKER_ENDPOINT` *`Your AWS IoT endpoint`*
   - `clientcredentialIOT_THING_NAME` *`Your board's AWS IoT thing name`*

To configure your AWS IoT credentials

To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device as an AWS IoT thing. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You need to format the certificate and private key for your device.

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

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

Build and Run Amazon FreeRTOS Samples

Now that you have configured your project, you are ready to build and run the demo project on your board.

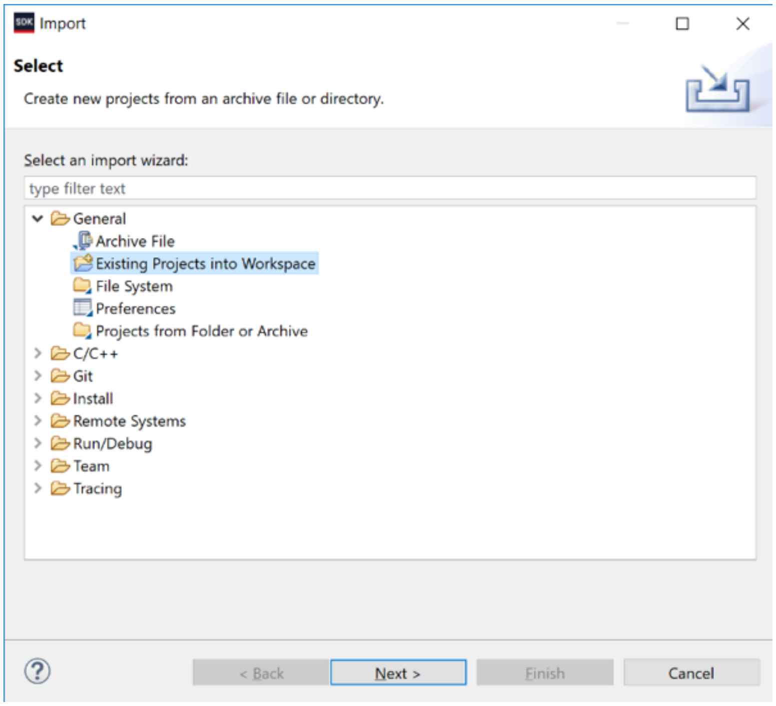
Before you run the demo project, use the MQTT client in the AWS IoT console to subscribe to the demo's MQTT topic.

To subscribe to the MQTT topic

1. Sign in to the AWS IoT console.
2. In the navigation pane, choose **Test** to open the MQTT client.
3. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.

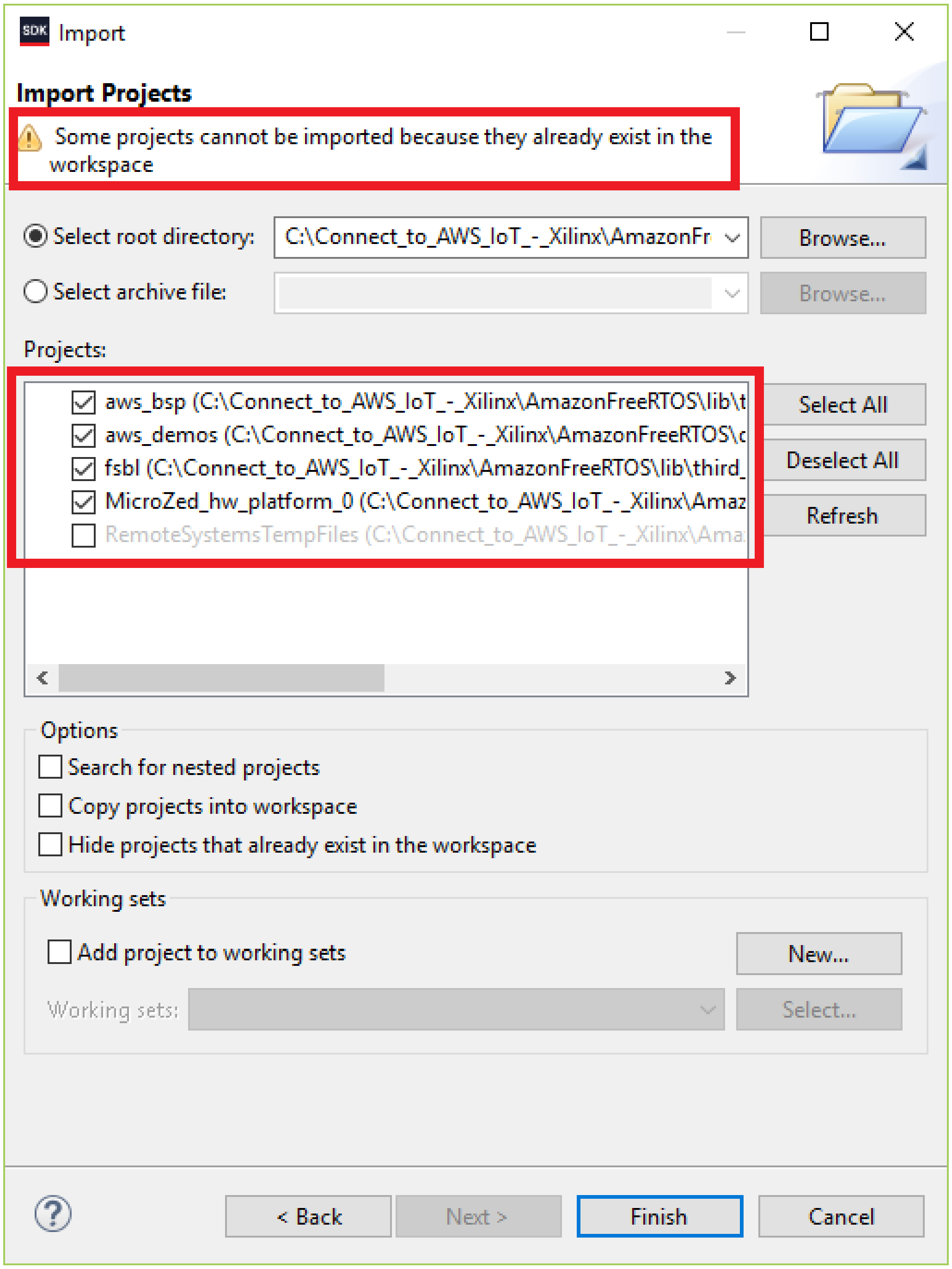
Open the Amazon FreeRTOS Sample Code in the XSDK IDE

1. Launch the XSDK IDE with the workspace directory set to *`<BASE_FOLDER>`*`\demos\xilinx\microzed\xsdk`.
2. Close the welcome page. From the menu, choose **Project**, and then clear **Build Automatically**.
3. From the menu, choose **File**, and then choose **Import**.
4. On the **Select** page, expand **General**, choose **Existing Projects into Workspace**, and then choose **Next**.



5. On the **Import Projects** page, choose **Select root directory**, and then enter the root directory of your demo project. To browse for the directory, choose **Browse**.

   After you specify a root directory, the projects in that directory appear on the **Import Projects** page. All available projects are selected by default.



Import

Import Projects

Some projects cannot be imported because they already exist in the workspace

● Select root directory: C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFr

○ Select archive file:

Projects:

- ☑ aws_bsp (C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\lib\t
- ☑ aws_demos (C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\c
- ☑ fsbl (C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\lib\third_
- ☑ MicroZed_hw_platform_0 (C:\Connect_to_AWS_IoT_-_Xilinx\Amaz
- □ RemoteSystemsTempFiles (C:\Connect_to_AWS_IoT_-_Xilinx\Ama

Options

- □ Search for nested projects
- □ Copy projects into workspace
- □ Hide projects that already exist in the workspace

Working sets

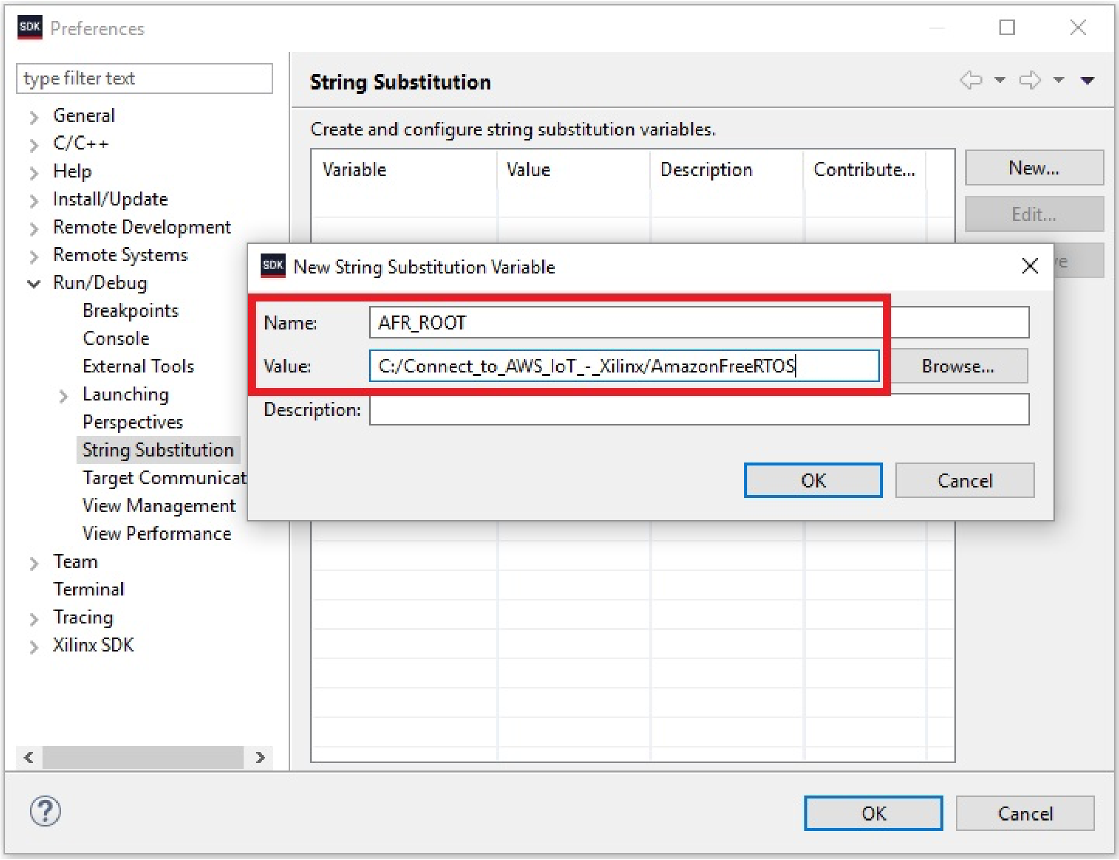
- □ Add project to working sets

Working sets:

Note

If you see a warning at the top of the **Import Projects** page ("Some projects cannot be imported because they already exist in the workspace.") you can ignore it.

6. With all of the projects selected, choose **Finish**. The XSDK IDE opens all of the projects that are required for the `aws_demos` project to build and run on the MicroZed board.
7. From the menu, choose **Window**, and then choose **Preferences**.
8. In the navigation pane, expand **Run/Debug**, choose **String Substitution**, and then choose **New**.
9. In **New String Substitution Variable**, for **Name**, enter **`AFR_ROOT`**. For **Value**, enter the root path of the `aws_demos`. Choose **OK**, and then choose **OK** to save the variable and close **Preferences**.



String Substitution

Create and configure string substitution variables.

New String Substitution Variable

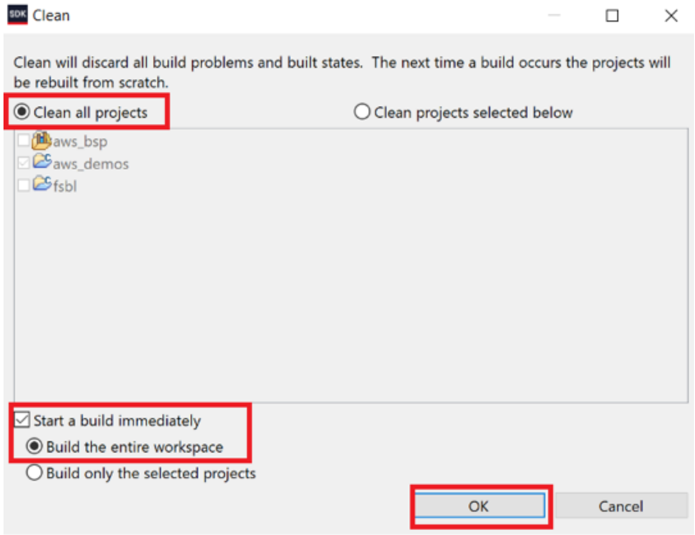
Name: AFR_ROOT

Value: C:/Connect_to_AWS_IoT_-_Xilinx/AmazonFreeRTOS

Description:

Build the Amazon FreeRTOS Project

1. In the XSDK IDE, from the menu, choose **Project**, and then choose **Clean**.
2. In **Clean**, leave the options at their default values, and then choose **OK**. XSDK cleans and builds all of the projects, and then generates `.elf` files.



Clean will discard all build problems and built states. The next time a build occurs the projects will be rebuilt from scratch.

● Clean all projects ○ Clean projects selected below

☑ Start a build immediately

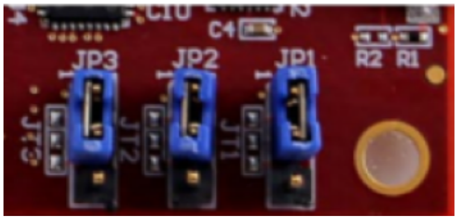
● Build the entire workspace

○ Build only the selected projects

Note
To build all projects without cleaning them, choose **Project**, and then choose **Build All**.
To build individual projects, select the project you want to build, choose **Project**, and then choose**Build Project**.

JTAG Debugging

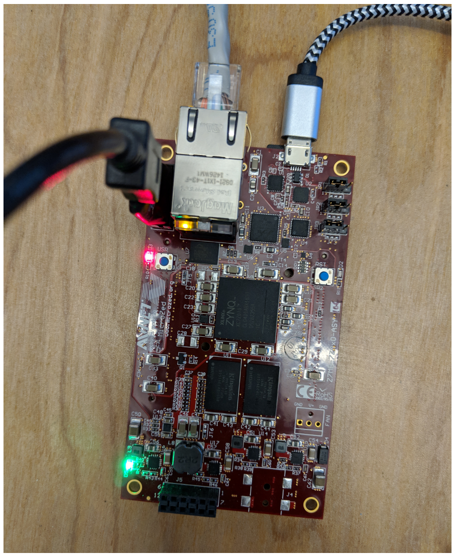
1. Set your MicroZed board's boot mode jumpers to the JTAG boot mode:



2. Insert your MicroSD card into the MicroSD card slot located directly under the USB-UART port.

   Note
   Before you debug, be sure to back up any content that you have on the MicroSD card.

   Your board should look similar to the following:



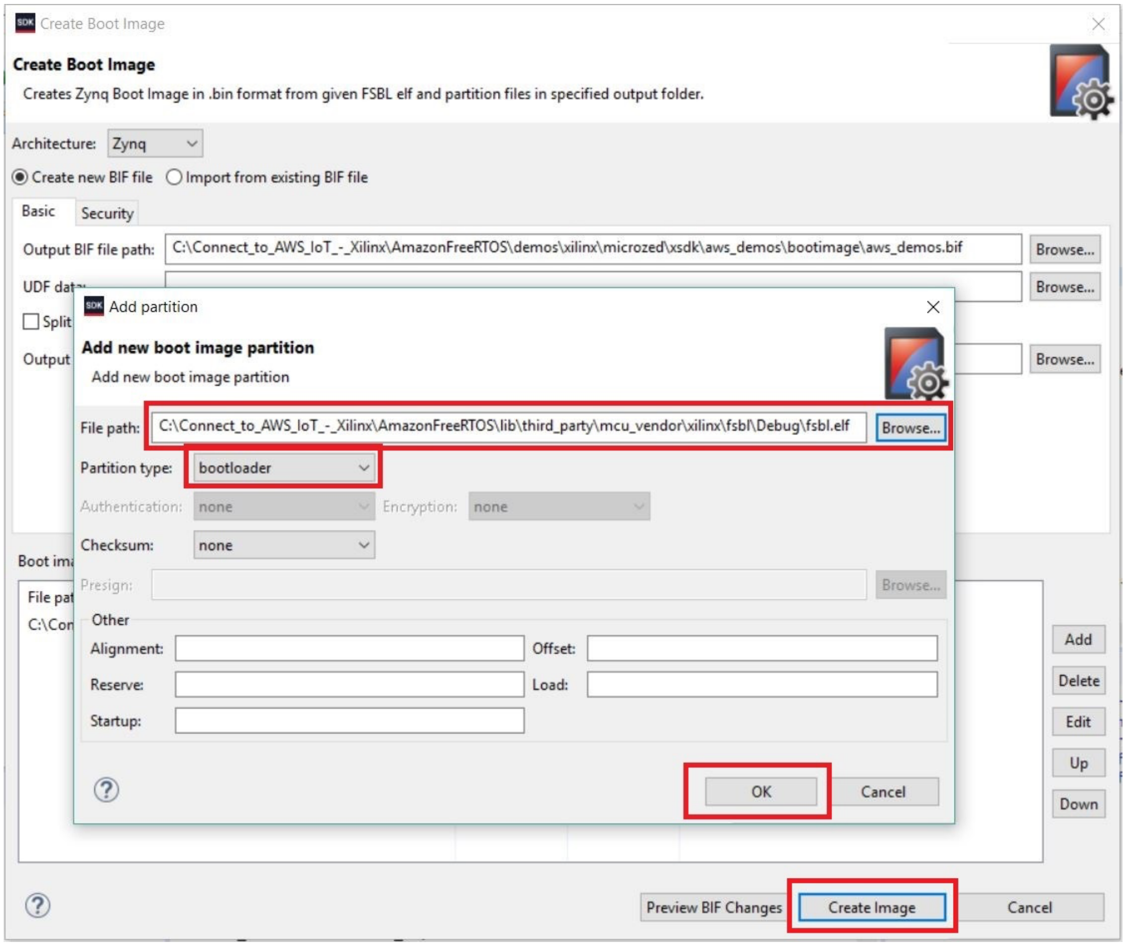
3. In the XSDK IDE, right-click **aws_demos**, choose **Debug As**, and then choose **1 Launch on System Hardware (System Debugger)**.
4. When the debugger stops at the breakpoint in `main()`, from the menu, choose **Run**, and then choose **Resume**.

   Note
   The first time you run the application, a new certificate-key pair is generated. For subsequent runs, you can comment out `vDevModeKeyProvisioning()` in the `main.c` file before you rebuild the images and the `BOOT.bin` file. This prevents the copying of the certificates and key to storage on every run.

You can opt to boot your MicroZed board from a MicroSD card or from QSPI flash to run the Amazon FreeRTOS demo project. For instructions, see Generate the Boot Image for the Amazon FreeRTOS Project (p. 49) and Run the Amazon FreeRTOS Project (p. 49).

Generate the Boot Image for the Amazon FreeRTOS Project

1. In the XSDK IDE, right-click **aws_demos**, and then choose **Create Boot Image**.
2. In **Create Boot Image**, choose **Create new BIF file**.
3. Next to **Output BIF file path**, choose **Browse**, and then choose `aws_demos.bif` located at *`<BASE_FOLDER>`*`\demos\xilinx\microzed\xsdk\aws_demos\bootimage\aws_demos.bif`.
4. Choose **Add**.
5. On **Add new boot image partition**, next to **File path**, choose **Browse**, and then choose `fsbl.elf`, located at *`<BASE_FOLDER>`*`\lib\third_party\mcu_vendor\xilinx\fsbl\Debug\fsbl.elf`.
6. For the **Partition type**, choose **bootloader**, and then choose **OK**.



Create Boot Image

Creates Zynq Boot Image in .bin format from given FSBL elf and partition files in specified output folder.

Architecture: Zynq

● Create new BIF file ○ Import from existing BIF file

Output BIF file path: C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\demos\xilinx\microzed\xsdk\aws_demos\bootimage\aws_demos.bif

Add new boot image partition

Add new boot image partition

File path: C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\lib\third_party\mcu_vendor\xilinx\fsbl\Debug\fsbl.elf

Partition type: bootloader

Authentication: none Encryption: none

Checksum: none

7. On **Create Boot Image**, choose **Create Image**. On **Override Files**, choose **OK** to overwrite the existing `aws_demos.bif` and generate the `BOOT.bin` file at `demos\xilinx\microzed\xsdk\aws_demos\bootimage\BOOT.bin`.

Run the Amazon FreeRTOS Project

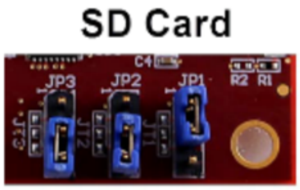
To run the Amazon FreeRTOS demo project, you can boot your MicroZed board from a MicroSD card or from QSPI flash.

As you set up your MicroZed board for running the Amazon FreeRTOS demo project, refer to the diagram in Setting Up the MicroZed Hardware (p. 41). Make sure that you have connected your MicroZed board to your computer.

Boot the Amazon FreeRTOS Project from a MicroSD Card

Format the MicroSD card that is provided with the Xilinx MicroZed Industrial IoT Kit.

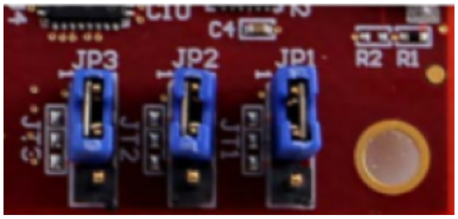
1. Copy the `BOOT.bin` file to the MicroSD card.
2. Insert the card into the MicroSD card slot directly under the USB-UART port.
3. Set the MicroZed boot mode jumpers to SD boot mode:

4. Press the RST button to reset the device and start booting the application. You can also unplug the USB-UART cable from the USB-UART port, and then reinsert the cable.

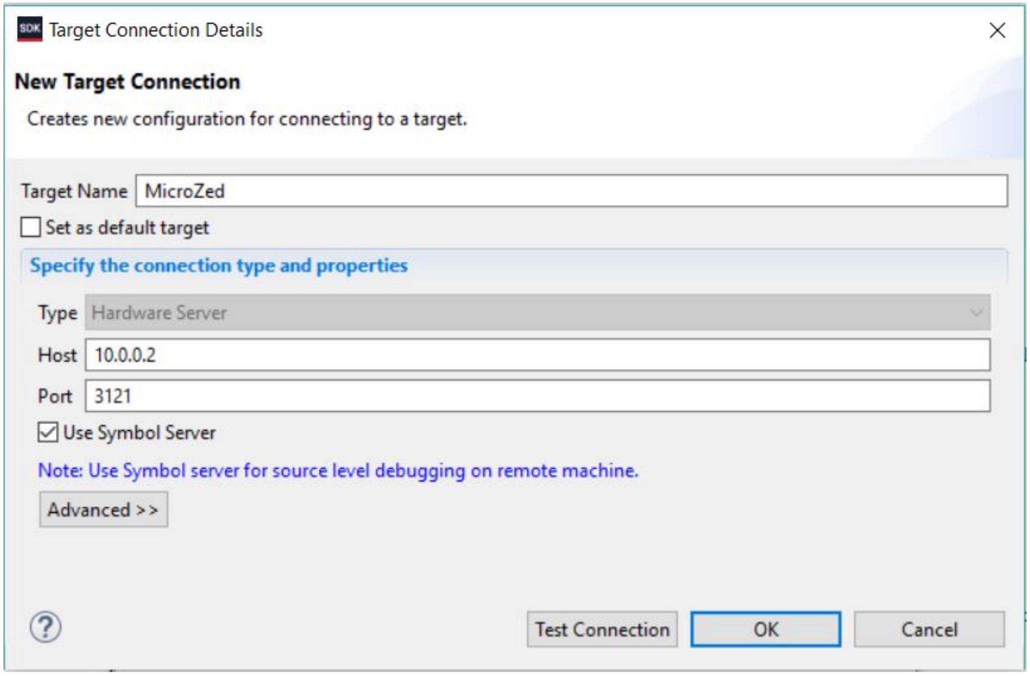
Boot the Amazon FreeRTOS Project from QSPI flash

1. Set your MicroZed board's boot mode jumpers to the JTAG boot mode:

2. Verify that your computer is connected to the USB-UART and JTAG Access ports. The green Power Good LED light should be illuminated.
3. In the XSDK IDE, from the menu, choose **Xilinx**, and then choose **Program Flash**.
4. In **Program Flash Memory**, the hardware platform should be filled in automatically. For **Connection**, choose your MicroZed hardware server to connect your board with your host computer.

   Note
   If you are using the Xilinx Smart Lync JTAG cable, you must create a hardware server in XSDK IDE. Choose **New**, and then define your server.



Target Connection Details

New Target Connection

Creates new configuration for connecting to a target.

Target Name: MicroZed

□ Set as default target

Specify the connection type and properties

Type: Hardware Server

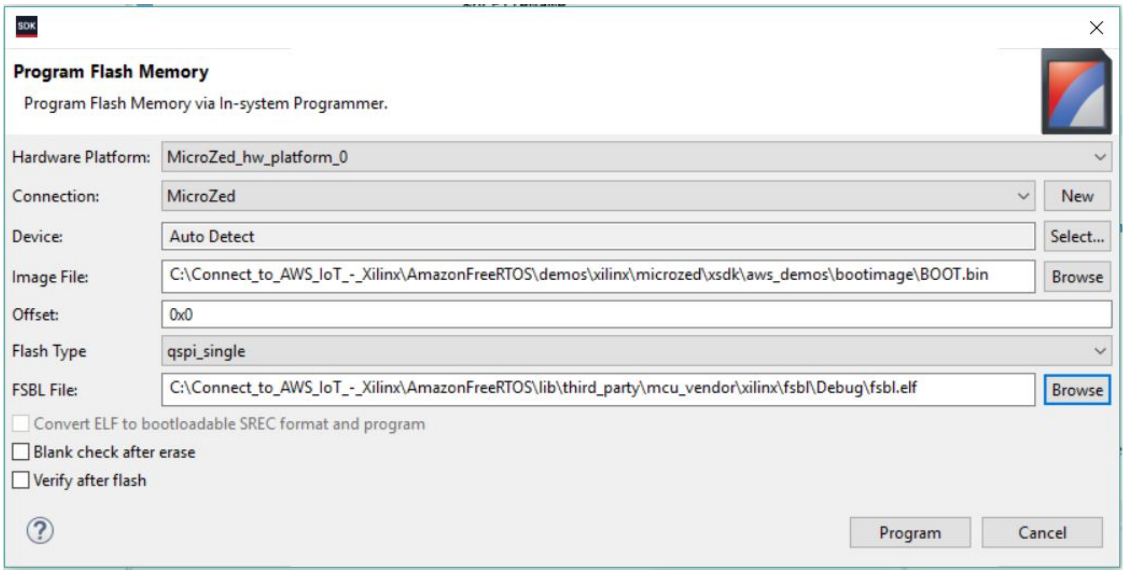
Host: 10.0.0.2

Port: 3121

☑ Use Symbol Server

Note: Use Symbol server for source level debugging on remote machine.

5. In **Image File**, enter the directory path to your `BOOT.bin` image file. Choose **Browse** to browse for the file instead.
6. In **Offset**, enter **`0x0`**.
7. In **FSBL File**, enter the directory path to your `fsbl.elf` file. Choose **Browse** to browse for the file instead.
8. Choose **Program** to program your board.



Program Flash Memory

Program Flash Memory via In-system Programmer.

Hardware Platform: MicroZed_hw_platform_0

Connection: MicroZed

Device: Auto Detect

Image File: C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\demos\xilinx\microzed\xsdk\aws_demos\bootimage\BOOT.bin

Offset: 0x0

Flash Type: qspi_single

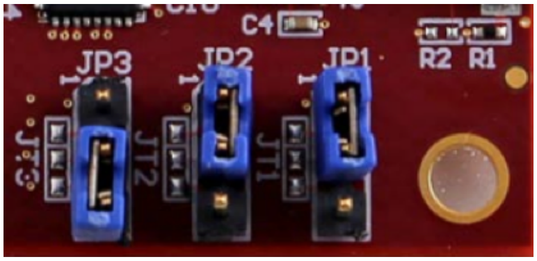
FSBL File: C:\Connect_to_AWS_IoT_-_Xilinx\AmazonFreeRTOS\lib\third_party\mcu_vendor\xilinx\fsbl\Debug\fsbl.elf

□ Convert ELF to bootloadable SREC format and program

□ Blank check after erase

□ Verify after flash

9. After the QSPI programming is complete, remove the USB-UART cable to power off the board.
10. Set your MicroZed board's boot mode jumpers to the QSPI boot mode:



11. Insert your card into the MicroSD card slot located directly under the USB-UART port.

    Note
    Be sure to back up any content that you have on the MicroSD card.
12. Press the RST button to reset the device and start booting the application. You can also unplug the USB-UART cable from the USB-UART port, and then reinsert the cable.

Troubleshooting

General Troubleshooting Tips

- If you encounter build errors that are related to incorrect paths, try to clean and rebuild the project, as described in Build the Amazon FreeRTOS Project (p. 47).

  Note
  If you are using Windows, make sure that you use forward slashes when you set the string substitution variables in the Windows XSDK IDE.

Getting Started with the FreeRTOS Windows Simulator

Before you begin, see Prerequisites (p. 4).

Amazon FreeRTOS is released as a zip file that contains the Amazon FreeRTOS libraries and sample applications for the platform you specify. To run the samples on a Windows machine, download the libraries and samples ported to run on Windows. This set of files is referred to as the FreeRTOS simulator for Windows.

Setting Up Your Environment

1. Install the latest version of WinPCap.
2. Install Microsoft Visual Studio Community 2017.
3. Make sure that you have an active hard-wired Ethernet connection.

Download and Configure Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

1. In the AWS IoT console, browse to the Amazon FreeRTOS page.

2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose **Download FreeRTOS Software**.
5. In the list of software configurations, find the **Connect to AWS IoT- Windows** predefined configuration for the Windows simulator, and then choose **Download**.
6. Unzip the downloaded file to the AmazonFreeRTOS folder, and make a note of the folder's path.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

Configure Your Network Interface

1. Run the project in Visual Studio. The program enumerates your network interfaces. Find the number for your hard-wired Ethernet interface. The output should look like this:

```
0 0 [None] FreeRTOS_IPInit
1 0 [None] vTaskStartScheduler
1. rpcap://\Device\NPF_{AD01B877-A0C1-4F33-8256-EE1F4480B70D}
(Network adapter 'Intel(R) Ethernet Connection (4) I219-LM' on local host)

2. rpcap://\Device\NPF_{337F7AF9-2520-4667-8EFF-2B575A98B580}
(Network adapter 'Microsoft' on local host)

The interface that will be opened is set by "configNETWORK_INTERFACE_TO_USE" which
 should be defined in FreeRTOSConfig.h Attempting to open interface number 1.
```

   You might see output in the debugger that says **Cannot find or open the PDB file**. You can ignore these messages.

   After you have identified the number for your hard-wired Ethernet interface, close the application window.

2. Open *`<BASE_FOLDER>`*`\demos\pc\windows\common\config_files\FreeRTOSConfig.h` and set `configNETWORK_INTERFACE_TO_USE` to the number that corresponds to your hard-wired network interface.

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. This is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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

   Your AWS IoT endpoint appears in the **Endpoint** text box. It should look like *`<1234567890123>`*`-ats.iot.`*`<us-east-1>`*`.amazonaws.com`. Make a note of this endpoint.

3. In the navigation pane, choose **Manage**, and then choose **Things**. Make a note of the AWS IoT thing name for your device.
4. With your AWS IoT endpoint and your AWS IoT thing name on hand, open *<BASE_FOLDER>*\demos\common\include\aws_clientcredential.h in your IDE, and specify values for the following #define constants:

   - clientcredentialMQTT_BROKER_ENDPOINT *Your AWS IoT endpoint*
   - clientcredentialIOT_THING_NAME *Your board's AWS IoT thing name*

To configure your AWS IoT credentials

To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device as an AWS IoT thing. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You need to format the certificate and private key for your device.

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

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

Build and Run Amazon FreeRTOS Samples

Load the Amazon FreeRTOS Sample Code into Visual Studio

1. In Visual Studio, from the **File** menu, choose **Open**. Choose **File/Solution**, navigate to *<BASE_FOLDER>*\demos\pc\windows\visual_studio\aws_demos.sln, and then choose **Open**.
2. From the **Build** menu, choose **Build Solution**, and make sure the solution builds without errors or warnings.

Run the Amazon FreeRTOS Samples

1. Rebuild your Visual Studio project to pick up changes made in the header files.
2. Sign in to the AWS IoT console.
3. In the navigation pane, choose **Test** to open the MQTT client.
4. In **Subscription topic**, enter **freertos/demos/echo**, and then choose **Subscribe to topic**.
5. From the **Debug** menu in Visual Studio, choose **Start Debugging**.

In the AWS IoT console, the MQTT client displays the messages received from the FreeRTOS Windows simulator.

Getting Started with the Nordic nRF52840-DK

Amazon FreeRTOS support for the Nordic nRF52840-DK is in public beta release. BLE demos are subject to change.

Before you begin, see Prerequisites (p. 4).

If you do not have the Nordic nRF52840-DK, you can purchase one from Nordic.

Setting Up the Nordic Hardware

Connect your host computer to the USB port labaled J2, located directly above the coin cell battery holder on your Nordic nRF52840 board.

For more information about setting up the Nordic nRF52840-DK, see the nRF52840 Development Kit User Guide.

Setting Up Your Environment

Download and Install Segger Embedded Studio

Amazon FreeRTOS supports Segger Embedded Studio as a development environment for the Nordic nRF52840-DK.

To set up your environment, you need to download and install Segger Embedded Studio.

1. Go to the Segger Embedded Studio Downloads page and choose the Embedded Studio for ARM option for your operating system.
2. Run the installer and follow the prompts to completion.

Establish a Serial Connection

After you connect your computer to your Nordic nRF52840 board and install Segger Embedded Studio, open a terminal tool, like PuTTy, Tera Term, or GNU Screen. Configure the terminal to connect to your board by a serial connection. Set the COM port to **`JLink CDC UART Port`** with the following serial port settings:

- Baud Rate: **`115200`**
- Data: **`8 bit`**
- Parity: **`None`**
- Stop: **`1 bit`**
- Flow Control: **`None`**

Note
Depending on your terminal tool, the serial port settings might vary in name.

Download and Configure Amazon FreeRTOS

After you set up your hardware and environment, you can download Amazon FreeRTOS.

Download Amazon FreeRTOS

To download Amazon FreeRTOS for the Nordic nRF52840-DK, go to the Amazon FreeRTOS GitHub page and clone the repository. The Amazon FreeRTOS BLE library is still in public beta, so you need to switch branches to access the code for the Nordic nRF52840-DK board. Check out the branch named `feature/ble-beta`.

> **Note**
> The maximum length of a file path on Microsoft Windows is 260 characters. The longest path in the Amazon FreeRTOS download is 122 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure that the path to the `AmazonFreeRTOS` directory is fewer than 98 characters long. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.
> In this tutorial, the path to the `AmazonFreeRTOS` directory is referred to as `BASE_FOLDER`.

Configure Your Project

To run the demo, you must configure your project to work with AWS IoT. To configure your project to work with AWS IoT, your board must be registered as an AWS IoT thing. This is a step in the Prerequisites (p. 4).

To configure your AWS IoT endpoint

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

   Your AWS IoT endpoint appears in the **Endpoint** text box. It should look like `<1234567890123>-ats.iot.<us-east-1>.amazonaws.com`. Make a note of this endpoint.
3. In the navigation pane, choose **Manage**, and then choose **Things**. Make a note of the AWS IoT thing name for your device.
4. With your AWS IoT endpoint and your AWS IoT thing name on hand, open `<BASE_FOLDER>\demos\common\include\aws_clientcredential.h` in your IDE, and specify values for the following `#define` constants:

   - `clientcredentialMQTT_BROKER_ENDPOINT` *`Your AWS IoT endpoint`*
   - `clientcredentialIOT_THING_NAME` *`Your board's AWS IoT thing name`*

To configure your AWS IoT credentials

To configure your AWS IoT credentials, you need the private key and certificate that you downloaded from the AWS IoT console when you registered your device as an AWS IoT thing. 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.

Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project. You need to format the certificate and private key for your device.

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

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

To enable the demo

1. Check that the BLE GATT Demo is enabled. Go to `<BASE_FOLDER>\demos\nordic\nrf52840-dk\common\config_files\aws_ble_config.h`, and make sure that `bleconfigENABLE_GATT_DEMO` is set to `1`.
2. Open `<BASE_FOLDER>\demos\common\demo_runner\aws_demo_runner.c`, and in the demo declarations, uncomment `extern void vStartMQTTBLEEchoDemo( void );`. In the `DEMO_RUNNER_RunDemos` definition, uncomment `vStartMQTTBLEEchoDemo();.`.

Build and Run Amazon FreeRTOS Samples

After you download Amazon FreeRTOS and configure your demo project, you are ready to build and run the demo project on your board.

Open Segger Embedded Studio. From the top menu, choose **File**, choose **Open Solution**, and then navigate to the project file `<BASE_FOLDER>\demos\nordic\nrf52840-dk\ses\aws_demos_ble.emProject`

From the top menu, choose **View**, and then choose **Debug Terminal** to display information from your serial connection terminal.

To build the BLE demo, right-click the `aws_ble_demos` demo project, and choose **Build**.

> **Note**
> If this is your first time using Segger Embedded Studio, you might see you a warning "No license for commercial use". Segger Embedded Studio can be used free of charge for Nordic Semiconductor devices. Choose **Activate Your Free License**, and follow the instructions.

To run the BLE demo on your board, from the Segger Embedded Studio menu, choose **Debug**, and then choose **Go**.

For more information about completing the demo with the Amazon FreeRTOS BLE Mobile SDK demo application as the mobile MQTT proxy, see MQTT over BLE Demo Application.

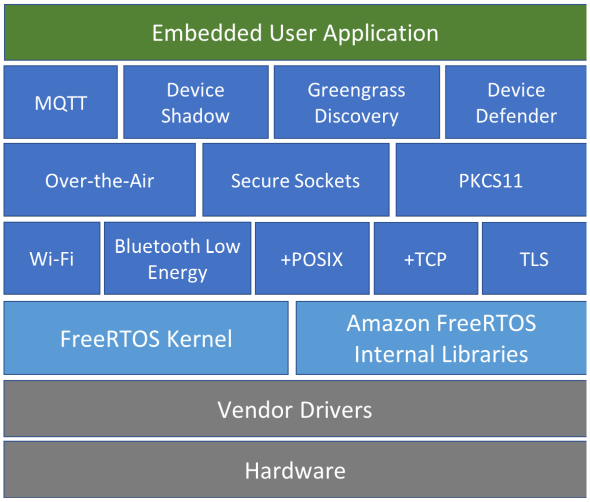
Amazon FreeRTOS Developer Guide

This section contains information required for writing embedded applications with Amazon FreeRTOS.

Topics

Amazon FreeRTOS Architecture

Amazon FreeRTOS is intended for use on embedded microcontrollers. It is typically flashed to devices as a single compiled image with all of the components required for the device application. This image combines functionality for the application written by the embedded developer, software libraries provided by Amazon, the FreeRTOS kernel, and drivers and board support packages (BSPs) for the hardware platform. Independent of the individual microcontroller being used, embedded application developers can expect the same standardized interfaces to the FreeRTOS kernel and all Amazon FreeRTOS software libraries.



FreeRTOS Kernel Fundamentals

The FreeRTOS kernel is a real-time operating system that supports numerous architectures. It is ideal for building embedded microcontroller applications. It provides:

- A multitasking scheduler.

- Multiple memory allocation options (including the ability to create completely statically allocated systems).
- Intertask coordination primitives, including task notifications, message queues, multiple types of semaphore, and stream and message buffers.

The FreeRTOS kernel never performs non-deterministic operations, such as walking a linked list, inside a critical section or interrupt. The FreeRTOS kernel includes an efficient software timer implementation that does not use any CPU time unless a timer needs servicing. Blocked tasks do not require time-consuming periodic servicing. Direct-to-task notifications allow fast task signaling, with practically no RAM overhead. They can be used in the majority of intertask and interrupt-to-task signaling scenarios.

The FreeRTOS kernel is designed to be small, simple, and easy to use. A typical RTOS kernel binary image is in the range of 4000 to 9000 bytes.

FreeRTOS Kernel Scheduler

An embedded application that uses an RTOS can be structured as a set of independent tasks. Each task executes within its own context, with no dependency on other tasks. Only one task in the application is running at any point in time. The real-time RTOS scheduler determines when each task should run. Each task is provided with its own stack. When a task is swapped out so another task can run, the task's execution context is saved to the task stack so it can be restored when the same task is later swapped back in to resume its execution.

To provide deterministic real-time behavior, the FreeRTOS tasks scheduler allows tasks to be assigned strict priorities. RTOS ensures the highest priority task that is able to execute is given processing time. This requires sharing processing time between tasks of equal priority if they are ready to run simultaneously. FreeRTOS also creates an idle task that executes only when no other tasks are ready to run.

Memory Management

This section provides information about kernel memory allocation and application memory management.

Kernel Memory Allocation

The RTOS kernel needs RAM each time a task, queue, or other RTOS object is created. The RAM can be allocated:

- Statically at compile time.
- Dynamically from the RTOS heap by the RTOS API object creation functions.

When RTOS objects are created dynamically, using the standard C library `malloc()` and `free()` functions is not always appropriate for a number of reasons:

- They might not be available on embedded systems.
- They take up valuable code space.
- They are not typically thread-safe.
- They are not deterministic.

For these reasons, FreeRTOS keeps the memory allocation API in its portable layer. The portable layer is outside of the source files that implement the core RTOS functionality, so you can provide an application-specific implementation appropriate for the real-time system you're developing. When the

RTOS kernel requires RAM, it calls `pvPortMalloc()` instead of `malloc()`(). When RAM is being freed, the RTOS kernel calls `vPortFree()` instead of `free()`.

Application Memory Management

When applications need memory, they can allocate it from the FreeRTOS heap. FreeRTOS offers several heap management schemes that range in complexity and features. You can also provide your own heap implementation.

The FreeRTOS kernel includes five heap implementations:

`heap_1`

Is the simplest implementation. Does not permit memory to be freed.

`heap_2`

Permits memory to be freed, but not does coalescence adjacent free blocks.

`heap_3`

Wraps the standard `malloc()` and `free()` for thread safety.

`heap_4`

Coalesces adjacent free blocks to avoid fragmentation. Includes an absolute address placement option.

`heap_5`

Is similar to heap_4. Can span the heap across multiple, non-adjacent memory areas.

Intertask Coordination

This section contains information about FreeRTOS primitives.

Queues

Queues are the primary form of intertask communication. They can be used to send messages between tasks and between interrupts and tasks. In most cases, they are used as thread-safe First In First Out (FIFO) buffers with new data being sent to the back of the queue. (Data can also be sent to the front of the queue.) Messages are sent through queues by copy, meaning the data (which can be a pointer to larger buffers) is itself copied into the queue rather than simply storing a reference to the data.

Queue APIs permit a block time to be specified. When a task attempts to read from an empty queue, the task is placed into the Blocked state until data becomes available on the queue or the block time elapses. Tasks in the Blocked state do not consume any CPU time, allowing other tasks to run. Similarly, when a task attempts to write to a full queue, the task is placed into the Blocked state until space becomes available in the queue or the block time elapses. If more than one task blocks on the same queue, the task with the highest priority is unblocked first.

Other FreeRTOS primitives, such as direct-to-task notifications and stream and message buffers, offer lightweight alternatives to queues in many common design scenarios.

Semaphores and Mutexes

The FreeRTOS kernel provides binary semaphores, counting semaphores, and mutexes for both mutual exclusion and synchronization purposes.

Binary semaphores can only have two values. They are a good choice for implementing synchronization (either between tasks or between tasks and an interrupt). Counting semaphores take more than two values. They allow many tasks to share resources or perform more complex synchronization operations.

Mutexes are binary semaphores that include a priority inheritance mechanism. This means that if a high priority task blocks while attempting to obtain a mutex that is currently held by a lower priority task, the priority of the task holding the token is temporarily raised to that of the blocking task. This mechanism is designed to ensure the higher priority task is kept in the Blocked state for the shortest time possible, to minimize the priority inversion that has occurred.

Direct-to-Task Notifications

Task notifications allow tasks to interact with other tasks, and to synchronize with interrupt service routines (ISRs), without the need for a separate communication object like a semaphore. Each RTOS task has a 32-bit notification value that is used to store the content of the notification, if any. An RTOS task notification is an event sent directly to a task that can unblock the receiving task and optionally update the receiving task's notification value.

RTOS task notifications can be used as a faster and lightweight alternative to binary and counting semaphores and, in some cases, queues. Task notifications have both speed and RAM footprint advantages over other FreeRTOS features that can be used to perform equivalent functionality. However, task notifications can only be used when there is only one task that can be the recipient of the event.

Stream Buffers

Stream buffers allow a stream of bytes to be passed from an interrupt service routine to a task, or from one task to another. A byte stream can be of arbitrary length and does not necessarily have a beginning or an end. Any number of bytes can be written at one time, and any number of bytes can be read at one time. Stream buffer functionality is enabled by including the `<BASE_DIR>/libs/FreeRTOS/stream_buffer.c` source file in your project.

Stream buffers assume there is only one task or interrupt that writes to the buffer (the writer), and only one task or interrupt that reads from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupt service routines, but it is not safe to have multiple writers or readers.

The stream buffer implementation uses direct to task notifications. Therefore, calling a stream buffer API that places the calling task into the Blocked state can change the calling task's notification state and value.

Sending Data

`xStreamBufferSend()` is used to send data to a stream buffer in a task. `xStreamBufferSendFromISR()` is used to send data to a stream buffer in an interrupt service routine (ISR).

`xStreamBufferSend()` allows a block time to be specified. If `xStreamBufferSend()` is called with a non-zero block time to write to a stream buffer and the buffer is full, the task is placed into the Blocked state until space becomes available or the block time expires.

`sbSEND_COMPLETED()` and `sbSEND_COMPLETED_FROM_ISR()` are macros that are called (internally by the FreeRTOS API) when data is written to a stream buffer. It takes the handle of the stream buffer that was updated. Both of these macros check to see if there is a task blocked on the stream buffer waiting for data, and if so, removes the task from the Blocked state.

You can change this default behavior by providing your own implementation of `sbSEND_COMPLETED()` in FreeRTOSConfig.h. This is useful when a stream buffer is used to pass data between cores on a multicore processor. In that scenario, `sbSEND_COMPLETED()` can be implemented to generate an interrupt in the other CPU core, and the interrupt's service routine can then use the `xStreamBufferSendCompletedFromISR()` API to check, and if necessary unblock, a task that is waiting for the data.

Receiving Data

`xStreamBufferReceive()` is used to read data from a stream buffer in a task. `xStreamBufferReceiveFromISR()` is used to read data from a stream buffer in an interrupt service routine (ISR).

`xStreamBufferReceive()` allows a block time to be specified. If `xStreamBufferReceive()` is called with a non-zero block time to read from a stream buffer and the buffer is empty, the task is placed into the Blocked state until either a specified amount of data becomes available in the stream buffer, or the block time expires.

The amount of data that must be in the stream buffer before a task is unblocked is called the stream buffer's trigger level. A task blocked with a trigger level of 10 is unblocked when at least 10 bytes are written to the buffer or the task's block time expires. If a reading task's block time expires before the trigger level is reached, the task receives any data written to the buffer. The trigger level of a task must be set to a value between 1 and the size of the stream buffer. The trigger level of a stream buffer is set when `xStreamBufferCreate()` is called. It can be changed by calling `xStreamBufferSetTriggerLevel()`.

`sbRECEIVE_COMPLETED()` and `sbRECEIVE_COMPLETED_FROM_ISR()` are macros that are called (internally by the FreeRTOS API) when data is read from a stream buffer. The macros check to see if there is a task blocked on the stream buffer waiting for space to become available within the buffer, and if so, removes the task from the Blocked state. You can change the default behavior of `sbRECEIVE_COMPLETED()` by providing an alternative implementation in FreeRTOSConfig.h.

Message Buffers

Message buffers allow variable length discrete messages to be passed from an interrupt service routine to a task, or from one task to another. For example, messages of length 10, 20 and 123 bytes can all be written to, and read from, the same message buffer. A 10-byte message can only be read as a 10-byte message, not as individual bytes. Message buffers are built on top of stream buffer implementation. Message buffer functionality is enabled by including the *<BASE_DIR>*`/libs/FreeRTOS/stream_buffer.c` source file in your project.

Message buffers assume there is only one task or interrupt that writes to the buffer (the writer), and only one task or interrupt that reads from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupt service routines, but it is not safe to have multiple writers or readers.

The message buffer implementation uses direct to task notifications. Therefore, calling a stream buffer API that places the calling task into the Blocked state can change the calling task's notification state and value.

To enable message buffers to handle variable-sized messages, the length of each message is written into the message buffer before the message itself. The length is stored in a variable of type `size_t`, which is typically 4 bytes on a 32-byte architecture. Therefore, writing a 10-byte message into a message buffer actually consumes 14 bytes of buffer space. Likewise, writing a 100-byte message into a message buffer actually uses 104 bytes of buffer space.

Sending Data

`xMessageBufferSend()` is used to send data to a message buffer from a task. `xMessageBufferSendFromISR()` is used to send data to a message buffer from an interrupt service routine (ISR).

`xMessageBufferSend()` allows a block time to be specified. If `xMessageBufferSend()` is called with a non-zero block time to write to a message buffer and the buffer is full, the task is placed into the Blocked state until either space becomes available in the message buffer, or the block time expires.

`sbSEND_COMPLETED()` and `sbSEND_COMPLETED_FROM_ISR()` are macros that are called (internally by the FreeRTOS API) when data is written to a stream buffer. It takes a single parameter, which is the handle of the stream buffer that was updated. Both of these macros check to see if there is a task blocked on the stream buffer waiting for data, and if so, they remove the task from the Blocked state.

You can change this default behavior by providing your own implementation of `sbSEND_COMPLETED()` in FreeRTOSConfig.h. This is useful when a stream buffer is used to pass data between cores on a multicore processor. In that scenario, `sbSEND_COMPLETED()` can be implemented to generate an interrupt in the other CPU core, and the interrupt's service routine can then use the `xStreamBufferSendCompletedFromISR()` API to check, and if necessary unblock, a task that was waiting for the data.

Receiving Data

`xMessageBufferReceive()` is used to read data from a message buffer in a task. `xMessageBufferReceiveFromISR()` is used to read data from a message buffer in an interrupt service routine (ISR). `xMessageBufferReceive()` allows a block time to be specified. If `xMessageBufferReceive()` is called with a non-zero block time to read from a message buffer and the buffer is empty, the task is placed into the Blocked state until either data becomes available, or the block time expires.

`sbRECEIVE_COMPLETED()` and `sbRECEIVE_COMPLETED_FROM_ISR()` are macros that are called (internally by the FreeRTOS API) when data is read from a stream buffer. The macros check to see if there is a task blocked on the stream buffer waiting for space to become available within the buffer, and if so, removes the task from the Blocked state. You can change the default behavior of `sbRECEIVE_COMPLETED()` by providing an alternative implementation in FreeRTOSConfig.h.

Software Timers

A software timer allows a function to be executed at a set time in the future. The function executed by the timer is called the timer’s callback function. The time between a timer being started and its callback function being executed is called the timer’s period. The FreeRTOS kernel provides an efficient software timer implementation because:

- It does not execute timer callback functions from an interrupt context.
- It does not consume any processing time unless a timer has actually expired.
- It does not add any processing overhead to the tick interrupt.
- It does not walk any link list structures while interrupts are disabled.

Low Power Support

Like most embedded operating systems, the FreeRTOS kernel users a hardware timer to generate periodic tick interrupts, which are used to measure time. The power saving of regular hardware timer implementations is limited by the necessity to periodically exit and then re-enter the low power state to process tick interrupts. If the frequency of the tick interrupt is too high, the energy and time consumed entering and exiting a low power state for every tick outweighs any potential power saving gains for all but the lightest power saving modes.

To address this limitation, FreeRTOS includes a tickless timer mode for low-power applications. The FreeRTOS tickless idle mode stops the periodic tick interrupt during idle periods (periods when there are no application tasks that are able to execute), and then makes a correcting adjustment to the RTOS tick count value when the tick interrupt is restarted. Stopping the tick interrupt allows the microcontroller to remain in a deep power saving state until either an interrupt occurs, or it is time for the RTOS kernel to transition a task into the ready state.

Amazon FreeRTOS Libraries

Amazon FreeRTOS libraries provide additional functionality to the FreeRTOS kernel and its internal libraries. You can use Amazon FreeRTOS libraries for networking and security in embedded applications. Amazon FreeRTOS libraries also enable your applications to interact with AWS IoT services.

You can download versions of Amazon FreeRTOS that are configured for Amazon FreeRTOS-qualified platforms from the Amazon FreeRTOS console. For a list of qualified platforms, see the Amazon FreeRTOS Partners website. Amazon FreeRTOS is also available on GitHub.

Amazon FreeRTOS Porting Libraries

The following porting libraries are included in configurations of Amazon FreeRTOS that are available for download on the Amazon FreeRTOS console. These libraries are platform-dependent. Their contents change according to your hardware platform.

Amazon FreeRTOS Porting Libraries

Library	API Reference	Description
Bluetooth Low Energy	Bluetooth Low Energy (BLE) API Reference	Using the Amazon FreeRTOS Bluetooth Low Energy (BLE) library, your microcontroller can communicate with the AWS IoT MQTT broker through a gateway device. For more information, see Amazon FreeRTOS Bluetooth Low Energy

Library	API Reference	Description
		Library (Beta) (p. 72). **Note** The Amazon FreeRTOS BLE library is in public beta.
Over-the-Air Updates	OTA Agent API Reference	The Amazon FreeRTOS AWS IoT Over-the-Air (OTA) Agent library connects your Amazon FreeRTOS device to the AWS IoT OTA agent. For more information, see Amazon FreeRTOS Over-the-Air (OTA) Agent Library (p. 93).

Library	API Reference	Description
FreeRTOS +POSIX	FreeRTOS +POSIX API Reference	You can use the FreeRTOS +POSIX library to port POSIX-compliant applications to the Amazon FreeRTOS ecosystem. For more information, see FreeRTOS +POSIX.
Secure Sockets	Secure Sockets API Reference	For more information, see Amazon FreeRTOS Secure Sockets Library (p. 97).

Library	API Reference	Description
FreeRTOS +TCP	FreeRTOS +TCP API Reference	FreeRTOS +TCP is a scalable, open source and thread safe TCP/IP stack for FreeRTOS. For more information, see FreeRTOS +TCP.
Wi-Fi	Wi-Fi API Reference	The Amazon FreeRTOS Wi-Fi library enables you to interface with your microcontroller's lower-level wireless stack. For more information, see Amazon FreeRTOS Wi-Fi Library (p. 103).

Library	API Reference	Description
PKCS #11		The Amazon FreeRTOS PKCS #11 library is a reference implementation of the Public Key Cryptography Standard #11, to support provisioning and TLS client authentication. For more information, see Amazon FreeRTOS Public Key Cryptography Standard (PKCS) #11 Library (p. 95).
TLS		For more information, see Amazon FreeRTOS Transport Layer Security (TLS) (p. 103).

Amazon FreeRTOS Application Libraries

You can optionally include the following standalone application libraries in your Amazon FreeRTOS configuration to interact with AWS IoT.

Amazon FreeRTOS application libraries

Library	API Reference	Description
Greengrass	Greengrass API Reference	The Amazon FreeRTOS AWS IoT Greengrass library connects your Amazon FreeRTOS device to AWS IoT Greengrass. For more information, see Amazon FreeRTOS AWS IoT Greengrass Discovery Library (p. 85).
MQTT	MQTT Library API Reference (Legacy) MQTT Agent API Reference (Legacy) MQTT API Reference (Beta)	The Amazon FreeRTOS MQTT library provides a client for your Amazon FreeRTOS device to publish and subscribe to

Library	API Reference	Description
		MQTT topics. MQTT is the protocol that devices use to interact with AWS IoT. For more information about the legacy Amazon FreeRTOS MQTT library, see Amazon FreeRTOS MQTT Library (Legacy) (p. 90). For more information about the new Amazon FreeRTOS MQTT library, in public beta, see Amazon FreeRTOS MQTT Library (Beta) (p. 87).

Library	API Reference	Description
Device Shadow	Device Shadow API Reference	The AWS IoT Device Shadow library enables your Amazon FreeRTOS device to interact with AWS IoT device shadows. For more information, see Amazon FreeRTOS AWS IoT Device Shadow Library (p. 101).

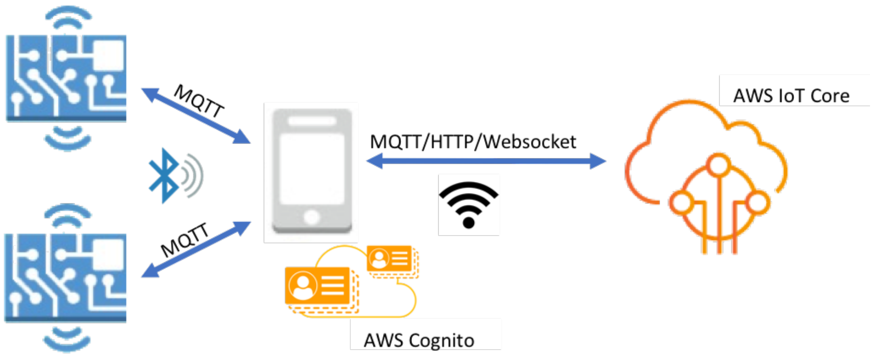
Library	API Reference	Description
Device Defender		The Amazon FreeRTOS AWS IoT Device Defender library connects your Amazon FreeRTOS device to AWS IoT Device Defender. For more information, see Amazon FreeRTOS AWS IoT Device Defender Library (p. 82).

Amazon FreeRTOS Bluetooth Low Energy Library (Beta)

Overview

> The Bluetooth Low Energy (BLE) Library is in public beta release for Amazon FreeRTOS and is subject to change.

Amazon FreeRTOS supports publishing and subscribing to MQTT topics over Bluetooth Low Energy (BLE) through a proxy device, such as a mobile phone. With the Amazon FreeRTOS BLE library, your microcontroller can securely communicate with the AWS IoT MQTT broker.

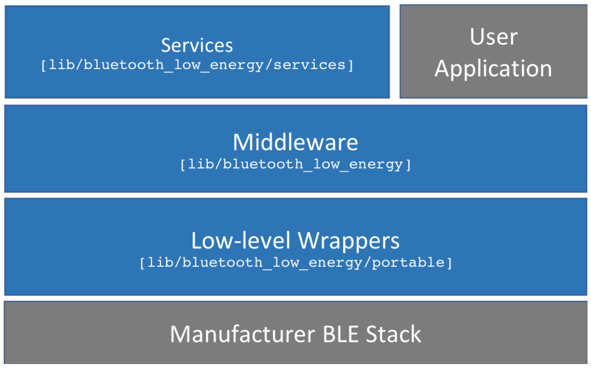


Using the Amazon FreeRTOS BLE Mobile SDKs, you can write native mobile applications that communicate with the embedded applications on your microcontroller over BLE. For more information about the Amazon FreeRTOS BLE Mobile SDKs, see Mobile SDKs for Amazon FreeRTOS Bluetooth Devices (p. 81). Amazon FreeRTOS BLE uses Amazon Cognito for user authentication on mobile devices.

In addition to supporting MQTT, the Amazon FreeRTOS BLE library includes services for configuring Wi-Fi networks. The Amazon FreeRTOS BLE library also includes some middleware and lower-level APIs for more direct control over your BLE stack. The source files for the Amazon FreeRTOS BLE library are located in `AmazonFreeRTOS/lib/bluetooth_low_energy`.

Amazon FreeRTOS BLE Architecture

The Amazon FreeRTOS BLE library is made up of three layers: services, middleware, and low-level wrappers.



Services
[lib/bluetooth_low_energy/services]

User Application

Middleware
[lib/bluetooth_low_energy]

Low-level Wrappers
[lib/bluetooth_low_energy/portable]

Manufacturer BLE Stack

Services

The Amazon FreeRTOS BLE services layer consists of three Generic Attributes (GATT) services that leverage the middleware APIs: Device Information, Wi-Fi Provisioning, and MQTT Communications over BLE. For more information, see Services (p. 74).

Middleware

Amazon FreeRTOS BLE middleware is an abstraction from the lower-level APIs. The middleware APIs make up a more user-friendly interface to the BLE stack. For more information, see Middleware (p. 74).

Low-level Wrappers

The low-level Amazon FreeRTOS BLE wrappers are an abstraction from the manufacturer's BLE stack. Low-level wrappers offer a common set of APIs for direct control over the hardware. The low-level APIs optimize RAM usage, but are limited in functionality. To use the Amazon FreeRTOS BLE services, you interact with the BLE service APIs, which demand more resources than the low-level APIs.

Dependencies and Requirements

Only the MQTT over BLE and Wi-Fi Provisioning services have library dependencies.

GATT Service	Dependency
MQTT over BLE	Amazon FreeRTOS MQTT Library (Beta) (p. 87)
Wi-Fi Provisioning	Amazon FreeRTOS Wi-Fi Library (p. 103)

To communicate with the AWS IoT MQTT broker, you must have an AWS account and you must register your devices as AWS IoT things. For more information about setting up, see the AWS IoT Developer Guide.

Amazon FreeRTOS BLE uses Amazon Cognito for user authentication on your mobile device. To use MQTT proxy services, you must create an Amazon Cognito identity and user pools. Each Amazon Cognito Identity must have the appropriate policy attached to it. For more information, see the Amazon Cognito Developer Guide.

Features

Services

Device Information

The Device Information service gathers information about your microcontroller, including:

- The version of Amazon FreeRTOS that your device is using.
- The AWS IoT endpoint of the account for which the device is registered.
- BLE Maximum Transmission Unit (MTU).

Wi-Fi Provisioning

The Wi-Fi Provisioning service enables microcontrollers with Wi-Fi capabilities to do the following:

- List networks in range.
- Save networks and network credentials to flash memory.
- Set network priority.
- Delete networks and network credentials from flash memory.

MQTT over BLE

The MQTT over BLE service connects your microcontroller to Bluetooth-enabled mobile devices to indirectly connect to the AWS IoT cloud with AWS Mobile SDKs. The microcontroller functions as an MQTT client, the mobile device as an MQTT proxy, and the AWS IoT cloud as the MQTT server.

Middleware

Using middleware APIs, you can register several callbacks, across multiple layers, to a single event.

Flexible Callback Subscription

Suppose your BLE hardware disconnects, and the MQTT over BLE service needs to detect the disconnection. An application that you wrote might also need to detect the same disconnection event. The BLE middleware can route the event to different parts of the code where you have registered callbacks, without making the higher layers compete for lower-level resources.

Source and Header Files

The following tree diagram shows the required source and header files, along with their location in the Amazon FreeRTOSdirectory structure. The project must also build the source files of the dependent libraries.

```
Amazon FreeRTOS
  |
  + - lib
      + - bluetooth_low_energy
      |   + - aws_ble_event_manager.c
      |   + - aws_ble_gap.c   [Middleware GAP]
      |   + - aws_ble_gatt.c  [Middleware GATT]
      |   + - portable      [Wrappers, wrapping APIs in lib/include/bluetooth_low_energy]
      |    + - services
      |        + - device_information  [Service providing device info to the phone APP]
      |        |   + - aws_ble_device_information.c
      |        + - mqtt_ble                          [Used to do MQTT over BLE]
      |        |   + - aws_mqtt_proxy.c
      |        + - wifi_provisioning            [WIFI provisioning service over BLE]
      |            + - aws_ble_wifi_provisioning.c
      + - include
          + - bluetooth_low_energy [Wrapping APIs in lib/include/bluetooth_low_energy]
          |   + - bt_hal_avsrc_profile.h
          + # bt_hal_gatt_client.h
          + # bt_hal_gatt_server.h
          + # bt_hal_gatt_types.h
          + # bt_hal_manager_adapter_ble.h
          + # bt_hal_manager_adapter_classic.h
          + # bt_hal_manager.h
          + # bt_hal_manager_types.h
          + - private                            [For internal library use only!]
          |   + - aws_ble_internals.h
          |   + - aws_ble_config_defaults.h
          |   + - aws_ble_event_manager.h
          + - aws_ble.h
          + - aws_ble_device_information.h
          + - aws_ble_services_init.h
          + - aws_ble_wifi_provisioning.h
```

Amazon FreeRTOS BLE Library Configuration File

Applications that use the Amazon FreeRTOS MQTT over BLE service must provide an `aws_ble_config.h` header file, in which configuration parameters are defined. Undefined configuration parameters take the default values specified in `lib\include\private\aws_ble_config_defaults.h`.

Optimization

When optimizing your board's performance, consider the following:

- Low-level APIs use less RAM, but offer limited functionality.

- You can set the `bleconfigMAX_NETWORK` parameter in the `aws_ble_config.h` header file to a lower value to reduce the amount of stack consumed.
- You can delete unused services to save RAM.
- You can increase the MTU size to its maximum value to limit message buffering, and make code run faster and consume less RAM.

Usage Restrictions

By default, the Amazon FreeRTOS BLE library sets the `eBTpropertySecureConnectionOnly` property to TRUE, which places the device in a Secure Connections Only mode. As specified by the Bluetooth Core Specification v5.0, Vol 3, Part C, 10.2.4, when a device is in a Secure Connections Only mode, the highest LE security mode 1 level, level 4, is required for access to any attribute that has permissions higher than the lowest LE security mode 1 level, level 1. At the LE security mode 1 level 4, a device must have input and output capabilities for numeric comparison.

To use a lower LE security level, set `eBTpropertySecureConnectionOnly` to FALSE, by calling the API `pxSetDeviceProperty` with the property `eBTpropertySecureConnectionOnly`.

For information about LE security modes, see the Bluetooth Core Specification v5.0, Vol 3, Part C, 10.2.1.

Initialization

If your application interacts with the BLE stack through middleware, you only need to initialize the middleware.

Middleware

Middleware takes care of initializing the lower layers of the stack.

To initialize the middleware

1. You must initialize any BLE hardware drivers before you call the BLE middleware API.
2. Enable BLE.

   ```
   const BTInterface_t * pxIface = BTGetBluetoothInterface();
   xStatus = pxIface->pxEnable( 0 );
   ```

3. To initialize BLE, call `BLE_Init`, along with a set of desired properties, such as secure connection mode, device name, and MTU size.

   ```
   xStatus = BLE_Init( &xServerUUID, xDeviceProperties, MAX_PROPERTIES );
   ```

Low-level APIs

If you don't want to use the Amazon FreeRTOS BLE GATT services, you can bypass the middleware and interact directly with the low-level APIs to save resources.

To initialize the low-level APIs

1. Driver initialization is not part of the BLE low-level APIs. You must initialize any BLE hardware drivers before you call the APIs.

2. The BLE low-level API provides an enable/disable call to the BLE stack for optimizing power and resources. Before calling the APIs, you must enable BLE.

   ```
   const BTInterface_t * pxIface = BTGetBluetoothInterface();
   xStatus = pxIface->pxEnable( 0 );
   ```

3. The Bluetooth manager contains APIs that are common to both BLE and Bluetooth classic. The callbacks for the common manager must be initialized second.

   ```
   xStatus = xBTInterface.pxBTInterface->pxBtManagerInit( &xBTManagerCb );
   ```

4. The BLE adapter fits on top of the common API. You must initialize its callbacks like you initialized the common API.

   ```
   xBTInterface.pxBTLeAdapterInterface = ( BTBleAdapter_t * ) xBTInterface.pxBTInterface-
   >pxGetLeAdapter();
   xStatus = xBTInterface.pxBTLeAdapterInterface->pxBleAdapterInit( &xBTBleAdapterCb );
   ```

5. Register your new user application.

   ```
   xBTInterface.pxBTLeAdapterInterface->pxRegisterBleApp( pxAppUuid );
   ```

6. Initialize the callbacks to the GATT servers.

   ```
   xBTInterface.pxGattServerInterface = ( BTGattServerInterface_t * )
    xBTInterface.pxBTLeAdapterInterface->ppvGetGattServerInterface();
   xBTInterface.pxGattServerInterface->pxGattServerInit( &xBTGattServerCb );
   ```

   After you initialize the BLE adapter, you can add a GATT server. You can register only one GATT server at a time.

   ```
   xStatus = xBTInterface.pxGattServerInterface->pxRegisterServer( pxAppUuid );
   ```

7. Set application properties like secure connection only and MTU size.

   ```
   xStatus = xBTInterface.pxBTInterface->pxSetDeviceProperty( &pxProperty[ usIndex ] );
   ```

API Reference

For a full API reference, see Bluetooth Low Energy (BLE) API Reference.

Example Usage

Advertising

1. Set advertisement parameters.

   ```
   BLEAdvertismentParams_t xAdvParams =
   {
    .bIncludeTxPower    = true,
   ```

```
 .bIncludeName       = true,
 .bSetScanRsp        = true,
 .ulAppearance       =                   0,
 .ulMinInterval      =                0x20,
 .ulMaxInterval      =                0x40,
 .usManufacturerLen  =                   0,
 .pcManufacturerData = NULL,
 .pxUUID1            = &xDeviceInfoSvcUUID,
 .pxUUID2            = NULL
};

if( xStatus == eBTStatusSuccess )
{
 ( void ) BLE_SetAdvData( BTAdvInd, &xAdvParams, vSetAdvCallback );
}
```

2. Start advertisement.

```
void vSetAdvCallback ( BTStatus_t xStatus )
{
    if( xStatus == eBTStatusSuccess )
    {
        ( void ) BLE_StartAdv( vStartAdvCallback );
    }
}
```

Adding a New Service

1. Allocate memory for new service.

```
xStatus = BLE_CreateService( &pxGattDemoService, gattDemoNUM_CHARS,
 gattDemoNUM_CHAR_DESCRS, xNumDescrsPerChar, gattDemoNUM_INCLUDED_SERVICES );
```

2. Create the service.

```
pxGattDemoService->xAttributeData.xUuid = xServiceUUID;

pxGattDemoService->pxDescriptors[ egattDemoCharCounterCCFGDESCR ].xAttributeData.xUuid
 = xClientCharCfgUUID;
pxGattDemoService-
>pxDescriptors[ egattDemoCharCounterCCFGDESCR ].xAttributeData.pucData = NULL;
pxGattDemoService->pxDescriptors[ egattDemoCharCounterCCFGDESCR ].xAttributeData.xSize
 = 0;
pxGattDemoService->pxDescriptors[ egattDemoCharCounterCCFGDESCR ].xPermissions =
 ( eBTPermReadEncryptedMitm | eBTPermWriteEncryptedMitm );
pxGattDemoService-
>pxDescriptors[ egattDemoCharCounterCCFGDESCR ].pxAttributeEventCallback =
 vEnableNotification;

xCharUUID.uu.uu16 = gattDemoCHAR_COUNTER_UUID;
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xAttributeData.xUuid =
 xCharUUID;
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xAttributeData.pucData =
 NULL;
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xAttributeData.xSize = 0;
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xPermissions =
 ( eBTPermRead );
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xProperties =
 ( eBTPropRead | eBTPropNotify );
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].pxAttributeEventCallback =
 vReadCounter;
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].xNbDescriptors = 1;
```

```
pxGattDemoService->pxCharacteristics[ egattDemoCharCounter ].pxDescriptors[ 0 ] =
 &pxGattDemoService->pxDescriptors[ egattDemoCharCounterCCFGDESCR ];

xCharUUID.uu.uu16 = gattDemoCHAR_CONTROL_UUID;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xAttributeData.xUuid =
 xCharUUID;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xAttributeData.pucData =
 NULL;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xAttributeData.xSize = 0;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xPermissions =
 ( eBTPermReadEncryptedMitm | eBTPermWriteEncryptedMitm );
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xProperties =
 ( eBTPropRead | eBTPropWrite );
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].pxAttributeEventCallback =
 vWriteCommand;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].xNbDescriptors = 0;
pxGattDemoService->pxCharacteristics[ egattDemoCharControl ].pxDescriptors = NULL;

pxGattDemoService->xServiceType = eBTServiceTypePrimary;
pxGattDemoService->ucInstId = 0;

xStatus = BLE_AddService( pxGattDemoService );
```

3. Start the service.

   ```
   xStatus = BLE_StartService( pxGattDemoService, vServiceStartedCb );
   ```

4. Subscribe to any event required for the service. In this example, we subscribe to a connection event.

   ```
   xCallback.pxConnectionCb = vConnectionCallback;
   BLE_RegisterEventCb( eBLEConnection, xCallback );
   ```

For full Amazon FreeRTOS BLE demo applications, see Bluetooth Low Energy Demo Applications.

Porting

User Input and Output Peripheral

A secure connection requires both input and output for numeric comparison. The `eBLENumericComparisonCallback` event can be registered using the event manager:

```
xEventCb.pxNumericComparisonCb = &prvNumericComparisonCb;
xStatus = BLE_RegisterEventCb( eBLENumericComparisonCallback, xEventCb );
```

The peripheral must display the numeric passkey and take the result of the comparison as an input.

Porting API Implementations

To port Amazon FreeRTOS to a new target, you must implement some APIs for the Wi-Fi Provisioning service and BLE functionality.

Wi-Fi Provisioning APIs

To use the Wi-Fi provisioning service you must implement the following APIs:

- `WIFI_NetworkGet`
- `WIFI_NetworkDelete`

- `WIFI_NetworkAdd`

BLE APIs

To use the Amazon FreeRTOS BLE middleware, you must implement some APIs.

APIs Common Between GAP for Bluetooth Classic and GAP for BLE

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

APIs Specific to GAP for BLE

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

GATT Server

- `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`

Mobile SDKs for Amazon FreeRTOS Bluetooth Devices

The Bluetooth Low Energy (BLE) Library is in public beta release for Amazon FreeRTOS and is subject to change.

You can use the Amazon FreeRTOS BLE Mobile SDKs to create mobile applications that interact with your microcontroller over BLE.

Android SDK for Amazon FreeRTOS Bluetooth Devices

Use the Amazon FreeRTOS BLE Android SDK to build Android mobile applications that interact with your microcontroller over BLE. For more information, see Amazon FreeRTOS BLE Mobile SDK for Android.

Android SDK for Amazon FreeRTOS Bluetooth Devices

Use the Amazon FreeRTOS BLE iOS SDK to build iOS mobile applications that interact with your microcontroller over BLE. For more information, see Amazon FreeRTOS BLE Mobile SDK for iOS.

Amazon FreeRTOS AWS IoT Device Defender Library

Overview

AWS IoT Device Defender is an AWS IoT service that allows you to audit the configuration of your devices, monitor connected devices to detect abnormal behavior, and to mitigate security risks. It gives you the ability to enforce consistent IoT configurations across your AWS IoT device fleet and respond quickly when devices are compromised.

Amazon FreeRTOS provides a library that allows your Amazon FreeRTOS-based devices to work with AWS IoT Device Defender. You can download the Amazon FreeRTOS Device Defender library using the Amazon FreeRTOS Console by adding the Device Defender library to your software configuration. You can also clone the Amazon FreeRTOS GitHub repository and find the library in the `lib` directory.

The source files for the Amazon FreeRTOS AWS IoT Device Defender library are located in `AmazonFreeRTOS/lib/defender`.

Source and Header Files

```
Amazon FreeRTOS
|
+ - lib
    |
    + - defender
    |    + # aws_defender.c
    |    + # aws_defender_states.dot
    |    + # aws_defender_states.png
    |    + # draw_states.py
    |    + # portable
    |    |   + # freertos
    |    |   |   + # aws_defender_cpu.c
    |    |   |   + # aws_defender_tcp_conn.c
    |    |   |   + # aws_defender_uptime.c
    |    |   + # stub
    |    |   |   + # aws_defender_cpu.c
    |    |   |   + # aws_defender_tcp_conn.c
    |    |   |   + # aws_defender_uptime.c
    |    |   |   + # makefile
    |    |   + # template
    |    |   |   + # aws_defender_cpu.c
    |    |   |   + # aws_defender_tcp_conn.c
    |    |   |   + # aws_defender_uptime.c
    |    |   |   + # makefile
    |    |   + # unit_test
    |    |   |   + # aws_defender_cpu.c
    |    |   |   + # aws_defender_tcp_conn.c
    |    |   |   + # aws_defender_uptime.c
    |    |   + # unix
    |    |        + # aws_defender_cpu.c
    |    |        + # aws_defender_tcp_conn.c
    |    |        + # aws_defender_uptime.c
    |    |        + # makefile
    |    + # report
    |        + # aws_defender_report.c
    |        + # aws_defender_report_cpu.c
    |        + # aws_defender_report_header.c
    |        + # aws_defender_report_tcp_conn.c
    |        + # aws_defender_report_uptime.c
    + - include
        + - aws_defender.h
        + - private
```

```
            + - aws_defender_cpu.h
            + - aws_defender_internals.h
            + - aws_defender_report_cpu.h
            + - aws_defender_report.h
            + - aws_defender_report_header.h
            + - aws_defender_report_tcp_conn.h
            + - aws_defender_report_types.h
            + - aws_defender_report_uptime.h
            + - aws_defender_report_utils.h
            + - aws_defender_tcp_conn.h
            + - aws_defender_uptime.h
```

Developer Support

Amazon FreeRTOS Device Defender API Error Codes

`eDefenderErrSuccess`

The operation was successful.

`eDefenderErrFailedToCreateTask`

The operation could not be started.

`eDefenderErrAlreadyStarted`

The operation is already in progress.

`eDefenderErrNotStarted`

The Device Defender agent has not been started.

`eDefenderErrOther`

An unspecified error occurred.

Amazon FreeRTOS Device Defender API

This section contains information about the Device Defender API.

DEFENDER_MetricsInit

Specifies the Device Defender metrics your device will send to AWS IoT Device Defender.

```
DefenderErr_t DEFENDER_MetricsInit(DefenderMetric_t * pxMetricsList);
```

Arguments

`metrics_list`

A list of Device Defender metrics. Valid values are:

- `DEFENDER_tcp_connections` - tracks the number of TCP connections.

Return Value

Returns one of the `DefenderErr_t` enums. For more information, see Amazon FreeRTOS Device Defender API Error Codes (p. 83).

DEFENDER_ReportPeriodSet

Sets the report period interval in seconds. Device Defender provides metric reports on an interval. If the device is awake, and the interval has elapsed, the device reports the metrics.

```
DefenderErr_t DEFENDER_ReportPeriodSet(int32_t LPeriodSec);
```

Arguments

`period_sec`

The number of seconds after which a report is sent to AWS IoT Device Defender.

Return Value

Returns one of the `DefenderErr_t` enums. For more information, see Amazon FreeRTOS Device Defender API Error Codes (p. 83).

DEFENDER_Start

Starts the Device Defender agent.

```
 DefenderErr_t DEFENDER_Start(void);
```

Return Value

Returns one of the `DefenderErr_t` enums. For more information, see Amazon FreeRTOS Device Defender API Error Codes (p. 83).

DEFENDER_Stop

Stops the Device Defender agent.

```
DefenderErr_t DEFENDER_Stop(void);
```

Return Value

Returns one of the `DefenderErr_t` enums. For more information, see Amazon FreeRTOS Device Defender API Error Codes (p. 83).

DEFENDER_ReportStatusGet

Gets the status of the last Device Defender report. Valid status code values are:

`eDefenderRepSuccess`

The last report was successfully sent and acknowledged.

`eDefenderRepInit`

Device Defender has been started, but no report has been sent.

`eDefenderRepRejected`

The last report was rejected.

`eDefenderRepNoAck`

The last report was not acknowledged.

`eDefenderRepNotSent`

The last report was not sent, likely due to a connectivity issue.

```
DefenderReportStatus_t DEFENDER_ReportStatusGet(void);
```

Example Usage

Using Device Defender in Your Embedded Application

The following code shows how to configure and start the Device Defender agent from your embedded application:

```
void MyDefenderInit(void)
{
 // Specify metrics to send to Device Defender
    defender_metric_t metrics_list[] = {
        DEFENDER_tcp_connections
    };
    ( void ) DEFENDER_MetricsInit( metrics_list );

  // Set the reporting interval
  // You can use a shorter period to trigger the violation faster, however
  // the Device Defender service is not guaranteed to accept reports faster
  // than every 300 seconds (5 minutes) per device.
    int report_period_sec = 300;
    ( void ) DEFENDER_ReportPeriodSet( report_period_sec );

  // Start the Device Defender agent
    DEFENDER_Start();
}
```

Amazon FreeRTOS AWS IoT Greengrass Discovery Library

Overview

The AWS IoT Greengrass Discovery library is used by your microcontroller devices to discover a Greengrass core on your network. Using the AWS IoT Greengrass Discovery APIs, your device can send messages to a Greengrass core after it finds the core's endpoint.

The source files for the Amazon FreeRTOS AWS IoT Greengrass library are located in `AmazonFreeRTOS/lib/greengrass`.

Dependencies and Requirements

To use the Greengrass Discovery library, you must create a thing in AWS IoT, including a certificate and policy. For more information, see AWS IoT Getting Started. You must set values for the following constants in the `AmazonFreeRTOS\demos\common\include\aws_client_credentials.h`` file:

`clientcredentialMQTT_BROKER_ENDPOINT`

Your AWS IoT endpoint.

`clientcredentialIOT_THING_NAME`

The name of your IoT thing.

`clientcredentialWIFI_SSID`

The SSID for your Wi-Fi network.

`clientcredentialWIFI_PASSWORD`

Your Wi-Fi password.

`clientcredentialWIFI_SECURITY`

The type of security used by your Wi-Fi network.

`keyCLIENT_CERTIFICATE_PEM`

The certificate PEM associated with your thing.

`keyCLIENT_PRIVATE_KEY_PEM`

The private key PEM associated with your thing.

You must have a Greengrass group and core device set up in the console. For more information, see Getting Started with AWS IoT Greengrass.

Although the MQTT library is not required for Greengrass connectivity, we strongly recommend you install it. The library can be used to communicate with the Greengrass core after it has been discovered.

Source and Header Files

```
Amazon FreeRTOS
|
+ - lib
    + - greengrass
    |    + # aws_greengrass_discovery.c
    |    + # aws_helper_secure_connect.c
    + - include
        + - aws_greengrass_discovery.h
        + - private
            + - aws_ggd_config_defaults.h
```

API Reference

For a full API reference, see Greengrass API Reference.

Example Usage

Greengrass Workflow

The MCU device initiates the discovery process by requesting from AWS IoT a JSON file that contains the Greengrass core connectivity parameters. There are two methods for retrieving the Greengrass core connectivity parameters from the JSON file:

- Automatic selection iterates through all of the Greengrass cores listed in the JSON file and connects to the first one available.

- Manual selection uses the information in `aws_ggd_config.h` to connect to the specified Greengrass core.

How to Use the Greengrass API

All default configuration options for the Greengrass API are defined in `lib\include\private\aws_ggd_config_defaults.h`. You can override any of these settings in `lib\include\`.

If only one Greengrass core is present, call `GGD_GetGGCIPandCertificate` to request the JSON file with Greengrass core connectivity information. When `GGD_GetGGCIPandCertificate` is returned, the `pcBuffer` parameter contains the text of the JSON file. The `pxHostAddressData` parameter contains the IP address and port of the Greengrass core to which you can connect.

For more customization options, like dynamically allocating certificates, you must call the following APIs:

`GGD_JSONRequestStart`

> Makes an HTTP GET request to AWS IoT to initiate the discovery request to discover a Greengrass core. `GD_SecureConnect_Send` is used to send the request to AWS IoT.

`GGD_JSONRequestGetSize`

> Gets the size of the JSON file from the HTTP response.

`GGD_JSONRequestGetFile`

> Gets the JSON object string. `GGD_JSONRequestGetSize` and `GGD_JSONRequestGetFile` use `GGD_SecureConnect_Read` to get the JSON data from the socket. `GGD_JSONRequestStart`, `GGD_SecureConnect_Send`, `GGD_JSONRequestGetSize` must be called to receive the JSON data from AWS IoT.

`GGD_GetIPandCertificateFromJSON`

> Extracts the IP address and the Greengrass core certificate from the JSON data. You can turn on automatic selection by setting the `xAutoSelectFlag` to `True`. Automatic selection finds the first core device your FreeRTOS device can connect to. To connect to a Greengrass core, call the `GGD_SecureConnect_Connect` function, passing in the IP address, port, and certificate of the core device. To use manual selection, set the following fields of the `HostParameters_t` parameter:
>
> `pcGroupName`
>
> > The ID of the Greengrass group to which the core belongs. You can use the `aws greengrass list-groups` CLI command to find the ID of your Greengrass groups.
>
> `pcCoreAddress`
>
> > The ARN of the Greengrass core to which you are connecting.

Amazon FreeRTOS MQTT Library (Beta)

The new MQTT library is in public beta release for Amazon FreeRTOS and is subject to change.

Overview

You can use the Amazon FreeRTOS MQTT library to create applications that publish and subscribe to MQTT topics, as MQTT clients on a network. The Amazon FreeRTOS MQTT library implements the MQTT

3.1.1 standard for compatibility with the AWS IoT MQTT server. The library is also compatible with other MQTT servers.

The source files for the Amazon FreeRTOS MQTT library are located in `AmazonFreeRTOS/lib/mqtt`.

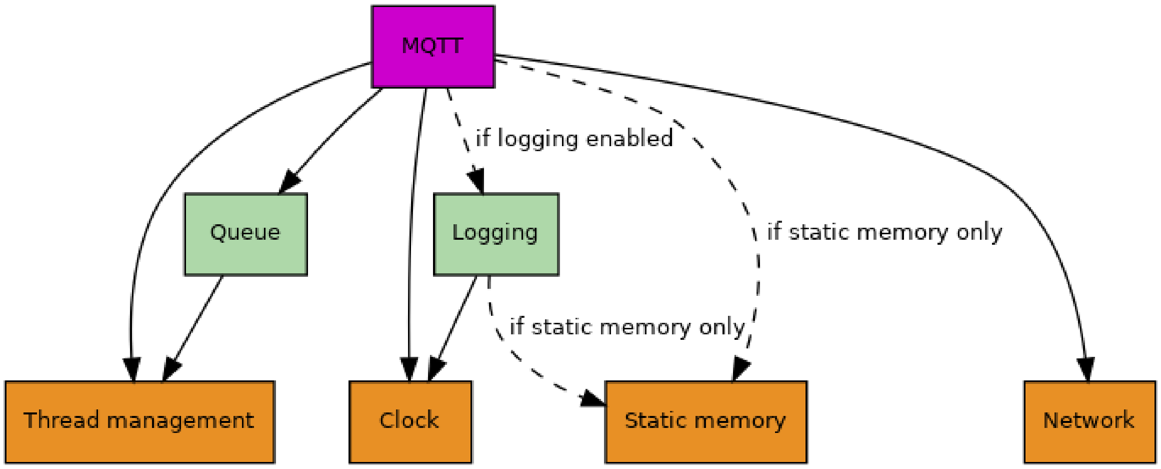
The Amazon FreeRTOS MQTT library documented here is in public beta. For more information about the legacy Amazon FreeRTOS MQTT library, see Amazon FreeRTOS MQTT Library (Legacy) (p. 90).

Dependencies and Requirements

The Amazon FreeRTOS MQTT library has the following dependencies:

- The queue library for maintaining the data structures that manage in-progress MQTT operations
- The logging library, if the configuration parameter `AWS_IOT_MQTT_LOG_LEVEL` is not set to `AWS_IOT_LOG_NONE`
- The platform layer that provides an interface to the operating system for thread management, clock functions, networking, and other platform-level functionality
- C standard library headers

The diagram below illustrates these dependencies.



Features

The Amazon FreeRTOS MQTT library has the following features:

- By default, the library has a fully asynchronous MQTT API. You can opt to use the library synchronously with the `AwsIotMqtt_Wait` function.
- The library is thread-aware and parallelizable for high throughput.
- The library features scalable performance and footprint. Use the configuration setting to tailored the library to a system's resources.

Configuration

Configuration settings for the Amazon FreeRTOS MQTT library are defined as C proprocessor constants. Set configuration settings as #define constants in a file named `AWS_IOT_CONFIG_FILE`, or by using a compiler option such as `-D` in `gcc`. Because configuration settings are defined as compile-time constants, a library must be rebuilt if a configuration setting is changed. The MQTT library uses default values when configuration settings are not defined.

For more information about configuring the Amazon FreeRTOS MQTT library, see MQTT API Reference (Beta).

API Reference

For a full API reference, see MQTT API Reference (Beta).

Example Usage

`aws_iot_demo_mqtt.c`

For example usage of the Amazon FreeRTOS MQTT library, see MQTT demo application defined in `aws_iot_demo_mqtt.c`.

The MQTT demo demonstrates the subscribe-publish workflow of MQTT. After subscribing to multiple topic filters, the application publishes bursts of data to various topic names. As each message arrives, the demo publishes an acknowledgement message back to the MQTT server.

To run the MQTT demo, you need to configure the following parameters:

Global Demo Configuration Parameters

These configuration parameters apply to all demos.

`AWS_IOT_DEMO_SECURED_CONNECTION`

Determines if the demo uses a TLS-secured connection with the remote host by default.

`AWS_IOT_DEMO_SERVER`

The default remote host to use.

`AWS_IOT_DEMO_PORT`

The default remote port to use.

`AWS_IOT_DEMO_ROOT_CA`

The path to the default trusted server root certificate to use.

`AWS_IOT_DEMO_CLIENT_CERT`

The path to the default client certificate to use.

`AWS_IOT_DEMO_PRIVATE_KEY`

The path to the default client certificate private key to use.

MQTT Demo Configuration Parameters

These configuration parameters apply to the MQTT demo.

`AWS_IOT_DEMO_MQTT_PUBLISH_BURST_SIZE`

The number of messages to publish in each burst.

`AWS_IOT_DEMO_MQTT_PUBLISH_BURST_COUNT`

The number of publish bursts in this demo.

Amazon FreeRTOS MQTT Library (Legacy)

Overview

Amazon FreeRTOS includes an open source MQTT client library that you can use to create applications that publish and subscribe to MQTT topics, as MQTT clients on a network.

The source files for the Amazon FreeRTOS MQTT library are located in `AmazonFreeRTOS/lib/mqtt`.

A new Amazon FreeRTOS MQTT Library is in public beta. For more information, see Amazon FreeRTOS MQTT Library (Beta) (p. 87).

The FreeRTOS MQTT Agent

Amazon FreeRTOS also includes an open source daemon, called the FreeRTOS MQTT agent, that manages the MQTT library for you. The MQTT agent provides a simple interface to connect, publish, and subscribe to MQTT topics with the underlying MQTT library.

The MQTT agent runs in a separate FreeRTOS task and automatically sends regular keep-alive messages, as documented by the MQTT protocol specification. All the MQTT APIs are blocking and take a timeout parameter, which is the maximum amount of time the API waits for the corresponding operation to complete. If the operation does not complete in the provided time, the API returns timeout error code.

Dependencies and Requirements

The Amazon FreeRTOS MQTT library uses the Amazon FreeRTOS Secure Sockets Library (p. 97) and the Amazon FreeRTOS Buffer Pool library. If the MQTT agent connects to a secure MQTT broker, the library also uses the Amazon FreeRTOS Transport Layer Security (TLS) (p. 103).

Features

Callback

You can specify an optional callback that is invoked whenever the MQTT agent is disconnected from the broker or whenever a publish message is received from the broker. The received publish message is stored in a buffer taken from the central buffer pool. This message is passed to the callback. This callback runs in the context of the MQTT task and therefore must be quick. If you need to do longer processing, you must take the ownership of the buffer by returning `pdTRUE` from the callback. You must then return the buffer back to the pool whenever you are done by calling `FreeRTOS_Agent_ReturnBuffer`.

Subscription Management

Subscription management enables you to register a callback per subscription filter. You supply this callback while subscribing. It is invoked whenever a publish message received on a topic matches the subscribed topic filter. The buffer ownership works the same way as described in the case of generic callback.

MQTT Task Wakeup

MQTT task wakeup wakes up whenever the user calls an API to perform any operation or whenever a publish message is received from the broker. This asynchronous wakeup upon receipt of a publish message is possible on platforms that are capable of informing the host MCU about the data received on a connected socket. Platforms that do not have this capability require the MQTT task to continuously poll for the received data on the connected socket. To ensure the delay between receiving a publish message and invoking the callback is minimal, the `mqttconfigMQTT_TASK_MAX_BLOCK_TICKS` macro controls the maximum time an MQTT task can remain blocked. This value must be short for the platforms that lack the capability to inform the host MCU about received data on a connected socket.

Source and Header Files

```
Amazon FreeRTOS
  |
  +-lib
      |
      +-mqtt
      |   +-aws_mqtt_lib.c                     [Required to use the MQTT library and the
 MQTT agent]
      |   +-aws_mqtt_agent.c                   [Required to use the MQTT agent]
      |
      +-include
          |
          +-private                            [For internal library use only!]
          |   +-aws_doubly_linked_list.h
          |   +-aws_mqtt_agent_config_defaults.h
          |   +-aws_mqtt_buffer.h
          |   +-aws_mqtt_config_defaults.h
          |
          +-aws_mqtt_agent.h                   [Include to use the MQTT agent API]
          +-aws_mqtt_lib.h                     [Include to use the MQTT library API]
```

Major Configurations

These flags can be specified during the MQTT connection request:

- `mqttconfigKEEP_ALIVE_ACTUAL_INTERVAL_TICKS`: The frequency of the keep-alive messages sent.
- `mqttconfigENABLE_SUBSCRIPTION_MANAGEMENT`: Enable subscription management.
- `mqttconfigMAX_BROKERS`: Maximum number of simultaneous MQTT clients.
- `mqttconfigMQTT_TASK_STACK_DEPTH`: The task stack depth.
- `mqttconfigMQTT_TASK_PRIORITY`: The priority of the MQTT task.
- `mqttconfigRX_BUFFER_SIZE`: Length of the buffer used to receive data.
- `mqttagentURL_IS_IP_ADDRESS`: Set this bit in `xFlags` if the provided URL is an IP address.
- `mqttagentREQUIRE_TLS`: Set this bit in `xFlags` to use TLS.
- `mqttagentUSE_AWS_IOT_ALPN_443`: Set this bit in `xFlags` to use AWS IoT support for MQTT over TLS port 443.

For more information about ALPN, see the AWS IoT Protocols in the AWS IoT Developer Guide and the MQTT with TLS Client Authentication on Port 443: Why It Is Useful and How It Works blog post on the Internet of Things on AWS blog.

Optimization

Processing Received Packets Without Delay

The task that implements the MQTT agent spends most of its time in the Blocked state (so not using any CPU cycles) waiting for events to process. MQTT throughput is maximized by unblocking the agent task as soon as an MQTT packet is received from the network. If that is done the received packet is processed at the earliest opportunity. If that is not done the received packet will not be processed until the MQTT agent leaves the Blocked state for another reason.

The MQTT agent is removed from the Blocked state by the execution of a callback that is installed by the MQTT agent calling SOCKETS_SetSockOpt() with the lOptionName parameter set to SOCKETS_SO_WAKEUP_CALLBACK. Links to the secure sockets documentation are needed here. If you are using the FreeRTOS+TCP TCP/IP stack the callback is executed at the correct time provided ipconfigSOCKET_HAS_USER_WAKE_CALLBACK is set to 1 in FreeRTOSIPConfig.h (which is the TCP/IP stack's configuration file). If you are not using the FreeRTOS+TCP TCP/IP stack then the secure sockets ensure this functionality is included in your implementation of the secure sockets abstraction layer for the stack in use.

If the TCP/IP stack cannot unblock the MQTT agent as soon as data is received then the maximum time between a packet being received and the packet being processed is set by the mqttconfigMQTT_TASK_MAX_BLOCK_TICKS constant.

Minimizing RAM Consumption

The following configuration constants directly affect the amount of RAM required by the MQTT agent:

- mqttconfigMQTT_TASK_STACK_DEPTH
- mqttconfigMQTT_TASK_STACK_DEPTH
- mqttconfigMAX_BROKERS
- mqttconfigMAX_PARALLEL_OPS
- mqttconfigRX_BUFFER_SIZE

You should set these constants to the minimum values possible.

Requirements and Usage Restrictions

The MQTT agent task is created using the xTaskCreateStatic() API function - so the task's stack and control block are statically allocated at compile time. That ensures the MQTT agent can be used in applications that do not allow dynamic memory allocation, but does mean there is a dependency on configSUPPORT_STATIC_ALLOCATION being set to 1 in FreeRTOSConfig.h.

he MQTT agent uses the FreeRTOS direct to task notification feature. Calling an MQTT agent API function may change the calling task's notification value and state.

MQTT packets are stored in buffers provided by the Buffer Pool module. It is highly recommended to ensure the number of buffers in the pool is at least double the number of MQTT transactions that will be in progress at any one time.

Developer Support

`mqttconfigASSERT`

mqttconfigASSERT() is equivalent to, and used in exactly the same way as, the FreeRTOS configASSERT() macro. If you want assert statements in the MQTT agent then define mqttconfigASSERT(). If you do not want assert statements in the MQTT agent then leave mqttconfigASSERT() undefined. If you define mqttconfigASSERT() to call the FreeRTOS configASSERT(), as shown below, then the MQTT agent will only include assert statements if the FreeRTOS configASSERT() is defined.

```
#define mqttconfigASSERT( x ) configASSERT( x )
```

`mqttconfigENABLE_DEBUG_LOGS`

Set `mqttconfigENABLE_DEBUG_LOGS` to **1** to print debug logs via calls to vLoggingPrintf().

Initialization

Both the MQTT agent and its dependent libraries must be initialized, as shown below, before attempting MQTT communication. Initialize the libraries after a network connection is established.

```
BaseType_t SYSTEM_Init() { BaseType_t xResult = pdPASS; /* The bufferpool libraries
 provides the buffers use to store MQTT packets.*/
      xResult = BUFFERPOOL_Init();
      if( xResult == pdPASS ) { /* Create the MQTT agent task. */
      xResult = MQTT_AGENT_Init(); }
      if( xResult == pdPASS ) { /* Initialize the secure sockets abstraction layer.*/
      xResult = SOCKETS_Init(); }
      return xResult; }
```

API Reference

For a full API reference, see MQTT Library API Reference (Legacy) and MQTT Agent API Reference (Legacy) .

Porting

The Secure Sockets abstraction layer that the MQTT agent calls must be ported to specific architectures. For more information, see the Amazon FreeRTOS Porting Guide.

Amazon FreeRTOS Over-the-Air (OTA) Agent Library

Overview

The OTA agent enables you to manage the notification, download, and verification of firmware updates for Amazon FreeRTOS devices. By using the OTA agent library, you can logically separate firmware updates and the application running on your devices. The OTA agent can share a network connection with the application. By sharing a network connection, you can potentially save a significant amount of RAM. In addition, the OTA agent library allows you to define application-specific logic for testing, committing, or rolling back a firmware update.

The source files for the Amazon FreeRTOS OTA agent library are located in `AmazonFreeRTOS/lib/ota`.

For more information about using Over-the-Air updates with Amazon FreeRTOS, see Amazon FreeRTOS Over-the-Air Updates (p. 108).

Features

Here is the complete OTA agent interface:

`OTA_AgentInit`

Initializes the OTA agent. The caller provides messaging protocol context, an optional callback, and a timeout.

`OTA_AgentShutdown`

Cleans up resources after using the OTA agent.

`OTA_GetAgentState`

Gets the current state of the OTA agent.

`OTA_ActivateNewImage`

Activates the newest microcontroller firmware image received through OTA. (The detailed job status should now be self-test.)

`OTA_SetImageState`

Sets the validation state of the currently running microcontroller firmware image (testing, accepted or rejected).

`OTA_GetImageState`

Gets the state of the currently running microcontroller firmware image (testing, accepted or rejected).

`OTA_CheckForUpdate`

Requests the next available OTA update from the OTA Update service.

Source and Header Files

```
Amazon FreeRTOS
|
+ - lib
    + - ota
    |   + # aws_ota_agent.c
    |   + # aws_ota_cbor.c
    |   + # portable
    |       + # README.md
    |       + # vendor
    |           + # board
    |               + # aws_ota_pal.c
    + - include
        + - aws_ota_agent.h
        + - private
            + - aws_ota_agent_internal.h
            + - aws_ota_cbor.h
            + - aws_ota_cbor_internal.h
            + - aws_ota_pal.h
            + - aws_ota_types.h
```

API Reference

For a full API reference, see OTA Agent API Reference.

Example Usage

A typical OTA-capable device application drives the OTA agent using the following sequence of API calls:

1. Connect to the AWS IoT MQTT broker. For more information, see Amazon FreeRTOS MQTT Library (Legacy) (p. 90).
2. Initialize the OTA agent by calling `OTA_AgentInit`. Your application may define a custom OTA callback function or use the default callback by specifying a NULL callback function pointer. You must also supply an initialization timeout.

   The callback implements application-specific logic that executes after completing an OTA update job. The timeout defines how long to wait for the initialization to complete.
3. If `OTA_AgentInit` timed out before the agent was ready, you can call `OTA_GetAgentState` to confirm that the agent is initialized and operating as expected.

4. When the OTA update is complete, Amazon FreeRTOS calls the job completion callback with one of the following events: `accepted`, `rejected`, or `self test`.
5. If the new firmware image has been rejected (for example, due to a validation error), the application can typically ignore the notification and wait for the next update.
6. If the update is valid and has been marked as accepted, call `OTA_ActivateNewImage` to reset the device and boot the new firmware image.

Porting

For information about porting OTA functionality to your platform, see OTA Portable Abstraction Layer.

Amazon FreeRTOS Public Key Cryptography Standard (PKCS) #11 Library

Overview

Public Key Cryptography Standard #11 (PKCS#11) is a cryptographic API that abstracts key storage, get/set properties for cryptographic objects, and session semantics. See `pkcs11.h` (obtained from OASIS, the standard body) in the Amazon FreeRTOS source code repository. In the Amazon FreeRTOS reference implementation, 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.

The source files for the Amazon FreeRTOS PKCS#11 library are located in `AmazonFreeRTOS/lib/secure_sockets/portable`.

Features

The following subset of PKCS#11 is used. This list is in roughly the order in which the routines are called in support of provisioning, TLS client authentication, and cleanup. For detailed descriptions of the functions, see the PKCS#11 documentation provided by the standard committee.

Provisioning API

- `C_GetFunctionList`
- `C_Initialize`
- `C_CreateObject CKO_PRIVATE_KEY` (for device private key)
- `C_CreateObject CKO_CERTIFICATE` (for device certificate and code verification certificate)
- `C_GenerateKeyPair`

Client Authentication

- `C_Initialize`
- `C_GetSlotList`
- `C_OpenSession`
- `C_FindObjectsInit`
- `C_FindObjects`

- `C_FindObjectsFinal`
- `C_GetAttributeValue`
- `C_FindObjectsInit`
- `C_FindObjects`
- `C_FindObjectsFinal`
- `C_GetAttributeValue`
- `C_GenerateRandom`
- `C_SignInit`
- `C_Sign`
- `C_DigestInit`
- `C_DigestUpdate`
- `C_DigestFinal`

Cleanup

- `C_CloseSession`
- `C_Finalize`

Asymmetric Cryptosystem Support

The Amazon FreeRTOS PKCS#11 reference implementation supports 2048-bit RSA (signing only) and ECDSA with the NIST P-256 curve. The following instructions describe how to create an AWS IoT thing based on a P-256 client certificate.

Make sure you are using the following (or more recent) versions of the AWS CLI and OpenSSL:

```
aws --version
aws-cli/1.11.176 Python/2.7.9 Windows/8 botocore/1.7.34

openssl version
OpenSSL 1.0.2g  1 Mar 2016
```

The following steps are written with the assumption that you have used the **aws configure** command to configure the AWS CLI.

Creating an AWS IoT thing based on a P-256 client certificate

1. Run `aws iot create-thing --thing-name dcgecc` to create an AWS IoT thing.
2. Run `openssl genpkey -algorithm EC -pkeyopt ec_paramgen_curve:P-256 -pkeyopt ec_param_enc:named_curve -outform PEM -out dcgecc.key` to use OpenSSL to create a P-256 key.
3. Run `openssl req -new -nodes -days 365 -key dcgecc.key -out dcgecc.req` to create a certificate enrollment request signed by the key created in step 2.
4. Run `aws iot create-certificate-from-csr --certificate-signing-request file://dcgecc.req --set-as-active --certificate-pem-outfile dcgecc.crt` to submit the certificate enrollment request to AWS IoT.
5. Run `aws iot attach-thing-principal --thing-name dcgecc --principal "arn:aws:iot:us-east-1:123456789012:cert/86e41339a6d1bbc67abf31faf455092cdebf8f21ffbc67c4d238d1326c7de` to attach the certificate (referenced by the ARN output by the previous command) to the thing.

6. Run `aws iot create-policy --policy-name FullControl --policy-document file://policy.json` to create a policy. (This policy is too permissive. It should be used for development purposes only.)

   The following is a listing of the policy.json file specified in the `create-policy` command. You can omit the `greengrass:*` action if you don't want to run the Amazon FreeRTOS demo for Greengrass connectivity and discovery.

   ```
   {
    "Version": "2012-10-17",
    "Statement": [{
     "Effect": "Allow",
     "Action": "iot:*",
     "Resource": "*"
    },
    {
     "Effect": "Allow",
     "Action": "greengrass:*",
     "Resource": "*"
    }]
   }
   ```
7. Run `aws iot attach-principal-policy --policy-name FullControl --principal "arn:aws:iot:us-east-1:785484208847:cert/86e41339a6d1bbc67abf31faf455092cdebf8f21ffbc67c4d238d1326c7de` to attach the principal (certificate) and policy to the thing.

Now, follow the steps in the AWS IoT Getting Started section of this guide. Don’t forget to copy the certificate and private key you created into your `aws_clientcredential_keys.h` file. Copy your thing name into `aws_clientcredential.h`.

Amazon FreeRTOS Secure Sockets Library

Overview

You can use the Amazon FreeRTOS Secure Sockets library to create embedded applications that communicate securely. The library is designed to make onboarding easy for software developers from various network programming backgrounds.

The Amazon FreeRTOS Secure Sockets library is based on the Berkeley sockets interface, with an additional secure communication option by TLS protocol. For information about the differences between the Amazon FreeRTOS Secure Sockets library and the Berkeley sockets interface, see `SOCKETS_SetSockOpt` in the Secure Sockets API Reference.

The source files for the Amazon FreeRTOS Secure Sockets library are located in `AmazonFreeRTOS/lib/secure_sockets/portable`.

> **Note**
> Currently, only client APIs are supported for Amazon FreeRTOS Secure Sockets.

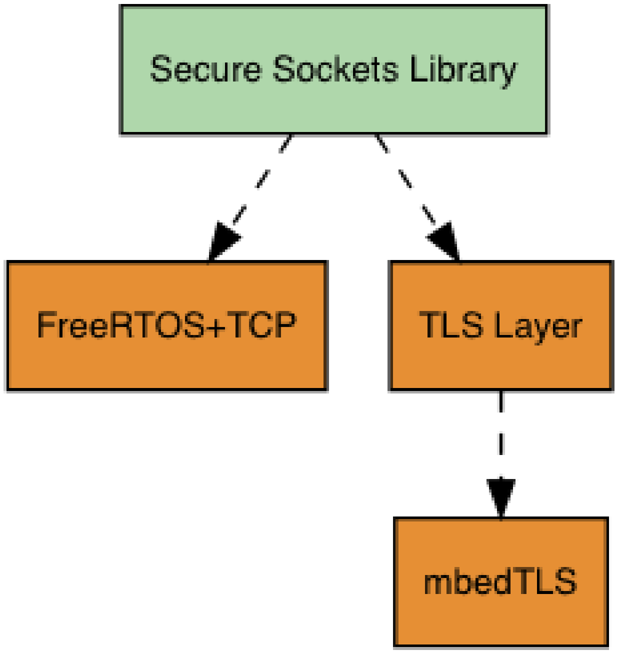
Dependencies and Requirements

The Amazon FreeRTOS Secure Sockets library depends on a TCP/IP stack and on a TLS implementation. Ports for Amazon FreeRTOS meet these dependencies in one of three ways:

- A custom implementation of both TCP/IP and TLS
- A custom implementation of TCP/IP, and the Amazon FreeRTOS TLS layer with mbedTLS

- FreeRTOS+TCP and the Amazon FreeRTOS TLS layer with mbedTLS

The dependency diagram below shows the the reference implementation included with the Amazon FreeRTOS Secure Sockets library. This reference implementation supports TLS and TCP/IP over Ethernet and Wi-Fi with FreeRTOS+TCP and mbedTLS as dependencies. For more information about the Amazon FreeRTOS TLS layer, see Amazon FreeRTOS Transport Layer Security (TLS) (p. 103).



Features

Amazon FreeRTOS Secure Sockets library features include:

- A standard, Berkeley Sockets-based interface
- Thread-safe APIs for sending and receiving data
- Easy-to-enable TLS

Footprint

Code Size (example generated with GCC for ARM Cortex-M)

File name	Size (optimized for speed)	Size (optimized for speed and size)	
Secure Sockets Library	Varies by port	Varies by port	
For example, for the TI CC3220SF: `lib/secure_sockets/portable/ti/cc3220_launchpad/aws_secure_sockets.c`	5.0 K	4.3 K	

Source and Header Files

```
Amazon FreeRTOS
|
+ # lib
   + # include
   |    + # aws_secure_sockets.h
   |    + # private
   |        + # aws_secure_sockets_config_defaults.h
   + # secure_sockets
        + - portable
            + - ...
                + # aws_secure_sockets.c
```

Troubleshooting

Error codes

The error codes that the Amazon FreeRTOS Secure Sockets library returns are negative values. For more information about each error code, see Secure Sockets Error Codes in the Secure Sockets API Reference.

> **Note**
> If the Amazon FreeRTOS Secure Sockets API returns an error code, the Amazon FreeRTOS MQTT Library (Legacy) (p. 90), which depends on the Amazon FreeRTOS Secure Sockets library, returns the error code `AWS_IOT_MQTT_SEND_ERROR`.

Developer Support

The Amazon FreeRTOS Secure Sockets library includes two helper macros for handling IP addresses:

`SOCKETS_inet_addr_quick`

This macro converts an IP address that is expressed as four separate numeric octets into an IP address that is expressed as a 32-bit number in network-byte order.

`SOCKETS_inet_ntoa`

This macro converts an IP address that is expressed as a 32-bit number in network byte order to a string in decimal-dot notation.

Usage Restrictions

Only TCP sockets are supported by the Amazon FreeRTOS Secure Sockets library. UDP sockets are not supported.

Only client APIs are supported by the Amazon FreeRTOS Secure Sockets library. Server APIs, including `Bind`, `Accept`, and `Listen`, are not supported.

Initialization

To use the Amazon FreeRTOS Secure Sockets library, you need to initialize the library and its dependencies. To initialize the Secure Sockets library, use the following code in your application:

```
BaseType_t xResult = pdPASS;
xResult = SOCKETS_Init();
```

Dependent libraries must be initialized separately. For example, if FreeRTOS+TCP is a dependency, you need to invoke `FreeRTOS_IPInit` in your application as well.

API Reference

For a full API reference, see Secure Sockets API Reference.

Example Usage

The following code connects a client to a server.

```
#include "aws_secure_sockets.h"

#define configSERVER_ADDR0                     127
#define configSERVER_ADDR1                     0
#define configSERVER_ADDR2                     0
#define configSERVER_ADDR3                     1
#define configCLIENT_PORT                      443

/* Rx and Tx timeouts are used to ensure the sockets do not wait too long for
 * missing data. */
static const TickType_t xReceiveTimeOut = pdMS_TO_TICKS( 2000 );
static const TickType_t xSendTimeOut = pdMS_TO_TICKS( 2000 );

/* PEM-encoded server certificate */
/* The certificate used below is one of the Amazon Root CAs.\
Change this to the certificate of your choice. */
static const char cTlsECHO_SERVER_CERTIFICATE_PEM[] =
"-----BEGIN CERTIFICATE-----\n"
"MIIBtjCCAVugAwIBAgITBmyf1XSXNmY/Owua2eiedgPySjAKBggqhkjOPQQDAjA5\n"
"MQswCQYDVQQGEwJVUzEPMA0GA1UEChMGQW1hem9uMRkwFwYDVQQDExBBbWF6b24g\n"
"Um9vdCBDQSAzMB4XDTE1MDUyNjAwMDAwMFoXDTQwMDUyNjAwMDAwMFowOTELMAkG\n"
"A1UEBhMCVVMxDzANBgNVBAoTBkFtYXpvbjEZMBcGA1UEAxMQQW1hem9uIFJvb3Qg\n"
"Q0EgMzBZMBMGByqGSM49AgEGCCqGSM49AwEHA0IABCmXp8ZBf8ANm+gBG1bG8lKl\n"
"ui2yEujSLtf6ycXYqm0fc4E7O5hrOXwzpcVOho6AF2hiRVd9RFgdszflZwjrZt6j\n"
"QjBAMA8GA1UdEwEB/wQFMAMBAf8wDgYDVR0PAQH/BAQDAgGGMB0GA1UdDgQWBBSr\n"
"ttvXBp43rDCGB5Fwx5zEGbF4wDAKBggqhkjOPQQDAgNJADBGAiEA4IWSoxe3jfkr\n"
"BqWTrBqYaGFy+uGh0PsceGCmQ5nFuMQCIQCcAu/xlJyzlvnrxir4tiz+OpAUFteM\n"
"YyRIHN8wfdVoOw==\n"
"-----END CERTIFICATE-----\n";

static const uint32_t ulTlsECHO_SERVER_CERTIFICATE_LENGTH =
 sizeof( cTlsECHO_SERVER_CERTIFICATE_PEM );

void vConnectToServerWithSecureSocket( void )
{
    Socket_t xSocket;
    SocketsSockaddr_t xEchoServerAddress;
    BaseType_t xTransmitted, lStringLength;

    xEchoServerAddress.usPort = SOCKETS_htons( configCLIENT_PORT );
    xEchoServerAddress.ulAddress = SOCKETS_inet_addr_quick( configSERVER_ADDR0,
                                                            configSERVER_ADDR1,
                                                            configSERVER_ADDR2,
                                                            configSERVER_ADDR3 );

    /* Create a TCP socket. */
    xSocket = SOCKETS_Socket( SOCKETS_AF_INET, SOCKETS_SOCK_STREAM, SOCKETS_IPPROTO_TCP );
    configASSERT( xSocket != SOCKETS_INVALID_SOCKET );

    /* Set a timeout so a missing reply does not cause the task to block indefinitely. */
    SOCKETS_SetSockOpt( xSocket, 0, SOCKETS_SO_RCVTIMEO, &xReceiveTimeOut,
 sizeof( xReceiveTimeOut ) );
    SOCKETS_SetSockOpt( xSocket, 0, SOCKETS_SO_SNDTIMEO, &xSendTimeOut,
 sizeof( xSendTimeOut ) );
```

```
   /* Set the socket to use TLS. */
   SOCKETS_SetSockOpt( xSocket, 0, SOCKETS_SO_REQUIRE_TLS, NULL, ( size_t ) 0 );
   SOCKETS_SetSockOpt( xSocket, 0, SOCKETS_SO_TRUSTED_SERVER_CERTIFICATE,
cTlsECHO_SERVER_CERTIFICATE_PEM, ulTlsECHO_SERVER_CERTIFICATE_LENGTH );

   if( SOCKETS_Connect( xSocket, &xEchoServerAddress, sizeof( xEchoServerAddress ) ) ==
0 )
   {
       /* Send the string to the socket. */
       xTransmitted = SOCKETS_Send( xSocket,                         /* The socket
receiving. */
                                    ( void * )"some message",        /* The data being
sent. */
                                    12,                              /* The length of the
data being sent. */
                                    0 );                             /* No flags. */

       if( xTransmitted < 0 )
       {
           /* Error while sending data*/
           return;
       }

       SOCKETS_Shutdown( xSocket, SOCKETS_SHUT_RDWR );
   }
   else
   {
       //failed to connect to server
   }

   SOCKETS_Close( xSocket );
}
```

For a full example, see the Secure Sockets Echo Client Demo.

Porting

Amazon FreeRTOS Secure Sockets depends on a TCP/IP stack and on a TLS implementation. Depending on your stack, to port the Secure Sockets library, you might need to port some of the following:

- The FreeRTOS+TCP TCP/IP stack
- The Amazon FreeRTOS Public Key Cryptography Standard (PKCS) #11 Library (p. 95)
- The Amazon FreeRTOS Transport Layer Security (TLS) (p. 103)

For more information about porting, see the Amazon FreeRTOS Qualification Program Developer Guide and the Amazon FreeRTOS Porting Guide.

Amazon FreeRTOS AWS IoT Device Shadow Library

Overview

The Amazon FreeRTOS device shadow APIs define functions to create, update, and delete device shadows. For more information about Amazon FreeRTOS device shadows, see Device Shadows. Device shadows are accessed using the MQTT protocol. The FreeRTOS device shadow API works with the MQTT API and handles the details of working with the MQTT protocol.

The source files for the Amazon FreeRTOS AWS IoT device shadow library are located in `AmazonFreeRTOS/lib/shadow`.

Dependencies and Requirements

To use AWS IoT Device Shadows with Amazon FreeRTOS, you need to create a thing in AWS IoT, including a certificate and policy. For more information, see AWS IoT Getting Started. You must set values for the following constants in the `AmazonFreeRTOS/demos/common/include/aws_client_credentials.h` file:

`clientcredentialMQTT_BROKER_ENDPOINT`

Your AWS IoT endpoint.

`clientcredentialIOT_THING_NAME`

The name of your IoT thing.

`clientcredentialWIFI_SSID`

The SSID of your Wi-Fi network.

`clientcredentialWIFI_PASSWORD`

Your Wi-Fi password.

`clientcredentialWIFI_SECURITY`

The type of Wi-Fi security used by your network.

`keyCLIENT_CERTIFICATE_PEM`

The certificate PEM associated with your IoT thing. For more information, see Configure Your Project (p. 10).

`keyCLIENT_PRIVATE_KEY_PEM`

The private key PEM associated with your IoT thing. For more information, see Configure Your Project (p. 10).

Make sure the Amazon FreeRTOS MQTT library is installed on your device. For more information, see Amazon FreeRTOS MQTT Library (Legacy) (p. 90). Make sure that the MQTT buffers are large enough to contain the shadow JSON files. The maximum size for a device shadow document is 8 KB. All default settings for the device shadow API can be set in the `lib\include\private\aws_shadow_config_defaults.h` file. You can modify any of these settings in the `demos/<platform>/common/config_files/aws_shadow_config.h` file.

You must have an IoT thing registered with AWS IoT, including a certificate with a policy that permits accessing the device shadow. For more information, see AWS IoT Getting Started.

Source and Header Files

```
Amazon FreeRTOS
|
+ - lib
    |
    + - shadow
    |   + # aws_shadow.c
    |   + # aws_shadow_json.c
    + - include
        + - aws_shadow.h
        + - private
            + - aws_shadow_config_defaults.h
            + - aws_shadow_json.h
```

API Reference

For a full API reference, see Device Shadow API Reference.

Example Usage

1. Use the `SHADOW_ClientCreate` API to create a shadow client. For most applications, the only field to fill is `xCreateParams.xMQTTClientType = eDedicatedMQTTClient`.
2. Establish an MQTT connection by calling the `SHADOW_ClientConnect` API, passing the client handle returned by `SHADOW_ClientCreate`.
3. Call the `SHADOW_RegisterCallbacks` API to configure callbacks for shadow update, get, and delete.

After a connection is established, you can use the following APIs to work with the device shadow:

`SHADOW_Delete`

Delete the device shadow.

`SHADOW_Get`

Get the current device shadow.

`SHADOW_Update`

Update the device shadow.

Note
When you are done working with the device shadow, call `SHADOW_ClientDisconnect` to disconnect the shadow client and free system resources.

Amazon FreeRTOS Transport Layer Security (TLS)

The Amazon FreeRTOS Transport Layer Security (TLS) interface is a thin, optional wrapper used to abstract cryptographic implementation details away from the Secure Sockets interface above it in the protocol stack. The purpose of the TLS interface is to make the current software crypto library, mbed TLS, easy to replace with an alternative implementation for TLS protocol negotiation and cryptographic primitives. The TLS interface can be swapped out without any changes required to the Secure Sockets interface. See `aws_tls.h` in the Amazon FreeRTOS source code repository.

The TLS interface is optional because you can choose to interface directly from Secure Sockets into a crypto library. The interface is not used for MCU solutions that include a full-stack offload implementation of TLS and network transport.

Amazon FreeRTOS Wi-Fi Library

Overview

The Amazon FreeRTOS Wi-Fi library abstracts port-specific Wi-Fi implementations into a common API that simplifies application development and porting for all Amazon FreeRTOS-qualified boards with Wi-Fi capabilities. Using this common API, applications can communicate with their lower-level wireless stack through a common interface.

The source files for the Amazon FreeRTOS Wi-Fi library are located in `AmazonFreeRTOS/lib/wifi/portable`.

Dependencies and Requirements

The Amazon FreeRTOS Wi-Fi library requires the FreeRTOS+TCP core.

Features

The Wi-Fi library includes the following features:

- Support for WEP, WPA, and WPA2 authentication
- Access Point Scanning
- Power management
- Network profiling

For more information about the features of the Wi-Fi library, see below.

Wi-Fi Modes

Wi-Fi devices can be in one of three modes: Station, Access Point, or P2P. You can get the current mode of a Wi-Fi device by calling `WIFI_GetMode`. You can set a device's wi-fi mode by calling `WIFI_SetMode`. Switching modes by calling `WIFI_SetMode` disconnects the device, if it is already connected to a network.

Station mode

Set your device to Station mode to connect the board to an existing access point.

Access Point (AP) mode

Set your device to AP mode to make the device an access point for other devices to connect to. When your device is in AP mode, you can connect another device to your FreeRTOS device and configure the new Wi-Fi credentials. To configure AP mode, call `WIFI_ConfigureAP`. To put your device into AP mode, call `WIFI_StartAP`. To turn off AP mode, call `WIFI_StopAP`.

P2P mode

Set your device to P2P mode to allow multiple devices to connect to each other directly, without an access point.

Security

The Wi-Fi API supports WEP, WPA, and WPA2 security types. When a device is in Station mode, you must specify the network security type when calling the `WIFI_ConnectAP` function. When a device is in AP mode, the device can be configured to use any of the supported security types:

- `eWiFiSecurityOpen`
- `eWiFiSecurityWEP`
- `eWiFiSecurityWPA`
- `eWiFiSecurityWPA2`

Scanning and Connecting

To scan for nearby access points, set your device to Station mode, and call the `WIFI_Scan` function. If you find a desired network in the scan, you can connect to the network by calling `WIFI_ConnectAP` and providing the network credentials. You can disconnect a Wi-Fi device from the network by calling

WIFI_Disconnect. For more information about scanning and connecting, see Example Usage (p. 106) and API Reference (p. 106).

Power Management

Different Wi-Fi devices have different power requirements, depending on the application and available power sources. A device might always be powered on to reduce latency or it might be intermittently connected and switch into a low power mode when Wi-Fi is not required. The interface API supports various power management modes like always on, low power, and normal mode. You set the power mode for a device using the WIFI_SetPMMode function. You can get the current power mode of a device by calling the WIFI_GetPMMode function.

Network Profiles

The Wi-Fi library enables you to save network profiles in the non-volatile memory of your devices. This allows you to save network settings so they can be retrieved when a device reconnects to a Wi-Fi network, removing the need to provision devices again after they have been connected to a network. WIFI_NetworkAdd adds a network profile. WIFI_NetworkGet retrieves a network profile. WIFI_NetworkDel deletes a network profile. The number of profiles you can save depends on the platform.

Footprint

Code Size (example generated with GCC for ARM Cortex-M)

File name	Size (with -O1 Optimization)	Size (with Os Optimization)	
Wi-Fi library, with all options enabled	Varies by port	Varies by port	
For example, for the TI CC3220SF: lib/wifi/portable/ti/cc3220_launchpad/aws_wifi.c	3.7 K	3.0 K	

Source and Header Files

```
Amazon FreeRTOS
|
+ - lib
      + - include
      |   + - aws_wifi.h              [Include to use the AFR WIFI API]
      + - wifi
          + - portable
              + ...                  [Port-specific folder structure]
                  + - aws_wifi.c      [Required to use the AFR WIFI API]
```

Configuration

To use the Wi-Fi library, you need to define several identifiers in a configuration file. For information about these identifiers, see the API Reference (p. 106).

Note
The library does not include the required configuration file. You must create one. When creating your configuration file, be sure to include any board-specific configuration identifiers that your board requires.

Initialization

Before you use the Wi-Fi library, you need to initialize some board-specific components, in addition to the FreeRTOS components. Using the `demos/vendor/board/common/application_code/main.c` file as a template for initialization, do the following:

1. Remove the sample Wi-Fi connection logic in `main.c` if your application handles Wi-Fi connections. Replace the following `DEMO_RUNNER_RunDemos()` function call:

```
if( SYSTEM_Init() == pdPASS )
 {
 ...
  DEMO_RUNNER_RunDemos();
 ...
  }
```

   With a call to your own application:

```
if( SYSTEM_Init() == pdPASS )
 {
 ...
  // This function should create any tasks
  // that your application requires to run.
  YOUR_APP_FUNCTION();
 ...
  }
```

2. Call `WIFI_On()` to initialize and power on your Wi-Fi chip.

   Note
   Some boards might require additional hardware initialization.

3. Pass a configured `WFINetworkParams_t` structure to `WIFI_ConnectAP()` to connect your board to an available Wi-Fi network. For more information about the `WFINetworkParams_t` structure, see Example Usage (p. 106) and API Reference (p. 106).

API Reference

For a full API reference, see Wi-Fi API Reference.

Example Usage

Connecting to a Known AP

```
#define clientcredentialWIFI_SSID    "MyNetwork"
#define clientcredentialWIFI_PASSWORD   "hunter2"

INetworkParams_t xNetworkParams;
WIFIReturnCode_t xWifiStatus;

xWifiStatus = WIFI_On(); // Turn on Wi-Fi module

// Check that Wi-Fi initialization was successful
```

```
if( xWifiStatus == eWiFiSuccess )
{
    configPRINT( ( "WiFi library initialized.\n") );
}
else
{
    configPRINT( ( "WiFi library failed to initialize.\n" ) );
    // Handle module init failure
}

/* Setup parameters. */
xNetworkParams.pcSSID = clientcredentialWIFI_SSID;
xNetworkParams.ucSSIDLength = sizeof( clientcredentialWIFI_SSID );
xNetworkParams.pcPassword = clientcredentialWIFI_PASSWORD;
xNetworkParams.ucPasswordLength = sizeof( clientcredentialWIFI_PASSWORD );
xNetworkParams.xSecurity = eWiFiSecurityWPA2;

// Connect!
xWifiStatus = WIFI_ConnectAP( &( xNetworkParams ) );

if( xWifiStatus == eWiFiSuccess )
{
    configPRINT( ( "WiFi Connected to AP.\n" ) );
    // IP Stack will receive a network-up event on success
}
else
{
    configPRINT( ( "WiFi failed to connect to AP.\n" ) );
    // Handle connection failure
}
```

Scanning for nearby APs

```
WIFINetworkParams_t xNetworkParams;
WIFIReturnCode_t xWifiStatus;

configPRINT(("Turning on wifi...\n"));
xWifiStatus = WIFI_On();

configPRINT(("Checking status...\n"));
if( xWifiStatus == eWiFiSuccess )
{
    configPRINT( ( "WiFi module initialized.\n") );
}
else
{
    configPRINTF( ( "WiFi module failed to initialize.\n" ) );
    // Handle module init failure
}

WIFI_SetMode(eWiFiModeStation);

/* Some boards might require additional initialization steps to use the Wi-Fi library. */

while (1){
    configPRINT(("Starting scan\n"));
    const uint8_t ucNumNetworks = 12; //Get 12 scan results
    WIFIScanResult_t xScanResults[ ucNumNetworks ];
    xWifiStatus = WIFI_Scan( xScanResults, ucNumNetworks ); // Initiate scan

    configPRINT(("Scan started\n"));

    // For each scan result, print out the SSID and RSSI
    if ( xWifiStatus == eWiFiSuccess ){
            configPRINT(("Scan success\n"));
            for (uint8_t i=0;i<ucNumNetworks;i++) {
                configPRINTF(("%s : %d \n", xScanResults[i].cSSID, xScanResults[i].cRSSI));
            }
        } else {
            configPRINTF(("Scan failed, status code: %d\n", (int)xWifiStatus));
        }

    vTaskDelay(200);
}
```

Porting

The `aws_wifi.c` implementation needs to implement the functions defined in `aws_wifi.h`. At the very least, the implementation needs to return `eWiFiNotSupported` for any non-essential or unsupported functions.

Amazon FreeRTOS Over-the-Air Updates

Over-the-air (OTA) updates allow you to deploy files to one or more devices in your fleet. Although OTA updates were designed to be used to update device firmware, you can use them to send any files to one or more devices registered with AWS IoT. When you send files over the air, it is a best practice to digitally sign them so that the devices that receive the files can verify they have not been tampered with en route. You can use Code Signing for Amazon FreeRTOS to sign and encrypt your files or you can sign your files with your own code-signing tools.

When you create an OTA update, the OTA Update Manager Service (p. 143) creates an AWS IoT job to notify your devices that an update is available. The OTA demo application runs on your device and creates an Amazon FreeRTOS task that subscribes to notification topics for AWS IoT jobs and listens for update messages. When an update is available, the OTA agent publishes requests to AWS IoT streaming topics and receives file blocks using the MQTT protocol. It reassembles the blocks into files and checks the digital signature of the downloaded files. If the files are valid, it installs the firmware update. If you are not using the Amazon FreeRTOS OTA Update demo application, you must integrate the Amazon FreeRTOS Over-the-Air (OTA) Agent Library (p. 93) into your own application to get the firmware update capability.

Amazon FreeRTOS over-the-air updates make it possible for you to:

- Digitally sign and encrypt firmware before deployment.
- 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, reset, or reprovisioned.
- Verify the authenticity and integrity of new firmware after it's deployed to devices.
- Monitor the progress of a deployment.
- Debug a failed deployment.

Over-the-Air Update Prerequisites

To use over-the-air updates, you need to:

- Create an S3 bucket to store your firmware update.
- Create an OTA service role.
- Create an OTA user policy.
- Create or purchase a code-signing certificate.

- If you are using Code Signing for Amazon FreeRTOS, import your code-signing key into ACM.
- If you are using Code Signing for Amazon FreeRTOS, create a code-signing policy.
- Download Amazon FreeRTOS with the OTA library for your platform or, if you are not using Amazon FreeRTOS, provide your own OTA agent implementation.

Create an Amazon S3 Bucket to Store Your Update

OTA update files are stored in Amazon S3 buckets. If you are using Code Signing for Amazon FreeRTOS, the command you use to create a code-signing job takes a source bucket (where the unsigned firmware image is located) and a destination bucket (where the signed firmware image is written). You can specify the same bucket for both the source and destination. The file names are changed to GUIDs so the original files are not overwritten.

To create an Amazon S3 bucket

1. Go to the https://console.aws.amazon.com/s3/.
2. Choose **Create bucket**.
3. Type a bucket name, and then choose **Next**.

   Note
   Your bucket name must begin with `afr-ota`.
4. On the **Create bucket** page, choose **Versioning**.
5. Choose **Enable versioning**, choose **Save**, and then choose **Next**.
6. Choose **Next** to accept the default permissions.
7. Choose **Create bucket**.

For more information about Amazon S3, see Amazon Simple Storage Service Console User Guide.

Creating an OTA Update Service Role

The OTA Update service assumes this role to create and manage OTA update jobs on your behalf.

To create an OTA service role

1. Sign in to the https://console.aws.amazon.com/iam/.
2. From the navigation pane, choose **Roles**.
3. Choose **Create role**.
4. Under **Select type of trusted entity**, choose **AWS Service**.
5. Choose **IoT** from the list of AWS services.
6. Under **Select your use case**, choose **IoT allows IoT to call AWS services on your behalf**.
7. Choose **Next: Permissions**.
8. Choose **Next: Review**.
9. Type a role name and description, and then choose **Create role**.

For more information about IAM roles, see IAM Roles.

To add OTA update permissions to your OTA service role

1. In the search box on the IAM console page, enter the name of your role, and then choose it from the list.
2. Choose **Attach policy**.

3. In the **Search** box, enter **`AmazonFreeRTOSOTAUpdate`**. In the list of managed policies, select **AmazonFreeRTOSOTAUpdate** , and then choose **Attach policy**.

To add the required permissions to your OTA service role

1. In the search box on the IAM console page, enter the name of your role and then choose it from the list.
2. In the lower right, choose **Add inline policy**.
3. Choose the **JSON** tab.
4. Copy and paste the following policy document into the text box. Replace *`<example-bucket>`* with the name of your bucket.

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": "iam:PassRole",
            "Resource":
            "arn:aws:iam::<your_account_id>:role/<your_role_name>"
        }
    ]
}
```

   If you provide your own bucket name, use the following policy to grant your service role access to your bucket:

```

 "Version": "2012-10-17",
 "Statement": [
  {
   "Effect": "Allow",
   "Action": [
    "s3:GetObjectVersion",
    "s3:GetObject"
   ],
   "Resource": "arn:aws:s3:::<example-bucket>/*"
  }
 ]
```

5. Choose **Review policy**.
6. Enter a name for the policy and then choose **Create policy**.

Creating an OTA User Policy

You must grant your IAM user permission to perform over-the-air updates. Your IAM user must have permissions to:

- Access the S3 bucket where your firmware updates are stored.
- Access certificates stored in AWS Certificate Manager.
- Access the AWS IoT Streaming service.
- Access Amazon FreeRTOS OTA updates.
- Access AWS IoT jobs.
- Access IAM.
- Access Code Signing for Amazon FreeRTOS.

- List Amazon FreeRTOS hardware platforms.

To grant your IAM user the required permissions, create an OTA user policy and then attach it to your IAM user. For more information, see IAM Policies.

To create an OTA user policy

1. Open the https://console.aws.amazon.com/iam/ console.
2. In the navigation pane, choose **Users**.
3. Choose your IAM user from the list.
4. Choose **Add permissions**.
5. Choose **Attach existing policies directly**.
6. Choose **Create policy**.
7. Choose the **JSON** tab, and copy and paste the following policy document into the policy editor:

```
{
 "Version":"2012-10-17",
 "Statement":[
 {
  "Effect":"Allow",
  "Action":[
   "s3:ListBucket",
   "s3:ListAllMyBuckets",
   "s3:CreateBucket",
   "s3:PutBucketVersioning",
   "s3:GetBucketLocation",
   "s3:GetObjectVersion",
   "acm:ImportCertificate",
   "acm:ListCertificates",
   "iot:*",
   "iam:ListRoles",
   "freertos:ListHardwarePlatforms",
   "freertos:DescribeHardwarePlatform"
  ],
  "Resource":"*"
 },
 {
 "Effect":"Allow",
 "Action":[
  "s3:GetObject",
  "s3:PutObject"
 ],
 "Resource":"arn:aws:s3:::<example-bucket>/*"
 },
 {
  "Effect":"Allow",
  "Action":"iam:PassRole",
  "Resource":"arn:aws:iam::<your-account-id>:role/<role-name>"
 }
 ]
}
```

   Replace *<example-bucket>* with the name of the Amazon S3 bucket where your OTA update firmware image is stored. Replace *<your-account-id>* with your AWS account ID. You can find your AWS account ID in the upper right of the console. When you enter your account ID, remove any dashes (-). Replace *<role-name>* with the name of the IAM service role you just created.
8. Choose **Review policy**.
9. Enter a name for your new OTA user policy, and then choose **Create policy**.

To attach the OTA user policy to your IAM user

1. In the IAM console, in the navigation pane, choose **Users**, and then choose your user.
2. Choose **Add permissions**.
3. Choose **Attach existing policies directly**.
4. Search for the OTA user policy you just created and select the check box next to it.
5. Choose **Next: Review**.
6. Choose **Add permissions**.

Creating a Code-Signing Certificate

To digitally sign firmware images, you need a code-signing certificate and private key. For testing purposes, you can create a self-signed certificate and private key. For production environments, purchase a certificate through a well-known certificate authority (CA).

Different platforms require different types of code-signing certificates. The following section describes how to create code-signing certificates for each of the Amazon FreeRTOS-qualified platforms.

Creating a Code-Signing Certificate for the Texas Instruments CC3200SF-LAUNCHXL

The SimpleLink Wi-Fi CC3220SF Wireless Microcontroller Launchpad Development Kit supports two certificate chains for firmware code signing:

- Production (certificate-catalog)

  To use the production certificate chain, you must purchase a commercial code-signing certificate and use the TI Uniflash tool to set the board to production mode.
- Testing and development (certificate-playground)

  The playground certificate chain allows you to try out OTA updates with a self-signed code-signing certificate.

Install the SimpleLink CC3220 SDK version 2.10.00.04. By default, the files you need are located here:

`C:\ti\simplelink_cc32xx_sdk_2_10_00_04\tools\cc32xx_tools\certificate-playground` (Windows)

`/Applications/Ti/simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground` (macOS)

The certificates in the SimpleLink CC3220 SDK are in DER format. To create a self-signed code-signing certificate, you must convert them to PEM format.

Follow these steps to create a code-signing certificate that is linked to the Texas Instruments playground certificate hierarchy and meets AWS Certificate Manager and Code Signing for Amazon FreeRTOS criteria.

To create a self-signed code signing certificate

1. In your working directory, use the following text to create a file named `cert_config`. Replace *test_signer@amazon.com* with your email address.

   ```
   [ req ]
   ```

```
prompt             = no
distinguished_name = my dn

[ my dn ]
commonName = test_signer@amazon.com

[ my_exts ]
keyUsage         = digitalSignature
extendedKeyUsage = codeSigning
```

2. Create a private key and certificate signing request (CSR):

```
openssl req -config cert_config -extensions my_exts -nodes -days 365 -newkey rsa:2048 -
keyout tisigner.key -out tisigner.csr
```

3. Convert the Texas Instruments playground root CA private key from DER format to PEM format.

   The TI playground root CA private key is located here:

   `C:\ti\simplelink_cc32xx_sdk_2_10_00_04\tools\cc32xx_tools\certificate-playground\dummy-root-ca-cert-key` (Windows)

   `/Applications/Ti/simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground/dummy-root-ca-cert-key` (macOS)

```
openssl rsa -inform DER -in dummy-root-ca-cert-key -out dummy-root-ca-cert-key.pem
```

4. Convert the Texas Instruments playground root CA certificate from DER format to PEM format.

   The TI playground root certificate is located here:

   `C:\ti\simplelink_cc32xx_sdk_2_10_00_04\tools\cc32xx_tools\certificate-playground/dummy-root-ca-cert` (Windows)

   `/Applications/Ti/simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground/dummy-root-ca-cert` (macOS)

```
openssl x509 -inform DER -in dummy-root-ca-cert -out dummy-root-ca-cert.pem
```

5. Sign the CSR with the Texas Instruments root CA:

```
openssl x509 -extfile cert_config -extensions my_exts  -req -days 365 -in tisigner.csr
 -CA dummy-root-ca-cert.pem -CAkey dummy-root-ca-cert-key.pem -set_serial 01 -out
 tisigner.crt.pem -sha1
```

6. Convert your code-signing certificate (tisigner.crt.pem) to DER format:

```
openssl x509 -in tisigner.crt.pem -out tisigner.crt.der -outform DER
```

   Note
   You write the `tisigner.crt.der` certificate onto the TI development board later.

7. Import the code-signing certificate, private key, and certificate chain into AWS Certificate Manager:

```
aws acm import-certificate --certificate file://tisigner.crt.pem --private-key file://
tisigner.key --certificate-chain file://dummy-root-ca-cert.pem
```

   This command displays an ARN for your certificate. You need this ARN when you create an OTA update job.

Note
This step is written with the assumption that you are going to use Code Signing for Amazon FreeRTOS to sign your firmware images. Although the use of Code Signing for Amazon FreeRTOS is recommended, you can sign your firmware images manually.

Creating a Code-Signing Certificate for the Microchip Curiosity PIC32MZEF

The Microchip Curiosity PIC32MZEF supports a self-signed SHA256 with ECDSA code-signing certificate.

1. In your working directory, use the following text to create a file named `cert_config`. Replace *`test_signer@amazon.com`* with your email address:

```
[ req ]
prompt             = no
distinguished_name = my_dn

[ my_dn ]
commonName = test_signer@amazon.com

[ my_exts ]
keyUsage         = digitalSignature
extendedKeyUsage = codeSigning
```

2. Create an ECDSA code-signing private key:

```
openssl genpkey -algorithm EC -pkeyopt ec_paramgen_curve:P-256 -pkeyopt
 ec_param_enc:named_curve -outform PEM -out ecdsasigner.key
```

3. Create an ECDSA code-signing certificate:

```
openssl req -new -x509 -config cert_config -extensions my_exts -nodes -days 365 -key
 ecdsasigner.key -out ecdsasigner.crt
```

4. Import the code-signing certificate, private key, and certificate chain into AWS Certificate Manager:

```
aws acm import-certificate --certificate file://ecdsasigner.crt --private-key
        file://ecdsasigner.key
```

   This command displays an ARN for your certificate. You need this ARN when you create an OTA update job.

   Note
   This step is written with the assumption that you are going to use Code Signing for Amazon FreeRTOS to sign your firmware images. Although the use of Code Signing for Amazon FreeRTOS is recommended, you can sign your firmware images manually.

Creating a Code-Signing Certificate for the Espressif ESP32

The Espressif ESP32 boards support a self-signed SHA256 with ECDSA code-signing certificate.

1. In your working directory, use the following text to create a file named `cert_config`. Replace *`test_signer@amazon.com`* with your email address:

```
[ req ]
prompt             = no
distinguished_name = my_dn
```

```
[ my_dn ]
commonName = test_signer@amazon.com

[ my_exts ]
keyUsage         = digitalSignature
extendedKeyUsage = codeSigning
```

2. Create an ECDSA code-signing private key:

   ```
   openssl genpkey -algorithm EC -pkeyopt ec_paramgen_curve:P-256 -pkeyopt
    ec_param_enc:named_curve -outform PEM -out ecdsasigner.key
   ```

3. Create an ECDSA code-signing certificate:

   ```
   openssl req -new -x509 -config cert_config -extensions my_exts -nodes -days 365 -key
    ecdsasigner.key -out ecdsasigner.crt
   ```

4. Import the code-signing certificate, private key, and certificate chain into AWS Certificate Manager:

   ```
   aws acm import-certificate --certificate file://ecdsasigner.crt --private-key
           file://ecdsasigner.key
   ```

   This command displays an ARN for your certificate. You need this ARN when you create an OTA update job.

   > **Note**
   > This step is written with the assumption that you are going to use Code Signing for Amazon FreeRTOS to sign your firmware images. Although the use of Code Signing for Amazon FreeRTOS is recommended, you can sign your firmware images manually.

Creating a Code-Signing Certificate for the Amazon FreeRTOS Windows Simulator

The Amazon FreeRTOS Windows simulator requires a code-signing certificate with an ECDSA P-256 key and SHA-256 hash to perform OTA updates. If you don't have a code-signing certificate, use these steps to create one:

1. In your working directory, use the following text to create a file named `cert_config`. Replace *`test_signer@amazon.com`* with your email address:

   ```
   [ req ]
   prompt             = no
   distinguished_name = my_dn

   [ my_dn ]
   commonName = test_signer@amazon.com

   [ my_exts ]
   keyUsage         = digitalSignature
   extendedKeyUsage = codeSigning
   ```

2. Create an ECDSA code-signing private key:

   ```
   openssl genpkey -algorithm EC -pkeyopt ec_paramgen_curve:P-256 -pkeyopt
    ec_param_enc:named_curve -outform PEM -out ecdsasigner.key
   ```

3. Create an ECDSA code-signing certificate:

```
openssl req -new -x509 -config cert_config -extensions my_exts -nodes -days 365 -key
 ecdsasigner.key -out ecdsasigner.crt
```

4. Import the code-signing certificate, private key, and certificate chain into AWS Certificate Manager:

```
aws acm import-certificate --certificate file://ecdsasigner.crt --private-key
        file://ecdsasigner.key
```

   This command displays an ARN for your certificate. You need this ARN when you create an OTA update job.

   > **Note**
   > This step is written with the assumption that you are going to use Code Signing for Amazon FreeRTOS to sign your firmware images. Although the use of Code Signing for Amazon FreeRTOS is recommended, you can sign your firmware images manually.

Creating a Code-Signing Certificate for Custom Hardware

Using an appropriate toolset, create a self-signed certificate and private key for your hardware.

After you create your code-signing certificate, import it into ACM:

```
aws acm import-certificate --certificate file://code-sign.crt --private-key file://code-
sign.key
```

The output from this command displays an ARN for your certificate. You need this ARN when you create an OTA update job.

ACM requires certificates to use specific algorithms and key sizes. For more information, see Prerequisites for Importing Certificates. For more information about ACM, see Importing Certificates into AWS Certificate Manager.

You must copy, paste, and format the contents of your code-signing certificate and private key into the `aws_ota_codesigner_certificate.h` file that is part of the Amazon FreeRTOS code you download later.

Granting Access to Code Signing for Amazon FreeRTOS

In production environments, you should digitally sign your firmware update to ensure the authenticity and integrity of the update. You can sign your update manually or you can use Code Signing for Amazon FreeRTOS to sign your code. To use Code Signing for Amazon FreeRTOS, you must grant your IAM user account access to Code Signing for Amazon FreeRTOS.

To grant your IAM user account permissions for Code Signing for Amazon FreeRTOS

1. Sign in to the https://console.aws.amazon.com/iam/.
2. In the navigation pane, choose **Policies**.
3. Choose **Create Policy**.
4. On the **JSON** tab, copy and paste the following JSON document into the policy editor. This policy allows the IAM user access to all code-signing operations.

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

5. Choose **Review policy**.
6. Enter a policy name and description, and then choose **Create policy**.
7. In the navigation pane, choose **Users**.
8. Choose your IAM user account.
9. On the **Permissions** tab, choose **Add permissions**.
10. Choose **Attach existing policies directly**, and then select the check box next to the code-signing policy you just created.
11. Choose **Next: Review**.
12. Choose **Add permissions**.

Download Amazon FreeRTOS with the OTA Library

Follow the steps in this section to download code and build demo applications.

Download and Build Amazon FreeRTOS for the Texas Instruments CC3200SF-LAUNCHXL

To download Amazon FreeRTOS and the OTA demo code

1. Browse to the AWS IoT console and from the navigation pane, choose **Software**.
2. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
3. From the list of software configurations, choose **Connect to AWS IoT - TI**. Choose the configuration name, not the **Download** link.
4. Under **Libraries**, choose **Add another library**, and then choose **OTA Updates**.
5. Under **Demo Projects**, choose **OTA Updates**.
6. Under **Name required**, enter **`Connect-to-IoT-OTA-TI`**, and then choose **Create and download**.

Save the zip file that contains Amazon FreeRTOS and the OTA demo code to your computer.

To build the demo application

1. Extract the .zip file.
2. Follow the instructions in Getting Started with Amazon FreeRTOS (p. 4), to import the `aws_demos` project into Code Composer Studio, configure your AWS IoT endpoint, your Wi-Fi SSID and password, and a private key and certificate for your board.
3. Open the project in Code Composer Studio and open `demos/common/demo_runner/aws_demo_runner.c`. Find the `DEMO_RUNNER_RunDemos` function and make sure all function calls are commented out except `vStartOTAUpdateDemoTask`.
4. Build the solution and make sure it builds without errors.
5. Start a terminal emulator and use the following settings to connect to your board:
   - Baud rate: 115200
   - Data bits: 8

- Parity: None
- Stop bits: 1

6. Run the project on your board to make sure it can connect to Wi-Fi and the AWS IoT MQTT message broker.

When run, the terminal emulator should display text like the following:

```
0 0 [Tmr Svc] Starting Wi-Fi Module ...
1 0 [Tmr Svc] Simple Link task created
Device came up in Station mode
2 142 [Tmr Svc] Wi-Fi module initialized.
3 142 [Tmr Svc] Starting key provisioning...
4 142 [Tmr Svc] Write root certificate...
5 243 [Tmr Svc] Write device private key...
6 340 [Tmr Svc] Write device certificate...
7 433 [Tmr Svc] Key provisioning done...
[WLAN EVENT] STA Connected to the AP: Mobile , BSSID: 24:de:c6:5d:32:a4
[NETAPP EVENT] IP acquired by the device

Device has connected to Mobile
Device IP Address is 192.168.111.12

8 2666 [Tmr Svc] Wi-Fi connected to AP Mobile.
9 2666 [Tmr Svc] IP Address acquired 192.168.111.12
10 2667 [OTA] OTA demo version 0.9.2
11 2667 [OTA] Creating MQTT Client...
12 2667 [OTA] Connecting to broker...
13 3512 [OTA] Connected to broker.
14 3715 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/OtaGA/jobs/$next/
get/accepted
15 4018 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/OtaGA/jobs/notify-
next
16 4027 [OTA Task] [prvPAL_GetPlatformImageState] xFileInfo.Flags = 0250
17 4027 [OTA Task] [prvPAL_GetPlatformImageState] eOTA_PAL_ImageState_Valid
18 4034 [OTA Task] [OTA_CheckForUpdate] Request #0
19 4248 [OTA] [OTA_AgentInit] Ready.
20 4249 [OTA Task] [prvParseJSONbyModel] Extracted parameter [ clientToken: 0:OtaGA ]
21 4249 [OTA Task] [prvParseJSONbyModel] parameter not present: execution
22 4249 [OTA Task] [prvParseJSONbyModel] parameter not present: jobId
23 4249 [OTA Task] [prvParseJSONbyModel] parameter not present: jobDocument
24 4249 [OTA Task] [prvParseJSONbyModel] parameter not present: afr_ota
25 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: streamname
26 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: files
27 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: filepath
28 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: filesize
29 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: fileid
30 4250 [OTA Task] [prvParseJSONbyModel] parameter not present: certfile
31 4251 [OTA Task] [prvParseJSONbyModel] parameter not present: sig-sha1-rsa
32 4251 [OTA Task] [prvParseJobDoc] Ignoring job without ID.
33 4251 [OTA Task] [prvOTA_Close] Context->0x2001b2c4
34 5248 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
35 6248 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
36 7248 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
37 8248 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
38 9248 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
```

Download and Build Amazon FreeRTOS for the Microchip Curiosity PIC32MZEF

To download the Amazon FreeRTOS OTA demo code

1. Browse to the AWS IoT console and from the navigation pane, choose **Software**.

2. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
3. From the list of software configurations, choose **Connect to AWS IoT - Microchip**. Choose the configuration name, not the **Download** link.
4. Under **Libraries**, choose **Add another library**, and then choose **OTA Updates**.
5. Under **Demo projects**, choose **OTA Update**.
6. Under **Name required**, enter a name for your custom Amazon FreeRTOS software configuration.
7. Choose **Create and download**.

To build the OTA update demo application

1. Extract the .zip file you just downloaded.
2. Follow the instructions in Getting Started with Amazon FreeRTOS (p. 4) to import the `aws_demos` project into the MPLAB X IDE, configure your AWS IoT endpoint, your Wi-Fi SSID and password, and a private key and certificate for your board.
3. Open `aws_demos/lib/aws/ota/aws_ota_codesigner_certificate.h`.
4. Paste the contents of your code-signing certificate into the `static const char signingcredentialSIGNING_CERTIFICATE_PEM` variable. Following the same format as `aws_clientcredential_keys.h`, each line must end with the new line character ('\n') and be enclosed in quotation marks.

   For example, your certificate should look similar to the following:

   ```
   "-----BEGIN CERTIFICATE-----\n"
   "MIIBXTCCAQOgAwIBAgIJAM4DeybZcTwKMAoGCCqGSM49BAMCMCExHzAdBgNVBAMM\n"
   "FnRlc3Rf62lnbmVyQGFtYXpvbi5jb20wHhcNMTcxMTAzMTkxODM1WhcNMTgxMTAz\n"
   "MTkxODM2WjAhMR8wHQYDVQBBZZZ0ZXN0X3NpZ25lckBhbWF6b24uY29tMFkwEwYH\n"
   "KoZIzj0CAQYIKoZIzj0DAQcDQgAERavZfvwL1X+E4dIF7dbkVMUn4IrJ1CAsFkc8\n"
   "gZxPzn683H40XMKltDZPEwr9ng78w9+QYQg7ygnr2stz8yhh06MkMCIwCwYDVR0P\n"
   "BAQDAgeAMBMGA1UdJQQMMAoGCCsGAQUFBwMDMAoGCCqGSM49BAMCA0gAMEUCIF0R\n"
   "r5cb7rEUNtWOvGd05MacrgOABfSoVYvBOK9fP63WAqt5h3BaS123coKSGg84twlq\n"
   "TkO/pV/xEmyZmZdV+HxV/OM=\n"
   "-----END CERTIFICATE-----\n";
   ```

5. Install Python 3 or later.
6. Install `pyOpenSSL` by running `pip install pyopenssl`.
7. Copy your code-signing certificate in .pem format in the path `\demos\common\ota\bootloader\utility\codesigner_cert_utility\`. Rename the certificate file `aws_ota_codesigner_certificate.pem`.
8. Open the project in MPLAB X IDE and open `demos/common/demo_runner/aws_demo_runner.c`. Find the `DEMO_RUNNER_RunDemos` function and make sure all function calls are commented out except `vStartOTAUpdateDemoTask`.
9. Build the solution and make sure it builds without errors.
10. Start a terminal emulator and use the following settings to connect to your board:
    - Baud rate: 115200
    - Data bits: 8
    - Parity: None
    - Stop bits: 1
11. Unplug the debugger from your board and run the project on your board to make sure it can connect to Wi-Fi and the AWS IoT MQTT message broker.

When you run the project, the MPLAB X IDE should open an output window. Make sure the ICD4 tab is selected. You should see the following output.

```
Bootloader version 00.09.00
[prvBOOT_Init] Watchdog timer initialized.
[prvBOOT_Init] Crypto initialized.

[prvValidateImage] Validating image at Bank : 0
[prvValidateImage] No application image or magic code present at: 0xbd000000
[prvBOOT_ValidateImages] Validation failed for image at 0xbd000000

[prvValidateImage] Validating image at Bank : 1
[prvValidateImage] No application image or magic code present at: 0xbd100000
[prvBOOT_ValidateImages] Validation failed for image at 0xbd100000

[prvBOOT_ValidateImages] Booting default image.


>0 36246 [IP-task] vDHCPProcess: offer ac140a0eip
                                                 1 36297 [IP-task] vDHCPProcess: offer
 ac140a0eip
                 2 36297 [IP-task]

IP Address: 172.20.10.14
3 36297 [IP-task] Subnet Mask: 255.255.255.240
4 36297 [IP-task] Gateway Address: 172.20.10.1
5 36297 [IP-task] DNS Server Address: 172.20.10.1


6 36299 [OTA] OTA demo version 0.9.2
7 36299 [OTA] Creating MQTT Client...
8 36299 [OTA] Connecting to broker...
9 38673 [OTA] Connected to broker.
10 38793 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/devthingota/jobs/
$next/get/accepted
11 38863 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/devthingota/jobs/
notify-next
12 38863 [OTA Task] [OTA_CheckForUpdate] Request #0
13 38964 [OTA] [OTA_AgentInit] Ready.
14 38973 [OTA Task] [prvParseJSONbyModel] Extracted parameter [ clientToken:
 0:devthingota ]
15 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: execution
16 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: jobId
17 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: jobDocument
18 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: streamname
19 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: files
20 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: filepath
21 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: filesize
22 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: fileid
23 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: certfile
24 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: sig-sha256-ecdsa
25 38975 [OTA Task] [prvParseJobDoc] Ignoring job without ID.
26 38975 [OTA Task] [prvOTA_Close] Context->0x8003b620
27 38975 [OTA Task] [prvPAL_Abort] Abort - OK
28 39964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
29 40964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
30 41964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
31 42964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
32 43964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
33 44964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
34 45964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
35 46964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
36 47964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
```

The terminal emulator should display text like the following:

```
AWS Validate: no valid signature in descr: 0xbd000000
AWS Validate: no valid signature in descr: 0xbd100000


>AWS Launch:  No Map performed. Running directly from address: 0x9d000020?
AWS Launch:  wait for app at: 0x9d000020
WILC1000: Initializing...
0 0

>[None] Seed for randomizer: 1172751941
1 0 [None] Random numbers: 00004272 00003B34 00000602 00002DE3
Chip ID 1503a0

[spi_cmd_rsp][356][nmi spi]: Failed cmd response read, bus error...

[spi_read_reg][1086][nmi spi]: Failed cmd response, read reg (0000108c)...

[spi_read_reg][1116]Reset and retry 10 108c

Firmware ver. : 4.2.1

Min driver ver : 4.2.1

Curr driver ver: 4.2.1

WILC1000: Initialization successful!

Start Wi-Fi Connection...
Wi-Fi Connected
2 7219 [IP-task] vDHCPProcess: offer c0a804beip
3 7230 [IP-task] vDHCPProcess: offer c0a804beip
4 7230 [IP-task]

IP Address: 192.168.4.190
5 7230 [IP-task] Subnet Mask: 255.255.240.0
6 7230 [IP-task] Gateway Address: 192.168.0.1
7 7230 [IP-task] DNS Server Address: 208.67.222.222


8 7232 [OTA] OTA demo version 0.9.0
9 7232 [OTA] Creating MQTT Client...
10 7232 [OTA] Connecting to broker...
11 7232 [OTA] Sending command to MQTT task.
12 7232 [MQTT] Received message 10000 from queue.
13 8501 [IP-task] Socket sending wakeup to MQTT task.
14 10207 [MQTT] Received message 0 from queue.
15 10256 [IP-task] Socket sending wakeup to MQTT task.
16 10256 [MQTT] Received message 0 from queue.
17 10256 [MQTT] MQTT Connect was accepted. Connection established.
18 10256 [MQTT] Notifying task.
19 10257 [OTA] Command sent to MQTT task passed.
20 10257 [OTA] Connected to broker.
21 10258 [OTA Task] Sending command to MQTT task.
22 10258 [MQTT] Received message 20000 from queue.
23 10306 [IP-task] Socket sending wakeup to MQTT task.
24 10306 [MQTT] Received message 0 from queue.
25 10306 [MQTT] MQTT Subscribe was accepted. Subscribed.
26 10306 [MQTT] Notifying task.
27 10307 [OTA Task] Command sent to MQTT task passed.
28 10307 [OTA Task] [OTA] Subscribed to topic: $aws/things/Microchip/jobs/$next/get/
accepted

29 10307 [OTA Task] Sending command to MQTT task.
30 10307 [MQTT] Received message 30000 from queue.
31 10336 [IP-task] Socket sending wakeup to MQTT task.
32 10336 [MQTT] Received message 0 from queue.
33 10336 [MQTT] MQTT Subscribe was accepted. Subscribed.
```

```
34 10336 [MQTT] Notifying task.
35 10336 [OTA Task] Command sent to MQTT task passed.
36 10336 [OTA Task] [OTA] Subscribed to topic: $aws/things/Microchip/jobs/notify-next

37 10336 [OTA Task] [OTA] Check For Update #0
38 10336 [OTA Task] Sending command to MQTT task.
39 10336 [MQTT] Received message 40000 from queue.
40 10366 [IP-task] Socket sending wakeup to MQTT task.
41 10366 [MQTT] Received message 0 from queue.
42 10366 [MQTT] MQTT Publish was successful.
43 10366 [MQTT] Notifying task.
44 10366 [OTA Task] Command sent to MQTT task passed.
45 10376 [IP-task] Socket sending wakeup to MQTT task.
46 10376 [MQTT] Received message 0 from queue.
47 10376 [OTA Task] [OTA] Set job doc parameter [ clientToken: 0:Microchip ]
48 10376 [OTA Task] [OTA] Missing job parameter: execution
49 10376 [OTA Task] [OTA] Missing job parameter: jobId
50 10376 [OTA Task] [OTA] Missing job parameter: jobDocument
51 10378 [OTA Task] [OTA] Missing job parameter: ts_ota
52 10378 [OTA Task] [OTA] Missing job parameter: files
53 10378 [OTA Task] [OTA] Missing job parameter: streamname
54 10378 [OTA Task] [OTA] Missing job parameter: certfile
55 10378 [OTA Task] [OTA] Missing job parameter: filepath
56 10378 [OTA Task] [OTA] Missing job parameter: filesize
57 10378 [OTA Task] [OTA] Missing job parameter: sig-sha256-ecdsa
58 10378 [OTA Task] [OTA] Missing job parameter: fileid
59 10378 [OTA Task] [OTA] Missing job parameter: attr
60 10378 [OTA Task] [OTA] Returned buffer to MQTT Client.
61 11367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
62 12367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
63 13367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
64 14367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
65 15367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
66 16367 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
```

This output shows the Microchip Curiosity PIC32MZEF is able to connect to AWS IoT and subscribe to the MQTT topics required for OTA updates. The `Missing job parameter` messages are expected because there are no OTA update jobs pending.

Download and Build Amazon FreeRTOS for the Espressif ESP32

1. Download the Amazon FreeRTOS source from GitHub. Create a project in your IDE that includes all required sources and libraries.
2. Follow the instructions in Getting Started with Espressif to set up the required GCC-based toolchain.
3. Open `demos/common/demo_runner/aws_demo_runner.c` in a text editor. Find the `DEMO_RUNNER_RunDemos` function and make sure all function calls are commented out except `vStartOTAUpdateDemoTask`.
4. Build the demo project by running `make`in the `demos/espressif/esp32_devkitc_esp_wrover_kit/make/` directory. You can flash the demo program and verify its output by running `make flash monitor`, as described in Getting Started with Espressif.
5. Before running the OTA Update demo:
   - Make sure that `vStartOTAUpdateDemoTask` is the only function called in the `DEMO_RUNNER_RunDemos()` function in `demos/common/demo_runner/aws_demo_runner.c`.
   - Make sure that your SHA-256/ECDSA code-signing certificate is copied into the `demos/common/include/aws_ota_codesigner_certificate.h`.

Download and Build Amazon FreeRTOS for a Custom Hardware Platform

Download the Amazon FreeRTOS source from GitHub. Create a project in your IDE that includes all required sources and libraries.

Build and run the project to make sure it can connect to AWS IoT.

For more information about porting Amazon FreeRTOS to a new platform, see Amazon FreeRTOS Porting Guide (p. 178).

OTA Tutorial

This section contains a tutorial for updating firmware on devices running Amazon FreeRTOS using OTA updates. You can, however, use OTA updates to send files to any devices connected to AWS IoT.

You can use the AWS IoT console or the AWS CLI to create an OTA update. The console is the easiest way to get started with OTA because it does a lot of the work for you. The AWS CLI is useful when you are automating OTA update jobs, working with a large number of devices, or are using devices that have not been qualified for Amazon FreeRTOS. For more information about qualifying devices for Amazon FreeRTOS, see the Amazon FreeRTOS Partners website.

To create a OTA update

1. Deploy an initial version of your firmware to one or more devices.
2. Verify that the firmware is running correctly.
3. When a firmware update is required, make the code changes and build the new image.
4. If you are manually signing your firmware, sign and then upload the signed firmware image to your Amazon S3 bucket.

   If you are using Code Signing for Amazon FreeRTOS, upload your unsigned firmware image to an Amazon S3 bucket.
5. Create an OTA update.

The Amazon FreeRTOS OTA agent on the device receives the updated firmware image and verifies the digital signature, checksum, and version number of the new image. If the firmware update is verified, the device is reset and, based on application-defined logic, commits the update. If your devices are not running Amazon FreeRTOS, you must implement an OTA agent that runs on your devices.

Installing the Initial Firmware

To update firmware, you must install an initial version of the firmware that uses the OTA agent library to listen for OTA update jobs. If you are not running Amazon FreeRTOS, skip this step. You must copy your OTA agent implementation onto your devices instead.

Topics

Install the Initial Version of Firmware on the Texas Instruments CC3200SF-LAUNCHXL

These steps are written with the assumption that you have already built the `aws_demos` project, as described in Download and Build Amazon FreeRTOS for the Texas Instruments CC3200SF-LAUNCHXL (p. 117).

1. On your Texas Instruments CC3200SF-LAUNCHXL, place the SOP jumper on the middle set of pins (position = 1) and reset the board.
2. Download and install the TI Uniflash tool.
3. Start Uniflash and from the list of configurations, choose **CC3220SF-LAUNCHXL**, then choose **Start Image Creator**.
4. Choose **New Project**.
5. On the **Start new project** page, enter a name for your project. For **Device Type**, choose **CC3220SF**. For **Device Mode**, choose **Develop**. Choose **Create Project**.
6. Disconnect your terminal emulator. On the right side of the Uniflash application window, choose **Connect**.
7. Under **Files**, choose **User Files**.
8. In the **File** selector pane, choose the **Add File** icon 🗎.
9. Browse to the `/Applications/Ti/simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground` directory, select `dummy-root-ca-cert`, choose **Open**, and then choose **Write**.
10. In the **File** selector pane, choose the **Add File** icon 🗎.
11. Browse to the working directory where you created the code-signing certificate and private key, choose `tisigner.crt.der`, choose **Open**, and then choose **Write**.
12. From the **Action** drop-down list, choose **Select MCU Image**, and then choose **Browse** to choose the firmware image to use write to your device (**aws_demos.bin**). This file is located in the `AmazonFreeRTOS/demos/ti/cc3200_launchpad/ccs/Debug` directory. Choose **Open**.

    a. In the file dialog box, confirm the file name is set to **mcuflashimg.bin**.

    b. Select the **Vendor** check box.

    c. Under **File Token**, type **`1952007250`**.

    d. Under **Private Key File Name**, choose **Browse** and then choose `tisigner.key` from the working directory where you created the code-signing certificate and private key.

    e. Under **Certification File Name**, choose `tisigner.crt.der`.

    f. Choose **Write**.
13. In the left pane, under **Files**, choose **Service Pack**.
14. Under **Service Pack File Name**, choose **Browse**, browse to `simplelink_cc32x_sdk_2_10_00_04/tools/cc32xx_tools/servicepack-cc3x20`, choose `sp_3.7.0.1_2.0.0.0_2.2.0.6.bin`, and then choose **Open**.
15. In the left pane, under **Files**, choose **Trusted Root-Certificate Catalog**.
16. Clear the **Use default Trusted Root-Certificate Catalog** check box.
17. Under **Source File**, choose **Browse**, choose **simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground\certcatalogPlayGround20160911.lst**, and then choose **Open**.
18. Under **Signature Source File**, choose **Browse**, choose **simplelink_cc32xx_sdk_2_10_00_04/tools/cc32xx_tools/certificate-playground\certcatalogPlayGround20160911.lst.signed.bin**, and then choose **Open**.

19. Choose the 💾 button to save your project.
20. Choose the 🔥 button.
21. Choose **Program Image (Create and Program)**.
22. After the programming process is complete, place the SOP jumper onto the first set of pins (position = 0), reset the board, and reconnect your terminal emulator to make sure the output is the same as when you debugged the demo with Code Composer Studio. Make a note of the application version number in the terminal output. You use this version number later to verify that your firmware has been updated by an OTA update.

    The terminal should display output like the following:

```
0 0 [Tmr Svc] Simple Link task created

Device came up in Station mode

1 369 [Tmr Svc] Starting key provisioning...
2 369 [Tmr Svc] Write root certificate...
3 467 [Tmr Svc] Write device private key...
4 568 [Tmr Svc] Write device certificate...
SL Disconnect...

5 664 [Tmr Svc] Key provisioning done...
Device came up in Station mode

Device disconnected from the AP on an ERROR..!!

[WLAN EVENT] STA Connected to the AP: Guest , BSSID: 11:22:a1:b2:c3:d4

[NETAPP EVENT] IP acquired by the device


Device has connected to Guest

Device IP Address is 111.222.3.44


6 1716 [OTA] OTA demo version 0.9.0
7 1717 [OTA] Creating MQTT Client...
8 1717 [OTA] Connecting to broker...
9 1717 [OTA] Sending command to MQTT task.
10 1717 [MQTT] Received message 10000 from queue.
11 2193 [MQTT] MQTT Connect was accepted. Connection established.
12 2193 [MQTT] Notifying task.
13 2194 [OTA] Command sent to MQTT task passed.
14 2194 [OTA] Connected to broker.
15 2196 [OTA Task] Sending command to MQTT task.
16 2196 [MQTT] Received message 20000 from queue.
17 2697 [MQTT] MQTT Subscribe was accepted. Subscribed.
18 2697 [MQTT] Notifying task.
19 2698 [OTA Task] Command sent to MQTT task passed.
20 2698 [OTA Task] [OTA] Subscribed to topic: $aws/things/TI-LaunchPad/jobs/$next/get/
accepted

21 2699 [OTA Task] Sending command to MQTT task.
22 2699 [MQTT] Received message 30000 from queue.
23 2800 [MQTT] MQTT Subscribe was accepted. Subscribed.
```

```
24 2800 [MQTT] Notifying task.
25 2801 [OTA Task] Command sent to MQTT task passed.
26 2801 [OTA Task] [OTA] Subscribed to topic: $aws/things/TI-LaunchPad/jobs/notify-next

27 2814 [OTA Task] [OTA] Check For Update #0
28 2814 [OTA Task] Sending command to MQTT task.
29 2814 [MQTT] Received message 40000 from queue.
30 2916 [MQTT] MQTT Publish was successful.
31 2916 [MQTT] Notifying task.
32 2917 [OTA Task] Command sent to MQTT task passed.
33 2917 [OTA Task] [OTA] Set job doc parameter [ clientToken: 0:TI-LaunchPad ]
34 2917 [OTA Task] [OTA] Missing job parameter: execution
35 2917 [OTA Task] [OTA] Missing job parameter: jobId
36 2918 [OTA Task] [OTA] Missing job parameter: jobDocument
37 2918 [OTA Task] [OTA] Missing job parameter: ts_ota
38 2918 [OTA Task] [OTA] Missing job parameter: files
39 2918 [OTA Task] [OTA] Missing job parameter: streamname
40 2918 [OTA Task] [OTA] Missing job parameter: certfile
41 2918 [OTA Task] [OTA] Missing job parameter: filepath
42 2918 [OTA Task] [OTA] Missing job parameter: filesize
43 2919 [OTA Task] [OTA] Missing job parameter: sig-sha1-rsa
44 2919 [OTA Task] [OTA] Missing job parameter: fileid
45 2919 [OTA Task] [OTA] Missing job parameter: attr
47 3919 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
48 4919 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
49 5919 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
```

Install the Initial Version of Firmware on the Microchip Curiosity PIC32MZEF

These steps are written with the assumption that you have already built the `aws_demos` project, as described in Download and Build Amazon FreeRTOS for the Microchip Curiosity PIC32MZEF (p. 118).

To burn the demo application onto your board

1. Rebuild the `aws_demos` project and make sure it compiles without errors.
2. On the tool bar, choose .
3. After the programming process is complete, disconnect the ICD 4 debugger and reset the board. Reconnect your terminal emulator to make sure the output is the same as when you debugged the demo with MPLAB X IDE.

   The terminal should display output similar to the following:

```
Bootloader version 00.09.00
[prvBOOT_Init] Watchdog timer initialized.
[prvBOOT_Init] Crypto initialized.

[prvValidateImage] Validating image at Bank : 0
[prvValidateImage] No application image or magic code present at: 0xbd000000
[prvBOOT_ValidateImages] Validation failed for image at 0xbd000000

[prvValidateImage] Validating image at Bank : 1
[prvValidateImage] No application image or magic code present at: 0xbd100000
[prvBOOT_ValidateImages] Validation failed for image at 0xbd100000

[prvBOOT_ValidateImages] Booting default image.


>0 36246 [IP-task] vDHCPProcess: offer ac140a0eip
```

```
                                                 1 36297 [IP-task] vDHCPProcess: offer
 ac140a0eip
                 2 36297 [IP-task]

IP Address: 172.20.10.14
3 36297 [IP-task] Subnet Mask: 255.255.255.240
4 36297 [IP-task] Gateway Address: 172.20.10.1
5 36297 [IP-task] DNS Server Address: 172.20.10.1


6 36299 [OTA] OTA demo version 0.9.2
7 36299 [OTA] Creating MQTT Client...
8 36299 [OTA] Connecting to broker...
9 38673 [OTA] Connected to broker.
10 38793 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/devthingota/
jobs/$next/get/accepted
11 38863 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/devthingota/
jobs/notify-next
12 38863 [OTA Task] [OTA_CheckForUpdate] Request #0
13 38964 [OTA] [OTA_AgentInit] Ready.
14 38973 [OTA Task] [prvParseJSONbyModel] Extracted parameter [ clientToken:
 0:devthingota ]
15 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: execution
16 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: jobId
17 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: jobDocument
18 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: streamname
19 38973 [OTA Task] [prvParseJSONbyModel] parameter not present: files
20 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: filepath
21 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: filesize
22 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: fileid
23 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: certfile
24 38975 [OTA Task] [prvParseJSONbyModel] parameter not present: sig-sha256-ecdsa
25 38975 [OTA Task] [prvParseJobDoc] Ignoring job without ID.
26 38975 [OTA Task] [prvOTA_Close] Context->0x8003b620
27 38975 [OTA Task] [prvPAL_Abort] Abort - OK
28 39964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
29 40964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
30 41964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
31 42964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
32 43964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
33 44964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
34 45964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
35 46964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
36 47964 [OTA] State: Ready  Received: 1   Queued: 1   Processed: 1   Dropped: 0
```

The following procedure creates a unified hex file or factory image consisting of a reference bootloader and an application with a cryptographic signature. The bootloader verifies the cryptographic signature of the application on boot and supports OTA updates.

To build and flash a factory image

1. Make sure you have the SRecord tools installed from Source Forge. Verify that the directory that contains the `srec_cat` and `srec_info` programs is in your system path.
2. Update the OTA sequence number and application version for the factory image.
3. Build the aws_demos project.
4. Run the factory_image_generator.py script to generate the factory image.

   ```
   factory_image_generator.py -b mplab.production.bin -p MCHP-Curiosity-PIC32MZEF -k
    private_key.pem  -x aws_bootloader.X.production.hex
   ```

   This command takes the following parameters:

- `mplab.production.bin`: The application binary.
- `MCHP-Curiosity-PIC32MZEF`: The platform name.
- `private_key.pem`: The code-signing private key.
- `aws_bootloader.X.production.hex`: The bootloader hex file.

When you build the aws_demos project, the application binary image and bootloader hex file are built as part of the process. Each project under the `demos/microchip/` directory contains a `dist/pic32mz_ef_curiosity/production/` directory that contains these files. The generated unified hex file is named `mplab.production.unified.factory.hex`.

5. Use the MPLab IPE tool to program the generated hex file onto the device.
6. You can check that your factory image works by watching the board's UART output as the image is uploaded. If everything is set up correctly, you should see the image boot successfully:

```
[prvValidateImage] Validating image at Bank : 0
[prvValidateImage] Valid magic code at: 0xbd000000
[prvValidateImage] Valid image flags: 0xfc at: 0xbd000000
[prvValidateImage] Addresses are valid.
[prvValidateImage] Crypto signature is valid.
[...]
[prvBOOT_ValidateImages] Booting image with sequence number 1 at 0xbd000000
```

7. If your certificates are incorrectly configured or if an OTA image is not properly signed, you might see messages like the following before the chip's bootloader erases the invalid update. Check that your code-signing certificates are consistent and review the previous steps carefully.

```
[prvValidateImage] Validating image at Bank : 0
[prvValidateImage] Valid magic code at: 0xbd000000
[prvValidateImage] Valid image flags: 0xfc at: 0xbd000000
[prvValidateImage] Addresses are valid.
[prvValidateImage] Crypto signature is not valid.
[prvBOOT_ValidateImages] Validation failed for image at 0xbd000000
[BOOT_FLASH_EraseBank] Bank erased at : 0xbd000000
```

Install the Initial Version of Firmware on the Espressif ESP32

This guide is written with the assumption that you have already performed the steps in Getting Started with the Espressif ESP32-DevKitC and the ESP-WROVER-KIT and Over-the-Air Update Prerequisites. Before you attempt an OTA update, you might want to run the MQTT demo project described in Getting Started with Amazon FreeRTOS to ensure that your board and toolchain are set up correctly.

To flash an initial factory image to the board

1. In `demos/common/demo_runner/aws_demo_runner.c`, in the `DEMO_RUNNER_RunDemos` function, comment out all functions calls except `vStartOTAUpdateDemoTask`.
2. With the OTA Update demo selected, follow the same steps outlined in Getting Started with ESP32 to build and flash the image. If you have previously built and flashed the project, you might need to run `make clean` first. After you run `make flash monitor`, you should see something like the following. The ordering of some messages might vary, because the demo application runs multiple tasks at once:

```
I (28) boot: ESP-IDF v3.1-dev-322-gf307f41-dirty 2nd stage bootloader
```

```
I (28) boot: compile time 16:32:33
I (29) boot: Enabling RNG early entropy source...
I (34) boot: SPI Speed : 40MHz
I (38) boot: SPI Mode : DIO
I (42) boot: SPI Flash Size : 4MB
I (46) boot: Partition Table:
I (50) boot: ## Label Usage Type ST Offset Length
I (57) boot: 0 nvs WiFi data 01 02 00010000 00006000
I (64) boot: 1 otadata OTA data 01 00 00016000 00002000
I (72) boot: 2 phy_init RF data 01 01 00018000 00001000
I (79) boot: 3 ota_0 OTA app 00 10 00020000 00100000
I (87) boot: 4 ota_1 OTA app 00 11 00120000 00100000
I (94) boot: 5 storage Unknown data 01 82 00220000 00010000
I (102) boot: End of partition table
I (106) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x14784 ( 83844)
 map
I (144) esp_image: segment 1: paddr=0x000347ac vaddr=0x3ffb0000 size=0x023ec ( 9196)
 load
I (148) esp_image: segment 2: paddr=0x00036ba0 vaddr=0x40080000 size=0x00400 ( 1024)
 load
I (151) esp_image: segment 3: paddr=0x00036fa8 vaddr=0x40080400 size=0x09068 ( 36968)
 load
I (175) esp_image: segment 4: paddr=0x00040018 vaddr=0x400d0018 size=0x719b8 (465336)
 map
I (337) esp_image: segment 5: paddr=0x000b19d8 vaddr=0x40089468 size=0x04934 ( 18740)
 load
I (345) esp_image: segment 6: paddr=0x000b6314 vaddr=0x400c0000 size=0x00000 ( 0) load
I (353) boot: Loaded app from partition at offset 0x20000
I (353) boot: ota rollback check done
I (354) boot: Disabling RNG early entropy source...
I (360) cpu_start: Pro cpu up.
I (363) cpu_start: Single core mode
I (368) heap_init: Initializing. RAM available for dynamic allocation:
I (375) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (381) heap_init: At 3FFC0748 len 0001F8B8 (126 KiB): DRAM
I (387) heap_init: At 3FFE0440 len 00003BC0 (14 KiB): D/IRAM
I (393) heap_init: At 3FFE4350 len 0001BCB0 (111 KiB): D/IRAM
I (400) heap_init: At 4008DD9C len 00012264 (72 KiB): IRAM
I (406) cpu_start: Pro cpu start user code
I (88) cpu_start: Starting scheduler on PRO CPU.
I (113) wifi: wifi firmware version: f79168c
I (113) wifi: config NVS flash: enabled
I (113) wifi: config nano formating: disabled
I (113) system_api: Base MAC address is not set, read default base MAC address from
 BLK0 of EFUSE
I (123) system_api: Base MAC address is not set, read default base MAC address from
 BLK0 of EFUSE
I (133) wifi: Init dynamic tx buffer num: 32
I (143) wifi: Init data frame dynamic rx buffer num: 32
I (143) wifi: Init management frame dynamic rx buffer num: 32
I (143) wifi: wifi driver task: 3ffc73ec, prio:23, stack:4096
I (153) wifi: Init static rx buffer num: 10
I (153) wifi: Init dynamic rx buffer num: 32
I (163) wifi: wifi power manager task: 0x3ffcc028 prio: 21 stack: 2560
0 6 [main] WiFi module initialized. Connecting to AP <Your_WiFi_SSID>...
I (233) phy: phy_version: 383.0, 79a622c, Jan 30 2018, 15:38:06, 0, 0
I (233) wifi: mode : sta (30:ae:a4:80:0a:04)
I (233) WIFI: SYSTEM_EVENT_STA_START
I (363) wifi: n:1 0, o:1 0, ap:255 255, sta:1 0, prof:1
I (1343) wifi: state: init -> auth (b0)
I (1343) wifi: state: auth -> assoc (0)
I (1353) wifi: state: assoc -> run (10)
I (1373) wifi: connected with <Your_WiFi_SSID>, channel 1
I (1373) WIFI: SYSTEM_EVENT_STA_CONNECTED
1 302 [IP-task] vDHCPProcess: offer c0a86c13ip
I (3123) event: sta ip: 192.168.108.19, mask: 255.255.224.0, gw: 192.168.96.1
```

```
I (3123) WIFI: SYSTEM_EVENT_STA_GOT_IP
2 302 [IP-task] vDHCPProcess: offer c0a86c13ip
3 303 [main] WiFi Connected to AP. Creating tasks which use network...
4 304 [OTA] OTA demo version 0.9.6
5 304 [OTA] Creating MQTT Client...
6 304 [OTA] Connecting to broker...
I (4353) wifi: pm start, type:0

I (8173) PKCS11: Initializing SPIFFS
I (8183) PKCS11: Partition size: total: 52961, used: 0
7 1277 [OTA] Connected to broker.
8 1280 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/
<Your_Thing_Name>/jobs/$next/get/accepted
I (12963) ota_pal: prvPAL_GetPlatformImageState
I (12963) esp_ota_ops: [0] aflags/seq:0x2/0x1, pflags/seq:0xffffffff/0x0
9 1285 [OTA Task] [prvSubscribeToJobNotificationTopics] OK: $aws/things/
<Your_Thing_Name>/jobs/notify-next
10 1286 [OTA Task] [OTA_CheckForUpdate] Request #0
11 1289 [OTA Task] [prvParseJSONbyModel] Extracted parameter [ clientToken:
 0:<Your_Thing_Name> ]
12 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: execution
13 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: jobId
14 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: jobDocument
15 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: afr_ota
16 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: streamname
17 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: files
18 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: filepath
19 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: filesize
20 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: fileid
21 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: certfile
22 1289 [OTA Task] [prvParseJSONbyModel] parameter not present: sig-sha256-ecdsa
23 1289 [OTA Task] [prvParseJobDoc] Ignoring job without ID.
24 1289 [OTA Task] [prvOTA_Close] Context->0x3ffbb4a8
25 1290 [OTA] [OTA_AgentInit] Ready.
26 1390 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
27 1490 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
28 1590 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
29 1690 [OTA] State: Ready Received: 1 Queued: 1 Processed: 1 Dropped: 0
[ ... ]
```

3. The ESP32 board is now listening for OTA updates. The ESP-IDF monitor is launched by the `make flash monitor` command. You can press Ctrl+] to quit. You can also use your favorite TTY terminal program (for example, PuTTY, Tera Term, or GNU Screen) to listen to the board's serial output; examples might include . Be aware that connecting to the board's serial port might cause it to reboot.

Initial Firmware on the Windows Simulator

When you use the Windows simulator, there is no need to flash an initial version of the firmware. The Windows simulator is part of the `aws_demos` application, which also includes the firmware.

Install the Initial Version of Firmware on a Custom Board

Using your IDE, build the `aws_demos` project, making sure to include the OTA library. For more information about the structure of the Amazon FreeRTOS source code, see Navigating the Demo Applications (p. 156).

Make sure to include your code-signing certificate, private key, and certificate trust chain either in the Amazon FreeRTOS project or on your device.

Using the appropriate tool, burn the application onto your board and make sure it is running correctly.

Update the Version of Your Firmware

The OTA agent included with Amazon FreeRTOS checks the version of any update and installs it only if it is more recent than the existing firmware version. The following steps show you how to increment the firmware version of the OTA demo application.

1. Open the `aws_demos` project in your IDE.
2. Open `demos/common/include/aws_application_version.h` and increment the `APP_VERSION_BUILD` token value.
3. If you are using the Microchip Curiosity PIC32MZEF, increment the OTA sequence number in `\demos\common\ota\bootloader\utility\user-config\ota-descriptor.config`. The OTA sequence number should be incremented for every new OTA image generated.
4. Rebuild the project.

You must copy your firmware update into the Amazon S3 bucket that you created as described in Create an Amazon S3 Bucket to Store Your Update (p. 109). The name of the file you need to copy to Amazon S3 depends on the hardware platform you are using:

- Texas Instruments CC3200SF-LAUNCHXL: `demos\ti\cc3220_launchpad\ccs\debug\aws_demos.bin`
- Microchip Curiosity PIC32MZEF: `demos\microchip\curiosity_pic32mzef\mplab\dist\pic32mz_ef_curiosity\production\mplab.production.ota.bin`
- Espressif ESP32: `demos/espressif/esp32_devkitc_esp_wrover_kit/make/build/aws_demos.bin`

Creating an OTA Update (AWS IoT Console)

1. In the navigation pane of the AWS IoT console, choose **Manage**, and then choose **Jobs**.
2. Choose **Create**.
3. Under **Create an Amazon FreeRTOS Over-the-Air (OTA) update job**, choose **Create OTA update job**.
4. You can deploy an OTA update to a single device or a group of devices. Under **Select devices to update**, choose **Select**. To update a single device, choose the **Things** tab. To update a group of devices, choose the **Thing Groups** tab.
5. If you are updating a single device, select the check box next to the IoT thing associated with your device. If you are updating a group of devices, select the check box next to the thing group associated with your devices. Choose **Next**.
6. Under **Select and sign your firmware image**, choose **Sign a new firmware image for me**.
7. Under **Code signing profile**, choose **Create**.
8. In **Create a code signing profile**, enter a name for your code-signing profile.

   a. Under **Device hardware platform**, choose your hardware platform.

      Note
      Only hardware platforms that have been qualified for Amazon FreeRTOS are displayed in this list. If you are using a non-qualified platform, you must use the CLI to create the OTA update. For more information, see Creating an OTA Update with the AWS CLI (p. 133).

   b. Under **Code signing certificate**, choose **Select** to select a previously imported certificate or **Import** to import a new certificate.

   c. Under **Pathname of code signing certificate on device**, enter the fully-qualified path name to the code-signing certificate on your device. This likely varies by platform.

> **Note**
> When running on the Microchip Curiosity PIC32MZEF, the code-signing certificate is first searched for in the certificate store by name. If not found, a built-in certificate is used.
>
> **Important**
> On the Texas Instruments CC3220SF-LAUNCHXL, do not include a leading slash character (**/**) in front of the file name if your code signing certificate exists in the root of the file system on this platform. Otherwise, the OTA update fails during authentication with a `file not found` error.

9. Under **Select your firmware image in S3 or upload it**, choose **Select**. A list of your Amazon S3 buckets is displayed. Choose the bucket that contains your firmware update, and then choose your firmware update in the bucket.

   > **Note**
   > The Microchip Curiosity PIC32MZEF demo projects produce two binary images with default names of `mplab.production.bin` and `mplab.production.ota.bin`. Use the second file when you upload an image for OTA updating.

10. Under **Pathname of firmware image on device**, enter the fully-qualified path name to the location where the firmware image will be copied onto your device. This location also varies by platform.

    > **Important**
    > On the Texas Instruments CC3220SF-LAUNCHXL, due to security restrictions, the firmware image path name must be `/sys/mcuflashimg.bin`.

11. Under **IAM role for OTA update job**, choose a role that allows access to your S3 bucket and has the following policies:
    - `AWSIoTThingsRegistration`
    - `AmazonFreeRTOSOTAUpdate`
12. Choose **Next**.
13. Under **Job type**, choose **Your job will complete after deploying to the selected devices/groups (snapshot)**.
14. Enter an ID and a description for your OTA update job and then choose **Create**.

To use a previously signed firmware image

1. Under **Select and sign your firmware image**, choose **Select a previously signed firmware image**.
2. Under **Pathname of firmware image on device**, enter the fully-qualified path name to the location where the firmware image will be copied onto your device. This might be different on different platforms.
3. Under **Previous code signing job**, choose **Select**, and then choose the previous code-signing job used to sign the firmware image you are using for the OTA update.

Using a custom signed firmware image

1. Under **Select and sign your firmware image**, choose **Use my custom signed firmware image**.
2. Under **Pathname of code signing certificate on device**, enter the fully-qualified path name to the code-signing certificate on your device. This might be different for different platforms.
3. Under **Pathname of firmware image on device**, enter the fully-qualified path name to the location where the firmware image will be copied onto your device. This might be different on different platforms.
4. Under **Signature**, paste your PEM format signature.
5. Under **Original hash algorithm**, choose the hash algorithm that was used when creating your file signature.

6. Under **Original encryption algorithm**, choose the algorithm that was used when creating your file signature.
7. Under **Select your firmware image in Amazon S3**, choose the Amazon S3 bucket and the signed firmware image in the Amazon S3 bucket.

After you have specified the code-signing information, specify the OTA update job type, service role, and an ID for your update.

> **Note**
> Do not use any personally identifiable information in the job ID for your OTA update. Examples of personally identifiable information include:
>
> - Your name.
> - Your IP address.
> - Your email address.
> - Your location.
> - Bank details.
> - Medical information.

1. Under **Job type**, choose **Your job will complete after deploying to the selected devices/groups (snapshot)**.
2. Under **IAM role for OTA update job**, choose your OTA service role.
3. Enter an alphanumeric ID for your job and then choose **Create**.

The job appears in the AWS IoT console with a status of **IN PROGRESS**.

> **Note**
> The AWS IoT console does not update the state of jobs automatically. Refresh your browser to see updates.

Connect your serial UART terminal to your device. You should see output that indicates the device is downloading the updated firmware.

After the device downloads the updated firmware, it restarts and then installs the firmware. You can see what's happening in the UART terminal.

For a complete walkthrough of how to use the console to create an OTA update, see OTA Demo Application (p. 168).

Creating an OTA Update with the AWS CLI

To create an OTA update with the AWS CLI you:

1. Digitally sign your firmware image.
2. Create a stream of your digitally signed firmware image.
3. Start an OTA update job.

Digitally Signing Your Firmware Update

When you use the CLI to perform OTA updates, you can use Code Signing for Amazon FreeRTOS or sign your firmware update yourself.

Signing Your Firmware Image with Code Signing for Amazon FreeRTOS

To sign your firmware image using Code Signing for Amazon FreeRTOS, you must install the Code Signing Tools. Download the tools and read the README file for installation instructions. For more information about Code Signing for Amazon FreeRTOS, see Code Signing for Amazon FreeRTOS.

After you install and configure the code signing tools, copy your unsigned firmware image to your Amazon S3 bucket and start a code signing job with the following CLI commands. The `put-signing-profile` command creates a reusable code-signing profile. The `start-signing-job` command starts the signing job.

```
aws signer put-signing-profile --profile-name <your_profile_name>
       --signing-material certificateArn=
       arn:aws:acm::<your-region>:<your-aws-account-id>:certificate/<your-certificate-id>
        --platform <your-hardware-platform> --signing-parameters
       certname=<your_certificate_path_on_device>
```

```
aws signer start-signing-job --source

 's3={bucketName=<your_s3_bucket>,key=<your_s3_object_key>,version=<your_s3_object_version_id>}'
        --destination 's3={bucketName=<your_destination_bucket>}' --profile-name
       <your_profile_name>
```

> **Note**
> *`<your-source-bucket-name>`* and *`<your-destination-bucket-name>`* can be the same Amazon S3 bucket.

The following text describes the parameters for the **start-signing-job** command:

`source`

Specifies the location of the unsigned firmware in an S3 bucket.

- `bucketName`: The name of your S3 bucket.
- `key`: The key (file name) of your firmware in your S3 bucket.
- `version`: The S3 version of your firmware in your S3 bucket. This is different from your firmware version. You can find it by browsing to the Amazon S3 console, choosing your bucket, and on the top of the page, next to **Versions**, choosing **Show**.

`destination`

The destination for the signed firmware in an S3 bucket. The format of this parameter is the same as the `source` parameter.

`signing-material`

The ARN of your code-signing certificate. This ARN is generated when you import your certificate into ACM.

`signing-parameters`

A map of key-value pairs for signing. These can include any information that you want to use during signing.

`platform`

The `platformId` of the hardware platform to which you are distributing the OTA update.

To return a list of the available platforms and their `platformId` values, use the `aws signer list-signing-platforms` command.

The signing job starts and writes the signed firmware image into the destination Amazon S3 bucket. The file name for the signed firmware image is a GUID. You need this file name when you create a stream. You can find the generated file name by browsing to the Amazon S3 console and choosing your bucket. If you don't see a file with a GUID file name, refresh your browser.

The command displays a job ARN and a job ID. You need these values later on. For more information about Code Signing for Amazon FreeRTOS, see Code Signing for Amazon FreeRTOS.

Signing Your Firmware Image Manually

Digitally sign your firmware image and upload your signed firmware image into your Amazon S3 bucket.

Creating a Stream of Your Firmware Update

The OTA Update service sends updates over MQTT messages. To do this, you must create a stream that contains your signed firmware update. Create a JSON file (stream.json) that identifies your signed firmware image. The JSON file should contain the following:

```
[
 {
     "fileId":<your_file_id>,
  "s3Location":{
      "bucket":"<your_bucket_name>",
      "key":"<your_s3_object_key<"
  }
 }
]
```

The following list describes the attributes in the JSON file.

`fileId`

An arbitrary integer between 0 - 255 that identifies your firmware image.

`s3Location`

The bucket and key for the firmware to stream.

`bucket`

The Amazon S3 bucket where your unsigned firmware image is stored.

`key`

The file name of your signed firmware image in the Amazon S3 bucket. You can find this value in the Amazon S3 console by looking at the contents of your bucket. If you are using Code Signing for Amazon FreeRTOS, the file name is a GUID generated by Code Signing for Amazon FreeRTOS.

Use the `create-stream` CLI command to create a stream:

```
aws iot create-stream --stream-id <your_stream_id> --description <your_description> --files
 file://<stream.json> --role-arn <your_role_arn>
```

The following list describes the arguments for the `create-stream` CLI command.

`stream-id`

An arbitrary string to identify the stream.

`description`

An optional description of the stream.

`files`

One or more references to JSON files that contain data about firmware images to stream. The JSON file must contain the following attributes:

`fileId`

An arbitrary file ID.

`s3Location`

The bucket name where the signed firmware image is stored and the key (file name) of the signed firmware image.

`bucket`

The Amazon S3 bucket where the signed firmware image is stored.

`key`

The key (file name) of the signed firmware image. When you use Code Signing for Amazon FreeRTOS, this key is a GUID.

The following is an example stream.json file:

```
[
 {
  "fileId":123,
  "s3Location":{
   "bucket":"codesign-ota-bucket",
   "key":"48c67f3c-63bb-4f92-a98a-4ee0fbc2bef6"
  }
 }
]
```

`role-arn`

An IAM role that grants access to the Amazon S3 bucket

To find the Amazon S3 object key of your signed firmware image, use the `aws signer describe-signing-job --job-id` *`<my-job-id>`* command where `my-job-id` is the job ID displayed by the `create-signing-job` CLI command. The output of the `describe-signing-job` command contains the key of the signed firmware image.

```
... text deleted for brevity ...
 "signedObject": {
  "s3": {
   "bucketName": "ota-bucket",
   "key": "7309da2c-9111-48ac-8ee4-5a4262af4429"
  }
 }

... text deleted for brevity ...
```

Creating an OTA Update

Use the `create-ota-update` CLI command to create an OTA update job:

```
aws iot create-ota-update --ota-update-id "<my_ota_update>" --target-selection SNAPSHOT
 --description "<a cli ota update>" --files file://<ota.json> --targets arn:aws:iot:<your-
aws-region>:<your-aws-account>:thing/<your-thing-name> --role-arn arn:aws:iam::<your-aws-
account>:role/<your-ota-service-role
```

Note

Do not use any personally identifiable information (PII) in your OTA update job ID. Examples of personally identifiable information include:

- Your name
- Your IP address
- Your email address
- Your location
- Bank details
- Medical information

`ota-update-id`

An arbitrary OTA update ID.

`target-selection`

Valid values are:

- `SNAPSHOT`: The job terminates after deploying the update to the selected IoT thing or groups.
- `CONTINUOUS`: The job continues to deploy updates to devices added to the selected groups.

`description`

A text description of the OTA update.

`files`

One or more references to JSON files that contain data about the OTA update. The JSON file can contain the following attributes:

- `fileName`: The fully-qualified firmware image file name. For Texas Instruments CC3200SF-LAUNCHXL, this must be `"/sys/mcuflashimg.bin"`. For Microchip, this must be `"mplab.production.bin"`
- `fileLocation`: Contains information about the firmware update.
  - `stream`: The stream that contains the firmware update.
    - `streamId`: The stream ID specified in the `create-stream` CLI command.
    - `fileId`: The file ID specified in the JSON file passed to `create-stream`.
  - `s3Location`: The location in Amazon S3 of the firmware update.
    - `bucket`: The Amazon S3 bucket that contains the firmware update.
    - `key`: The firmware update key.
    - `version`: The firmware update version.
- `codeSigning`: Contains information about the code-signing job.
  - `awsSignerJobId`: The signer job ID generated by the `start-siging-job` command.
  - `startSigningJobParamater`: The information required to start a code-signing job.
    - `signingProfileParameter`: The information required for creating a signing job profile.
      - `certificateArn`: The ACM ARN of the certificate used to create a code-signing job.
      - `platformId`: The ID of the hardware platform you are using.
      - `certificatePathOnDevice`: The path to the certificate on your device.
    - `signingProfileName`: The signing profile name. If a profile with this name does not exist, you must provide values for `signingProfileParameter`. If a profile with the specified name exists, and you provide values for `signingProfileParameter`, the values you provide must match exactly the values you used for the signing profile.
    - `destination`: The location where the signed artifact is placed.

        - `s3Destination`: The Amazon S3 bucket where the signed artifact is placed.
            - `bucket`: The Amazon S3 bucket.
            - `prefix`: The prefix of the code-signing artifact. By default, this is `signedImage/`. This creates a folder called `signedImage` under your folder.
- `customCodeSigning`: Contains information about a custom signature.
    - `signature`: Contains a custom signature.
        - `inlineDocument`: The custom signature.
    - `certificateChain`: Contains a certificate chain for a custom signature.
        - `certificateName`: The path name of the code-signing certificate on the device.
        - `inlineDocument`: The certificate chain.
    - `hashAlgorithm`: The hash algorithm used to create the signature.
    - `signatureAlgorithm`: The signature algorithm used for code signing.
- `attributes`: Arbitrary key/value pairs.

`targets`

One or more IoT thing ARNs that specify the devices to be updated by the OTA update.

`role-arn`

The ARN of your service role.

The following is an example of a JSON file passed into the **create-ota-update** command that uses Code Signing for Amazon FreeRTOS :

```
[
 {
     "fileName": "firmware.bin",
     "fileLocation": {
         "stream": {
             "streamId": "004",
             "fileId":123
         }
     },
     "codeSigning": {
         "awsSignerJobId": "48c67f3c-63bb-4f92-a98a-4ee0fbc2bef6"
     }
 }
]
```

The following is an example of a JSON file passed into the **create-ota-update** CLI command that uses an inline file to provide custom code-signing material:

```
[
 {
     "fileName": "firmware.bin",
     "fileLocation": {
         "stream": {
             "streamId": "004",
             "fileId": 123
         }
     },
     "codeSigning": {
         "customCodeSigning":{
             "signature":{
                 "inlineDocument":"<your_signature>"
             },
             "certificateChain": {
              "certificateName": "<your_certificate_name>
                 "inlineDocument":"<your_certificate_chain>"
             },
             "hashAlgorithm":"<your_hash_algorithm>",
             "signatureAlgorithm":"<your_signature_algorithm>"
         }
     }
 }
]
```

The following is an example of a JSON file passed into the **create-ota-update** CLI command that allows Amazon FreeRTOS OTA to start a code-signing job and create a code-signing profile and stream:

```
[
 {
  "fileName": "<your_firmware_path_on_device>",
  "fileVersion": "1",
  "fileLocation": {
   "s3Location": {
    "bucket": "<your_bucket_name>>",
    "key": "<your_object_key>",
    "version": "<your_S3_object_version>"
   }
  },
  "codeSigning":{
   "startSigningJobParameter":{
    "signingProfileName": "myTestProfile",
    "signingProfileParameter": {
     "certificateArn": "<your_certificate_arn>",
     "platformId": "<your_platform_id>",
     "certificatePathOnDevice": "<certificate_path>"
    },
    "destination": {
     "s3Destination": {
      "bucket": "<your_destination_bucket>"
     }
    }
   }
  }
 }
]
```

The following is an example of a JSON file passed into the **create-ota-update** CLI command that creates an OTA update that starts a code signing job with an existing profile and uses the specified stream:

```
[
 {
 "fileName": "<your_firmware_path_on_device>",
  "fileVersion": "1",
  "fileLocation": {
   "s3Location": {
    "bucket": "<your_bucket_name>",
    "key": "<your_object_key>",
    "version": "<your_S3_object_version>"
   }
  },
  "codeSigning":{
   "startSigningJobParameter":{
    "signingProfileName": "<your_unique_profile_name>",
    "destination": {
     "s3Destination": {
      "bucket": "<our_destination_bucket>"
     }
    }
   }
  }
 }
]
```

The following is an example of a JSON file passed into the **create-ota-update** CLI command that allows Amazon FreeRTOS OTA to create a stream with an existing code-signing job ID:

```
[
 {
  "fileName": "<your_firmware_path_on_device>",
  "fileVersion": "1"
  "codeSigning":{
   "awsSignerJobId": "<your_signer_job_id>"
  }
 }
]
```

The following is an example of a JSON file passed into the **create-ota-update** CLI command that creates an OTA update. The update creates a stream from the specified S3 object and uses custom code signing:

```
[
 {
  "fileName": "<your_firmware_path_on_device>",
  "fileVersion": "1",
  "fileLocation": {
   "s3Location": {
    "bucket": "<your_bucket_name>>",
    "key": "<your_object_key>",
    "version": "<your_S3_object_version>"
   }
  },
  "codeSigning":{
   "customCodeSigning": {
    "signature":{
     "inlineDocument":"<your_signature>>"
    },
    "certificateChain": {
     "inlineDocument":"<your_certificate_chain>",
     "certificateName": "<your_certificate_path_on_device>"
    },
    "hashAlgorithm":"<your_hash_algorithm>",
    "signatureAlgorithm":"<your_sig_algorithm>"
   }
  }
 }
]
```

You can use the **get-ota-update** CLI command to get the status of an OTA update:

```
aws iot get-ota-update --ota-update-id <your-ota-update-id>
```

This command returns one of the following values:

`CREATE_PENDING`

The creation of an OTA update is pending.

`CREATE_IN_PROGRESS`

An OTA update is being created.

`CREATE_COMPLETE`

An OTA update has been created.

`CREATE_FAILED`

The creation of an OTA update failed.

`DELETE_IN_PROGRESS`

An OTA update is being deleted.

`DELETE_FAILED`

The deletion of an OTA update failed.

Listing OTA Updates

You can use the **list-ota-updates** CLI command to get a list of all OTA updates by :

```
aws iot list-ota-updates
```

The output from the **list-ota-updates** command looks like this:

```
{
    "otaUpdates": [

        {
            "otaUpdateId": "my_ota_update2",
            "otaUpdateArn": "arn:aws:iot:us-west-2:123456789012:otaupdate/my_ota_update2",
            "creationDate": 1522778769.042
        },
        {
            "otaUpdateId": "my_ota_update1",
            "otaUpdateArn": "arn:aws:iot:us-west-2:123456789012:otaupdate/my_ota_update1",
            "creationDate": 1522775938.956
        },
        {
            "otaUpdateId": "my_ota_update",
            "otaUpdateArn": "arn:aws:iot:us-west-2:123456789012:otaupdate/my_ota_update",
            "creationDate": 1522775151.031
        }
    ]
}
```

Getting Information About an OTA Update

You can use the **get-ota-update** CLI command to get information about a specific OTA update:

```
aws iot get-ota-update --ota-update-id <my-ota-update-id>
```

The output from the **get-ota-update** command looks like this:

```
{
    "otaUpdateInfo": {
        "otaUpdateId": "myotaupdate1",
        "otaUpdateArn":
        "arn:aws:iot:us-west-2:123456789012:otaupdate/my_ota_update",
        "creationDate": 1522444438.424,
        "lastModifiedDate": 1522444440.681,
        "description": "a test OTA update",
        "targets": [
            "arn:aws:iot:us-west-2:123456789012:thing/myDevice"
        ],
        "targetSelection": "SNAPSHOT",
        "otaUpdateFiles": [
            {
                "fileName": "app.bin",
                "fileLocation": {
                 "stream": {
                     "streamId": "003",
                     "fileId": 123
                 }
                }

                "codeSigning": {
                    "awsSignerJobId": "592932bb-24a1-4f91-8ddd-66145352ad19",
                    "customCodeSigning": {}
                }
            }
        ],
        "otaUpdateStatus": "CREATE_COMPLETE",
        "awsIotJobId": "f76da3c0_10eb_41df_9029_ba7abc20f609",
        "awsIotJobArn": "arn:aws:iot:us-
west-2:123456789012:job/f76da3c0_10eb_41df_9029_ba7abc20f609"
    }
}
```

Deleting OTA-Related Data

Currently, you cannot use the AWS IoT console to delete streams or OTA updates. You can use the AWS CLI to delete streams, OTA updates, and the IoT jobs created during an OTA update.

Deleting an OTA Stream

When you create an OTA update either you or the AWS IoT console creates a stream to break the firmware up into chunks so it can be sent over MQTT. You can delete this stream with the `delete-stream` CLI command. For example:

```
aws iot delete-stream --stream-id <your_stream_id>
```

Deleting an OTA Update

When you create an OTA update, these things are created:

- An entry in the OTA update job database.
- An AWS IoT job to perform the update.
- An AWS IoT job execution for each device being updated.

The **delete-ota-update** command deletes the entry in the OTA update job database only. You must use the **delete-job** command to delete the AWS IoT job.

Use the **delete-ota-update** command to delete an OTA update:

```
aws iot delete-ota-update --ota-update-id <your_ota_update_id>
```

`ota-update-id`

The ID of the OTA update to delete.

`delete-stream`

Deletes the stream associated with the OTA update.

`force-delete-aws-job`

Deletes the AWS IoT job associated with the OTA update. If this flag is not set and the job is in the `In_Progress` state, the job is not deleted.

Deleting an IoT Job Created for an OTA Update

Amazon FreeRTOS creates an AWS IoT job when you create an OTA update. A job execution is also created for each device that processes the job. You can use the **delete-job** CLI command to delete a job and its associated job executions:

```
aws iot delete-job --job-id <your-job-id --no-force
```

The `no-force` parameter specifies that only jobs that are in a terminal state (COMPLETED or CANCELLED) can be deleted. You can delete a job that is in a non-terminal state by passing the `force` parameter. For more information, see DeleteJob API.

Note
Deleting a job with a status of IN_PROGRESS interrupts any job executions that are IN_PROGRESS on your devices and can result in a device being left in a nondeterministic state. Make sure that each device executing a job that has been deleted can recover to a known state.

Depending on the number of job executions created for the job and other factors, a few minutes to delete a job. While the job is being deleted, the status of the job appears as DELETION_IN_PROGRESS. Attempting to delete or cancel a job whose status is already DELETION_IN_PROGRESS results in an error.

You can use the **delete-job-execution** to delete a job execution. You might want to delete a job execution when a small number of devices are unable to process a job. This deletes the job execution for a single device. For example:

```
aws iot delete-job-execution --job-id <your-job-id --thing-name
     <your-thing-name> --execution-number
 <your-job-execution-number --no-force
```

As with the **delete-job** CLI command, you can pass the `--force` parameter to the **delete-job-execution** to force the deletion of an execution job execution. For more information , see DeleteJobExecution API.

Note
Deleting a job execution with a status of IN_PROGRESS interrupts any job executions that are IN_PROGRESS on your devices and can result in a device being left in a nondeterministic state. Make sure that each device executing a job that has been deleted is able to recover to a known state.

For more information about using the OTA update demo application, see OTA Demo Application (p. 168).

OTA Update Manager Service

The OTA Update Manager service provides a way to:

- Create an OTA update.
- Get information about an OTA update.
- List all OTA updates associated with your AWS account.

- Delete an OTA update.

An OTA update is a data structure maintained by the OTA Update Manager service. It contains:

- An OTA update ID.
- An optional OTA update description.
- A list of devices to update (*targets*).
- The type of OTA update: CONTINUOUS or SNAPSHOT.
- A list of files to send to the target devices.
- An IAM role that allows access to the AWS IoT Jobs service.
- An optional list of user-defined name-value pairs.

OTA updates were designed to be used to update device firmware, but you can use them to send any files you want to one or more devices registered with AWS IoT. When you send files over the air, it is best practice to digitally sign them so the devices that receive the files can verify they have not been tampered with en route. You can sign your files with Code Signing for Amazon FreeRTOS or you can use your own code-signing tools.

After your files have been digitally signed, you use the Amazon Streaming service to create a stream. The service breaks up your files into blocks that can be sent over MQTT to your devices.

When you create an OTA update, the OTA Manager service creates an AWS IoT job to notify your devices an update is available. The Amazon FreeRTOS OTA agent runs on your devices and listens for update messages. When an update is available, it streams the update over MQTT and stores the files locally. It checks the digital signature of the downloaded files and if valid, installs the firmware update. If you are not using Amazon FreeRTOS, you must implement your own OTA agent to listen for and download updates and perform any installation operations.

Integrating the OTA Agent into Your Application

The OTA agent is designed to simplify the amount of code you must write to add OTA update functionality to your product. That integration burden consists primarily of initialization of the OTA agent and, optionally, creating a custom callback function for responding to the OTA completion event messages.

> **Note**
> Although the integration of the OTA update feature into your application is rather simple, the OTA update system requires an understanding of more than just device code integration. To familiarize yourself with how to configure your AWS account with AWS IoT things, credentials, code-signing certificates, provisioning devices, and OTA update jobs, see Amazon FreeRTOS Prerequisites.

MQTT Connection Management

The OTA agent uses the MQTT protocol for all of its communication with AWS IoT services, but it does not manage the MQTT connection. To assure that the OTA agent does not interfere with the connection management policy of your application, the MQTT connection, including disconnect and any reconnect functionality, must be handled by the main “user” application.

Simple OTA Demo

The following is an excerpt of a simple OTA demo that shows how the agent connects to the MQTT broker and initializes the OTA agent. In this example, we configure the demo to use the default OTA completion callback and simply print out some statistics once per second. For brevity, we leave out some details from this demo.

For a working example that uses the AWS IoT MQTT broker, see the OTA demo code.

Because the OTA agent is its own task, the intentional one-second delay in this example affects this application only. It has no impact on the performance of the agent.

```
/* Create the MQTT Client. */
if( MQTT_AGENT_Create( &( xMQTT_h ) ) == eMQTTAgentSuccess )
{
    for ( ; ; )
    {
        memset( &xConnParm, 0, sizeof( xConnParm ) );

        /* ... Set MQTT connection parameters here per your application needs ... */

        configPRINTF( ( "Connecting to %s\r\n", clientcredentialMQTT_BROKER_ENDPOINT ) );
        if( MQTT_AGENT_Connect( xMQTT_h, &( xConnParm ),
 myappMAX_AWS_CONNECT_WAIT_IN_TICKS ) == eMQTTAgentSuccess )
        {
      configPRINTF( ( "Connected to broker.\r\n" ) );

      /* Initialize the OTA Agent with the default completion callback handler. */
      OTA_AgentInit( xMQTT_h, ( const uint8_t * ) ( clientcredentialIOT_THING_NAME ), NULL,
  /* NULL uses the default
      callback handler. */ ( TickType_t ) ~0 );

            while( ( eState = OTA_GetAgentState() ) != eOTA_AgentState_NotReady )
            {
                /* Wait forever for OTA traffic but allow other tasks to run
                   and output statistics only once per second. */

                vTaskDelay( myappONE_SECOND_DELAY_IN_TICKS );
                configPRINTF( ( "State: %s  Received: %u   Queued: %u   Processed: %u
 Dropped: %u\r\n",
                    pcStateStr[eState],
                    OTA_GetPacketsReceived(),
                    OTA_GetPacketsQueued(),
                    OTA_GetPacketsProcessed(),
                    OTA_GetPacketsDropped() ) );
            }
            /* ... Handle MQTT disconnect per your application needs ... */
        }
        else
        {
            configPRINTF( ( "ERROR:  MQTT_AGENT_Connect() Failed.\r\n" ) );
        }
        /* After failure to connect or a disconnect, wait an arbitrary one second before
 retry. */
        vTaskDelay( myappONE_SECOND_DELAY_IN_TICKS );
    }
}
else
{
    configPRINTF( ( "Failed to create MQTT client.\r\n" ) );
}
```

Here is the high-level flow of this demo application:

- Create an MQTT agent context.
- Connect to your AWS IoT endpoint.
- Initialize the OTA agent.

- Loop allowing an OTA update job and output statistics once a second.
- If the agent stops, wait one second and try connecting again.

Using a Custom Callback for OTA Completion Events

The previous example used the built-in callback handler for OTA completion events by specifying `NULL` for the third parameter to the `OTA_AgentInit` API. If you want to implement custom handling of the completion events, you must pass the function address of your callback handler to the `OTA_AgentInit` API. During the OTA process, the agent can send one of the following event enums to the callback handler. It is up to the application developer to decide how and when to handle these events.

```
/**
* @brief OTA Job callback events.
*
* After an OTA update image is received and authenticated, the agent calls the user
* callback (set with the OTA_AgentInit API) with the value eOTA_JobEvent_Activate to
* signal that the device must be rebooted to activate the new image. When the device
* boots, if the OTA job status is in self test mode, the agent calls the user callback
* with the value eOTA_JobEvent_StartTest, signaling that any additional self tests
* should be performed.
*
* If the OTA receive fails for any reason, the agent calls the user callback with
* the value eOTA_JobEvent_Fail instead to allow the user to log the failure and take
* any action deemed appropriate by the user code.
*
*/
typedef enum {
 eOTA_JobEvent_Activate,  /*! OTA receive is authenticated and ready to activate. */
 eOTA_JobEvent_Fail,      /*! OTA receive failed. Unable to use this update. */
 eOTA_JobEvent_StartTest  /*! OTA job is now in self test, perform user tests. */
} OTA_JobEvent_t;
```

The OTA agent can receive an update in the background during active processing of the main application. The purpose of delivering these events is to allow the application to decide if action can be taken immediately or if it should be deferred until after completion of some other application-specific processing. This prevents an unanticipated interruption of your device during active processing (for example, vacuuming) that would be caused by a reset after a firmware update. These are the job events received by the callback handler:

eOTA_JobEvent_Activate event

> When this event is received by the callback handler, you can either reset the device immediately or schedule a call to reset the device later. This allows you to postpone the device reset and self-test, if necessary.

eOTA_JobEvent_Fail event

> When this event is received by the callback handler, the update has failed. You do not need to do anything in this case. You might want to output a log message or do something application-specific.

eOTA_JobEvent_StartTest event

> The self test phase is meant to allow newly updated firmware to execute and test itself before determining that it is properly functioning and commit it to be the latest permanent application image. When a new update is received and authenticated and the device has been reset, the OTA agent will send the eOTA_JobEvent_StartTest event to the callback function when it is ready for testing. The developer may choose to add any tests deemed required to determine if the device firmware is functioning properly after update. When the device firmware is deemed reliable by the self tests, the code must commit the firmware as the new permanent image by calling the OTA_SetImageState(eOTA_ImageState_Accepted) function.

If your device has no special hardware or mechanisms that need to be tested, you can use the default callback handler. Upon receipt of the eOTA_JobEvent_Activate event, the default handler resets the device immediately.

OTA Security

The following are three aspects of OTA security:

Connection security

> The OTA Update Manager relies on existing security mechanisms, like TLS mutual authentication, used by AWS IoT. OTA update traffic passes through the AWS IoT device gateway and uses AWS IoT security mechanisms. Each incoming and outgoing MQTT message through the device gateway undergoes strict authentication and authorization.

Authenticity and integrity of OTA updates

> Firmware can be digitally signed before an OTA update to ensure that it is from a reliable source and has not been tampered with. The Amazon FreeRTOS OTA Update Manager uses the Code Signing for Amazon FreeRTOS to automatically sign your firmware. For more information, see Code Signing for Amazon FreeRTOS. The OTA agent, which runs on your devices, performs integrity checks on the firmware when it arrives on the device.

Operator security

> Every API call made through the control plane API undergoes standard IAM Signature Version 4 authentication and authorization. To create a deployment, you must have permissions to invoke the `CreateDeployment`, `CreateJob`, and `CreateStream` APIs. In addition, in your Amazon S3 bucket policy or ACL, you must give read permissions to the AWS IoT service principal so that the firmware update stored in Amazon S3 can be accessed during streaming.

Code Signing for Amazon FreeRTOS

The AWS IoT console uses Code Signing for Amazon FreeRTOS to automatically sign your firmware image for any device supported by AWS IoT.

Code Signing for Amazon FreeRTOS uses a certificate and private key that you import into ACM. You can use a self–signed certificate for testing, but we recommend that you obtain a certificate from a well–known commercial certificate authority (CA).

Code–signing certificates use the X.509 version 3 **Key Usage** and **Extended Key Usage** extensions. The **Key Usage** extension is set to `Digital Signature` and the **Extended Key Usage** extension is set to `Code Signing`. For more information about signing your code image, see the Code Signing for Amazon FreeRTOS Developer Guide and the Code Signing for Amazon FreeRTOS API Reference.

> **Note**
> You can download the Code Signing for Amazon FreeRTOS SDK from https://tools.signer.aws.a2z.com/awssigner-tools-v2.zip.

OTA Troubleshooting

The following sections contain information to help you troubleshoot issues with OTA updates.

Topics

Setting Up Cloudwatch Logs for OTA Updates

The OTA Update service supports logging with Amazon CloudWatch. You can use the AWS IoT console to enable and configure Amazon CloudWatch logging for OTA updates. For more information about CloudWatch Logs, see Cloudwatch Logs.

To enable logging, you must create an IAM role and configure OTA update logging.

> **Note**
> Before you enable OTA update logging, make sure you understand the CloudWatch Logs access permissions. Users with access to CloudWatch Logs can see your debugging information. For information, see Authentication and Access Control for Amazon CloudWatch Logs.

Create a Logging Role and Enable Logging

Use the AWS IoT console to create a logging role and enable logging.

1. From the navigation pane, choose **Settings**.
2. Under **Logs**, choose **Edit**.
3. Under **Level of verbosity**, choose **Debug**.
4. Under **Set role**, choose **Create new** to create an IAM role for logging.
5. Under **Name**, enter a unique name for your role. Your role will be created with all required permissions.
6. Choose **Update**.

OTA Update Logs

The OTA Update service publishes logs to your account when one of the following occurs:

- An OTA update is created.
- An OTA update is completed.
- A code-signing job is created.
- A code-signing job is completed.
- An AWS IoT job is created.
- An AWS IoT job is completed.
- A stream is created.

You can view your logs in the CloudWatch console.

To view an OTA Update in CloudWatch Logs

1. From the navigation pane, choose **Logs**.
2. In **Log Groups**, choose **AWSIoTLogsV2**.

OTA update logs can contain the following properties:

accountId

The AWS account ID in which the log was generated.

actionType

The action that generated the log. This can be set to one of the following values:

- CreateOTAUpdate: An OTA update was created.
- DeleteOTAUpdate: An OTA update was deleted.
- StartCodeSigning: A code-signing job was started.
- CreateAWSJob: An AWS IoT job was created.
- CreateStream: A stream was created.
- GetStream: A request for a stream was sent to the AWS IoT Streaming service.
- DescribeStream: A request for information about a stream was sent to the AWS IoT Streaming service.

awsJobId

The AWS IoT job ID that generated the log.

clientId

The MQTT client ID that made the request that generated the log.

clientToken

The client token associated with the request that generated the log.

details

Additional information about the operation that generated the log.

logLevel

The logging level of the log. For OTA update logs, this is always set to DEBUG.

otaUpdateId

The ID of the OTA update that generated the log.

protocol

The protocol used to make the request that generated the log.

status

The status of the operation that generated the log. Valid values are:

- Success
- Failure

streamId

The AWS IoT stream ID that generated the log.

timestamp

The time when the log was generated.

topicName

An MQTT topic used to make the request that generated the log.

Example Logs

The following is an example log generated when a code-signing job is started:

```
{
    "timestamp": "2018-07-23 22:59:44.955",
    "logLevel": "DEBUG",
    "accountId": "875157236366",
    "status": "Success",
    "actionType": "StartCodeSigning",
    "otaUpdateId": "08957b03-eea3-448a-87fe-743e6891ca3a",
    "details": "Start code signing job. The request status is SUCCESS."
}
```

The following is an example log generated when an AWS IoT job is created:

```

{
    "timestamp": "2018-07-23 22:59:45.363",
    "logLevel": "DEBUG",
    "accountId": "123456789012",
    "status": "Success",
    "actionType": "CreateAWSJob",
    "otaUpdateId": "08957b03-eea3-448a-87fe-743e6891ca3a",
    "awsJobId": "08957b03-eea3-448a-87fe-743e6891ca3a",
    "details": "Create AWS Job The request status is SUCCESS."
}

```

The following is an example log generated when an OTA update is created:

```

{
    "timestamp": "2018-07-23 22:59:45.413",
    "logLevel": "DEBUG",
    "accountId": "123456789012",
    "status": "Success",
    "actionType": "CreateOTAUpdate",
    "otaUpdateId": "08957b03-eea3-448a-87fe-743e6891ca3a",
    "details": "OTAUpdate creation complete. The request status is SUCCESS."
}

```

The following is an example log generated when a stream is created:

```

{
 "timestamp": "2018-07-23 23:00:26.391",
 "logLevel": "DEBUG",
 "accountId": "123456789012",
 "status": "Success",
 "actionType": "CreateStream",
 "otaUpdateId": "3d3dc5f7-3d6d-47ac-9252-45821ac7cfb0",
 "streamId": "6be2303d-3637-48f0-ace9-0b87b1b9a824",
 "details": "Create stream. The request status is SUCCESS."
}
```

The following is an example log generated when an OTA update is deleted:

```

{
 "timestamp": "2018-07-23 23:03:09.505",
 "logLevel": "DEBUG",
 "accountId": "123456789012",
 "status": "Success",
 "actionType": "DeleteOTAUpdate",
 "otaUpdateId": "9bdd78fb-f113-4001-9675-1b595982292f",
 "details": "Delete OTA Update. The request status is SUCCESS."
}
```

The following is an example log generated when a device requests a stream from the streaming service:

```
{
 "timestamp": "2018-07-25 22:09:02.678",
 "logLevel": "DEBUG",
 "accountId": "123456789012",
 "status": "Success",
 "actionType": "GetStream",
 "protocol": "MQTT",
 "clientId": "b9d2e49c-94fe-4ed1-9b07-286afed7e4c8",
 "topicName": "$aws/things/b9d2e49c-94fe-4ed1-9b07-286afed7e4c8/streams/1e51e9a8-9a4c-4c50-
b005-d38452a956af/get/json",
 "streamId": "1e51e9a8-9a4c-4c50-b005-d38452a956af",
 "details": "The request status is SUCCESS."
}
```

The following is an example log generated when a device calls the `DescribeStream` API:

```
{
 "timestamp": "2018-07-25 22:10:12.690",
 "logLevel": "DEBUG",
 "accountId": "123456789012",
 "status": "Success",
 "actionType": "DescribeStream",
 "protocol": "MQTT",
 "clientId": "581075e0-4639-48ee-8b94-2cf304168e43",
 "topicName": "$aws/things/581075e0-4639-48ee-8b94-2cf304168e43/streams/71c101a8-
bcc5-4929-9fe2-af563af0c139/describe/json",
 "streamId": "71c101a8-bcc5-4929-9fe2-af563af0c139",
 "clientToken": "clientToken",
 "details": "The request status is SUCCESS."
}
```

Logging AWS IoT OTA API Calls with AWS CloudTrail

Amazon FreeRTOS is integrated with CloudTrail, a service that captures all of the AWS IoT OTA API calls and delivers the log files to an Amazon S3 bucket that you specify. CloudTrail captures API calls from your code to the AWS IoT OTA APIs. Using the information collected by CloudTrail, you can determine the request that was made to AWS IoT OTA, the source IP address from which the request was made, who made the request, when it was made, and so on.

To learn more about CloudTrail, including how to configure and enable it, see the *AWS CloudTrail User Guide*.

Amazon FreeRTOS Information in CloudTrail

When CloudTrail logging is enabled in your AWS account, most API calls made to AWS IoT OTA actions are tracked in CloudTrail log files where they are written with other AWS service records. CloudTrail determines when to create and write to a new file based on a time period and file size.

> **Note**
> AWS IoT OTA data plane actions (device side) are not logged by CloudTrail. Use CloudWatch to monitor these.

AWS IoT OTA control plane actions are logged by CloudTrail. For example, calls to the CreateOTAUpdate, GetOTAUpdate, and CreateStream sections generate entries in the CloudTrail log files.

Every log entry contains information about who generated the request. The user identity information in the log entry helps you determine the following:

- Whether the request was made with root or IAM user credentials.
- Whether the request was made with temporary security credentials for a role or federated user.
- Whether the request was made by another AWS service.

For more information, see the CloudTrail userIdentity Element. AWS OTA IoT actions are documented in the AWS IoT OTA API Reference.

You can store your log files in your Amazon S3 bucket for as long as you want, but you can also define Amazon S3 lifecycle rules to archive or delete log files automatically. By default, your log files are encrypted with Amazon S3 server-side encryption (SSE).

If you want to be notified upon log file delivery, you can configure CloudTrail to publish Amazon SNS notifications when new log files are delivered. For more information, see Configuring Amazon SNS Notifications for CloudTrail.

You can also aggregate AWS IoT OTA log files from multiple AWS regions and multiple AWS accounts into a single Amazon S3 bucket.

For more information, see Receiving CloudTrail Log Files from Multiple Regions and Receiving CloudTrail Log Files from Multiple Accounts.

Understanding Amazon FreeRTOS Log File Entries

CloudTrail log files can contain one or more log entries. Each entry lists multiple JSON-formatted events. A log entry represents a single request from any source and includes information about the requested action, the date and time of the action, request parameters, and so on. Log entries are not an ordered stack trace of the public API calls, so they do not appear in any specific order.

The following example shows a CloudTrail log entry that demonstrates the log from a call to `CreateOTAUpdate` action.

```
{
 "eventVersion": "1.05",
 "userIdentity": {
  "type": "IAMUser",
  "principalId": "EXAMPLE",
  "arn": "arn:aws:iam::<your_aws_account>:user/<your_user_id>",
  "accountId": "<your_aws_account>",
  "accessKeyId": "<your_access_key_id>",
  "userName": "<your_username>",
  "sessionContext": {
   "attributes": {
    "mfaAuthenticated": "false",
    "creationDate": "2018-08-23T17:27:08Z"
   }
  },
  "invokedBy": "apigateway.amazonaws.com"
 },
 "eventTime": "2018-08-23T17:27:19Z",
 "eventSource": "iot.amazonaws.com",
 "eventName": "CreateOTAUpdate",
 "awsRegion": "<your_aws_region>",
 "sourceIPAddress": "apigateway.amazonaws.com",
 "userAgent": "apigateway.amazonaws.com",
 "requestParameters": {
  "targets": [
   "arn:aws:iot:<your_aws_region>:<your_aws_account>:thing/Thing_CMH"
  ],
  "roleArn": "arn:aws:iam::<your_aws_account>:role/Role_FreeRTOSJob",
  "files": [
   {
    "fileName": "/sys/mcuflashimg.bin",
    "fileSource": {
     "fileId": 0,
     "streamId": "<your_stream_id>"
    },
    "codeSigning": {
     "awsSignerJobId": "<your_signer_job_id>"
    }
   }
  ],
  "targetSelection": "SNAPSHOT",
  "otaUpdateId": "FreeRTOSJob_CMH-23-1535045232806-92"
 },
 "responseElements": {
  "otaUpdateArn": "arn:aws:iot:<your_aws_region>:<your_aws_account>:otaupdate/
FreeRTOSJob_CMH-23-1535045232806-92",
  "otaUpdateStatus": "CREATE_PENDING",
  "otaUpdateId": "FreeRTOSJob_CMH-23-1535045232806-92"
 },
 "requestID": "c9649630-a6f9-11e8-8f9c-e1cf2d0c9d8e",
 "eventID": "ce9bf4d9-5770-4cee-acf4-0e5649b845c0",
 "eventType": "AwsApiCall",
 "recipientAccountId": "<recipient_aws_account>"
}
```

Troubleshooting OTA Updates with the Texas Instruments CC3220SF Launchpad

The CC3220SF Launchpad platform provides a software tamper detection mechanism that uses a security-alert counter that is incremented whenever there is an integrity violation. The device is locked when the security-alert counter reaches a pre-determined threshold (the default is 15) and the host receives the asynchronous event `SL_ERROR_DEVICE_LOCKED_SECURITY_ALERT`. The locked device will then have limited accessibility. To recover the device, you can reprogram it or use the “restore-to-factory” process to revert to the factory image. You should program the desired behavior by updating the asynchronous event handler in “network_if.c”. For more information, see Texas Instruments SimpleLink CC3120, CC3220 Wi-Fi Internet-on-a-chip Solution Built-In Security Features Application Report.

Amazon FreeRTOS Console User Guide

Managing Amazon FreeRTOS Configurations

You can use the Amazon FreeRTOS console to manage software configurations and download Amazon FreeRTOS software for your device. The Amazon FreeRTOS software is prequalified on a variety of platforms. It includes the required hardware drivers, libraries, and example projects to help get you started quickly. You can choose between predefined configurations or create custom configurations.

Predefined Amazon FreeRTOS Configurations

Predefined configurations are defined for the prequalified platforms:

- TI CC3220SF-LAUNCHXL
- STM32 IoT Discovery Kit

- NXP LPC54018 IoT Module
- Microchip Curiosity PIC32MZEF
- Espressif ESP32-DevKitC
- Espressif ESP3-WROVER-KIT
- Infineon XMC4800 IoT Connectivity Kit
- Xilinx Avnet MicroZed Industrial IoT Starter Kit
- FreeRTOS Windows Simulator

The predefined configurations make it possible for you to get started quickly with the supported use cases without thinking about which libraries are required. To use a predefined configuration, browse to the Amazon FreeRTOS console, find the configuration you want to use, and then choose **Download**.

You can also customize a predefined configuration if you want to change the Amazon FreeRTOS version, hardware platform, or libraries of the configuration. Customizing a predefined configuration creates a new custom configuration and does not overwrite the predefined configuration in the Amazon FreeRTOS console.

To create a custom configuration from a predefined configuration

1. Browse to the Amazon FreeRTOS console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose the ellipsis next to the predefined configuration that you want to customize, and then choose **Customize**.
5. On the **Configure Amazon FreeRTOS Software** page, choose the Amazon FreeRTOS version, hardware platform, and libraries, and give the new configuration a name and a description.
6. At the bottom of the page, choose **Create and download** to create and download the custom configuration.

Custom Amazon FreeRTOS Configurations

Custom configurations allow you to specify your hardware platform, integrated development platform (IDE), compiler, and only those RTOS libraries you require. This leaves more space on your devices for application code.

To create a custom configuration

1. Browse to the Amazon FreeRTOS console and choose **Create new**.
2. Select the version of Amazon FreeRTOS that you want to use. The latest version is used by default.
3. On the **New Software Configuration** page, choose **Select a hardware platform**, and choose one of the prequalified platforms.
4. Choose the IDE and compiler you want use.
5. For the Amazon FreeRTOS libraries you require, choose **Add Library**. If you choose a library that requires another library, it is added for you. If you want to choose more libraries, choose **Add another library**.
6. In the **Demo Projects** section, enable one of the demo projects. This enables the demo in the project files.
7. In **Name required**, enter a name for your custom configuration.

   Note
   Do not use any personally identifiable information in your custom configuration name.
8. In **Description**, enter a description for your custom configuration.

9. At the bottom of the page, choose **Create and download** to create and download your custom configuration.

To edit a custom configuration

1. Browse to the Amazon FreeRTOS console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose the ellipsis next to the configuration you want to edit, and then choose **Edit**.
5. On the **Configure Amazon FreeRTOS Software** page, you can change your configuration's Amazon FreeRTOS version, hardware platform, libraries, and description.
6. At the bottom of the page, choose **Save and download** to save and download the configuration.

To delete a custom configuration

1. Browse to the Amazon FreeRTOS console.
2. In the navigation pane, choose **Software**.
3. Under **Amazon FreeRTOS Device Software**, choose **Configure download**.
4. Choose the ellipsis next to the configuration you want to delete, and then choose **Delete**.

Amazon FreeRTOS Demo Projects

This section contains resources that are useful after you have a basic understanding of Amazon FreeRTOS. If you haven't already, we recommend that you first read the Getting Started with Amazon FreeRTOS (p. 4).

Topics

Navigating the Demo Applications

This section contains information about directory and file organization and configuration files for the demos.

Directory and File Organization

There are two subfolders in the main Amazon FreeRTOS directory:

- `demos`

  Contains example code that can be run on an Amazon FreeRTOS device to demonstrate Amazon FreeRTOS functionality. There is one subdirectory for each target platform selected. These subdirectories contain code used by the demos, but not all demos can be run independently. If you use the Amazon FreeRTOS console, only the target platform you choose has a subdirectory under `demos`.

  The function `DEMO_RUNNER_RunDemos()` located in `AmazonFreeRTOS\demos\common\demo_runner\aws_demo_runner.c` contains code that calls each example. By default, only the `vStartMQTTEchoDemo()` function is called. Depending on the configuration you selected when you downloaded the code, or whether you obtained the code from GitHub, the other example runner functions are either commented out or omitted entirely. Although you can change the selection of demos here, be aware that not all combinations of examples work together. Depending on the combination, the software might not be able to be executed on the selected target due to memory constraints. All of the examples that can be executed by Amazon FreeRTOS appear in the common directory under `demos`.
- `lib`

  The `lib` directory contains the source code of the Amazon FreeRTOS libraries. These libraries are available to you as part of Amazon FreeRTOS:
  - MQTT
  - Device shadow
  - Greengrass
  - Wi-Fi

There are helper functions that assist in implementing the library functionality. We do not recommend that you change these helper functions. If you need to change one of these libraries, make sure it conforms to the library interface defined in the `libs/include` directory.

Configuration Files

The demos have been configured to get you started quickly. You might want to change some of the configurations for your project to create a version that runs on your platform. You can find configuration files at `AmazonFreeRTOS/<vendor>/<platform>/common/config_files`.

The configuration files include:

`aws_bufferpool.h`

Configures the size and quantity of static buffers available for use by the application.

`aws_clientcredential_keys.h`

Configures your device certificate and private key.

`aws_demo_config.h`

Configures the task parameters used in the demos: stack size, priorities, and so on.

`aws_ggd_config.h`

Configures the parameters used to configure a Greengrass core, such as network interface IDs.

`aws_mqtt_agent_config.h`

Configures the parameters related to MQTT operations, such as task priorities, MQTT brokers, and keep-alive counts.

`aws_mqtt_library.h`

Configures MQTT library parameters, such as the subscription length and the maximum number of subscriptions.

`aws_secure_sockets_config.h`

Configures the timeouts and the byte ordering when using SSL.

`aws_shadow_configure.h`

Configures the parameters used for an AWS IoT shadow, such as the number of JSMN tokens used when parsing a JSON file received from a shadow.

`aws_clientcredential.h`

Configures parameters, including the Wi-Fi (SSID, password, and security type), the MQTT broker endpoint, and IoT thing name.

`FreeRTOSConfig.h`

Configures the FreeRTOS kernel for multitasking operations.

Bluetooth Low Energy Demo Applications (Beta)

> The Bluetooth Low Energy (BLE) Library is in public beta release for Amazon FreeRTOS and is subject to change.

Overview

Amazon FreeRTOS BLE includes three demo applications:

MQTT over BLE (p. 160) Demo

This application demonstrates how to use the MQTT over BLE service.

Wi-Fi Provisioning (p. 162) Demo

This application demonstrates how to use the Wi-Fi Provisioning service.

Generic Attributes Server (p. 164) Demo

This application demonstrates how to use the Amazon FreeRTOS BLE middleware APIs to create a simple GATT server.

Prerequisites

To follow along with these demos, you need a microcontroller with Bluetooth Low Energy capabilities.

Before you begin, do the following:

Set Up AWS IoT

To set up AWS IoT, you need to do the following:

- Set up an AWS account.
- Register your device as an AWS IoT thing.
- Download your AWS IoT credentials.

For more information about setting up AWS IoT, see the AWS IoT Developer Guide.

Set Up Amazon Cognito

To set up Amazon Cognito, you need to do the following:

- Set up an AWS account.
- Create an Amazon Cognito user pool.
- Create an Amazon Cognito identity pool.
- Attach an IAM policy to the authenticated identity.

For more information about setting up Amazon Cognito, see the Amazon Cognito Developer Guide.

Set Up Your Environment

To set up your enviroment, do the following:

- Set up your microcontroller's environment with Amazon FreeRTOS and the Amazon FreeRTOS BLE library. You can download Amazon FreeRTOS from GitHub.

For information about getting started with Amazon FreeRTOS on an Amazon FreeRTOS-qualified microcontroller, see information for your board in Getting Started with Amazon FreeRTOS.

> **Note**
> You can run the demos on any BLE-enabled microcontroller with Amazon FreeRTOS and ported Amazon FreeRTOS BLE libraries. Currently, the Amazon FreeRTOS MQTT over BLE (p. 160) demo project is fully ported to the following BLE-enabled devices:
>
> - STMicroelectronics STM32L4 Discovery Kit IoT Node, with the STBTLE-1S BLE module
> - Espressif ESP32-DevKitC and the ESP-WROVER-KIT
> - Nordic nRF52840-DK

- Install the Amazon FreeRTOS BLE Mobile SDK Demo Application (p. 159) on your Android or iOS device. The demo application is a common component of the demos.

  For information about installing the demo app, see the GitHub README files for the Amazon FreeRTOS BLE Mobile SDK for Android or the Amazon FreeRTOS BLE Mobile SDK for iOS.

Common Components

The Amazon FreeRTOS demo applications have two common components:

- Network Manager
- BLE Mobile SDK demo application

Network Manager

Network Manager manages your microcontroller's network connection. It is located in your Amazon FreeRTOS directory at `\demos\common\network_manager\aws_iot_network_manager.c`. If the network manager is enabled for both Wi-Fi and BLE, the demos start with BLE by default. If the BLE connection is disrupted, and your board is Wi-Fi-enabled, the Network Manager switches to an available Wi-Fi connection to prevent you from disconnecting from the network.

To enable a network connection type with the Network Manager, add the network connection type to the `configENABLED_NETWORKS` parameter in `demos/`*`vendor`*`/`*`board`*`/common/config_files/aws_iot_network_config.h`. For example, if you have both BLE and Wi-Fi enabled, the line that starts with `#define configENABLED_NETWORKS` in `aws_iot_network_config.h` reads as follows:

```
#define  configENABLED_NETWORKS  ( AWSIOT_NETWORK_TYPE_BLE | AWSIOT_NETWORK_TYPE_WIFI )
```

To get a list of currently supported network connection types, see `lib\include\aws_iot_network_manager.h`.

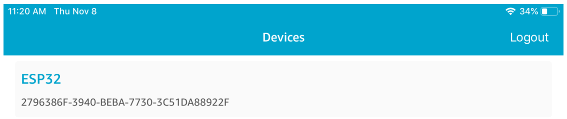
Amazon FreeRTOS BLE Mobile SDK Demo Application

Each demo uses the Amazon FreeRTOS BLE Mobile SDK demo application, which can be found in the BLE Android SDK or the BLE iOS SDK under `FreeRTOSDemo/Examples`. In this example, we use the iOS version of the demo mobile application.

To discover and establish secure connections with your microcontroller across BLE with the demo mobile application, for each demo, do the following:

1. Run the MQTT over BLE (p. 160), Wi-Fi Provisioning (p. 162), or Generic Attributes Server (p. 164) demo on your microcontroller.
2. Start the BLE mobile SDK demo application on your mobile device.

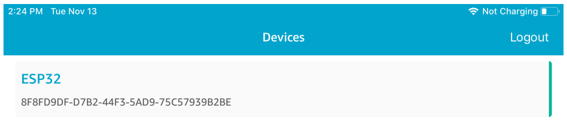
3. Confirm that your microcontroller appears under **Devices** on the BLE mobile SDK demo app.



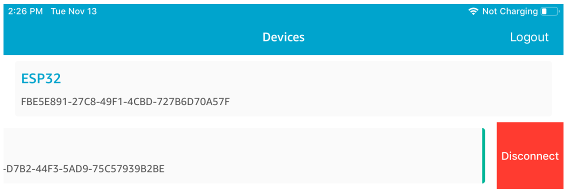
Note

Only devices with Amazon FreeRTOS and the device information service (`\lib\bluetooth_low_energy\services\device_information`) appear in the list.

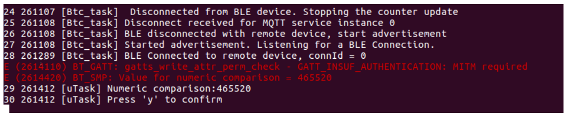
4. Choose your microcontroller from the list of devices. The application establishes a connection with the board, and a green line appears next to the connected device.



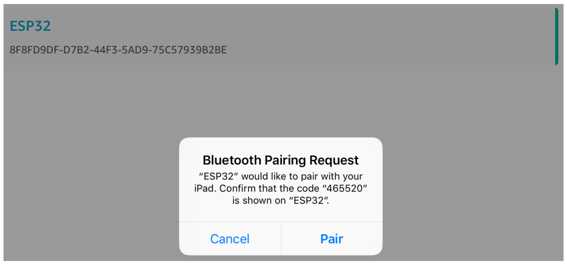
You can disconnect from your microntroller by dragging the line to the left.


2:26 PM Tue Nov 13
Not Charging
Devices
Logout
ESP32
FBE5E891-27C8-49F1-4CBD-727B6D70A57F
-D7B2-44F3-5AD9-75C57939B2BE
Disconnect

5. You might be prompted to pair your microcontroller and mobile device.



```
24 261107 [Btc_task]  Disconnected from BLE device. Stopping the counter update
25 261108 [Btc_task] Disconnect received for MQTT service instance 0
26 261108 [Btc_task] BLE disconnected with remote device, start advertisement
27 261108 [Btc_task] Started advertisement. Listening for a BLE Connection.
28 261289 [Btc_task] BLE Connected to remote device, connId = 0
E (2614110) BT_GATT: gatts_write_attr_perm_check - GATT_INSUF_AUTHENTICATION: MITM required
E (2614420) BT_SMP: Value for numeric comparison = 465520
29 261412 [uTask] Numeric comparison:465520
30 261412 [uTask] Press 'y' to confirm
```



Bluetooth Pairing Request

“ESP32” would like to pair with your iPad. Confirm that the code “465520” is shown on “ESP32”.

If the code for numeric comparison is the same on both devices, pair the devices.

Note

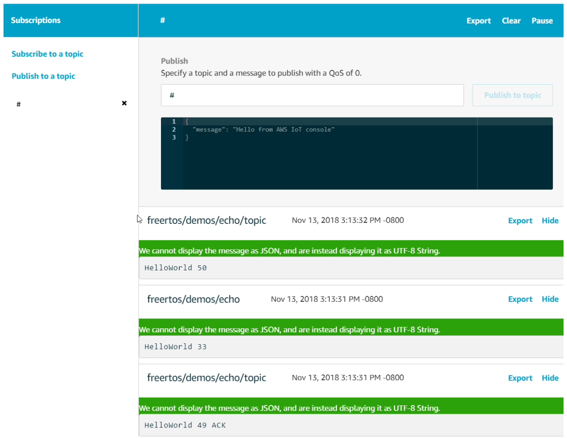
The BLE Mobile SDK demo application uses Amazon Cognito for user authentication. Make sure that you have set up a Amazon Cognito user and identity pools, and that you have attached IAM policies to authenticated identities.

MQTT over BLE

In the MQTT over BLE demo, your microcontroller publishes messages to the AWS IoT cloud through an MQTT proxy.

To subscribe to a demo MQTT topic

1. Sign in to the AWS IoT console.
2. In the navigation pane, choose **Test** to open the MQTT client.
3. In **Subscription topic**, enter **`freertos/demos/echo`**, and then choose **Subscribe to topic**.



Publish
Specify a topic and a message to publish with a QoS of 0.

#

```
{
  "message": "Hello from AWS IoT console"
}
```

freertos/demos/echo/topic Nov 13, 2018 3:13:32 PM -0800

We cannot display the message as JSON, and are instead displaying it as UTF-8 String.

```
HelloWorld 50
```

freertos/demos/echo Nov 13, 2018 3:13:31 PM -0800

We cannot display the message as JSON, and are instead displaying it as UTF-8 String.

```
HelloWorld 33
```

freertos/demos/echo/topic Nov 13, 2018 3:13:31 PM -0800

We cannot display the message as JSON, and are instead displaying it as UTF-8 String.

```
HelloWorld 49 ACK
```

You can run the MQTT demo across a BLE or Wi-Fi connection. The configuration of the Network Manager (p. 159) determines which connection type is used.

If you use BLE to pair the microcontroller with your mobile device, the MQTT messages are routed through the BLE mobile SDK demo application on your mobile device.

If you use Wi-Fi, the demo is the same as the MQTT Hello World demo project located in `demos/`*`vendor`*`/`*`board`*`/ide`. That demo is used in most of the Getting Started with Amazon FreeRTOS demo projects.

To enable the demo

If you have already enabled the demo by following the instructions in the getting started guide for your device, you can skip these instructions.

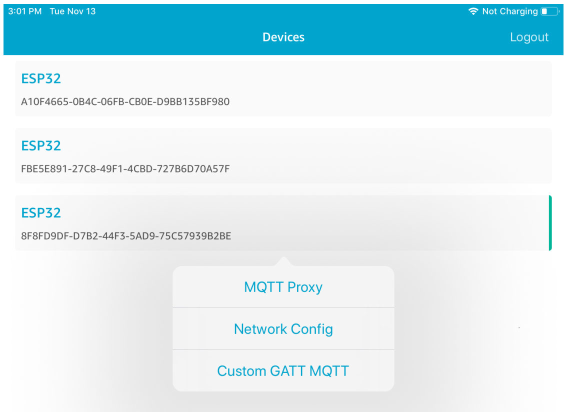
1. Confirm that the MQTT over BLE and Wi-Fi Provisioning services are enabled in `lib\utils\aws_ble_services_init.c`. The services are enabled by default.
2. Open `demos\common\demo_runner\aws_demo_runner.c`, and in the demo declarations, uncomment `extern void vStartMQTTBLEEchoDemo( void );`. In the `DEMO_RUNNER_RunDemos` definition, uncomment `vStartMQTTBLEEchoDemo();`.

To run the demo

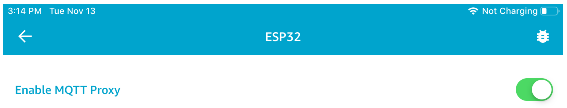
If the Network Manager is configured for Wi-Fi only, simply build and run the demo project on your board.

If the Network Manager is configured for BLE, do the following:

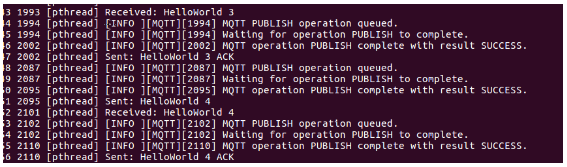
1. Build and run the demo project on your microcontroller.
2. Make sure that you have paired your board and your mobile device using the Amazon FreeRTOS BLE Mobile SDK Demo Application (p. 159).
3. From the **Devices**list in the demo mobile app, choose your microcontroller, and then choose **MQTT Proxy** to open the MQTT proxy settings.


3:01 PM Tue Nov 13
Not Charging
Devices
Logout
ESP32
A10F4665-0B4C-06FB-CB0E-D9BB135BF980
ESP32
FBE5E891-27C8-49F1-4CBD-727B6D70A57F
ESP32
8F8FD9DF-D7B2-44F3-5AD9-75C57939B2BE
MQTT Proxy
Network Config
Custom GATT MQTT

4. Touch **Enable MQTT proxy** to enable the MQTT proxy. The slider should turn green.



After you enable the MQTT proxy, MQTT messages appear on the `freertos/demos/echo` topic, and data is printed to the UART terminal.



```
3 1993 [pthread] Received: HelloWorld 3
4 1994 [pthread] [INFO ][MQTT][1994] MQTT PUBLISH operation queued.
5 1994 [pthread] [INFO ][MQTT][1994] Waiting for operation PUBLISH to complete.
6 2002 [pthread] [INFO ][MQTT][2002] MQTT operation PUBLISH complete with result SUCCESS.
7 2002 [pthread] Sent: HelloWorld 3 ACK
8 2087 [pthread] [INFO ][MQTT][2087] MQTT PUBLISH operation queued.
9 2087 [pthread] [INFO ][MQTT][2087] Waiting for operation PUBLISH to complete.
0 2095 [pthread] [INFO ][MQTT][2095] MQTT operation PUBLISH complete with result SUCCESS.
1 2095 [pthread] Sent: HelloWorld 4
2 2101 [pthread] Received: HelloWorld 4
3 2102 [pthread] [INFO ][MQTT][2102] MQTT PUBLISH operation queued.
4 2102 [pthread] [INFO ][MQTT][2102] Waiting for operation PUBLISH to complete.
5 2110 [pthread] [INFO ][MQTT][2110] MQTT operation PUBLISH complete with result SUCCESS.
6 2110 [pthread] Sent: HelloWorld 4 ACK
```

Wi-Fi Provisioning

Wi-Fi Provisioning is an Amazon FreeRTOS BLE service that allows you to securely send Wi-Fi network credentials from a mobile device to a microcontroller over BLE. The source code for the Wi-Fi Provisioning service can be found at `lib/bluetooth_low_energy/services/wifi_provisioning`.

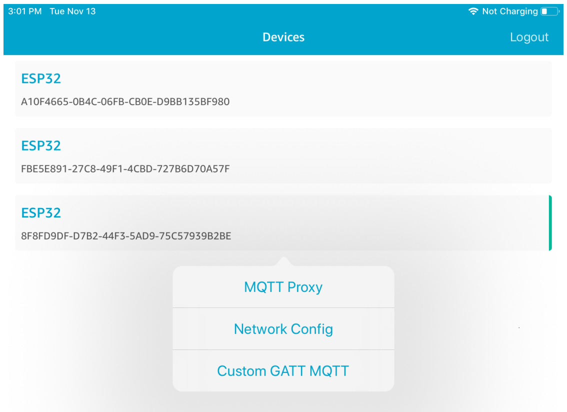
> **Note**
> The Wi-Fi provisioning demo is currently supported on the Espressif ESP32-DevKitC.
> The Android version of the demo mobile application does not currently support Wi-Fi Provisioning.

To enable the demo

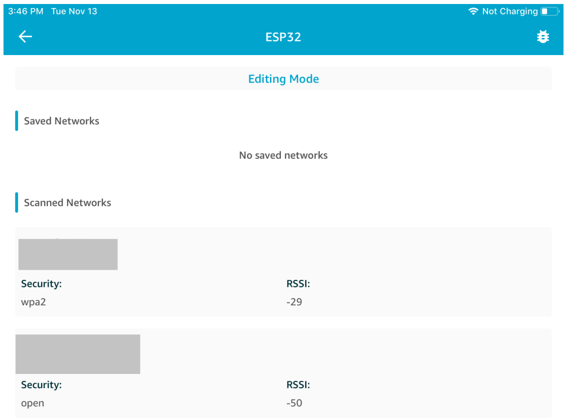
1. Confirm that the Wi-Fi Provisioning service is enabled in the `lib\utils\aws_ble_services_init.c` file. The service is enabled by default.
2. Configure the Network Manager (p. 159) to enable both BLE and Wi-Fi.

To run the demo

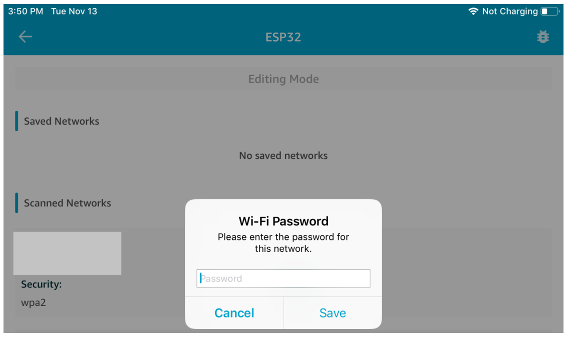
1. Build and run the demo project on your microcontroller.
2. Make sure that you have paired your microntroller and your mobile device using the Amazon FreeRTOS BLE Mobile SDK Demo Application (p. 159).
3. From the **Devices** list in the demo mobile app, choose your microcontoller, and then choose **Network Config** to open the network configuration settings.


3:01 PM Tue Nov 13
Not Charging
Devices
Logout
ESP32
A10F4665-0B4C-06FB-CB0E-D9BB135BF980
ESP32
FBE5E891-27C8-49F1-4CBD-727B6D70A57F
ESP32
8F8FD9DF-D7B2-44F3-5AD9-75C57939B2BE
MQTT Proxy
Network Config
Custom GATT MQTT

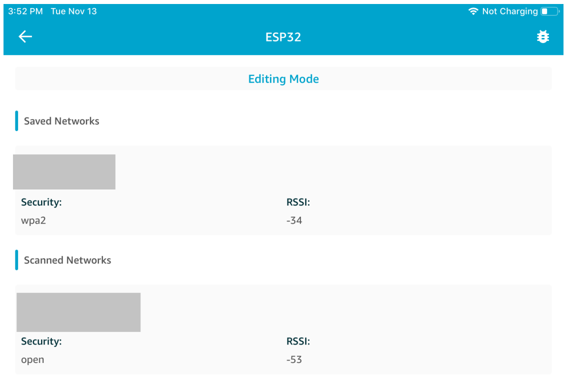
4. After you choose **Network Config** for your board, the microcontroller sends a list of the networks in the vicinity to the mobile device. Available Wi-Fi networks appear in a list under **Scanned Networks**.



From the **Scanned Networks** list, choose your network, and then enter the SSID and password, if required.



The micrcontroller connects to and saves the network. The network appears under the **Saved Networks**.



3:52 PM Tue Nov 13 Not Charging

ESP32

Editing Mode

Saved Networks

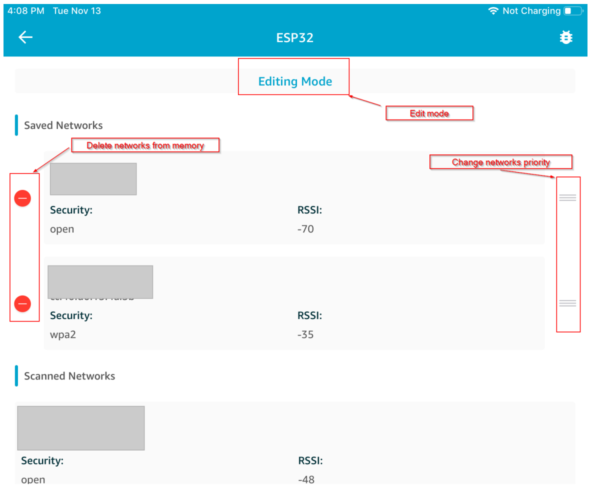
Security: wpa2 RSSI: -34

Scanned Networks

Security: open RSSI: -53

You can save several networks in the demo mobile app. When you restart the application and demo, the microcontroller connects to the first available saved network, starting from the top of the **Saved Networks** list.

To change the network priority order or delete networks, on the **Network Configuration** page, choose **Editing Mode**. To change the network priority order, choose the right side of the network that you want to reprioritize, and drag the network up or down. To delete a network, choose the red button on the left side of the network that you want to delete.



4:08 PM Tue Nov 13 Not Charging

ESP32

Editing Mode

Saved Networks

Security: open RSSI: -70

Security: wpa2 RSSI: -35

Scanned Networks

Security: open RSSI: -48

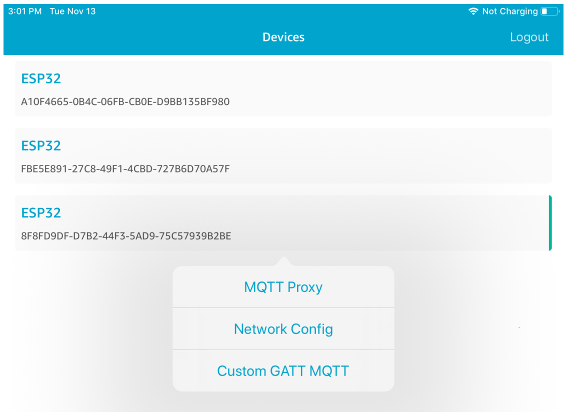
Generic Attributes Server

In this example, a demo Generic Attributes (GATT) server application on your microcontroller sends a simple counter value to the Amazon FreeRTOS BLE Mobile SDK Demo Application (p. 159) that is used for MQTT over BLE (p. 160) and Wi-Fi Provisioning (p. 162).

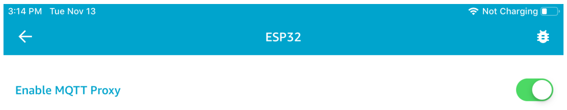
Using the BLE Mobile SDKs, you can create your own GATT client for a mobile device that connects to the GATT server on your microcontroller and runs in parallel with the demo mobile application.

To run the demo

1. Build and run the demo project on your microcontroller.
2. Make sure that you have paired your board and your mobile device using the Amazon FreeRTOS BLE Mobile SDK Demo Application (p. 159).
3. From the **Devices** list in the mobile SDK app, choose your board, and then choose **Custom GATT MQTT** to open the custom GATT service options.


3:01 PM Tue Nov 13
Not Charging
Devices
Logout
ESP32
A10F4665-0B4C-06FB-CB0E-D9BB135BF980
ESP32
FBE5E891-27C8-49F1-4CBD-727B6D70A57F
ESP32
8F8FD9DF-D7B2-44F3-5AD9-75C57939B2BE
MQTT Proxy
Network Config
Custom GATT MQTT

4. Touch **Enable MQTT proxy** to enable the MQTT proxy. The slider should turn green.
5. Choose **Start Counter** to start publishing data to the `freertos/demos/echo` MQTT topic.

   After you enable the MQTT proxy, Hello World and incrementing counter messages appear on the `freertos/demos/echo` topic.

Secure Sockets Echo Client Demo

The following example uses a single RTOS task. The source code for this example can be found at demos/common/tcp/aws_tcp_echo_client_single_task.c.

Before you begin, verify that you have downloaded Amazon FreeRTOS to your microcontroller and built and run the Amazon FreeRTOS demo projects. You can download Amazon FreeRTOS from GitHub. For more information about setting up an Amazon FreeRTOS-qualfied board, see Getting Started with Amazon FreeRTOS.

To run the demo

1. Follow the instructions in the "TLS Server Setup" section of the Amazon FreeRTOS Qualification Program Developer Guide to set up a TLS Echo Server.

   By the end of step 6, the TLS Echo Server should be running and listening on the port 9000. You do not need to complete steps 7, 8, and 9.

   During the setup, you should have generated four files:

   - `client.pem` (client certificate)
   - `client.key` (client private key)
   - `server.pem` (server certificate)
   - `server.key` (server private key)
2. Use the tool `tools\certificate_configuration\CertificateConfigurator.html` to copy the client certificate (`client.pem`) and client private key (`client.key`) to `aws_clientcredential_keys.h`.
3. Open the `FreeRTOSConfig.h` file.

4. Set the `configECHO_SERVER_ADDR0`, `configECHO_SERVER_ADDR1`, `configECHO_SERVER_ADDR2`, and `configECHO_SERVER_ADDR3` variables to the four integers that make up the IP address where the TLS Echo Server is running.
5. Set the `configTCP_ECHO_CLIENT_PORT` variable to `9000`, the port where the TLS Echo Server is listening.
6. Set the `configTCP_ECHO_TASKS_SINGLE_TASK_TLS_ENABLED` variable to `1`.
7. Use the tool `tools\certificate_configuration\PEMfiileToCString.html` to copy the server certificate (`server.pem`) to `cTlsECHO_SERVER_CERTIFICATE_PEM` in the file `aws_tcp_echo_client_single_task.c`.
8. In `demos/common/demo_runneraws_demo_runner.c`, switch the demo function to `vStartTCPEchoClientTasks_SingleTasks()`:

```
//extern void vStartMQTTEchoDemo( void );
extern void *vStartTCPEchoClientTasks_SingleTasks*( void );

/**
 * @brief Runs demos in the system.
 */
void DEMO_RUNNER_RunDemos( void )
{
    //vStartMQTTEchoDemo();
    vStartTCPEchoClientTasks_SingleTasks();
}
```

The microcontroller and the TLS Echo Server should be on the same network. When the demo starts (`main.c`), you should see a log message that reads `Received correct string from echo server`.

Device Shadow Demo Application

The device shadow example demonstrates how to programmatically update and respond to changes in a device shadow. The device in this scenario is a light bulb whose color can be set to red or green. The device shadow example app is located in the `AmazonFreeRTOS/demos/common/shadow` directory. This example creates three tasks:

- A main demo task that calls `prvShadowMainTask`.
- A device update task that calls `prvUpdateTask`.
- A number of shadow update tasks that call `prvShadowUpdateTasks`.

`prvShadowMainTask` initializes the device shadow client and initiates an MQTT connection to AWS IoT. It then creates the device update task. Finally, it creates shadow update tasks and then terminates. The `democonfigSHADOW_DEMO_NUM_TASKS` constant defined in `AmazonFreeRTOS/demos/common/shadow/aws_shadow_lightbulb_on_off.c` controls the number of shadow update tasks created.

`prvShadowUpdateTasks` generates an initial thing shadow document and updates the device shadow with the document. It then goes into an infinite loop that periodically updates the thing shadow's desired state, requesting the light bulb change its color (from red to green to red).

`prvUpdateTask` responds to changes in the device shadow's desired state. When the desired state changes, this task updates the reported state of the device shadow to reflect the new desired state.

1. Add the following policy to your device certificate:

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": "iot:Connect",
      "Resource": "arn:aws:iot:us-west-2:123456789012:client/<yourClientId>"
    },
    {
      "Effect": "Allow",
      "Action": "iot:Subscribe",
      "Resource": "arn:aws:iot:us-west-2:123456789012:topicfilter/$aws/things/
thingName/shadow/*"
    },
    {
      "Effect": "Allow",
      "Action": "iot:Receive",
      "Resource":
      "arn:aws:iot:us-west-2:123456789012:topic/$aws/things/thingName/shadow/*"
    },
    {
      "Effect": "Allow",
      "Action": "iot:Publish",
      "Resource":
      "arn:aws:iot:us-west-2:123456789012:topic/$aws/things/thingName/shadow/*"
    }
  ]
}
```

2. Uncomment the declaration of and call to `vStartShadowDemoTasks` in `aws_demo_runner.c`. This function creates a task that runs the `prvShadowMainTask` function.

You can use the AWS IoT console to view your device's shadow and confirm that its desired and reported states change periodically.

1. In the AWS IoT console, from the left navigation pane, choose **Manage**.
2. Under **Manage**, choose **Things**, and then choose the thing whose shadow you want to view.
3. On the thing detail page, from the left navigation pane, choose **Shadow** to display the thing shadow.

For more information about how devices and shadows interact, see Device Shadow Data Flow.

Greengrass Discovery Demo Application

Before you run the FreeRTOS Greengrass Discovery demo, you must create a Greengrass group and then add a Greengrass core. For more information, see Getting Started with AWS Greengrass.

After you have a core running the Greengrass software, create an AWS IoT thing, certificate, and policy for your Amazon FreeRTOS device. For more information, see Registering Your MCU Board with AWS IoT (p. 5).

After you have created an IoT thing for your Amazon FreeRTOS device, follow the instructions to set up your environment and build Amazon FreeRTOS on one of the supported devices:

> **Note**
> Use the Registering Your MCU Board with AWS IoT (p. 5) instructions, but instead of downloading one of the predefined Connect to AWS IoT- XX configurations (where XX is TI, ST, NXP, Microchip, or Windows), download one of the Connect to AWS IoT Greengrass - XX configurations (where XX is TI, ST, NXP, Microchip, or Windows). Follow the steps in "Configure Your Project." Return to this topic after you have built Amazon FreeRTOS for your device.

- Getting Started with the Texas Instruments CC3220SF-LAUNCHXL (p. 7)
- Getting Started with the STMicroelectronics STM32L4 Discovery Kit IoT Node (p. 13)
- Getting Started with the NXP LPC54018 IoT Module (p. 16)
- Getting Started with the Microchip Curiosity PIC32MZEF (p. 20)
- Getting Started with the Infineon XMC4800 IoT Connectivity Kit (p. 36)
- Getting Started with the FreeRTOS Windows Simulator (p. 52)

At this point, you have downloaded the Amazon FreeRTOS software, imported it into your IDE, and built the project without errors. The project is already configured to run the Greengrass Connectivity demo. In the AWS IoT console, choose **Test**, and then add a subscription to `freertos/demos/ggd`. The demo publishes a series of messages to the Greengrass core. The messages are also published to AWS IoT, where they are received by the AWS IoT MQTT client.

In the MQTT client, you should see the following strings:

```
Message from Thing to Greengrass Core: Hello world msg #1!
Message from Thing to Greengrass Core: Hello world msg #0!
Message from Thing to Greengrass Core: Address of Greengrass Core
 found! <123456789012>.<us-west-2>.compute.amazonaws.com
```

OTA Demo Application

Amazon FreeRTOS includes a demo application that demonstrates the use of the OTA library. The OTA demo application is located in the `demos\common\ota` subdirectory.

Before you create an OTA update, read Amazon FreeRTOS Over-the-Air Updates (p. 108) and complete all prerequisites listed there.

The OTA demo application:

1. Initializes the FreeRTOS network stack and MQTT buffer pool. (See `main.c`.)
2. Creates a task to exercise the OTA library. (See `vOTAUpdateDemoTask` in `aws_ota_update_demo.c`.)
3. Creates an MQTT client using `MQTT_AGENT_Create`.
4. Connects to the AWS IoT MQTT broker using `MQTT_AGENT_Connect`.
5. Calls `OTA_AgentInit` to create the OTA task and registers a callback to be used when the OTA task is complete.

You can use the AWS IoT console or the AWS CLI to create an OTA update job. After you have created an OTA update job, connect a terminal emulator to see the progress of the OTA update. Make a note of any errors generated during the process.

A successful OTA update job displays output like the following. Some lines in this example have been removed from the listing for brevity.

```
313 267848 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
314 268733 [OTA Task] [OTA] Set job doc parameter [ jobId:
 fe18c7ec_8c31_4438_b0b9_ad55acd95610 ]
315 268734 [OTA Task] [OTA] Set job doc parameter [ streamname: 327 ]
316 268734 [OTA Task] [OTA] Set job doc parameter [ filepath: /sys/mcuflashimg.bin ]
```

```
317 268734 [OTA Task] [OTA] Set job doc parameter [ filesize: 130388 ]
318 268735 [OTA Task] [OTA] Set job doc parameter [ fileid: 126 ]
319 268735 [OTA Task] [OTA] Set job doc parameter [ attr: 0 ]
320 268735 [OTA Task] [OTA] Set job doc parameter [ certfile: tisigner.crt.der ]
321 268737 [OTA Task] [OTA] Set job doc parameter [ sig-sha1-rsa:
 Q56qxHRq3Lxv6KkorvilVs4AyGJbWsJd ]
322 268737 [OTA Task] [OTA] Job was accepted. Attempting to start transfer.
323 268737 [OTA Task] Sending command to MQTT task.
324 268737 [MQTT] Received message 50000 from queue.
325 268848 [OTA] [OTA] Queued: 2   Processed: 1   Dropped: 0
326 269039 [MQTT] MQTT Subscribe was accepted. Subscribed.
327 269039 [MQTT] Notifying task.
328 269040 [OTA Task] Command sent to MQTT task passed.
329 269041 [OTA Task] [OTA] Subscribed to topic: $aws/things/TI-LaunchPad/streams/327

330 269848 [OTA] [OTA] Queued: 2   Processed: 1   Dropped: 0
... // Output removed for brevity
346 284909 [OTA Task] [OTA] file token: 74594452
.. // Output removed for brevity
363 301327 [OTA Task] [OTA] file ready for access.
364 301327 [OTA Task] [OTA] Returned buffer to MQTT Client.
365 301328 [OTA Task] Sending command to MQTT task.
366 301328 [MQTT] Received message 60000 from queue.
367 301328 [MQTT] Notifying task.
368 301329 [OTA Task] Command sent to MQTT task passed.
369 301329 [OTA Task] [OTA] Published file request to $aws/bin/things/TI-LaunchPad/
streams/327/get
370 301632 [OTA Task] [OTA] Received file block 0, size 1024
371 301647 [OTA Task] [OTA] Remaining: 127
... // Output removed for brevity
508 304622 [OTA Task] Sending command to MQTT task.
509 304622 [MQTT] Received message 70000 from queue.
510 304622 [MQTT] Notifying task.
511 304623 [OTA Task] Command sent to MQTT task passed.
512 304623 [OTA Task] [OTA] Published file request to $aws/bin/things/TI-LaunchPad/
streams/327/get
513 304860 [OTA] [OTA] Queued: 47   Processed: 47   Dropped: 83
514 304926 [OTA Task] [OTA] Received file block 4, size 1024
515 304941 [OTA Task] [OTA] Remaining: 82
... // Output removed for brevity
797 315047 [MQTT] MQTT Publish was successful.
798 315048 [MQTT] Notifying task.
799 315048 [OTA Task] Command sent to MQTT task passed.
800 315049 [OTA Task] [OTA] Published 'IN_PROGRESS' status to $aws/things/TI-LaunchPad/
jobs/fe18c7ec_8c31_4438_b0b9_ad55acd9561801 315049 [OTA Task] Sending command to MQTT task.
802 315049 [MQTT] Received message d0000 from queue.
803 315150 [MQTT] MQTT Unsubscribe was successful.
804 315150 [MQTT] Notifying task.
805 315151 [OTA Task] Command sent to MQTT task passed.
806 315152 [OTA Task] [OTA] Un-subscribed from topic: $aws/things/TI-LaunchPad/streams/327

807 315172 [OTA Task] Sending command to MQTT task.
808 315172 [MQTT] Received message e0000 from queue.
809 315273 [MQTT] MQTT Unsubscribe was successful.
810 315273 [MQTT] Notifying task.
811 315274 [OTA Task] Command sent to MQTT task passed.
812 315274 [OTA Task] [OTA] Un-subscribed from topic: $aws/things/TI-LaunchPad/streams/327

813 315275 [OTA Task] [OTA] Resetting MCU to activate new image.
0 0 [Tmr Svc] Starting Wi-Fi Module ...
1 0 [Tmr Svc] Simple Link task created

Device came up in Station mode

2 137 [Tmr Svc] Wi-Fi module initialized.
3 137 [Tmr Svc] Starting key provisioning...
```

```
4 137 [Tmr Svc] Write root certificate...
5 243 [Tmr Svc] Write device private key...
6 339 [Tmr Svc] Write device certificate...
7 436 [Tmr Svc] Key provisioning done...
Device disconnected from the AP on an ERROR..!!

[WLAN EVENT] STA Connected to the AP: Guest , BSSID: 44:48:c1:ba:b2:c3

[NETAPP EVENT] IP acquired by the device


Device has connected to Guest

Device IP Address is 192.168.3.72


8 1443 [Tmr Svc] Wi-Fi connected to AP Guest.
9 1444 [Tmr Svc] IP Address acquired 192.168.3.72
10 1444 [OTA] OTA demo version 0.9.1
11 1445 [OTA] Creating MQTT Client...
12 1445 [OTA] Connecting to broker...
13 1445 [OTA] Sending command to MQTT task.
14 1445 [MQTT] Received message 10000 from queue.
15 2910 [MQTT] MQTT Connect was accepted. Connection established.
16 2910 [MQTT] Notifying task.
17 2911 [OTA] Command sent to MQTT task passed.
18 2912 [OTA] Connected to broker.
19 2913 [OTA Task] Sending command to MQTT task.
20 2913 [MQTT] Received message 20000 from queue.
21 3014 [MQTT] MQTT Subscribe was accepted. Subscribed.
22 3014 [MQTT] Notifying task.
23 3015 [OTA Task] Command sent to MQTT task passed.
24 3015 [OTA Task] [OTA] Subscribed to topic: $aws/things/TI-LaunchPad/jobs/$next/get/
accepted

25 3028 [OTA Task] Sending command to MQTT task.
26 3028 [MQTT] Received message 30000 from queue.
27 3129 [MQTT] MQTT Subscribe was accepted. Subscribed.
28 3129 [MQTT] Notifying task.
29 3130 [OTA Task] Command sent to MQTT task passed.
30 3138 [OTA Task] [OTA] Subscribed to topic: $aws/things/TI-LaunchPad/jobs/notify-next

31 3138 [OTA Task] [OTA] Check For Update #0
32 3138 [OTA Task] Sending command to MQTT task.
33 3138 [MQTT] Received message 40000 from queue.
34 3241 [MQTT] MQTT Publish was successful.
35 3241 [MQTT] Notifying task.
36 3243 [OTA Task] Command sent to MQTT task passed.
37 3245 [OTA Task] [OTA] Set job doc parameter [ clientToken: 0:TI-LaunchPad ]
38 3245 [OTA Task] [OTA] Set job doc parameter [ jobId:
 fe18c7ec_8c31_4438_b0b9_ad55acd95610 ]
39 3245 [OTA Task] [OTA] Identified job doc parameter [ self_test ]
40 3246 [OTA Task] [OTA] Set job doc parameter [ updatedBy: 589827 ]
41 3246 [OTA Task] [OTA] Set job doc parameter [ streamname: 327 ]
42 3246 [OTA Task] [OTA] Set job doc parameter [ filepath: /sys/mcuflashimg.bin ]
43 3247 [OTA Task] [OTA] Set job doc parameter [ filesize: 130388 ]
44 3247 [OTA Task] [OTA] Set job doc parameter [ fileid: 126 ]
45 3247 [OTA Task] [OTA] Set job doc parameter [ attr: 0 ]
46 3247 [OTA Task] [OTA] Set job doc parameter [ certfile: tisigner.crt.der ]
47 3249 [OTA Task] [OTA] Set job doc parameter [ sig-sha1-rsa:
 Q56qxHRq3Lxv6KkorvilVs4AyGJbWsJd ]
48 3249 [OTA Task] [OTA] Job is ready for self test.
49 3250 [OTA Task] Sending command to MQTT task.
51 3351 [MQTT] MQTT Publish was successful.
52 3352 [MQTT] Notifying task.
53 3352 [OTA Task] Command sent to MQTT task passed.
```

```
54 3353 [OTA Task] [OTA] Published 'IN_PROGRESS' status to $aws/things/TI-LaunchPad/jobs/
fe18c7ec_8c31_4438_b0b9_ad55acd95610/u55 3353 [OTA Task] Sending command to MQTT task.
56 3353 [MQTT] Received message 60000 from queue.
57 3455 [MQTT] MQTT Unsubscribe was successful.
58 3455 [MQTT] Notifying task.
59 3456 [OTA Task] Command sent to MQTT task passed.
60 3456 [OTA Task] [OTA] Un-subscribed from topic: $aws/things/TI-LaunchPad/streams/327

61 3456 [OTA Task] [OTA] Accepted final image. Commit.
62 3578 [OTA Task] Sending command to MQTT task.
63 3578 [MQTT] Received message 70000 from queue.
64 3779 [MQTT] MQTT Publish was successful.
65 3780 [MQTT] Notifying task.
66 3780 [OTA Task] Command sent to MQTT task passed.
67 3781 [OTA Task] [OTA] Published 'SUCCEEDED' status to $aws/things/TI-LaunchPad/jobs/
fe18c7ec_8c31_4438_b0b9_ad55acd95610/upd68 3781 [OTA Task] [OTA] Returned buffer to MQTT
 Client.
69 4251 [OTA] [OTA] Queued: 1   Processed: 1   Dropped: 0
70 4381 [OTA Task] [OTA] Missing job parameter: execution
71 4382 [OTA Task] [OTA] Missing job parameter: jobId
72 4382 [OTA Task] [OTA] Missing job parameter: jobDocument
73 4382 [OTA Task] [OTA] Missing job parameter: ts_ota
74 4382 [OTA Task] [OTA] Missing job parameter: files
75 4382 [OTA Task] [OTA] Missing job parameter: streamname
76 4382 [OTA Task] [OTA] Missing job parameter: certfile
77 4382 [OTA Task] [OTA] Missing job parameter: filepath
78 4383 [OTA Task] [OTA] Missing job parameter: filesize
79 4383 [OTA Task] [OTA] Missing job parameter: sig-sha1-rsa
80 4383 [OTA Task] [OTA] Missing job parameter: fileid
81 4383 [OTA Task] [OTA] Missing job parameter: attr
82 4383 [OTA Task] [OTA] Returned buffer to MQTT Client.
83 5251 [OTA] [OTA] Queued: 2   Processed: 2   Dropped: 0
```

Demo Bootloader for the Microchip Curiosity PIC32MZEF

This demo bootloader implements firmware version checking, cryptographic signature verification, and application self-testing. These capabilities support over-the-air (OTA) firmware updates for Amazon FreeRTOS.

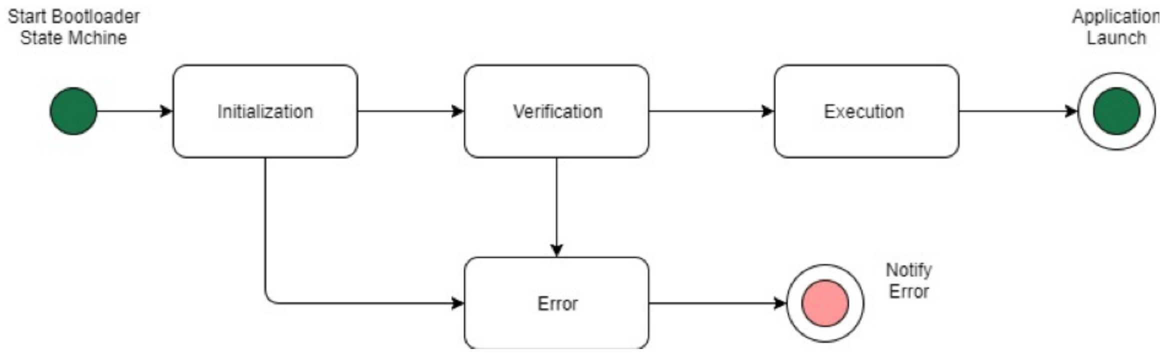
The firmware verification includes verifying the authenticity and integrity of the new firmware received over the air. The bootloader verifies the cryptographic signature of the application before booting. The demo uses elliptic-curve digital signature algorithm (ECDSA) over SHA256. The utilities provided can be used to generate a signed application that can be flashed on the device.

The bootloader supports the following features required for OTA:

- Maintains application images on the device and switches between them.
- Allows self-test execution of a received OTA image and roll-back on failure.
- Checks signature and version of the OTA update image.

Bootloader States

The bootloader process is described by the following state machine.



The following table describes the bootloader states.

Bootloader State	Description
Initialization	Bootloader is in the initialization state.
Verification	Bootloader is verifying the images present on the device.
Execute Image	Bootloader is launching the selected image.
Execute Default	Bootloader is launching the default image.
Error	Bootloader is in the error state.

In the preceding diagram, both `Execute Image` and `Execute Default` are shown as the `Execution` state.

Bootloader Execution State

> The bootloader is in the `Execution` state and is ready to launch the selected verified image. If the image to be launched is in the upper bank, the banks are swapped before executing the image, because the application is always built for the lower bank.

Bootloader Default Execution State

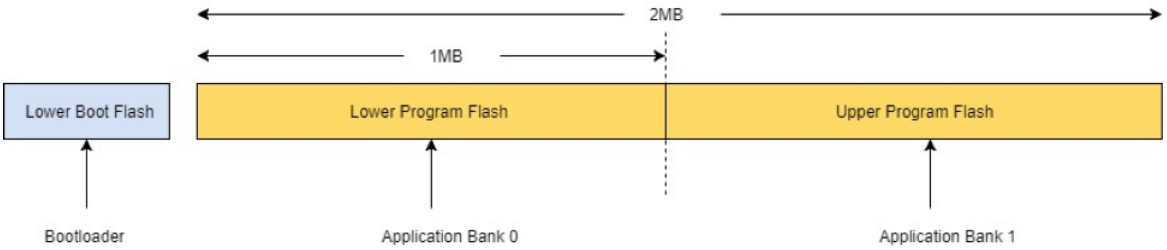
> If the configuration option to launch the default image is enabled, the bootloader launches the application from a default execution address. This option must be disabled except while debugging.

Bootloader Error State

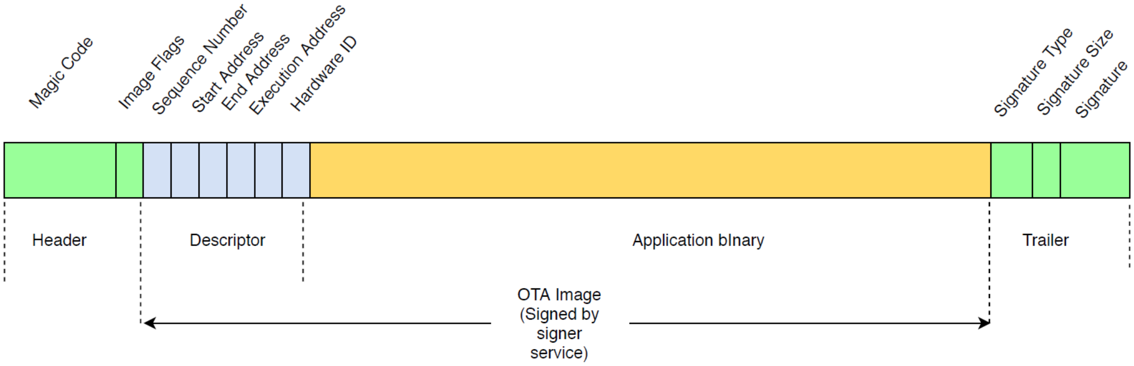
> The bootloader is in an error state and no valid images are present on the device. The bootloader must notify the user. The default implementation sends a log message to the console and fast-blinks the LED on the board indefinitely.

Flash Device

The Microchip Curiosity PIC32MZEF platform contains an internal program flash of two megabytes divided into two banks. It supports memory map swapping between these two banks and live updates. The demo bootloader is programmed in a separate lower boot flash region.



Application Image Structure



The diagram shows the main components of the application image stored on each bank of the device.

Component	Size (in bytes)
Image header	8 bytes
Image descriptor	24 bytes
Application binary	< 1 MB - (324)
Trailer	292 bytes

Image Header

The application images present on the device must start with a header that consists of a magic code and image flags.

Header Field	Size (in bytes)
Magic Code	7 bytes
Image Flags	1 byte

Magic Code

The image on the flash device must start with a magic code. The default magic code is `@AFRTOS`. The bootloader checks if a valid magic code is present before booting the image. This is the first step of verification.

Image Flags

The image flags are used to store the status of the application images. The flags are used in the OTA process. The image flags of both banks determine the state of the device. If the executing image is marked as commit pending, it means the device is in the OTA self-test phase. Even if images on the devices are marked valid, they go through the same verification steps on every boot. If an image is marked as new, the bootloader marks it as commit pending and launches it for self-test after verification. The bootloader also initializes and starts the watchdog timer so that if the new OTA image fails self-test, the device reboots and bootloader rejects the image by erasing it and executes the previous valid image.

The device can have only one valid image. The other image can be a new OTA image or a commit pending (self-test). After a successful OTA update, the old image is erased from the device.

Status	Value	Description
New image	0xFF	Application image is new and never executed.
Commit pending	0xFE	Application image is marked for test execution.
Valid	0xFC	Application image is marked valid and committed.
Invalid	0xF8	Application image is marked invalid.

Image Descriptor

The application image on the flash device must contain the image descriptor following the image header. The image descriptor is generated by a post-build utility that uses configuration files (`ota-descriptor.config`) to generate the appropriate descriptor and prepends it to the application binary. The output of this post-build step is the binary image that can be used for OTA.

Descriptor Field	Size (in bytes)	
Sequence Number	4 bytes	
Start Address	4 bytes	
End Address	4 bytes	
Execution Address	4 bytes	
Hardware ID	4 bytes	
Reserved	4 bytes	

Sequence Number

> The sequence number must be incremented before building a new OTA image. See the `ota-descriptor.config` file. The bootloader uses this number to determine the image to boot. Valid values are from 1 to 4294967295.

Start Address

The starting address of the application image on the device. As the image descriptor is prepended to the application binary, this address is the start of the image descriptor.

End Address

The ending address of the application image on the device, excluding the image trailer.

Execution Address

The execution address of the image.

Hardware ID

A unique hardware ID used by the bootloader to verity the OTA image is built for the correct platform.

Reserved

This is reserved for future use.

Image Trailer

The image trailer is appended to the application binary. It contains the signature type string, signature size, and signature of the image.

Trailer Field	Size (in bytes)	
Signature Type	32 bytes	
Signature Size	4 bytes	
Signature	256 bytes	

Signature Type

The signature type is a string that represents the cryptographic algorithm being used and serves as a marker for the trailer. The bootloader supports the elliptic-curve digital signature algorithm (ECDSA). The default is sig-sha256-ecdsa.

Signature Size

The size of the cryptographic signature, in bytes.

Signature

The cryptographic signature of the application binary prepended with the image descriptor.

Bootloader Configuration

The basic bootloader configuration options are provided in `aws_boot_config.h`. Some options are provided for debugging purposes only. `aws_boot_config.h` is located in `/demos/microchip/curiosity_pic32_bl/config_files/`.

Enable Default Start

Enables the execution of the application from the default address and must be enabled for debugging only. The image is executed from the default address without any verification.

Enable Crypto Signature Verification

Enables cryptographic signature verification on boot. Failed images are erased from the device. This option is provided for debugging purposes only and must remain enabled in production.

Erase Invalid Image

Enables a full bank erase if image verification on that bank fails. The option is provided for debugging and must remain enabled in production.

Enable Hardware ID Verification

Enables verification of the hardware ID in the descriptor of the OTA image and the hardware ID programmed in the bootloader. This is optional and can be disabled if hardware ID verification is not required.

Enable Address Verification

Enables verification of the start, end, and execution addresses in the descriptor of OTA image. We recommend that you keep this option enabled.

Building the Bootloader

The demo bootloader is included as a loadable project in the `aws_demos` project located under `demos\microchip\curiosity_pic32mzef\mplab` in the Amazon FreeRTOS source code repository. When the `aws_demos` project is built, it builds the bootloader first, followed by the application. The final output is a unified hex image including the bootloader and the application. The `factory_image_generator.py` utility is provided to generate a unified hex image with cryptographic signature. The bootloader utility scripts are located in `/demos/common/ota/bootloader/utility/`.

Bootloader Pre-Build Step

This pre-build step executes a utility script called `codesigner_cert_utility.py` that extracts the public key from the code-signing certificate and generates a C header file that contains the public key in ASN.1 encoded format. This header is compiled into the bootloader project. The generated header contains two constants: an array of the public key and the length of the key. The bootloader project can also be built without `aws_demos` and can be debugged as normal application.

Troubleshooting Amazon FreeRTOS

Amazon FreeRTOS supports Amazon CloudWatch and AWS CloudTrail logging services to help troubleshoot issues with Amazon FreeRTOS Over-the-Air updates. For more information about troubleshooting OTA updates, see OTA Troubleshooting.

Amazon FreeRTOS Porting Guide

This porting guide walks you through modifying the Amazon FreeRTOS software package to work on boards that are not Amazon FreeRTOS qualified. Amazon FreeRTOS is designed to let you choose only those libraries required by your board or application. The MQTT, Shadow, and Greengrass libraries are designed to be compatible with most devices as-is, so there is no porting guide for these libraries.

For information about porting FreeRTOS kernel, see FreeRTOS Kernel Porting Guide.

Topics

Bootloader

The bootloader must be dual-bank capable and include logic for checking a CRC and app version in the image header. The bootloader boots the newest image, based on the app version in the header, provided that the CRC is valid. If the CRC check fails, the bootloader should zero out the header as an optimization for future reboots.

Since the OTA v1 agent performs cryptographic signature verification, we suggest that v1 bootloaders not link to cryptographic code, so as to be as small as possible. You must provide a compliant bootloader.

Logging

Amazon FreeRTOS provides a thread-safe logging task that can be used by calling the `configPRINTF` function. `configPRINTF` is designed to behave like `printf`. To port `configPRINTF`, initialize your communications peripheral, and define the `configPRINT_STRING` macro so that it takes an input string and displays it on your preferred output.

Logging Configuration

`configPRINT_STRING` should be defined for your board's implementation of logging. Current examples use a UART serial terminal, but other interfaces can also be used.

```
#define configPRINT_STRING( x )
```

Use `configLOGGING_MAX_MESSAGE_LENGTH` to set the maximum number of bytes to be printed. Messages longer than this length are truncated.

```
#define configLOGGING_MAX_MESSAGE_LENGTH
```

When configLOGGING_INCLUDE_TIME_AND_TASK_NAME is set to 1, all printed messages are prepended with additional debug information (the message number, FreeRTOS tick count, and task name).

```
#define configLOGGING_INCLUDE_TIME_AND_TASK_NAME    1
```

vLoggingPrintf is the name of the FreeRTOS thread-safe printf call. You do not need to change this value to use AmazonFreeRTOS logging.

```
#define configPRINTF( X )    vLoggingPrintf X
```

Connectivity

You must first configure your connectivity peripheral. You can use Wi-Fi, Bluetooth, Ethernet, or other connectivity mediums. At this time, only a Wi-Fi management API is defined for board ports, but if you are using Ethernet, the FreeRTOS TCP/IP software can provide a good place to start.

Wi-Fi Management

The Wi-Fi management library supports network connectivity following the 802.11 (a/b/n) protocol. If your hardware does not support Wi-Fi, you do not need to port this library.

The functions that must be ported are listed in the lib/wifi/portable/*<vendor>*/*<platform>*/aws_wifi.c file. You can find a detailed explanation for each public interface in lib/include/aws_wifi.h.

The following functions must be ported:

```
WiFiReturnCode_t WIFI_On( void );
WIFIReturnCode_t WIFI_Off( void );
WiFiReturnCode_t WIFI_ConnectAP( const WiFiNetworkParams_t * const pxNetworkParams );
WiFiReturnCode_t WIFI_Disconnect( void );
WiFiReturnCode_t WIFI_Reset( void );
WiFiReturnCode_t WIFI_Scan( WiFiScanResult_t * pxBuffer, uint8_t uxNumNetworks );
```

Sockets

The sockets library supports TCP/IP network communication between your board and another node in the network. The sockets APIs are based on the Berkeley sockets interface, but also include a secure communication option. At this time, only client APIs are supported. We recommend that you port the TCP/IP functionality first, before you add the TLS functionality.

Libraries for MQTT, Shadow, and Greengrass all make calls into the sockets layer. A successful port of the sockets layer allows the protocols built on sockets to just work.

Major Differences from Berkeley Sockets Implementation

Security

The sockets interface must be configured to use TLS for secure communication. The SetSockOpt command has a couple of nonstandard options that must be implemented to work with AmazonFreeRTOS examples.

```
SOCKETS_SO_REQUIRE_TLS
SOCKETS_SO_SERVER_NAME_INDICATION
SOCKETS_SO_TRUSTED_SERVER_CERTIFICATE
```

For information about these nonstandard options, see the secure sockets documentation (p. 97). For information about porting TLS and cryptographic operations, see the TLS (p. 103) and Public Key Cryptography Standard #11 (p. 95) sections.

Error Codes

The SOCKETS library returns error codes from the API (rather than setting a global errno). All error codes returned must be negative values.

The public interfaces that must be ported are listed in `lib/secure_sockets/portable/`*`<vendor>`*`/`*`<platform>`*`/aws_secure_sockets.c`.

A detailed explanation for each public interface can be found in `lib/include/aws_secure_sockets.h`.

If you are using TLS based on mbed TLS, you can save refactoring effort by implementing network send and network receive functions that can be registered with the TLS layer for sending and receiving plaintext or encrypted buffers.

Security

Amazon FreeRTOS has two libraries that work together to provide platform security: TLS and PKCS#11. Amazon FreeRTOS provides a software security solution built on mbed TLS (a third-party TLS library). The TLS API uses mbed TLS to encrypt and authenticate network traffic. PKCS#11 provides an standard interface to handle cryptographic material and replace software cryptographic operations with implementations that fully use the hardware.

TLS

If you choose to use an mbed TLS-based implementation, you can use aws_tls.c as-is, provided that PKCS#11 is implemented.

The public interfaces of this library and a detailed explanation for each TLS interface are listed in `lib/include/aws _tls.h`. The Amazon FreeRTOS implementation of the TLS library is in `lib/tls/aws_tls.c`. If you decide to use your own TLS support, you can either implement the TLS public interfaces and plug them into the sockets public interfaces, or you can directly port the sockets library using your own TLS interfaces.

The `mbedtls_hardware_poll` function provides randomness for the deterministic random bit generator. For security, no two boards should provide identical randomness, and a board must not provide the same random value repeatedly, even if the board is reset. Examples of implementations for this function can be found in ports using mbed TLS at `demos\`*`<vendor>`*`\`*`<platform>`*`\common\application_code\`*`<vendor code>`*` \aws_entropy_hardware_poll.c`

Using TLS Libraries Other Than mbed TLS

If you are porting another TLS library to Amazon FreeRTOS, make sure that a compatible TLS cipher suite is implemented in your port. For more information, see Cipher Suites Compatible with AWS IoT. The following cipher suites are compatible with AWS IoT Greengrass devices:

- `TLS_RSA_WITH_AES_128_GCM_SHA256`

- `TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384`
- `TLS_RSA_WITH_AES_256_GCM_SHA384`
- `TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA` (not recommended)
- `TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA` (not recommended)
- `TLS_RSA_WITH_AES_128_CBC_SHA` (not recommended)
- `TLS_RSA_WITH_AES_256_CBC_SHA` (not recommended)

Due to attacks on SHA1, we recommend that you use SHA256 or SHA384 for Amazon FreeRTOS connections.

PKCS#11

Amazon FreeRTOS implements a PKCS#11 standard for cryptographic operations and key storage. The header file for PKCS#11 is an industry standard. To port PKCS#11, you must implement functions to read and write credentials to and from non-volatile memory (NVM).

The functions you need to implement are listed in `lib/third_party/pkcs11/pkcs11f.h`. The implementation of the public interfaces is located in: `lib/pkcs11/portable/vendor/board/pkcs11.c`.

The following functions are the minimum required to support TLS client authentication in Amazon FreeRTOS:

- `C_GetFunctionList`
- `C_Initialize`
- `C_GetSlotList`
- `C_OpenSession`
- `C_FindObjectsInit`
- `C_FindObjects`
- `C_FindObjectsFinal`
- `C_GetAttributeValue`
- `C_FindObjectsInit`
- `C_FindObjects`
- `C_FindObjectsFinal`
- `C_GetAttributeValue`
- `C_SignInit`
- `C_Sign`
- `C_CloseSession`
- `C_Finalize`

For a general porting guide, see the open standard, PKCS #11 Cryptographic Token Interface Base Specification.

Two additional non-PKCS#11 standard functions must be implemented for keys and certificates to survive power cycle:

`prvSaveFile`

Writes the client (device) private key and certificate to memory. If your NVM is susceptible to damage from write cycles, you might want to use an additional variable to record whether the device private key and device certificate have been initialized.

`prvReadFile`

Retrieves either the device private key or device certificate from NVM into RAM for use by the TLS library.

Using Custom Libraries with Amazon FreeRTOS

All Amazon FreeRTOS libraries can be replaced with custom developed libraries. All custom libraries must conform to the API of the Amazon FreeRTOS library they replace.

OTA Portable Abstraction Layer

Amazon FreeRTOS defines an OTA portable abstraction layer (PAL) in order to ensure that the OTA library is useful on a wide variety of hardware. The OTA PAL interface is listed below.

`prvAbort`

Aborts an OTA update.

`prvCreateFileForRx`

Creates a new file to store the data chunks as they are received.

`prvCloseFile`

Closes the specified file. This may authenticate the file if it is marked as secure.

`prvCheckFileSignature`

Verifies the signature of the specified file. For device file systems with built-in signature verification enforcement, this may be redundant and should therefore be implemented as a no-op.

`prvWriteBlock`

Writes a block of data to the specified file at the given offset. Returns the number of bytes written on success or negative error code.

`prvActivateNewImage`

Activates the new firmware image. For some ports, this function may not return.

`prvSetImageState`

Does whatever is required by the platform to accept or reject the last firmware image (or bundle). Refer to the platform implementation to determine what happens on your platform.

`prvReadAndAssumeCertificate`

Reads the specified signer certificate from the file system and returns it to the caller. This is optional on some platforms.

Amazon FreeRTOS Qualification Program

Amazon FreeRTOS Qualification Program

The Amazon FreeRTOS Qualification Program is now a part of the Device Qualification Program. For more information about the Device Qualification Program, visit the AWS Partner Network website.

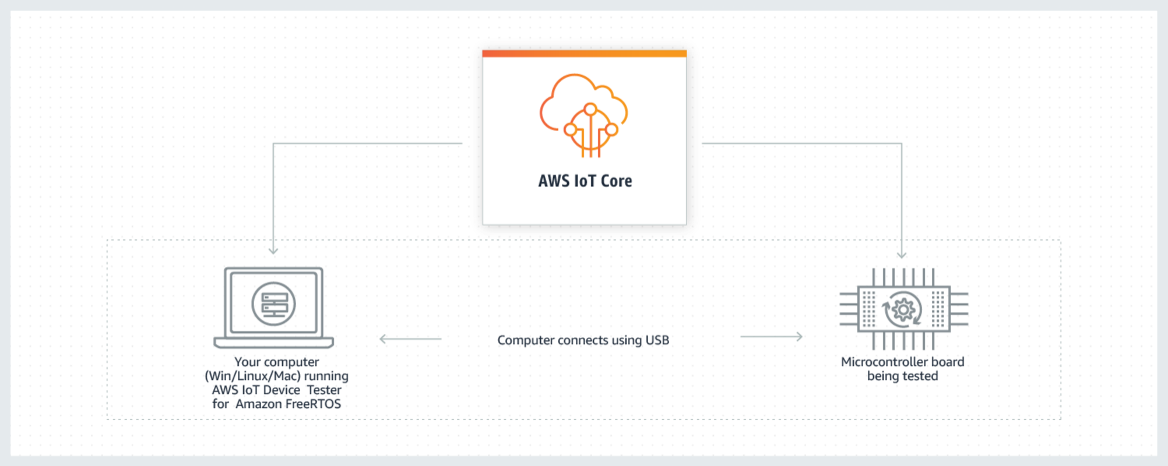
AWS IoT Device Tester for Amazon FreeRTOS User Guide

AWS IoT Device Tester allows you to test that the Amazon FreeRTOS operating system works locally on your device and can communicate with the AWS IoT cloud. AWS IoT Device Tester checks if the porting layer interfaces for Amazon FreeRTOS libraries function correctly on top of microcontroller board device drivers. In addition, it performs end-to-end tests with AWS IoT Core (for example, to test if the board is able to send or receive MQTT messages and process correctly). AWS IoT Device Tester for Amazon FreeRTOS uses the test cases published in the Amazon FreeRTOS GitHub repository. AWS IoT Device Tester consists of a Test Manager command-line tool and a set of test cases.

Test Manager runs on a host computer (Windows, Mac, or Linux) that is connected to the device to be tested. The Test Manager executes test cases and aggregates results. It also provides a command line interface to manage test execution. Test cases contain test logic and set up the resources required for tests.

Test cases are part of the application binary image that is flashed onto your board. Application binary images include Amazon FreeRTOS, the semiconductor vendor's ported Amazon FreeRTOS interfaces, and board device drivers. Test Cases run as embedded applications and verify the ported Amazon FreeRTOS interfaces function correctly on top of the device drivers.

The following diagram shows the test infrastructure setup:


AWS IoT Core
Computer connects using USB
Your computer (Win/Linux/Mac) running AWS IoT Device Tester for Amazon FreeRTOS
Microcontroller board being tested

Prerequisites

This section describes the prerequisites for testing microcontrollers with AWS IoT Device Tester.

Download Amazon FreeRTOS

You can download the version of Amazon FreeRTOS that you want to test from GitHub. If you are using Windows, you must keep the file path short. For example, to avoid a Windows limitation with long file paths, clone to `C:\AFreeRTOS` rather than `C:\Users\username\programs\projects\AmazonFreeRTOS\`.

Download AWS IoT Device Tester for Amazon FreeRTOS

Every version of Amazon FreeRTOS has a corresponding version of AWS IoT Device Tester for performing qualification tests. Download the appropriate version of AWS IoT Device Tester.

Extract AWS IoT Device Tester into a location on the file system where you have read and write permissions. Due to a path length limitation, on Microsoft Windows, extract AWS IoT Device Tester into a root directory like C:\ or D:\.

Create and Configure an AWS Account

If you don't have an AWS account, follow the instructions on the AWS webpage to create one. Choose **Create an AWS Account** and follow the prompts.

Create an IAM User in Your AWS Account

When you create an AWS account, a root user that has access to all resources in your account is created for you. It is a best practice to create another user for everyday tasks. To create an IAM user, follow the instructions in Creating an IAM User in Your AWS Account. For more information about the root user, see The AWS Account Root User.

Create and Attach an IAM Policy to Your AWS Account

IAM policies grant your IAM user access to AWS resources.

To create an IAM policy

1. Browse to the IAM console.
2. In the navigation pane, choose **Policies**, and then choose **Create Policy**.
3. Select the **JSON** tab and copy and paste the policy template located in Permissions Policy Template (p. 202) the ??? (p. 202) into the editor window.
4. Choose **Review policy**.
5. In **Name**, enter a name for your policy. In **Description**, enter an optional description. Choose **Create Policy**.

After you create an IAM policy, you must attach it to your IAM user.

To attach an IAM policy to your IAM user

1. Browse to the IAM console.
2. In the navigation pane, choose **Users**. Find and select your IAM user.
3. Choose **Add permissions**, and then choose **Attach existing policies directly**. Find and select your IAM policy, choose **Next: Review**, and then choose **Add Permissions**.

Install the AWS Command Line Interface (CLI)

You will need to use the CLI to perform some operations, if you don't have the CLI installed, follow the instructions in Install the AWS CLI.

Test to Qualify Your Microcontroller Board for the First Time

You can use AWS IoT Device Tester to test as you port the Amazon FreeRTOS interfaces. After you have ported the Amazon FreeRTOS interfaces for your board's device drivers, you use AWS IoT Device Tester to run the qualification tests on your microcontroller board.

Add Library Porting Layers

To add library porting layers for Amazon FreeRTOS device libraries (TCP/IP, WiFi, and so on) compatible with your MCU architecture, you must:

1. Implement the `configPRINT_STRING()` method before running AWS IoT Device Tester tests. AWS IoT Device Tester calls the `configPRINT_STRING()` macro to output test results as human-readable ASCII strings.
2. Port the drivers to implement the Amazon FreeRTOS library's interfaces. For more information, see the Amazon FreeRTOS Qualification Developer Guide.

Configure Your AWS Credentials

You must configure your AWS credentials in the `<devicetester_extract_location>/ devicetester_afreertos_[win|mac|linux]/configs/ config.json`. You can specify your credentials in one of two ways:

- Environment variables
- Credentials file

Configuring AWS Credentials with Environment Variables

Environment variables are variables maintained by the operating system and used by system commands. AWS IoT Device Tester can use the `AWS_ACCESS_KEY_ID` and `AWS_SECRET_ACCESS_KEY` environment variables to store your AWS credentials. The way you set environment variables depends on the operating system you are running.

To set environment variables on Windows

1. From the Windows 10 desktop, open the **Power User Task Menu**. To open the menu, move your mouse cursor to the bottom-left corner of the screen (the **Start** menu icon) and right-click.
2. From the **Power User Task Menu**, choose **System**, and then choose **Advanced System Settings**.

   > **Note**
   > In Windows 10, you might need to scroll to **Related settings** and choose **System info**. In **System**, choose **Advanced system settings**.

   In **System Properties**, choose the **Advanced** tab, and then choose the **Environment Variables** button.
3. Under **User variables for <user-name>**, choose **New** to create an environment variable. Enter a name and value for each environment variable.

To set environment variables on macOS, Linux, or UNIX

- Open `~/.bash_profile` in any text editor and add the following lines:

```
export AWS_ACCESS_KEY_ID="<your-aws-access-key-id>"
export AWS_SECRET_ACCESS_KEY="<your-aws-secret-key>"
```

Replace the items in angle brackets (< & >) with your AWS access key ID and AWS secret key.

After you set your environment variables, close your command line window or terminal and reopen it so the new values take effect.

To configure your AWS credentials using environment variables, set the `AWS_ACCESS_KEY_ID` and `AWS_SECRET_ACCESS_KEY`. In the `config.json`, for `method`, specify `environment`:

```
{
 "awsRegion": "us-west-2",
 "auth": {
  "method": "environment"
 }
}
```

Configuring AWS Credentials with a Credentials File

Create a credentials file that contains your credentials. AWS IoT Device Tester uses the same credentials file as the AWS CLI. For more information, see . You must also specify a named profile. For more information, see Configuration and Credential Files. The following is an example JSON snippet that shows how to specify AWS credentials using a credentials file in the config.json file:

```
{
 "awsRegion": "us-west-2",
 "auth": {
  "method": "file",
  "credentials": {
   "profile": "default"
  }
 }
}
```

Configuring the AWS Region

AWS IoT Device Tester creates cloud resources in your AWS account. You can specify the AWS Region to use for testing by setting the `awsRegion` parameter in the config.json file. By default, AWS IoT Device Tester uses the us-west-2 region.

Create a Device Pool in AWS IoT Device Tester

Devices to be tested are organized in device pools. Each device pool consists of one or more devices with identical specifications. You can configure Device Tester to test a single device in a pool or multiple devices in a pool. To accelerate the qualification process, AWS IoT Device Tester can test devices with the same specification in parallel. It uses a round-robin method to execute a different test group on each device in a device pool.

Configuring AWS IoT Device Tester for Single Device Testing

You define a device pool by editing the `device.json` file template in the configs folder. The following is an example `device.json` file used to create a device pool with one device:

```
[
  {
    "id": "<pool-id>",
    "sku": "<sku>",
    "features": [
      {
        "name": "WIFI",
        "value": "Yes | No"
      },
      {
        "name": "OTA",
        "value": "Yes | No"
      },
      {
        "name": "TCP/IP",
        "value": "On-chip | Offloaded | No"
      },
      {
        "name": "TLS",
        "value": "On-chip | Offloaded | No"
      }
    ],
    "devices": [
      {
        "id": "<device-id>",
        "connectivity": {
          "protocol": "uart",
          "serialPort": "<serial-port>"
        },
        "identifiers": [
          {
            "name": "serialNo",
            "value": "<serialNo-value>"
          }
        ]
      }
    ]
  }
]
```

The following list describes the attributes used in the `device.json` file:

`id`

A user-defined alphanumeric ID that uniquely identifies a pool of devices. Devices that belong to a pool must be of the same type. When a suite of tests is running, devices in the pool are used to parallelize the workload.

`sku`

An alphanumeric value that uniquely identifies the board you are testing. The SKU is used to track qualified boards.

> **Note**
> If you want to list your board in AWS Partner Device Catalog, the SKU you specify here must match the SKU that you use in the listing process.

`features`

An array that contains the device's supported features. The Device Tester uses this information to select the qualification tests to run.

Supported values are:

- `TCP/IP`: Indicates if your board supports a TCP/IP stack and whether it is supported on-chip (MCU) or offloaded to another module.

- WIFI: Indicates if your board has Wi-Fi capabilities.
- TLS: Indicates if your board supports TLS and if it is supported on-chip (MCU) or offloaded to another module.
- OTA: Indicates if your board supports over-the-air (OTA) update functionality.

devices.id

A user-defined unique identifier for the device being tested.

devices.connectivity.protocol

The communication protocol used to communicate with this device. Supported value: uart.

devices.connectivity.serialPort

The serial port of the host computer used to connect to the devices being tested.

identifiers

Optional. An array of arbitrary name-value pairs. You can use these values in the build and flash commands described in the next section.

Configuring AWS IoT Device Tester for Multiple Device Testing

You can add multiple devices by editing the devices section of the device.json template in the configs folder. For more information about the structure and contents of the device.json file, see Configuring AWS IoT Device Tester for Single Device Testing (p. 187).

Note
All devices in the same pool must be of same technical specification and SKU.

The following is an example device.json file used to create a device pool with multiple devices:

```
[{
 "id": "<pool-id>",
 "sku": "<sku>",
 "features": [
  {
   "name": "WIFI",
   "value": "Yes | No"
  },
  {
   "name": "OTA",
   "value": "Yes | No"
  },
  {
   "name": "TCP/IP",
   "value": "On-chip | Offloaded | No"
  },
  {
   "name": "TLS",
   "value": "On-chip | Offloaded | No"
  }
 ],
 "devices": [{
  "id": "<device-id1>",
  "connectivity": {
   "protocol": "uart",
   "serialPort": "<computer_serial_port_1>"
  },
  "identifiers": [{
   "name": "serialNo",
   "value": "<serialNo-value>"
  }]
  "id": "<device-id2>",
  "connectivity": {
   "protocol": "uart",
   "serialPort": "<computer_serial_port_2>"
  },
  "identifiers": [{
   "name": "serialNo",
   "value": "<serialNo-value>"
  }]
 }]
}]
```

Configure Build, Flash, and Test Settings

For AWS IoT Device Tester to build and flash test cases on to your board automatically, you must configure AWS IoT Device Tester with command line interfaces of your build and flash tools. The build and flash settings are configured in the `userdata.json` template file located in the config folder.

Configure Settings for Testing One Device

The `userdata.json` must have the following structure:

```
{
   "sourcePath":"<path-to-afr-source-code>",
   "buildTool":{
      "name":"<your-build-tool-name>",
      "version":"<your-build-tool-version>",
      "command":[
         "<your-build-script>"
      ]
   },
   "flashTool":{
      "name":"<your-flash-tool-name>",
      "version":"<your-flash-tool-version>",
      "command":[
         "<your-flash-script>"
      ]
   },
   "clientWifiConfig":{
      "wifiSSID":"<your-wifi-ssid",
      "wifiPassword":""<your-wifi-password>",
      "wifiSecurityType":"<wifi-security-type>"
   },
   "testWifiConfig":{
      "wifiSSID":"<your-wifi-ssid",
      "wifiPassword":""<your-wifi-password>",
      "wifiSecurityType":"<wifi-security-type>"
   },
   "otaConfiguration":{
      "otaFirmwareFilePath":"<path-to-the-device-binary>",
      "deviceFirmwareFileName":"<your-device-firmware-name>.bin",
      "awsSignerPlatform":"AmazonFreeRTOS-Default",
      "awsSignerCertificateArn":"arn:aws:acm:us-east-1:1000000001:certificate/e416379d-
f3d6-46f3-868e-8721075ff076",
      "awsUntrustedSignerCertificateArn":"arn:aws:acm:us-
east-1:1000000001:certificate/0c81e2c6-f85e-46b1-9ed1-2c404309b210",
      "awsSignerCertificateFileName":"ecdsa-sha256-signer.crt.pem",
      "compileCodesignerCertificate":true
   }
}
```

The following lists the attributes used in the `userdata.json` file:

`sourcePath`

The path to the root of the ported Amazon FreeRTOS source code. AWS IoT Device Tester stores the value in the `{{testData.sourcePath}}` variable.

`buildTool`

The full path to your build script (.bat or .sh) that contains the commands to build your source code.

> **Note**
> If you are using an IDE, you must provide the command line to the IDE to run in headless mode.

`flashTool`

Full path to your flash script (.sh or .bat) that contains the flash commands for your device.

`clientWifiConfig`

Client Wi-Fi configuration. The Wi-Fi library tests require an MCU board to connect to two access points. This attribute configures the Wi-Fi settings for the first access point. The client Wi-Fi settings are configured in `$AFR_HOME/tests/common/include/aws_clientcredential.h.`. The following macros are set by using the values found in `aws_clientcredential.h`. Some of the Wi-Fi test cases expect the access point to have some security and not to be open.

- wifi_ssid: The Wi-Fi SSID as a C string.
- wifi_password: The Wi-Fi password as a C string.
- wifiSecurityType: The type of Wi-Fi security used.

`testWifiConfig`

Test Wi-Fi configuration. The Wi-Fi library tests require a board to connect to two access points. This attribute configures the second access point. The test Wi-Fi settings are configured in `$AFR_HOME/tests/common/wifi/aws_test_wifi.c.`. The following macros are set by using the values found in `aws_test_wifi.c`. Some of the Wi-Fi test cases expect the access point to have some security and not to be open.

> **Note**
> If your board does not support Wi-Fi, you must still include the `clientWifiConfig` and `testWifiConfig` section in your `device.json` file, but you can omit values for these attributes.

- testwifiWIFI_SSID: The Wi-Fi SSID as a C string.
- testwifiWIFI_PASSWORD: The Wi-Fi password as a C string.
- testwifiWIFI_SECURITY: The type of Wi-Fi security used. One of the following values:
  - `eWiFiSecurityOpen`
  - `eWiFiSecurityWEP`
  - `eWiFiSecurityWPA`
  - `eWiFiSecurityWPA2`

`otaConfiguration`

The OTA configuration.

`otaFirmwareFilePath`

The full path to the OTA image created after the build.

`deviceFirmwareFileName`

The full file path on the MCU device where the OTA firmware will be downloaded. Some devices do not use this field, but you still must provide a value.

`awsSignerPlatform`

The signing algorithm used by AWS Code Signer while creating the OTA update job. Currently, the possible values for this field are `AmazonFreeRTOS-TI-CC3220SF` and `AmazonFreeRTOS-Default`.

`awsSignerCertificateArn`

The Amazon Resource Name (ARN) for the trusted certificate uploaded to AWS Certificate Manager (ACM). For more information about creating a trusted certificate, see Creating a Code Signing Certificate.

`awsUntrustedSignerCertificateArn`

The Amazon Resource Name (ARN) for a certificate uploaded to ACM which your device should not trust. This is used to test invalid certificate test cases.

`compileCodesignerCertificate`

Set to `true` if the code-signer signature verification certificate is not provisioned or flashed, so it must be compiled into the project. AWS IoT Device Tester fetches the trusted certificate from ACM and compiles it into `aws_codesigner_certifiate.h`.

Configure Settings for Testing Multiple Devices

Build, flash, and test settings are made in the `userdata.json` file. The following JSON example shows how you can configure AWS IoT Device Tester for testing multiple devices:

```
    {
       "sourcePath":"<absolute-path-to/amazon-freertos>",
       "buildTool":{
          "name":"<your-build-tool-name>",
          "version":"<your-build-tool-version>",
          "command":[
             "<absolute-path-to/build-parallel-script> {{testData.sourcePath}}"
          ]
       },
       "flashTool":{
          "name":"<your-flash-tool-name>",
          "version":"<your-flash-tool-version>",
          "command":[
             "<absolute-path-to/flash-parallel-script> {{testData.sourcePath}}
 {{device.connectivity.serialPort}}"
          ]
       },
       "clientWifiConfig":{
          "wifiSSID":"<ssid>",
          "wifiPassword":"<password>",
          "wifiSecurityType":"eWiFiSecurityOpen | eWiFiSecurityWEP | eWiFiSecurityWPA |
 eWiFiSecurityWPA2"
       },
       "testWifiConfig":{
          "wifiSSID":"<ssid>",
          "wifiPassword":"<password>",
          "wifiSecurityType":"eWiFiSecurityOpen | eWiFiSecurityWEP | eWiFiSecurityWPA |
 eWiFiSecurityWPA2"
       },
       "otaConfiguration":{
          "otaFirmwareFilePath":"{{testData.sourcePath}}/<relative-path-to/ota-image-
generated-in-build-process>",
          "deviceFirmwareFileName":"<absolute-path-to/ota-image-on-device>",
          "awsSignerPlatform":"AmazonFreeRTOS-Default | AmazonFreeRTOS-TI-CC3220SF",
          "awsSignerCertificateArn":"arn:aws:acm:<region>:<account-
id>:certificate:<certificate-id>",
          "awsUntrustedSignerCertificateArn":"arn:aws:acm:<region>:<account-
id>:certificate:<certificate-id>",
          "awsSignerCertificateFileName":"<awsSignerCertificate-file-name>",
          "compileCodesignerCertificate":true | false
       }
    }
```

The following lists the attributes used in `userdata.json`:

`sourcePath`

The path to the root of the ported Amazon FreeRTOS source code. AWS IoT Device Tester stores the value in the `{{testData.sourcePath}}` variable.

`buildTool`

The full path to your build script (.bat or .sh) that contains the commands to build your source code. All references to the source code path in the build command must be replaced by the AWS IoT Device Tester variable `{{testdata.sourcePath}}`.

`flashTool`

Full path to your flash script (.sh or .bat) that contains the flash commands for your device. All references to the source code path in the flash command must be replaced by the AWS IoT Device Tester variable `{{testdata.sourcePath}}`.

`clientWifiConfig`

Client Wi-Fi configuration. The Wi-Fi library tests require an MCU board to connect to two access points. This attribute configures the Wi-Fi settings for the first access point. The client Wi-Fi settings are configured in `$AFR_HOME/tests/common/include/aws_clientcredential.h.`. The following macros are set using the values found in `aws_clientcredential.h`. Some of the Wi-Fi test cases expect the access point to have some security and not to be open.

- wifi_ssid: The Wi-Fi SSID as a C string.
- wifi_password: The Wi-Fi password as a C string.
- wifiSecurityType: The type of Wi-Fi security used.

`testWifiConfig`

Test Wi-Fi configuration. The Wi-Fi library tests require a board to connect to two access points. This attribute configures the second access point. The test Wi-Fi settings are configured in `$AFR_HOME/tests/common/wifi/aws_test_wifi.c.`. The following macros are set using the values found in `aws_test_wifi.c`. Some of the Wi-Fi test cases expect the access point to have some security and not to be open.

> **Note**
> If your board does not support Wi-Fi, you must still include the `clientWifiConfig` and `testWifiConfig` section in your `device.json` file, but you can omit values for these attributes.

- testwifiWIFI_SSID: The Wi-Fi SSID as a C string.
- testwifiWIFI_PASSWORD: The Wi-Fi password as a C string.
- testwifiWIFI_SECURITY: The type of Wi-Fi security used. One of the following values:
  - `eWiFiSecurityOpen`
  - `eWiFiSecurityWEP`
  - `eWiFiSecurityWPA`
  - `eWiFiSecurityWPA2`

`otaConfiguration`

The OTA configuration.

`otaFirmwareFilePath`

The full path to the OTA image created after the build.

`deviceFirmwareFileName`

The name of the OTA firmware file to be downloaded to the board.

`awsSignerPlatform`

The signing algorithm used by AWS Code Signer while creating the OTA update job. Currently, the possible values for this field are `AmazonFreeRTOS-TI-CC3220SF` and `AmazonFreeRTOS-Default`.

`awsSignerCertificateArn`

The Amazon Resource Name (ARN) for the trusted certificate uploaded to AWS Certificate Manager (ACM). For more information about creating a trusted certificate, see Creating a Code Signing Certificate.

`awsUntrustedSignerCertificateArn`

The ARN for the code-signing certificate uploaded to ACM.

`compileCodesignerCertificate`

Set to `true` if the code-signer signature verification certificate is not provisioned or flashed, so it must be compiled into the project. AWS IoT Device Tester fetches the trusted certificate from ACM and compiles it into `aws_codesigner_certifiate.h`.

AWS IoT Device Tester Variables

The commands to build your code and flash the device might require connectivity or other information about your devices to run successfully. AWS IoT Device Tester allows you to reference device information in flash and build commands using JsonPath. By using simple JsonPath expressions, you can fetch the required information as specified in your `device.json` file.

AWS IoT Device Tester Variables and Concurrent Testing

To enable parallel builds of the source code for different test groups, AWS IoT Device Tester copies the source code to a results folder inside the AWS IoT Device Tester extracted folder. The source code path in your build or flash command must be referenced using the `testdata.sourcePath` variable. AWS IoT Device Tester replaces this variable with a temporary path of the copied source code.

File Paths and the Windows Operating System

If you are running AWS IoT Device Tester on Windows, use forward slashes (/) in your file paths in AWS IoT Device Tester config files. For example, `sourcePath` in `userdata.json` should be represented as `c:/<dir1>/<dir2>`.

Running the Amazon FreeRTOS Qualification Suite

You use the AWS IoT Device Tester executable to interact with AWS IoT Device Tester. The following command line shows you how to run the qualification tests for a device pool (set of identical devices).

devicetester_*[linux | mac | win_x86-64]* run-suite --suite-id *<suite-id>* --pool-id *<your-device-pool>* --userdata *<userdata.json>*

The `userdata.json` file should be located in the *<devicetester_extract_location>* / `devicetester_afreertos_`*[win|mac|linux]*`/configs/` directory.

> **Note**
> If you are running AWS IoT Device Tester on Windows, specify the path to the `userdata.json` by using forward slashes (/).

Use the following command to run all test groups in a specified suite:

devicetester_*[linux | mac | win_x86-64]* run-suite --suite-id AFQ_1 --pool-id *<pool-id>*

Use the following command to run a specific test group:

devicetester_*[linux | mac | win_x86-64]* run-suite --suite-id AFQ_1 --group-id *<group-id>* --pool-id *<pool-id>* *<pool-id>*

`suite-id` and `pool-id` are optional if you are running a single test suite on a single device pool (that is, you have only one device pool defined in your `device.json` file).

AWS IoT Device Tester command line options

suite-id

Optional. Specifies the test suite to run.

pool-id

Specifies the device pool to test. If you only have one device pool, you can omit this option.

AWS IoT Device Tester Commands

The AWS IoT Device Tester command supports the following operations:

help

Lists information about the specified command.

list-groups

Lists the groups in a given suite.

list-suites

Lists the available suites.

run-suite

Runs a suite of tests on a pool of devices.

Results and Logs

This section describes how to view and interpret test results and logs.

Viewing Results

After AWS IoT Device Tester executes the qualification test suite, it generates two reports for each run of the qualification test suite: `awsiotdevicetester_report.xml` and `AFQ_Report.xml`. These reports can be found in *<devicetester-extract-location>*/results/*<execution-id>*/.

`awsiotdevicetester_report.xml` is the qualification test report that you submit to AWS for listing your device in the AWS Partner Device Catalog. The report contains the following elements:

- The AWS IoT Device Tester version.
- The Amazon FreeRTOS version that was tested.
- The SKU and the device name specified in the `device.json` file.
- The features of the device specified in the `device.json` file.
- The aggregate summary of test case results.
- A breakdown of test case results by libraries that were tested based on the device features (for example, FullWiFi, FullMQTT, and so on).

The `AFQ_report.xml` is a report in standard junit.xml format, which you can integrate into your exiting CI/CD platforms like Jenkins, Bamboo, and so on. The report contains the following elements:

- An aggregate summary of test case results.
- A breakdown of test case results by libraries that were tested based on the device features (for example, FullWiFi, FullMQTT, and so on).

Interpreting AWS IoT Device Tester Results

The report section in `awsiotdevicetester_report.xml` or `AFQ_report.xml` lists the tests that were run and the results of the tests.

The first XML tag `<testsuites>` contains the overall summary of the test execution. For example:

```
<testsuites name="AFQ results" time="5633" tests="184" failures="0" errors="0"
 disabled="0">
```

Attributes used in the `<testsuites>` tag

`name`

The name of the test suite.

`time`

The time (in seconds) it took to run the qualification suite.

`tests`

The number of test cases executed.

`failures`

The number of test cases that were run, but did not pass.

`errors`

The number of test cases that AWS IoT Device Tester couldn't execute.

`disabled`

This attribute is not used and can be ignored.

If there are no test case failures or errors, your device meets the technical requirements to run Amazon FreeRTOS and can interoperate with AWS IoT services. If you choose to list your device in the AWS Partner Device Catalog, you can use this report as qualification evidence.

In the case of test case failures or errors, you can identify the test case that failed by reviewing the `<testsuites>` XML tags. The `<testsuite>` XML tags inside the `<testsuites>` tag shows the test case result summary for a test group.

```
<testsuite name="FullMQTT" package="" tests="16" failures="0" time="76" disabled="0"
 errors="0" skipped="0">
```

The format is similar to the `<testsuites>` tag, but with an additional attribute called `skipped` that is not used and can be ignored. Inside each `<testsuite>` XML tag, there are `<testcase>` tags for each of the test cases that were executed for a test group. For example:

```
<testcase classname="mcu.Full_MQTT" name="AFQP_MQTT_Connect_HappyCase" attempts="1"></
testcase>
```

Attributes used in the `<testcase>` tag

`name`

The name of the test case.

`attempts`

The number of times AWS IoT Device Tester executed the test case.

When a test case fails or an error occurs, `<failure>` or `<error>` tags are added to the `<testcase>` tag with additional information for troubleshooting. For example:

```
<testcase classname="mcu.Full_MQTT" name="AFQP_MQTT_Connect_HappyCase" attempts="1">
 <failure type="Failure">Reason for the test case failure</failure>
 <error>Reason for the test case execution error</error>
</testcase>
```

Viewing Logs

You can find logs that AWS IoT Device Tester generates from test execution in *`<devicetester-extract-location>`*`/results/`*`<execution-id>`*`/logs`. Two sets of logs are generated:

`test_manager.log`

Contains logs generated from the Test Manager component of AWS IoT Device Tester. For example, logs related configuration, test sequencing, and report generation are here.

`<test_group_name>``.log (for example, Full_MQTT.log)`

The logs of the test group, including logs from the device under test.

Test for Requalifications

As new versions of AWS IoT Device Tester qualification tests are released, as you update your board-specific packages or device drivers, you can use AWS IoT Device Tester to test your microcontroller boards. For subsequent qualifications, make sure that you have the latest versions of Amazon FreeRTOS and AWS IoT Device Tester and run the qualification tests again.:

Troubleshooting

We recommend the following workflow for troubleshooting testing an Amazon FreeRTOS device:

1. Read the console output.

2. Look in the AFQ_Report.xml file.
3. Look in the logs files located under /results/<uuid>/logs.
4. Investigate one of the following problem areas:

   - Device configuration
   - Device interface
   - Device tooling
   - Amazon FreeRTOS source code

Troubleshooting Device Configuration

When you use AWS IoT Device Tester, you must get the correct configuration files in place before you execute the binary. If you are getting parsing and configuration errors, your first step should be to locate and use a configuration template appropriate for your environment.

If you are still having issues, see the debugging following process.

Where Do I Look?

Start by looking in the results.xml file in the /results/<uuid> directory. This file contains all of the test cases that were run and error snippets for each failure. To get all of the execution logs, look under /results/<uuid>/<test-case-id>.log for each test group.

Parsing Errors

Occasionally, a typo in a JSON configuration can lead to parsing errors. Most of the time, the issue is a result of omitting a bracket, comma, or quote from your JSON file. AWS IoT Device Tester performs JSON validation and prints debugging information. It prints the line where the error occurred, the line number, and the column number of the syntax error. This information should be enough to help you fix the error, but if you are still having issues locating the error, you can perform validation manually in your IDE, a text editor such as Atom or Sublime, or through an online tool like JSONLint.

Required Parameter Missing Error

Because new features are being added to AWS IoT Device Tester, changes to the configuration files might be introduced. Using an old configuration file might break your configuration. If this happens, the <test_case_id>.log file under /results/<uuid>/logs explicitly lists all missing parameters. AWS IoT Device Tester validates your JSON configuration file schemas to ensure that the latest supported version has been used.

Could Not Start Test Error

You might encounter errors that point to failures during test start. Since there are several possible causes for this, please make sure to check the following areas for correctness:

- Make sure that the pool name you've included in your execution command actually exists. This is referenced directly from your device.json file.
- Ensure that the device(s) in your pool have correct configuration parameters.

Device Interface and Port

This section contains information about the device interfaces AWS IoT Device Tester uses to connect to your devices.

Supported Platforms

AWS IoT Device Tester supports Linux, macOS, and Windows. All three platforms have different naming schemes for serial devices that are attached to them:

- Linux: /dev/tty*
- macOS: /dev/tty.*
- Windows: COM*

To check your device ID:

- For Linux/macOS, open a terminal and run **ls /dev/tty***.
- For Windows, open Device Manager and expand the serial devices group.

Device Interfaces

Each embedded device is different, which means that they can have one or more serial ports. It is common for devices to have two ports when connected to a machine, one being a data port for flashing the device and the other to read output. It is crucial to set the correct port in your `device.json` file. Otherwise, flashing or reading output might fail.

In the case of multiple ports, make sure to use the data port of the device in your `device.json` file. For example, if you plug in an Espressif WRover device and the two ports assigned to it are /dev/ttyUSB0 and /dev/ttyUSB1, Use `/dev/ttyUSB1` in your `device.json` file.

For Windows, follow the same logic.

Reading Device Data

AWS IoT Device Tester uses individual device build and flash tooling to specify port configuration. If you are testing your device and don't get output, try the following default settings:

```
Baud rate - 115200
Data Bits - 8
Parity - None
Stop Bits - 1
Flow Control - None
```

These settings are handled by AWS IoT Device Tester without any configuration on your end. However, you can use the same method to manually read device output. On on Linux or macOS, you can do this with the **screen** command. On Windows, you can use a program such as TeraTerm.

```
Screen: screen /dev/cu.usbserial 115200
```

```
TeraTerm: Use the above-provided settings to set the fields explicitly in the
GUI.
```

Development Toolchain Problems

This section discusses problems that can occur with your toolchain.

Code Composer Studio on Ubuntu

For TI devices, we recommend that you download and install Code Composer Studio 7.3. The newer versions of Ubuntu (17.10 and 18.04) have a version of the glibc package that is not compatible with Code Composer Studio 7.*x* versions. We recommended that you install Code Composer Studio version 8.2 or later.

Symptoms of incompatibility might include:

- Amazon FreeRTOS failing to build or flash to your device.
- The Code Composer Studio installer might freeze.
- No log output is displayed in the console during the build or flash process.
- Build command attempting to launch in GUI mode even when invoked as headless.

Amazon FreeRTOS Source Code

The following sections discuss troubleshooting problems with the Amazon FreeRTOS source code.

Code Errata

Every Amazon FreeRTOS release is bundled with a document, located under the `/amazon-freertos/tests` directory, that contains all of the errata information for that release. We recommend that you read through this document before you run any tests.

The errata document contains an entry for any devices that currently fail tests due to reasons like:

- The hardware doesn't support a specific feature.
- The hardware supports the feature, but Amazon FreeRTOS doesn't support it on the device yet.
- The hardware supports the feature, but the underlying software stack doesn't support the hardware (non-AFR).

If the errata does not contain information specific to your device, continue the debugging process as outlined in the next section.

Debugging Amazon FreeRTOS

When a source code error occurs, AWS IoT Device Tester will write debug output to the *<test-group-id>*.log file in the `/results/`*<uuid>*`/logs` directory. Search the file for any instances of errors. The error will point to a location in the Amazon FreeRTOS source code. You can then use the line number and file path information in that log to reference the piece of source code that resulted in the error.

Logging

AWS IoT Device Tester logs are placed in a single location. From the root AWS IoT Device Tester directory, the available files are:

- `./results/`*<uuid>*
- `AFQ_Report.xml`
- `awsiotdevicetester_report.xml`
- `/logs/`*<test_group_id>*`.log`

The most important logs to look at will be *<test_group_id>*.log and results.xml. The latter will contain information about which tests failed with a specific error message. You can then use the former to dig further into the problem in order to get better context.

Console Errors

When AWS IoT Device Tester is run, failures are reported to console with brief messages. Look in *<test_group_id>*.log to learn more about the error.

Log Errors

The *<test-group-id>*.log file is located in the /results/*<uuid>* directory. Each test execution has a unique test ID that is used to create the *<uuid>* directory. Individual test group logs are under the *<uuid>* directory. Use the AWS IoT console to look up the test group that failed and then open the log file for that group in the /results/*<uuid>* directory. The information in this file includes the full build and flash command output, as well as test execution output and more verbose AWS IoT Device Tester console output.

Path Variables

AWS IoT Device Tester defines the following path variables that can be used in command lines and configuration files:

`{{testData.sourcePath}}`

A variable that expands to the source code path.

`{{device.connectivity.serialPort}}`

A variable that expands to the serial port.

`{{device.identifiers[?(@.name == 'serialNo')].value}}`

A variable that expands to the serial number of your device.

The following is an example `userdata.json` file:

```
{
       "sourcePath":"</path/to/amazon-freertos>",
       "buildTool":{
          "name":"<TOOL_NAME>",
          "version":"<TOOL_VERSION>",
          "command":[
             "</path/to/build>.sh {{testData.sourcePath}}"
          ]
       },
       "flashTool":{
          "name":"<TOOL_NAME>",
          "version":"<TOOL_VERSION>",
          "command":[
             "</path/to/flash>.sh {{device.connectivity.serialPort}}
 {{testData.sourcePath}}"
          ]
       },
       "clientWifiConfig":{
          "wifiSSID":"<SSID1>",
          "wifiPassword":"<PASSWORD>",
          "wifiSecurityType":"eWiFiSecurityWPA2"
       },
       "testWifiConfig":{
          "wifiSSID":"<SSID2>",
          "wifiPassword":"<PASSWORD>",
          "wifiSecurityType":"eWiFiSecurityWPA2"
       },
       "otaConfiguration":{
          "otaFirmwareFilePath":"{{testData.sourcePath}}/<relative-path/to/ota-image/from/
root/of/afrsourcecode>",
          "deviceFirmwareFileName":"<deviceFirmwareFileName>",
          "awsSignerPlatform":"AmazonFreeRTOS-Default",
          "awsSignerCertificateArn":"arn:aws:acm:<region>:<account-
id>:certificate:<certificate-id>",
          "awsUntrustedSignerCertificateArn":"arn:aws:acm:<region>:<account-
id>:certificate:<certificate-id>",
          "awsSignerCertificateFileName":"<awsSignerCertificateFileName>",
          "compileCodesignerCertificate":true
       }
    }
```

The following is an example `device.json` file:

```
[
 {
  "id": "<POOL_NAME>",
  "sku": "<armsku>",
  "features": [
  {
   "name": "WIFI",
   "value": "<Yes>"
  },
  {
   "name": "OTA",
   "value": "<Yes>"
  },
  {
   "name": "TCP/IP",
   "value": "Offloaded"
  },
  {
   "name": "TLS",
   "value": "On-chip"
  }
 ],
 "devices": [
 {
  "id": "<DEVICE_NAME>",
  "connectivity": {
   "protocol": "uart",
   "serialPort": "/dev/tty<PORT>" OR "/dev/tty.<PORT>"
  },
  "identifiers": [
  {
   "name": "serialNo",
   "value": "<ABCDEZAGHJI>"
  }
  ]
 }
 ]
}
]
```

On the Windows platform, the userdata and device configuration files are formatted in the same manner. Pay close attention to the direction of the path-separator slashes. We recommend using the forward slash (/) because newer versions of Windows support it. If you are using Windows 7 or earlier, use the back slash (\).

Permissions Policy Template

The following is a policy template that grants the permissions required for AWS IoT Device Tester:

```
{
 "Version": "2012-10-17",
    "Statement": [
     {
   "Sid": "VisualEditor0",
         "Effect": "Allow",
         "Action": [
          "iam:CreatePolicy",
             "iam:DetachRolePolicy",
             "iam:DeleteRolePolicy",
             "s3:CreateBucket",
             "iam:DeletePolicy",
             "iam:CreateRole",
             "iam:DeleteRole",
             "iam:AttachRolePolicy",
             "s3:DeleteBucket",
             "s3:PutBucketVersioning"
   ],
         "Resource": [
          "arn:aws:s3:::idt*",
             "arn:aws:s3:::afr-ota*",
             "arn:aws:iam::*:policy/idt*",
             "arn:aws:iam::*:role/idt*"
   ]
  },
  {
      "Sid": "VisualEditor1",
         "Effect": "Allow",
         "Action": [
          "iot:DeleteCertificate",
             "iot:AttachPolicy",
             "iot:DetachPolicy",
             "s3:DeleteObjectVersion",
             "iot:DeleteOTAUpdate",
             "s3:PutObject",
             "s3:GetObject",
             "iam:PassRole",
             "iot:DeleteStream",
             "iot:DeletePolicy",
             "iot:UpdateCertificate",
             "iot:GetOTAUpdate",
             "s3:DeleteObject",
             "iot:DescribeJobExecution",
             "s3:GetObjectVersion"
   ],
         "Resource": [
    "arn:aws:iot:*:*:thinggroup/idt*",
    "arn:aws:iot:*:*:policy/idt*",
    "arn:aws:iot:*:*:otaupdate/idt*",
             "arn:aws:iot:*:*:thing/idt*",
    "arn:aws:iot:*:*:cert/*",
    "arn:aws:iot:*:*:job/*",
    "arn:aws:iot:*:*:stream/*",
    "arn:aws:iam::*:role/idt*",
    "arn:aws:s3:::afr-ota*/*",
    "arn:aws:s3:::idt*/*",
    "arn:aws:iam:::role/idt*"
   ]
  },
  {
      "Sid": "VisualEditor2",
         "Effect": "Allow",
         "Action": [
          "iot:DetachThingPrincipal",
             "iot:AttachThingPrincipal",
             "s3:ListBucketVersions",
             "iot:CreatePolicy",
             "iam:ListRoles",
             "freertos:ListHardwarePlatforms",
             "signer:DescribeSigningJob",
             "s3:ListBucket",
             "signer:*",
             "iot:DescribeEndpoint",
             "iot:CreateStream",
             "signer:StartSigningJob",
             "s3:ListAllMyBuckets",
             "signer:ListSigningJobs",
             "acm:GetCertificate",
             "acm:ListCertificates",
             "acm:ImportCertificate",
             "freertos:DescribeHardwarePlatform",
             "iot:CreateKeysAndCertificate",
             "iot:CreateCertificateFromCsr",
             "s3:GetBucketLocation",
             "iot:GetRegistrationCode",
             "iot:RegisterCACertificate",
             "iot:RegisterCertificate",
             "iot:UpdateCACertificate",
             "iot:DeleteCACertificate",
             "iot:DeleteCertificate",
             "iot:UpdateCertificate"
   ],
         "Resource": "*"
  },
     {
   "Sid": "VisualEditor3",
         "Effect": "Allow",
         "Action": [
          "s3:PutObject",
             "s3:GetObject"
   ],
         "Resource": [
          "arn:aws:s3:::afr*/*",
    "arn:aws:s3:::idt*/*"
   ]
  },
     {
      "Sid": "VisualEditor4",
         "Effect": "Allow",
         "Action": [
          "iot:CreateOTAUpdate",
             "iot:CreateThing",
             "iot:DeleteThing"
   ],
         "Resource": "*"
  }
 ]
}
```