Amazon FreeRTOS

User Guide

Amazon FreeRTOS: User Guide

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What Is Amazon FreeRTOS?

Amazon FreeRTOS is a microcontroller operating system based on the FreeRTOS kernel. It includes libraries for connectivity and security. You can use the Amazon FreeRTOS console to configure and download the FreeRTOS kernel and software libraries for your application. The Amazon FreeRTOS Qualification Program gives you the confidence that the microcontroller you choose fully supports the Amazon FreeRTOS features and capabilities.

The FreeRTOS Kernel

The FreeRTOS kernel is a real-time operating system 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 completely 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 Greengrass cores.
- Manage Wi-Fi connections.

Amazon FreeRTOS Console

The Amazon FreeRTOS console is used to create software configurations that you can download onto your development computers to get started with Amazon FreeRTOS. The console allows you to select the hardware platform, compiler and IDE used for development, and Amazon FreeRTOS libraries required for your application. After you have made these selections, a custom zip file of the required files is created along with demo projects that make it easy to get started with Amazon FreeRTOS. This zip file includes

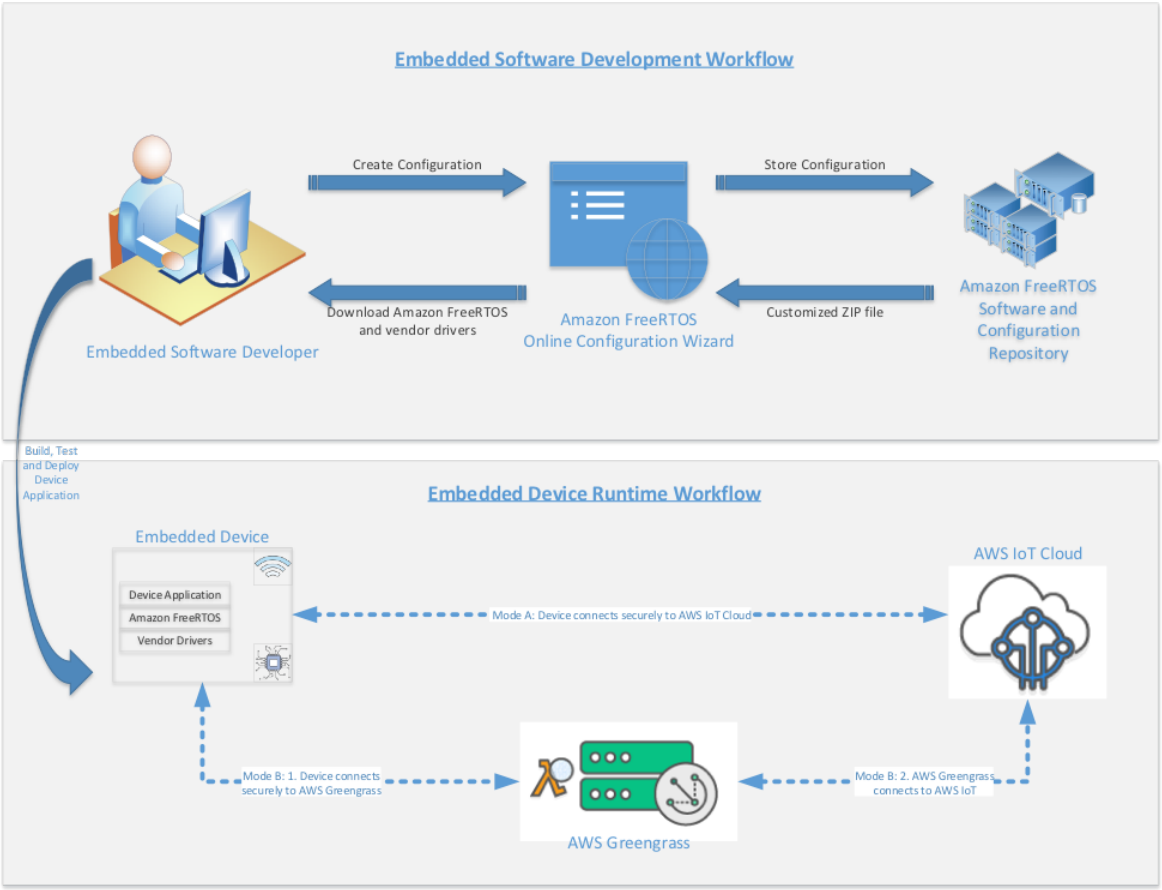
the FreeRTOS kernel, Amazon FreeRTOS libraries, and board support packages (BSPs) and hardware drivers for the hardware platform.

Amazon FreeRTOS Qualification Program

The Amazon FreeRTOS Qualification Program (Amazon FQP) is for microcontroller vendors who want to qualify their microcontroller-based hardware on Amazon FreeRTOS. The goal of Amazon FQP is to ensure that developers can use Amazon FreeRTOS on their choice of microcontroller-based hardware. In order to deliver a consistent experience for developers, the Amazon FQP outlines a set of security, functionality, and performance requirements that all microcontrollers (and the associated hardware abstraction layers and drivers) must meet.

Development Workflow

During the development process, you can customize and download Amazon FreeRTOS source code from the Amazon FreeRTOS console. Each of your configurations is saved in AWS. You can download the source code using these configurations at any time. After you have the source code, you can 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 Greengrass as part of a complete IoT solution. The following diagram shows the development workflow and the subsequent connectivity from Amazon FreeRTOS-based devices.



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

Getting Started with Amazon FreeRTOS

This section walks you through configuring Amazon FreeRTOS and running it on one of the qualified microcontroller boards. In this tutorial, we assume you are familiar with the AWS IoT console. If not, we recommend that you start with the AWS IoT Getting Started tutorial first.

Granting FreeRTOS Permissions

In order to access the Amazon FreeRTOS console, you must grant your IAM user `AmazonFreeRTOSFullAccess` permissions:

1. Browse to the IAM console, and from the left navigation pane, choose **Users.**
2. Type in your user name in the search text box and press return. Choose your user name from the list of users.
3. Choose **Add permissions**.
4. Choose **Attach existing policies directly.**
5. In the search box type **AWSFreeRTOSFullAccess**, select it from the list of policies, and choose **Next: Review**.
6. Choose **Add permissions**.

Amazon FreeRTOS Prerequisites

Before you install Amazon FreeRTOS, you need an AWS account and one of the supported hardware platforms.

1. To create an AWS account, see Create and Activate an AWS Account.
2. Purchase one of the supported hardware platforms:
   - STMicroelectronicsSTM32L4 Discovery kit IoT node
   - Texas Instruments CC3220SF-LAUNCHXL
   - NXP LPC54018 IoT Module
   - Microsoft Windows 7 or later, with at least a dual core and a hard-wired Ethernet connection

Create Your AWS IoT Credentials

A device connected to AWS IoT is represented by an IoT thing. The IoT thing is associated with a device certificate, private key, and an AWS IoT policy. The device uses the certificate and private key to authenticate with AWS IoT. The AWS IoT policy is associated with the certificate and determines which AWS IoT operations the device can perform. For more information, see Security and Identity in AWS IoT.

To create an IoT thing for your device

1. Browse to the AWS IoT Console.
2. In the left 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**.
4. On the **Creating AWS IoT things** page, choose **Create a single thing**.
5. On the **Add your device to the thing registry** page, type 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 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 **Create new policy**.
11. On the **Create a policy** page, type a name for your policy, and in **Add statements**, choose **Advanced mode**.
12. Replace the *region* and *aws-account* in the following JSON and then copy and paste the configuration into the policy editor window.

```
{
 "Version": "2012-10-17",
 "Statement": [
 {
  "Effect": "Allow",
  "Action": "iot:Connect",
  "Resource": "arn:aws:iot:<us-west-2>:<aws-account-id>:client/MQTTEcho"
 },
 {
  "Effect": "Allow",
  "Action": "iot:Publish",
  "Resource": "arn:aws:iot:<us-west-2>:<aws-account-id>:topic/freertos/demos/echo"
 },
 {
  "Effect": "Allow",
  "Action": "iot:Subscribe",
  "Resource": "arn:aws:iot:<us-west-2>:<aws-account-id>:topicfilter/freertos/demos/
echo"
 },
 {
  "Effect": "Allow",
  "Action": "iot:Receive",
  "Resource": "arn:aws:iot:<us-west-2>:<aws-account-id>:topic/freertos/demos/echo"
 }
 ]
}
```

Choose **Create** to create the policy.

13. In the left navigation pane, choose **Secure**, and then choose **Certificates**.
14. On **Certificates** page, choose your certificate (they are listed by ID), choose the ellipsis (**. . .**), and then choose **Attach policy**.
15. On the **Attach policies to certificate(s)** page, select your policy, and then choose **Attach**.

Getting Started with the Texas Instruments (TI) CC3220SF-LAUNCHXL

If you do not have the TI CC3220SF-LAUNCHXL development kit, you can purchase one from Texas Instruments.

Setting Up Your Environment

Install TI Code Composer Studio

1. Browse to TI Code Composer Studio.
2. Download the offline installer for your host machines's platform (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**.

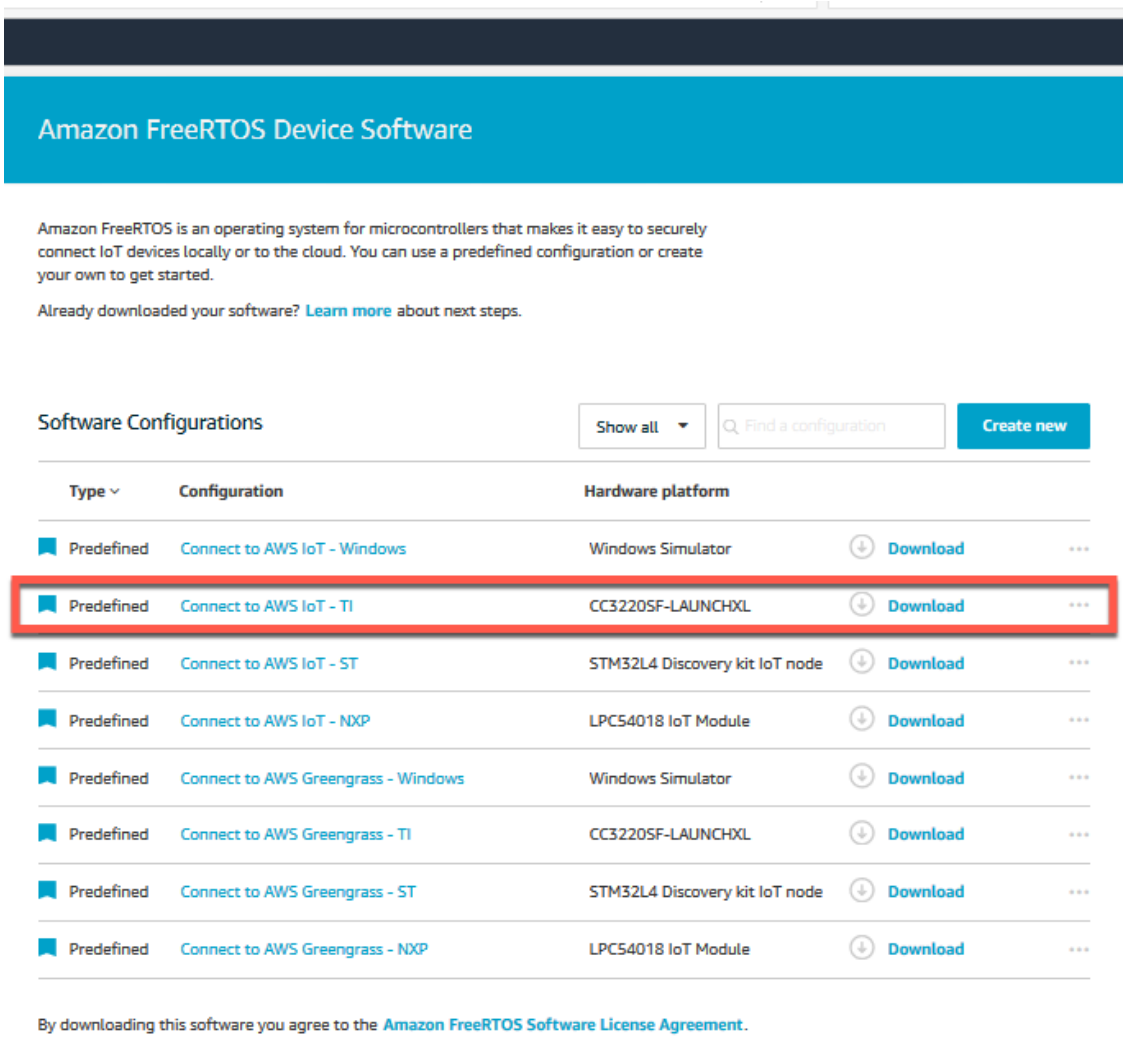
If you experience installation issues, see TI Development Tools Support, Code Composer Studio FAQs, and Troubleshooting Code Composer Studio.

Download and Build Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS and run the sample code.

Download Amazon FreeRTOS

1. In the AWS IoT console, browse to the Amazon FreeRTOS page.
2. In the left 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- TI**, and then choose **Download**.



6. Unzip the downloaded file to a folder, and make note of the folder path. In this tutorial, this folder is referred to as `BASE_FOLDER`.

   Note
   In Microsoft Windows, the maximum length of a file path is 260 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure the path to your BASE_FOLDER is less than 36 characters. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS` causes build failures.

Import the Amazon FreeRTOS Sample Code into TI Code Composer

1. Open TI Code Composer and type a name for a new workspace.
2. On the **Getting Started** page, choose **Import Project**.
3. In the **Select search-directory** text box, type *<BASE_FOLDER>*`\AmazonFreeRTOS\demos\ti\cc3220_launchpad\ccs`.
4. The project `aws_demos` should be selected by default.

5. To import the project into TI Code Composer, choose **Finish**.
6. From the **Project** menu, choose **Build Project** to make sure it compiles without errors or warnings.

Configure Your Project

Configure Your Wi-Fi Credentials

1. In the **Project Explorer** window, open `aws_demos\application_code\common_demos\include\aws_clientcredentials.h`.
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 for your Wi-Fi network. Valid values are:
     - `eWiFiSecurityOpen`: Open, no security.
     - `eWiFiSecurityWEP`: WEP security.
     - `eWiFiSecurityWPA`: WPA security.
     - `eWiFiSecurityWPA2`: WPA2 security.

Configure Your AWS IoT Endpoint

You must specify a custom AWS IoT endpoint in order for the FreeRTOS sample code to connect to AWS IoT.

1. Browse to the AWS IoT console.
2. In the left navigation pane, choose **Settings**.
3. Copy your custom AWS IoT endpoint from the **Endpoint** text box. It should look like *<1234567890123>*`.iot.`*<us-east-1>*`.amazonaws.com`.
4. Open `aws_demos/application_code/common_demos/include/aws_clientcredential.h` and set `clientcredentialMQTT_BROKER_ENDPOINT` to your AWS IoT endpoint.

Configure Your AWS IoT Credentials

The certificate and private key must be hard-coded into the Amazon FreeRTOS simulator code. Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project.

To format your certificate and private key

1. In a browser window, open *<BASE_FOLDER>*`\demos\common\devmode_key_provisioning\CertificateConfigurationTool\CertificateConfigurator.html`.
2. Under **Certificate PEM file**, choose the *<ID>*`-certificate.pem.crt` you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *<ID>*`-private.pem.key` 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 stub file that is in the directory.

Run the FreeRTOS Samples

1. Rebuild your project.
2. Sign in to the AWS IoT Console.
3. In the left navigation pane, choose **Test** to open the MQTT client.
4. In the **Subscription topic** text box, type `freertos/demos/echo`, and then choose **Subscribe to topic**.
5. From the **Run** menu in TI Code Composer, choose **Debug** to start debugging.
6. When the debugger stops at the breakpoint in `main()`, go to the **Run** menu, and then choose **Resume**.

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

Troubleshooting

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

1. In Code Composer, on **Project Explorer**, choose **aws_demos**.
2. From the **Run** menu, choose **Debug Configurations**.
3. In the left navigation pane, choose **aws_demos**.
4. Choose the **Target** tab in the main window.
5. Scroll down to the **Connection Options** section and select the **Reset the target on a connect** check box.
6. Choose **Apply** and then choose **Close** to close the **Debug Configurations** dialog box.

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 (ST) STM32L4 Discovery kit IoT node

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

Setting Up Your Environment

Install System Workbench for STM32

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

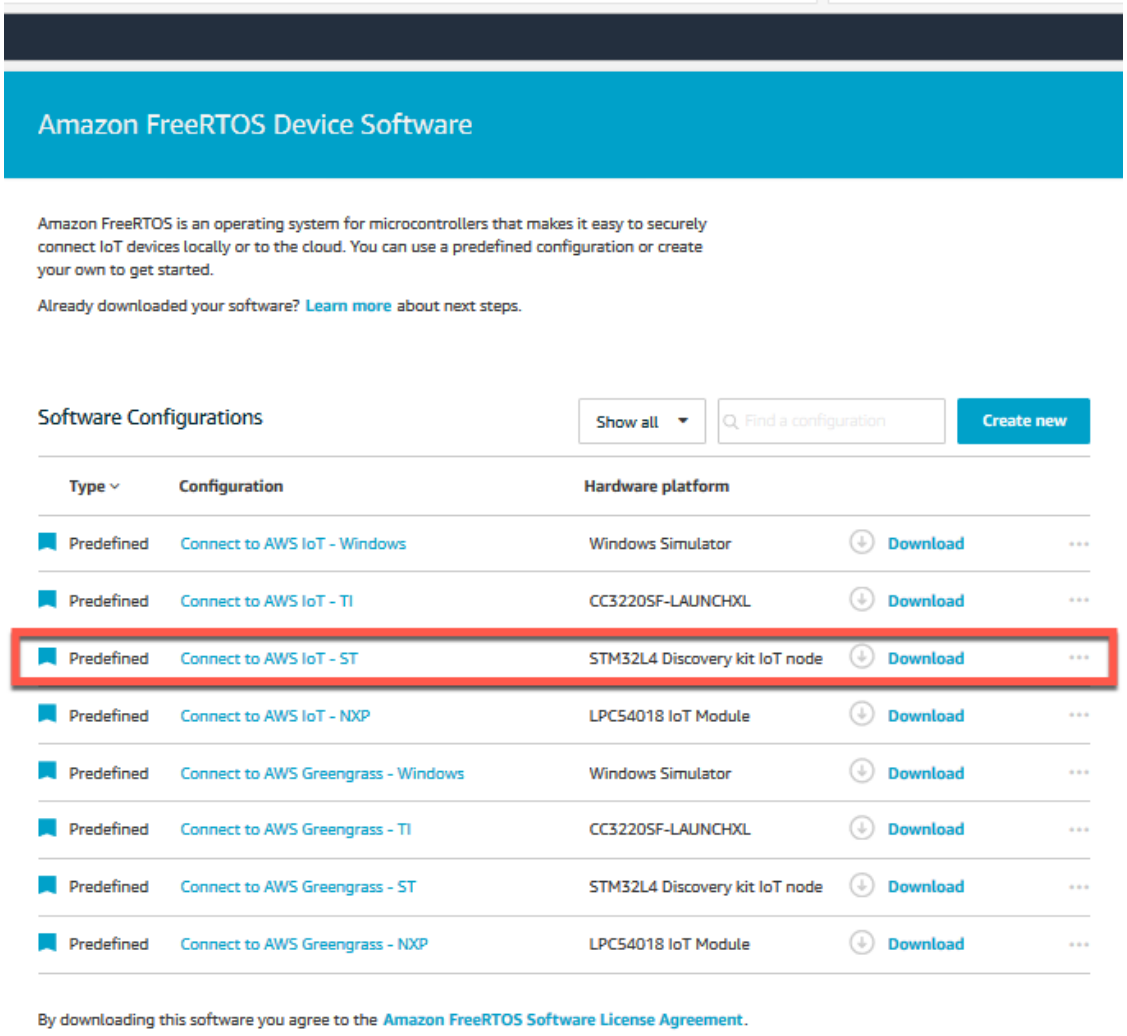
If you encounter installation issues, see the FAQs on the System Workbench website.

Download and Build Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS and run the sample code.

Download Amazon FreeRTOS

1. In the AWS IoT console, browse to the Amazon FreeRTOS page.
2. In the left 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 choose **Download**.



6. Unzip the downloaded file to a folder, and make note of the folder path. In this tutorial, this folder is referred to as `BASE_FOLDER`.

Import the Amazon FreeRTOS Sample Code into the STM32 System Workbench

1. Open the STM32 System Workbench and type a name for a new workspace.
2. On the **Getting Started** page, choose **Import Project**.

3. In the **Select search-directory** text box, type *<BASE_FOLDER>*\AmazonFreeRTOS\demos\st\stm32l475_discovery\ac6.
4. The project aws_demos should be found and selected by default.
5. Choose **Finish** to import the project into STM32 System Workbench.
6. From the **Project** menu, choose **Build Project** to make sure it compiles without any errors or warnings.

Configure Your Project

Configure Your Wi-Fi Credentials

1. In the **Project Explorer** window, open aws_demos\application_code\common_demos\include\aws_clientcredentials.h.
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 for your Wi-Fi network. Valid values are:
     - eWiFiSecurityOpen: Open, no security.
     - eWiFiSecurityWEP: WEP security.
     - eWiFiSecurityWPA: WPA security.
     - eWiFiSecurityWPA2: WPA2 security.

Configure Your AWS IoT Endpoint

You must specify a custom AWS IoT endpoint in order for the FreeRTOS sample code to connect to AWS IoT.

1. Browse to the AWS IoT console.
2. In the left navigation pane, choose **Settings**.
3. Copy your custom AWS IoT endpoint from the **Endpoint** text box. It should look like *<1234567890123>*.iot.*<us-east-1>*.amazonaws.com.
4. Open aws_demos/application_code/common_demos/include/aws_clientcredential.h and set clientcredentialMQTT_BROKER_ENDPOINT to your AWS IoT endpoint.

Configure Your AWS IoT Credentials

The certificate and private key must be hard-coded into the Amazon FreeRTOS simulator code. Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project.

To format your certificate and private key

1. In a browser window, open *<BASE_FOLDER>*\demos\common\devmode_key_provisioning\CertificateConfigurationTool\CertificateConfigurator.html.
2. Under **Certificate PEM file**, choose the *<ID>*-certificate.pem.crt you downloaded from the AWS IoT console.
3. Under **Private Key PEM file**, choose the *<ID>*-private.pem.key you downloaded from the AWS IoT console.

4. Select the **Generate and save aws_clientcredential_keys.h** and save the file in `<BASE_FOLDER>\demos\common\include`. This will overwrite the stub file that is in the directory already.

Run the FreeRTOS Samples

1. Rebuild your project.
2. Sign in to the AWS IoT console.
3. In the left navigation pane, choose **Test** to open the MQTT client.
4. In the **Subscription topic** text box, type `freertos/demos/echo`, and then choose **Subscribe to topic**.
5. From the **Run** menu in the STM32 System Workbench, choose **Debugging**.
6. The first time you attempt to debug the sample, a **Debug As** dialog is displayed. Choose **Ac6STM32 C/C++ Application**, and then choose **OK**. This tells System Workbench to load the code onto your STM32 board and debug it.
7. When the debugger stops at the breakpoint in `main()`, from the **Run** menu, choose **Resume**.

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

Getting Started with the NXP LPC54018 IoT Module

If you do not have an NXP LPC54018 IoT Module, you can order one from NXP

Setting up Your Environment

Install IAR Embedded Workbench for Arm

1. Browse to Software for NXP Kits and select **Download Software** to install **IAR Embedded Workbench for Arm**.

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

Note
If you encounter any installation issues, see NXP Support or NXP Developer Resources.

Connecting a JTAG Debugger

You will 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 Users' Guide.

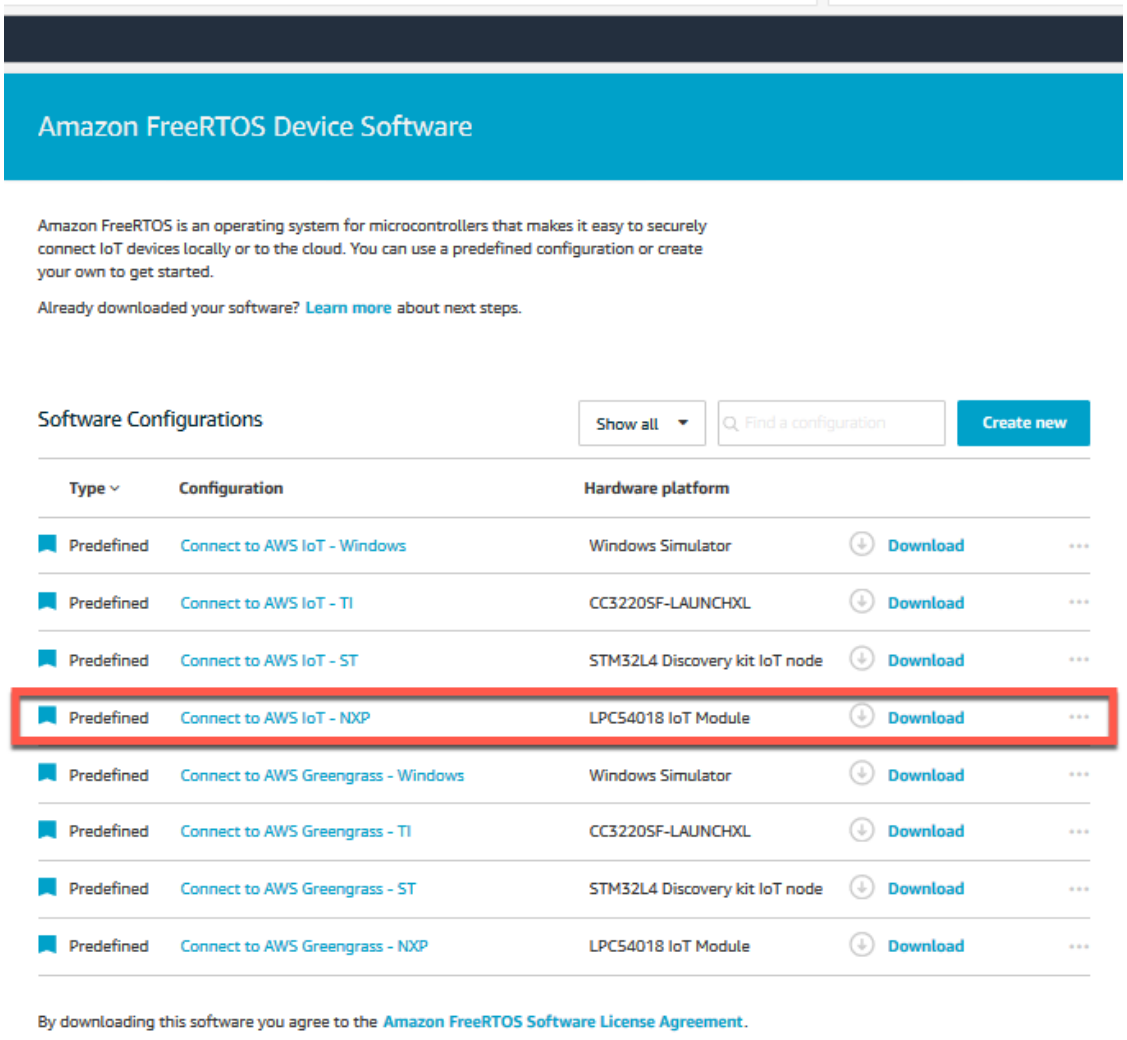
Note
If you are using a Segger J-Link debugger, you will need a converter cable to connect the 20-pin connector from the debugger to the 10-pin connector on the NXP IoT module.

Download and Build Amazon FreeRTOS

Once you have your environment setup, you can download Amazon FreeRTOS and run the sample code.

Download Amazon FreeRTOS

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



6. Unzip the downloaded file to a folder, and remember the folder path. We will refer to this folder as `BASE_FOLDER` in this tutorial.

Note
The maximum length of a file path on Microsoft Windows is 260 characters. In order to accommodate the files in the Amazon FreeRTOS projects, ensure the path to your BASE_FOLDER is less than [XYZ] characters long. For example, `C:\Users\Username\Dev`

`\AmazonFreeRTOS` will work, but `C:\Users\Username\Documents\Development \Projects\AmazonFreeRTOS` will cause build failures.

Import the Amazon FreeRTOS Sample Code into IAR Embedded Workbench

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

Configure your Project

Configure your WiFi Credentials

1. In the **Project Explorer** window, open `aws_demos\application_code\common_demos\include \aws_clientcredentials.h`.
2. Specify values for the following `#define` constants:

   - `clientcredentialWIFI_SSID` – your WiFi network's Wi-Fi SSID.
   - `clientcredentialWIFI_PASSWORD` – your WiFi network's password.
   - `clientcredentialWIFI_SECURITY` – your WiFi network's security type, valid values are:
     - `eWiFiSecurityOpen` - Open, no security.
     - `eWiFiSecurityWEP` - WEP security.
     - `eWiFiSecurityWPA` - WPA security.
     - `eWiFiSecurityWPA2` - WPA2 Security.

Configure your AWS IoT Endpoint

In order for the FreeRTOS sample code to connect to AWS IoT, you must specify your custom AWS IoT endpoint.

1. Browse to the AWS IoT Console.
2. In the left navigation pane, select **Settings**.
3. Copy your custom AWS IoT endpoint from the **Endpoint** textbox (it should look like *<1234567890123>*`.iot.`*<us-east-1>*`.amazonaws.com`).
4. Open `aws_demos/application_code/common_demos/include/aws_clientcredential.h` and set `clientcredentialMQTT_BROKER_ENDPOINT` to your AWS IoT endpoint.

Configure your AWS IoT Credentials

The certificate and private key need to be hard coded into the Amazon FreeRTOS simulator code. Amazon FreeRTOS is a C language project and the certificate and private key must be specially formatted to be added to the project.

To format your certificate and private key

1. In a browser window, open *<BASE_FOLDER>*`\demos\common\devmode_key_provisioning \CertificateConfigurationTool\CertificateConfigurator.html`.
2. Under **Certificate PEM file** select the *<ID>*`-certificate.pem.crt` you downloaded from the AWS IoT console.

3. Under **Private Key PEM file** select the *<ID>*-private.pem.key you downloaded from the AWS IoT console
4. Select the **Generate and save aws_clientcredential_keys.h** and save the file in *<BASE_FOLDER>*\demos\common\include. This will overwrite the stub file that is in the directory already.

Run the FreeRTOS Samples

In order 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. Log into the AWS IoT Console.
3. In the left navigation pane, select **Test** to open the MQTT client.
4. In the **Subscription topic** textbox, type `freertos/demos/echo` and click **Subscribe to topic**
5. In IAR Embedded Workbench go to the **Project** menu and select **Build**.
6. Connect both the NXP IoT Module and the Segger J-Link Debugger to the USB ports on your computer using mini-USB to USB cables.
7. In IAR Embedded Workbench go to the **Project** menu and select **Download and Debug**.
8. In IAR Embedded Workbench go to the **Debug** menu and select **Start Debugging**.
9. When the debugger stops at the breakpoint in `main()`, go to the **Debug** and select **Go**

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

> **Note**
> If a **J-Link ... Device Selection** dialog box opens, click **OK** to continue. In the **Target Device Settings** dialog box, select **Unspecified**, **Cortex-M4** and click OK. This will only need to be done once.

Troubleshooting

If no messages are received at the IOT console, try the following:

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

Getting Started with the FreeRTOS Windows Simulator

Amazon FreeRTOS ships 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, you 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.

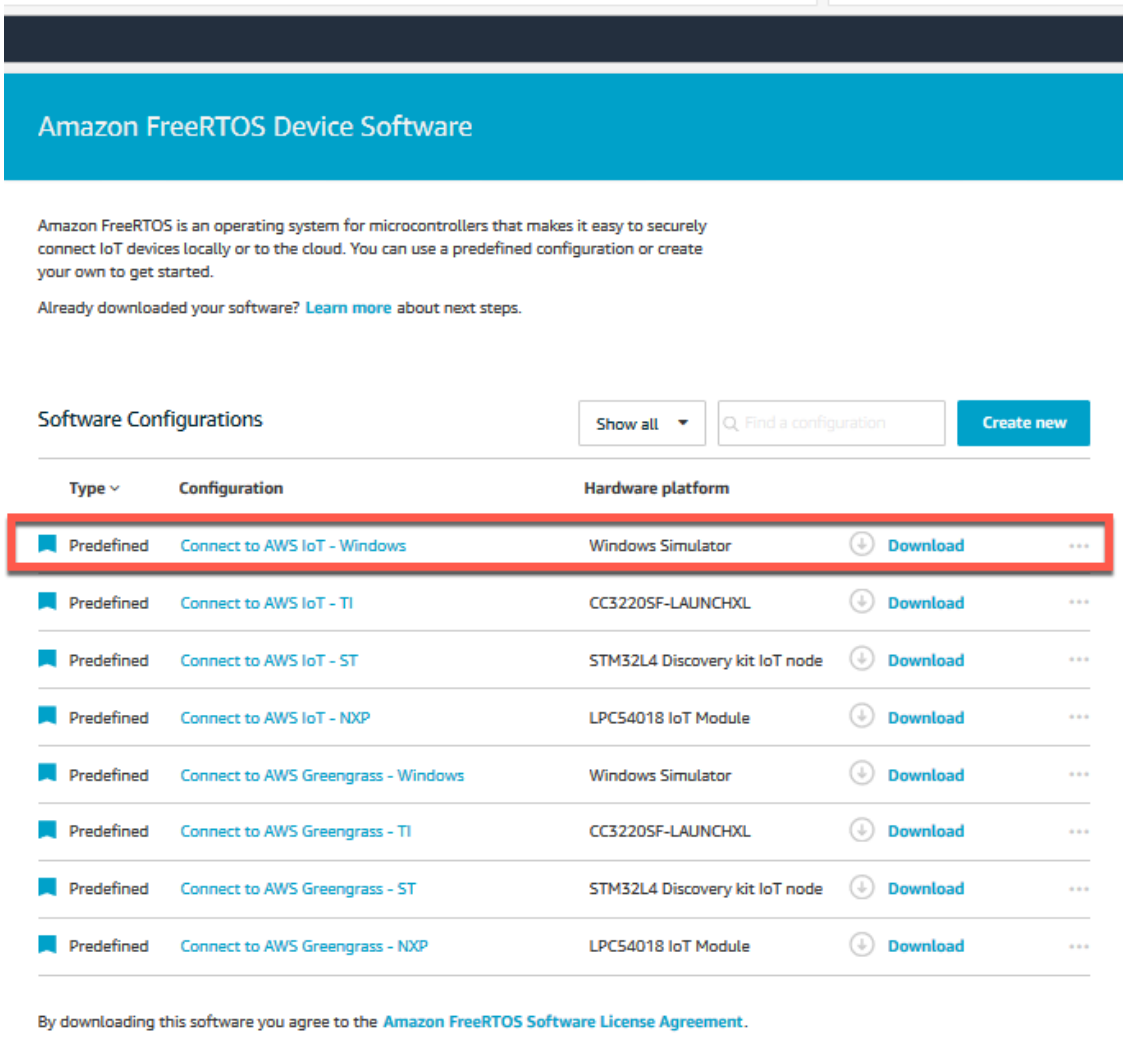
2. Install Microsoft Visual Studio Community 2017.
3. Make sure that you have an active hard-wired Ethernet connection.

Download and Build Amazon FreeRTOS

After your environment is set up, you can download Amazon FreeRTOS and run the sample code.

Download Amazon FreeRTOS

1. In the AWS IoT console, browse to the Amazon FreeRTOS page.
2. In the left 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 a folder, and make note of the folder path. In this tutorial, this folder is referred to as `BASE_FOLDER`.

Note
In Microsoft Windows, the maximum length of a file path is 260 characters. To accommodate the files in the Amazon FreeRTOS projects, make sure the path to your BASE_FOLDER is less than 36 characters. For example, `C:\Users\Username\Dev\AmazonFreeRTOS` works, but `C:\Users\Username\Documents\Development\Projects\AmazonFreeRTOS`causes build failures.

Load the Amazon FreeRTOS Sample Code into Visual Studio

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

Configure Your Project

Configure Your Network Interface

1. Run the project in Visual Studio. The program will enumerate 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 may see output in the debugger that says **Cannot find or open the PDB file**. These messages can be ignored.

   You can close the application window after you have identified the number for your hard-wired Ethernet interface.
2. Open `aws_demos/config_files/FreeRTOSConfig.h` and set `configNETWORK_INTERFACE_TO_USE` to the number that corresponds to your hard-wired network interface.

Configure Your AWS IoT Endpoint

You must specify a custom AWS IoT endpoint in order for the FreeRTOS sample code to connect to AWS IoT.

1. Browse to the AWS IoT console.
2. In the left navigation pane, choose **Settings**.
3. Copy your custom AWS IoT endpoint from the **Endpoint** text box. It should look like *<c3p0r2d2a1b2c3>*`.iot.`*<us-east-1>*`.amazonaws.com`.
4. Open `aws_demos/application_code/common_demos/include/aws_clientcredential.h` and set `clientcredentialMQTT_BROKER_ENDPOINT` to your AWS IoT endpoint.

Configure Your AWS IoT Credentials

The certificate and private key must be hard-coded into the Amazon FreeRTOS simulator code. Amazon FreeRTOS is a C language project, and the certificate and private key must be specially formatted to be added to the project.

To format your certificate and private key

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

Run the 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 left navigation pane, choose **Test** to open the MQTT client.
4. In the **Subscription topic** text box, type freertos/demos/echo, and then choose **Subscribe to topic**.
5. From the **Debug** menu in Visual Studio, choose **Start Debugging**.

Output like the following should be displayed in the output window for the aws_demo application.

```
0 0 [None] FreeRTOS_IPInit
1 0 [None] vTaskStartScheduler


The following network interfaces are available:

Interface 1 - rpcap://\Device\NPF_{FD3E22FF-2E53-4791-8522-AD889B6ABF1F}
(Network adapter 'Intel(R) Ethernet Connection (3) I218-LM' on local host)

Interface 2 - rpcap://\Device\NPF_{260D089E-CECC-43A7-8FC3-021FA7D17903}
(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.
2 92 [IP-task] vDHCPProcess: offer 10.0.0.189
3 152 [IP-task] vDHCPProcess: offer 10.0.0.189
4 152 [IP-task] Creating MQTT Echo Task...
5 152 [IP-task]

IP Address: 10.0.0.189
6 152 [IP-task] Subnet Mask: 255.255.255.0
7 152 [IP-task] Gateway Address: 10.0.0.1
8 152 [IP-task] DNS Server Address: 75.75.75.75


9 152 [MQTT] Blocking on queue with timeout set to 0.
10 152 [MQTT] Timed out on queue read.
```

```
11 152 [MQTT] Blocking on queue with timeout set to ffffffff.
12 153 [MQTTEcho] MQTT echo attempting to connect to 12345678901234.iot.us-
west-2.amazonaws.com.
13 153 [MQTTEcho] Sending command to MQTT task.
14 153 [MQTT] Received message 10000 from queue.
15 212 [IP-task] Socket sending wakeup to MQTT task.
16 492 [MQTT] Blocking on queue with timeout set to 2ee0.
17 492 [MQTT] Received message 0 from queue.
18 492 [MQTT] Blocking on queue with timeout set to 2ee0.
19 552 [IP-task] Socket sending wakeup to MQTT task.
20 552 [MQTT] Received message 0 from queue.
21 552 [MQTT] MQTT Connect was accepted. Connection established.
22 552 [MQTT] Notifying task.
23 552 [MQTT] Blocking on queue with timeout set to 493e0.
24 552 [MQTTEcho] Command sent to MQTT task passed.
25 552 [MQTTEcho] MQTT echo connected.
26 552 [MQTTEcho] MQTT echo test echoing task created.
27 552 [MQTTEcho] Sending command to MQTT task.
28 552 [MQTT] Received message 20000 from queue.
29 552 [MQTT] Blocking on queue with timeout set to 12c.
30 612 [IP-task] Socket sending wakeup to MQTT task.
31 612 [MQTT] Received message 0 from queue.
32 612 [MQTT] MQTT Subscribe was accepted. Subscribed.
33 612 [MQTT] Notifying task.
34 612 [MQTT] Blocking on queue with timeout set to 493a4.
35 612 [MQTTEcho] Command sent to MQTT task passed.
36 612 [MQTTEcho] MQTT Echo demo subscribed to freertos/demos/echo
37 612 [MQTTEcho] Sending command to MQTT task.
38 612 [MQTT] Received message 30000 from queue.
39 612 [MQTT] Blocking on queue with timeout set to 12c.
40 672 [IP-task] Socket sending wakeup to MQTT task.
41 672 [MQTT] Received message 0 from queue.
42 672 [MQTT] MQTT Publish was successful.
43 672 [MQTT] Notifying task.
44 672 [MQTT] Blocking on queue with timeout set to 493e0.
45 672 [MQTTEcho] Command sent to MQTT task passed.
46 672 [MQTTEcho] Echo successfully published 'Hello World 0'
47 672 [Echoing] Sending command to MQTT task.
48 672 [MQTT] Received message 40000 from queue.
49 672 [MQTT] Blocking on queue with timeout set to 12c.
50 712 [IP-task] Socket sending wakeup to MQTT task.
51 712 [MQTT] Received message 0 from queue.
52 712 [MQTT] MQTT Publish was successful.
53 712 [MQTT] Notifying task.
54 712 [MQTT] Blocking on queue with timeout set to 493e0.
55 712 [Echoing] Command sent to MQTT task passed.
56 712 [Echoing] Message returned with ACK: 'Hello World 0 ACK'
```

The sample sends 11 Hello World messages and then displays the following messages to indicate the sample has completed successfully:

```
350 61473 [MQTTEcho] Command sent to MQTT task passed.
351 61473 [MQTTEcho] MQTT echo demo finished.
```

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

Next Steps

This section describes the structure of the Amazon FreeRTOS download package and how to work with the thing shadow and Greengrass demos. If you haven't already, we recommend that you first read the Getting Started Guide (p. 3).

Topics

Navigating the Example Project

Directory and File Organization

There are two subfolders in the main Amazon FreeRTOS directory:

- demos
- lib

The `demos` directory 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 its own subdirectory under `demos`.

The function `DEMO_RUNNER_RunDemos()` located in Treadstone\\demos\\common\ \demo_runner\\aws_demo_runner.c contains code that calls each example. By default, only the `vStartpubsubDemotasks()` function is called. All others are commented. 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 the examples that can be executed by Amazon FreeRTOS can be found in the common directory under `demos`.

The `lib` directory contains the source code of the Amazon FreeRTOS libraries. The libraries that are available to you as part of Amazon FreeRTOS include:

- MQTT
- Thing shadow
- Greengrass
- Wi-Fi

There are helper functionsthat 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.

The `tests` directory is available only if the software was directly downloaded from GitHub. This directory contains tests that you can use to validate the implementation of Amazon FreeRTOS. The tests in this directory are based on the Unity Test Framework. They are intended for use with Amazon FreeRTOS libraries only.

Configuration Files

The demos have been configured to get you started quickly. You might want to change some of the configurations for your project in order to create a version that runs on your platform. You can find configuration files for a given platform vendor 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_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 secure sockets.

`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_wifi_config.h`

Configures the Wi-Fi parameters, such as SSID and security type.

`FreeRTOSConfig.h`

Configures the FreeRTOS kernel for multitasking operations.

Thing Shadow Demo

The thing shadow example demonstrates how to programmatically update and respond to changes in a thing shadow. The device in this scenario is a light bulb whose color can be set to red or green. The thing shadow example app is located in the `AmazonFreeRTOS/demos/common/shadow` directory. This example creates three tasks:

1. A main demo task that calls `prvShadowMainTask`.
2. A device update task that calls `prvUpdateTask`.
3. A number of shadow update tasks that call `prvShadowUpdateTasks`.

`prvShadowMainTask` initializes the thing 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 number of shadow update tasks created is controlled by the `democonfigSHADOW_DEMO_NUM_TASKS` constant defined in `AmazonFreeRTOS/demos/common/shadow/aws_shadow_lightbulb_on_off.c`.

`prvShadowUpdateTasks` generates an initial thing shadow document and updates the thing 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 (red -> green -> red).

`prvUpdateTask` responds to changes in the thing shadow's desired state. When the thing shadow's desired state changes, this task updates the thing shadow's reported state to reflect the thing shadow's 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/update/delta"
    },
    {
      "Effect": "Allow",
      "Action": "iot:Publish",
      "Resource": "arn:aws:iot:us-west-2:123456789012:topic/$aws/things/thingName/
shadow/update"
    }
  ]
}
```

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 thing'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 thing shadows interact, see Thing Shadows Data Flow.

Greengrass Discovery Demo

Before running the FreeRTOS Greengrass discovery demo, you must create a Greengrass group and 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 Create Your AWS IoT Credentials (p. 4).

After you have created an IoT thing for your Amazon FreeRTOS device, follow the instructions for setting up your environment and building Amazon FreeRTOS on one of the supported devices:

> **Note**
> Use the Getting Started instructions, but instead of downloading one of the predefined **Connect to AWS IoT- XX** configurations (where XX is TI, ST, or Windows), download one of the **Connect to AWS Greengrass - XX** configurations (where XX is TI, ST, or Windows). Be sure to follow the steps in the "Configure Your Project" sections. Return to this topic after you have built Amazon FreeRTOS for your device.

- Getting Started with the Texas Instruments (TI) CC3220SF-LAUNCHXL (p. 5)
- Getting Started with the STMicroelectronics (ST) STM32L4 Discovery kit IoT node (p. 8)
- Getting Started with the NXP LPC54018 IoT Module (p. 11)
- Getting Started with the FreeRTOS Windows Simulator (p. 14)

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
```

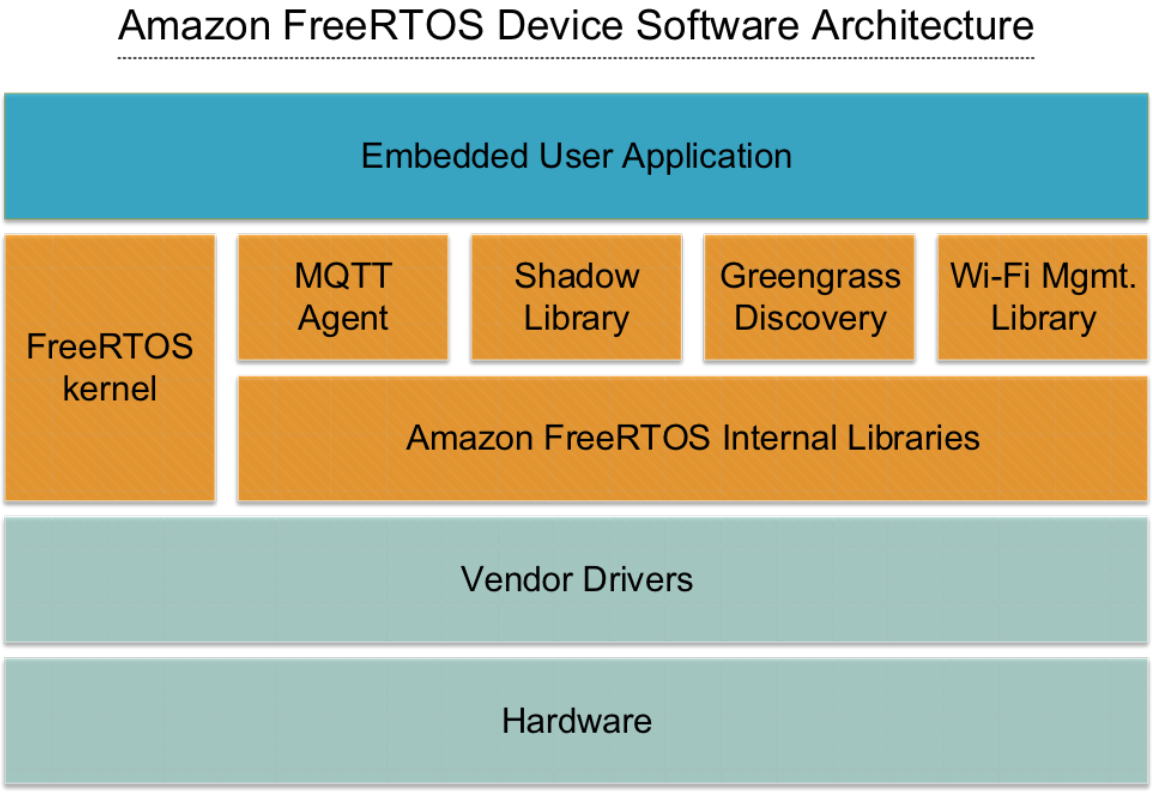
Amazon FreeRTOS Developer Guide

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, and is typically flashed to devices as a single compiled image with all the relevant components required for the device application. This image will combine functionality for the application written by the embedded developer, software libraries provided by Amazon, the FreeRTOS kernel, and relevant drivers and BSP (board support packages) 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 and 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).
- Inter-task 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 actually needs servicing. Blocked tasks do not require time-consuming periodic servicing. Direct-to-task notifications allow fast task signaling, with practically no RAM overhead, and can be used in the majority of inter-task 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 executeswithin its own context with no dependency on other tasks. Only one task within 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 require 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

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, which allows you to provide an application-specific implementation appropriate for the real-time system being developed. 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`

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`

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

Inter-task Coordination

Queues

Queues are the primary form of inter-task communication. They can be used to send messages between tasks and between interrupts and tasks. In most cases, they are used as thread-safe FIFO (First In First Out) 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 will be placed into the blocked state until either 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 behaviour 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 will be 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 will be 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 will receive 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 behaviour 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 will actually consume 14 bytes of buffer space. Likewise, writing a 100 byte message into a message buffer will actually use 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 will be 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, removes the task from the blocked state.

You can change this default behaviour 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 will be 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 behaviour 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:

- 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.

FreeRTOS Libraries

This section describes how to use the Amazon FreeRTOS libraries when writing embedded applications.

Topics

Cloud Connectivity

Topics

MQTT

The MQTT agent implements the MQTT protocol, which is a lightweight protocol designed for constrained devices. 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.

Callback

You can specify an optional callback which 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 `Treadstone_MQTT_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.

Major Configurations

You can use these configuration options to customize the MQTT agent's behavior:

- `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.

Thing Shadows

The Amazon FreeRTOS API provides functions to create, delete, and update a thing shadow. For more information, see Thing Shadows. Thing shadows are accessed using the MQTT protocol. The FreeRTOS thing shadow API works with the MQTT API and handles the details of working with the MQTT protocol.

The Amazon FreeRTOS shadow APIs define functions to create, update, and delete thing shadows.

Prerequisites

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 `Treadstone/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.

`clientcredentialCLIENT_CERTIFICATE_PEM`

The certificate PEM associated with your IoT thing.

`clientcredentialCLIENT_PRIVATE_KEY_PEM`

The private key PEM associated with your IoT thing.

Make sure the Amazon FreeRTOS MQTT library is installed on your device. For more information about the MQTT library, see MQTT (p. 30). Make sure that the MQTT buffers are large enough to contain the shadow JSON files. The maximum size for a thing shadow document is 8 KB. All default settings for the thing 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 thing shadow. For more information, see AWS IoT Getting Started.

Using the Thing Shadow APIs

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 thing shadow:

`SHADOW_Delete`

Delete the thing shadow.

`SHADOW_Get`

Get the current thing shadow.

`SHADOW_Update`

Update the thing shadow.

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

Greengrass Connectivity

The Greengrass Discovery API is used by your microcontroller devices to discover a Greengrass core on your network. Your device can send messages to a Greengrass core after it finds the core's endpoint.

Prerequisites

To use the Greengrass Discovery API, 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.

`clientcredentialCLIENT_CERTIFICATE_PEM`

The certificate PEM associated with your thing.

`clientcredentialCLIENT_PRIVATE_KEY_PEM`

The private key PEM associated with your thing.

A Greengrass group and core device must be set up in the console. For more information, see Getting Started with AWS Greengrass.

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

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

available. Manual selection uses the information in `aws_treadstone_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` returns, 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. These last two functions use `GGD_SecureConnect_Read` to get the JSON data from the socket. `GGD_JSONRequestStart`, `GGD_SecureConnect_Send`, `GGD_JSONRequestGetSize` must be called in order to successfully 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 to which your FreeRTOS device can connect. To connect to a Greengrass core, call the `GGD_SecureConnect_Connect` function, passing in the core device's IP address, port, and certificate. 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 greengrasss 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 Security

The Amazon FreeRTOS security API allows you to create embedded applications that communicate securely. The information in this section is intended to complement the API documentation.

Secure Sockets

The Secure Sockets interface is based on the Berkeley socket interface. It is provided for the easy onboarding of software developers from a variety of network programming backgrounds. The reference implementation for Secure Sockets supports TLS and TCP/IP over Ethernet and Wi-Fi. See `aws_secure_sockets.h` in the Amazon FreeRTOS source code repository.

Transport Layer Security

The Transport Layer Security (TLS) interface is a thin, optional wrapper used to abstract cryptographic implementation details away from the Secure Sockets interface that sits 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 library 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 library is optional because you can choose to interface directly from Secure Sockets into a crypto library. The Amazon FreeRTOS library is not used for MCU solutions that include a full-stack offload implementation of TLS and network transport.

Public Key Cryptography Standard #11

Public Key Cryptography Standard #11 (PKCS#11) is a cryptographic API that abstracts key storage, get/set properties for cryptographic objects, and session semantics. Please 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 work flow in order 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 only a small subset of the PKCS#11 interface standard to be implemented.

The following subset of PKCS#11 is used. This list is in roughly the order that the routines are called in support of provisioning, TLS client authentication, and clean-up. For detailed descriptions of the functions, please consult the PKCS#11 documentation provided by the standard committee.

Provisioning API

- `C_GetFunctionList`
- `C_Initialize`
- `C_CreateObject CKO_PRIVATE_KEY`
- `C_CreateObject CKO_CERTIFICATE pkcs11CERTIFICATE_TYPE_USER`
- `C_CreateObject CKO_CERTIFICATE pkcs11CERTIFICATE_TYPE_ROOT`
- `C_DestroyObject`

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`

Clean-up

- `C_CloseSession`
- `C_Finalize`

Asymmetric Cryptosystem Support

The Amazon FreeRTOS PKCS#11 reference implementation supports 2048-bit RSA (signing only) and the NIST P-256 curve for ECDSA. The AWS IoT Thing registry supports ECDSA certificates, but they can only be created by submitting a CSR (Certificate Service Request). The following section contains a walk through for creating a certificate with a CSR.

Make sure you are using the following (or newer) versions of the AWS CLI and Open SSL:

```
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.

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 new 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 and should be used for development purposes only. The following is a listing of the policy.json file specified in the `create-policy` command:

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

```
}
```

7. Finally, 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 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`.

FreeRTOS Wi-Fi Interface

The Wi-Fi interface API provides a common abstraction layer that enables application to communicate with the lower level wireless stack. Wi-Fi chip sets differ in features, driver implementations and APIs. The common Wi-Fi interface simplifies application development and porting for all supported Wi-Fi chip sets. The interface provides a primary API for managing all aspects of Wi-Fi devices.

Setup, Provisioning, and Configuration

The setup APIs provide functionality to turn Wi-Fi on by initializing the radio, peripherals, and drivers. Your application must turn Wi-Fi on by calling `WIFI_On` before calling any other API. An application can turn WI-Fi off by calling `WIFI_Off` to save power. This is useful for power constrained devices which can have intermittent connectivity. Calling `WIFI_Reset` will reset the Wi-Fi radio.

The Amazon FreeRTOS demos hard code Wi-Fi credentials into the application. If you are not able to connect to your Wi-FI network using these credentials, you can put your FreeRTOS device into soft Access Point (AP) mode. This allows you to connect the FreeRTOS device and configure a different set of Wi-Fi credentials (SSID, password, security type, and channel). To configure AP mode call `WIFI_ConfigureAP`. To put your device into soft AP mode, call `WIFI_StartAP`. When your device is in soft AP mode you can connect another device, using a web browser to your FreeRTOS device and configure the new Wi-Fi credentials. To turn off soft AP mode, call `WIFI_StopAP`.

A Wi-Fi device can be configured to be in a particular role at a time. Device roles like Station, Access Point, P2P can be configured by calling `WIFI_SetMode`. You can get the current mode of a Wi-Fi device by calling `WIFI_GetMode`. Switching modes by calling `WIFI_SetMode` will disconnect the device if it is already connected to a network.

Connection

A Wi-Fi device turned on and switched to Station mode is ready to connect to the network using the connectivity API. When calling the connection API, you pass network parameters like SSID, password and security type to establish a connection. You can perform a scan operation to look for networks which returns the SSID, BSSID, Channel, RSSI and security type. The scan can be performed for hidden networks. If you find a desired network in the scan, a you can connect to the network by calling and providing the network password. You can disconnect a Wi-Fi device from the network by calling `WIFI_Disconnect`.

Security

The interface API support several security types like WEP, WPA, WPA2 and Open (no security). When a device is in the Station role, you must specify the network security type when calling the `WIFI_ConnectAP` function. When a device is in soft AP mode, the device can be configured to use any of the supported security types:

- `eWiFiSecurityOpen`

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

Power Management

Different Wi-Fi devices have different power requirements depending upon the application and available power sources. A device may always be powered on to reduce latency or it may be intermittently connected and switch into a low power mode when Wi-Fi is not required. The interface API support 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 API 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 re-provision devices 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 limit of profiles you can save is platform dependent.

Network Utilities

The Wi-Fi API also provides utility functions described in the following table:

API	Description
`WIFI_GetIP`	Gets the IP address of a device.
`WIFI_GetHostIP`	Gets the host IP address.
`WIFI_GetMAC`	Gets the MAC address of a device.
`WIFI_Ping`	Sends a ping to a device on the network.
`WIFI_Scan`	Scans for available Wi-Fi networks.

Amazon FreeRTOS Console User Guide

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 configurations are defined for the prequalified platforms:

- TI CC3220SF-LAUNCHXL
- STM32 IoT Discovery Kit
- FreeRTOS Windows Simulator

The predefined configurations allow 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**.

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. On the **New Software Configuration** page, choose **Select a hardware platform**, and choose one of the prequalified platforms.
3. Choose the IDE and compiler you want use.
4. 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**.
5. In the **Demo Projects** section, enable one of the demo projects. This enables the demo in the project files.
6. In **Name required**, type a name for your custom configuration.
7. In **Description**, you can type a description for your custom configuration.
8. At the bottom of the page, choose **Create and download** to create and download your custom configuration.

Downloading Amazon FreeRTOS from GitHub

Although we recommend that you download the Amazon FreeRTOS kernel and software libraries from the Amazon FreeRTOS console, all Amazon FreeRTOS files are available on GitHub.

Amazon FreeRTOS Qualification Program

This section provides information for MCU vendors about the Amazon FreeRTOS qualification workflow, which includes:

- Creating an Amazon FreeRTOS project.
- Porting Amazon FreeRTOS abstraction layers.
- Running tests.
- Submitting test results to the Amazon FreeRTOS team for final qualification.

What's in it for OEMs?

The Amazon FreeRTOS Qualification Program intends to give confidence to OEM/ODM developers that by using a qualified microcontroller (MCU) from this program for their IoT device, they can run Amazon FreeRTOS on the device without compatibility issues. It works with AWS IoT or AWS Greengrass. This allows OEM/ODM developers to focus on the code for their device functionality.

Qualification Program for MCU Vendors

The Amazon FreeRTOS Qualification Program gives MCU vendors confidence that their qualified MCUs are secure and interoperable with AWS IoT and AWS Greengrass. This means that the MCUs and associated libraries meet the security, functionality, and performance requirements to work seamlessly

with AWS IoT and AWS Greengrass. A qualified MCU is included in the Amazon FreeRTOS console, where customers can select it and download the relevant libraries. These include Amazon FreeRTOS and board support packages (BSPs) and drivers. Details of the qualified MCU, along with relevant links and the MCU vendor company logo, are available on the Amazon FreeRTOS Partners webpage. The rest of this FAQ describes the steps to qualify your MCU and verify that your software (including drivers and BSPs) functionally integrates with Amazon FreeRTOS software.

Contact Amazon

If you want to qualify an MCU, send a request to `<freertos-qual@amazon.com>`. A representative from the qualification support team will send an acknowledgement and support you through the qualification steps.

Sign Up for the AWS Partner Network

The AWS Partner Network (APN) is the global partner program for AWS. It is focused on helping APN Partners build successful AWS-based businesses or solutions by providing business, technical, marketing, and go-to-market support. To find and register for the APN Partner program, see AWS Partner Network.

Jointly Agree on Terms and Conditions

After you become an APN Partner, you and AWS jointly review and agree on general terms and conditions, schedules, and initiatives in the partnership. The agreement includes topics such as the purpose of collaboration, alliance team, initiative development, marketing and collateral, indemnification, limitations of liability, and other general terms. After you and AWS sign the agreement, you can start the qualification workflow process.

Pass Qualification Test Suite

There are several steps to verify that your software (including drivers and BSPs) is functionally integrated with Amazon FreeRTOS software. The goal of this process is to create an MCU development project that successfully builds and runs a range of functional, performance, and security tests on your MCU.

The high-level steps are:

1. Download the latest version of the Amazon FreeRTOS source code.
2. Create a project using the target IDE and compiler that demonstrates the equivalent of a “Hello World” example for the target MCU.
3. Add Amazon FreeRTOS files and resources to the created project, and confirm the project still builds. At this stage, the included TQP tests should build and run, but are expected to fail because they have not yet been ported to your hardware.
4. Enable each Amazon FreeRTOS feature to work successfully on your MCU. This involves implementing each hardware-dependent layer of the Amazon FreeRTOS feature abstractions. Test these implementations and fix issues.
5. When all included tests are passing, submit your results (test reports) and your microcontroller hardware to Amazon to confirm the qualification process.

Amazon FreeRTOS Qualified

After your hardware passes the verification tests, it is considered Amazon FreeRTOS-qualified. Information about your hardware will be displayed in the Amazon FreeRTOS console and the Amazon FreeRTOS Getting Started page.

Supported Platforms

Texas Instruments CC3220SF-LAUNCHXL

The SimpleLink Wi-Fi® CC3220SF LaunchPad development kit (CC3220SF-LAUNCHXL) includes the CC3220SF, a single-chip wireless microcontroller (MCU) with ARM Cortex -M4 Core at 80 MHz, 1MB Flash, 256KB of RAM and enhanced security features. The on-chip Wi-Fi module offloads TLS and TCP/IP processing, freeing up memory and compute for the application on the main microcontroller. For more information about this platform, see, Texas Instruments CC3220SF-LAUNCHXL.

STMicroelectronics STM32L4 Discovery Kit – IoT Node

The STM32L4 IoT Discovery kit (B-L475E-IOT01A) supports Wi-Fi® and integrates additional sensors. The kit has an STM32L4 Series MCU based on ARM Cortex -M4 core at 80 MHz with 1 Mbyte of Flash memory and 128 Kbytes of SRAM, and Wi-Fi module Inventek ISM43362-M3G-L44. The Wi-Fi module offloads TCP/IP processing from the MCU. The interface to the Wi-Fi module for this kit has not yet been optimized for use with Amazon FreeRTOS, and as such, contains limitations on its use. We recommend only using the Secure Sockets APIs from low priority tasks, and to limit transmit throughput. Future revisions are planned to improve this interface. For more information about this platform, see STMicroelectronicsSTM32L4D iscovery kit IoT node

NXP LPC54108 IoT Module

The LPC54018 IoT Module from NXP includes an LPC54018 MCU with a 180MHz ARM® Cortex®-M4 core with 360KB of SRAM, 128Mb of Quad-SPI Flash (Macronix MX25L12835FM2), and a Longsys IEEE802.11b/g/n Wi-Fi® module based on Qualcomm GT1216. The Wi-Fi module offloads TCP/IP processing from the MCU. The LPC54018 IoT Module requires a debugger and J-Link connector (available in the NXP Direct store) or a baseboard. For more information about this platform, see NXP LPC54018 IoT Module.

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

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. 33). For information about porting TLS and cryptographic operations, see the TLS (p. 34) and Public Key Cryptography Standard #11 (p. 34) 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.

Secure Sockets Porting for the STM32 IoT Discovery Kit

- This port supports up to four sockets.
- `SOCKETS_PERIPHERAL_RESET` means that the Wi-Fi module has been reset. This occurs when the Wi-Fi module stops responding or gets out of sync with the SPI driver. Call `WiFi_ConnectAP` to reconnect to your Wi-Fi network.

`Sockets_Connect`

- `SocketsSockaddr_t` uses the `usPort` and `ulAddress` fields only. `ucLength` and `ucSocketDomain` are not used.
- Supports IPv4 only.
- Sends connection information to the Wi-Fi module only. A successful return does not guarantee that the socket was able to reach the provided IP address.

`Sockets_SetSockOpt`

For `SOCKETS_SO_SNDTIMEO` and `SOCKETS_SO_RCVTIMEO`, valid values are 0 (block forever) and 30,000 milliseconds.

SOCKETS_Shutdown

`SOCKETS_Shutdown` does not send a FIN packet, but does prevent the socket from being used for send and receive.

Secure Sockets Porting for the TI CC3220SF-LAUNCHXL Board

This port supports up to 16 sockets. The sockets can be secured with TLS.

`Sockets_Connect`

- `SocketsSockaddr_t` uses the `usPort` and `ulAddress` fields only. `ucLength` and `ucSocketDomain` are not used.
- Supports IPv4 only.
- Receiving a negative error code from `SOCKETS_Connect` does not mean that the socket was closed. Applications must close sockets after receving a negative error code.

- When using a TLS-enabled socket, sometimes a connection is made even though `SOCKETS_Connect` returned an error. This might indicate that the connection cannot be authenticated using the provided root of trust. We strongly recommend that you explicitly close the socket if a handshake-related error is returned, even if the connection is made.
- In the event of handshake error, you can get information by enabling printing or by investigating the asynchronous event handler structure set in `SimpleLinkSockEventHandler`.

`Sockets_SetSockOpt`

`SOCKETS_SO_RCVTIMEO` can be specified in 10 millisecond increments.

`SOCKETS_SO_SNDTIMEO` is not used. It might be used in future versions.

SOCKETS_Send

In the event of a TX error, you can get information by investigating the TX Failed event handler structure in `SimpleLinkSockEventHandler`.

SOCKETS_Shutdown

`SOCKETS_Shutdown` does not send a FIN packet, but does prevent the socket from being used for send and receive.

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 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.

If you download code from GitHub, you can use the tests in the `AmazonFreeRTOS/tests` directory to test the operation of your custom library. The tests directory follows the same organization as the `lib` directory, so the respective tests can be used to verify the corresponding libraries. For example, if you create your own MQTT Library, you can run the tests defined in `AmazonFreeRTOS/tests/common/mqtt/aws_test_mqtt_lib.c` to verify your library's operation.