User manual

Getting started with X-CUBE-AWS STM32Cube Expansion Package for Amazon Web Services® IoT

Introduction

This user manual describes the content of the X-CUBE-AWS STM32Cube Expansion Package for AWS (Amazon Web Services®) IoT (Internet of Things) Core.

The X-CUBE-AWS STM32Cube Expansion Package for AWS IoT Core™

- provides a qualified port of FreeRTOS™ to the supported boards (refer to the *User Guide* and *FreeRTOS Qualification Guide* sections on the AWS website at docs.aws.amazon.com/freertos for details)
- offloads – wherever available – the security-critical operations to the on-board STSAFE-A110 Secure Element during
  - the MCU boot process
  - the TLS device authentication towards the AWS IoT Core™ server
  - the verification of the over-the-air (OTA) update firmware image integrity and authenticity.
    It leverages the Secure Element provisioned certificate with the *AWS IoT Core Multi-Account Registration* feature

Refer to Section 1 General information for a presentation of AWS IoT Core™ and FreeRTOS™.

This user manual focuses on X-CUBE-AWS v2.x, which follows the v1.x versions, connecting to the same AWS IoT Core™ services and therefore compatible with the same cloud services.

X-CUBE-AWS v2.x is a different solution from X-CUBE-AWS v1.x. It is based on the complete FreeRTOS™ software distribution, which coexists with the STM32Cube environment, and not on the *AWS IoT Device SDK for Embedded C* single middleware library anymore.

Both the *aws_demos* and *aws_tests* FreeRTOS™ reference applications are provided:

- *aws_demos* is configured to illustrate the usage of the FreeRTOS™ *OTA Update Manager* service.
- *aws_tests* is the test application of the *AWS Qualification Program for FreeRTOS™*. It is provided as a possible comparison point for the users who plan to get their product go through the qualification process. Its usage is beyond the scope of the present document.

X-CUBE-AWS version v2.0.0 is available for the B-L4S5I-IOT01A Discovery kit.

1 General information

The X-CUBE-AWS Expansion Package is dedicated to FreeRTOS™ projects running on STM32 32-bit microcontrollers based on the Arm® Cortex®-M processor. The descriptions in the current revision of the user manual are based on X-CUBE-AWS v2.0.0.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

1.1 What is AWS IoT Core™?

As described on the AWS website at docs.aws.amazon.com/iot,

> *AWS IoT Core is a managed cloud service that lets connected devices securely interact with cloud applications and other devices. AWS IoT Core also makes it easy to use AWS and Amazon services like AWS Lambda, Amazon Kinesis, Amazon S3, Amazon SageMaker, Amazon DynamoDB, Amazon CloudWatch, AWS CloudTrail, Amazon QuickSight, and Alexa Voice Service to build IoT applications that gather, process, analyze and act on data generated by connected devices.*

Note: © 2020, Amazon Web Services, Inc. or its affiliates. All rights reserved.

1.2 What is FreeRTOS™?

As described on the AWS website at docs.aws.amazon.com/freertos,

> *FreeRTOS is an open source, real-time operating system for microcontrollers that makes small, low-power edge devices easy to program, deploy, secure, connect, and manage. FreeRTOS includes a kernel and a growing set of software libraries suitable for use across industry sectors and applications. This includes securely connecting small, low-power devices to AWS cloud services like AWS IoT Core.*

Note: © 2020, Amazon Web Services, Inc. or its affiliates. All rights reserved.

1.3 What is STM32Cube?

STM32Cube is an STMicroelectronics original initiative to significantly improve designer's productivity by reducing development effort, time and cost. STM32Cube covers the whole STM32 portfolio.

STM32Cube includes:

- A set of user-friendly software development tools to cover project development from the conception to the realization, among which are:
  – STM32CubeMX, a graphical software configuration tool that allows the automatic generation of C initialization code using graphical wizards
  – STM32CubeIDE, an all-in-one development tool with peripheral configuration, code generation, code compilation, and debug features
  – STM32CubeProgrammer (STM32CubeProg), a programming tool available in graphical and command-line versions
  – STM32CubeMonitor (STM32CubeMonitor, STM32CubeMonPwr, STM32CubeMonRF, STM32CubeMonUCPD) powerful monitoring tools to fine-tune the behavior and performance of STM32 applications in real-time
- STM32Cube MCU and MPU Packages, comprehensive embedded-software platforms specific to each microcontroller and microprocessor series (such as STM32CubeL4 for the STM32L4 Series), which include:
  – STM32Cube hardware abstraction layer (HAL), ensuring maximized portability across the STM32 portfolio
  – STM32Cube low-layer APIs, ensuring the best performance and footprints with a high degree of user control over the HW
  – A consistent set of middleware components such as FAT file system, RTOS, USB Host and Device, TCP/IP, Touch library, and Graphics
  – All embedded software utilities with full sets of peripheral and applicative examples
- STM32Cube Expansion Packages, which contain embedded software components that complement the functionalities of the STM32Cube MCU and MPU Packages with:
  – Middleware extensions and applicative layers
  – Examples running on some specific STMicroelectronics development boards

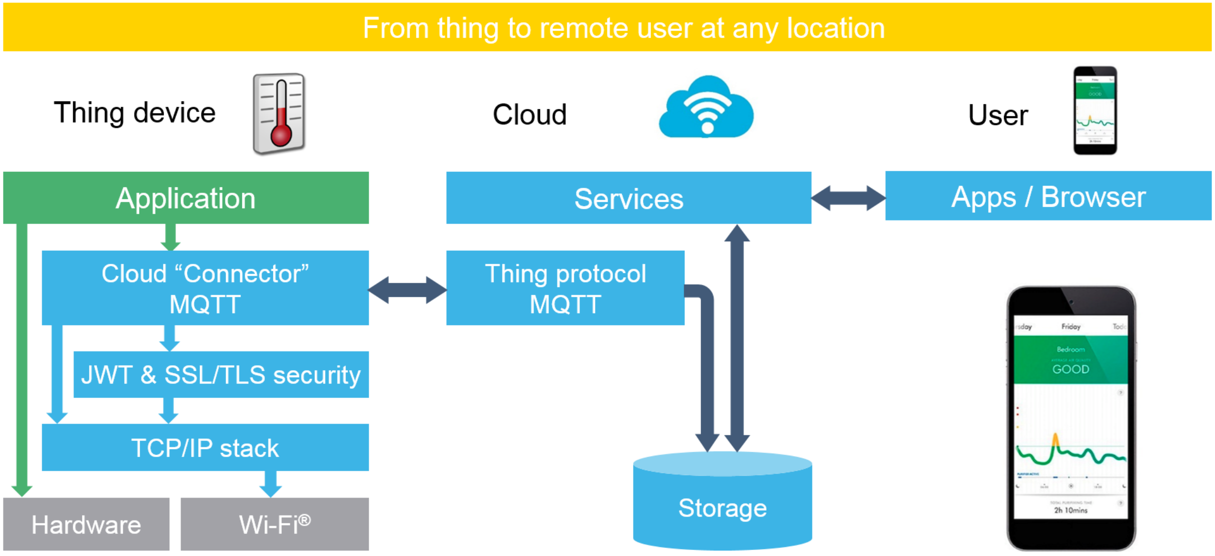
1.4 How does X-CUBE-AWS complement STM32Cube?

X-CUBE-AWS extends STM32CubeL4 by providing a qualified port of FreeRTOS™ to the B-L4S5I-IOT01A board, with a pre-integrated secure bootloader derived from the X-CUBE-SBSFU Expansion Package and adapted to offload the most sensitive cryptographic operations to the embedded STSAFE-A110 Secure Element.

By exception to the STM32Cube physical architecture, the whole FreeRTOS™ source tree, with its own dependencies and third party libraries, is installed as a whole, as a third-party middleware in the STM32Cube source tree.

2 Amazon Web Services® IoT Core

Figure 1. **Amazon Web Services® IoT Core ecosystem**



2.1 Online documentation

The user application presented in this document relies on FreeRTOS™ and AWS (mostly the AWS IoT Core™ services).

General documentation, user guide, developer guide, porting guide, OTA Firwmare Update guide, and others are available on the AWS website.

Most of the documentation of the OTA demo application on the FreeRTOS™ web site (documentation of the OTA library, *Basic OTA Demo (with Code Signing)* page) is also relevant – with differences in the *Configuring the Demo Project* section, due to the usage of the multi-account device registration method on the B-L4S5I-IOT01A board.

While Section 5.2.2 User application configuration provides a quick guide on how to get and authorize AWS credentials, the information presented in this document cannot substitute for the Amazon™ information, which is the reference.

2.2 Account configuration, device registration, device provisioning

The included B-L4S5I-IOT01A user applications use the *Multi-Account Registration* feature of the AWS IoT Core™ service.

A unique immutable X.509 device certificate is stored in the physical device at production time, in the STSAFE-A110 Secure Element. This certificate must be extracted from the physical device to be registered at AWS when the logical device (called *thing* in AWS terminology) is created by the user.

The instructions of the present section must be followed through before proceeding to the operations in Section 5.2.2 User application configuration and launch.

Step 1. Extract the device certificate.

This is done in two steps (refer to Section 4.3 Programming a firmware image to the STM32 board and Section 4.2 Virtual terminal setup)

a. Program and run the image `Projects/<board_name>/Applications/BootLoader_STSAFE/STSAFE_Provisioning/Binary/Provisioning.bin` so that the STSAFE-A110 Secure Element and the MCU bootloader are paired and may communicate securely with each other.

b. Build, program and run the image `Projects\<board_name>\Applications\Cloud\aws_demos\<toolchain>\PostBuild\SBSFU_<board_name>_aws_demos.bin`.(no need to configure in the source code at this stage). Copy the PEM format certificate displayed on the virtual terminal to a text file. It is referred to it as *"`my_extracted_cert.pem`"* in the next steps.

   The `.bin` file above is automatically produced by the post-build stage of the *aws_demos* application build project. Refer to Section 5.1.3 Building the whole firmware image for information on the SBSFU build system.

Important: The `.pem` file must exactly contain the text block starting with (and including) `-----BEGIN CERTIFICATE-----` and ending with `-----END CERTIFICATE-----`.

```
= [SBOOT] System Security Check successfully passed. Starting...
= [FWIMG] Slot #0 @: 8105000 / Slot #1 @: 8036000 / Swap @: 81d5000
======================================================================
=              (C) COPYRIGHT 2017 STMicroelectronics                 =
=                                                                    =
=              Secure Boot and Secure Firmware Update                =
======================================================================
= [SBOOT] STATE: WARNING: SECURE ENGINE INITIALIZATION WITH FACTORY DEFAULT VALUES!
= [SBOOT] STATE: CHECK STATUS ON RESET
                 INFO: A Reboot has been triggered by a Software reset!
                 Consecutive Boot on error counter = 0
                 INFO: Last execution detected error was:No error. Success.
= [SBOOT] STATE: CHECK NEW FIRMWARE TO DOWNLOAD
= [SBOOT] STATE: CHECK KMS BLOB TO INSTALL
= [SBOOT] STATE: CHECK USER FW STATUS
= [SBOOT] LOADING CERTS FROM SECURE ENGINEOK
= [SBOOT] Verifying the Certificate chain... OK
= [SBOOT] Verify Header Signature... OK A valid FW is installed in the active slot
- version: 1
= [SBOOT] STATE: VERIFY USER FW SIGNATURE
= [SBOOT] CHECKING IMAGE STATE = SFU_IMG_CheckImageState Image State = 1
= [SBOOT] IMAGE STATE OK = [SBOOT] STATE: EXECUTE USER FIRMWARE0 524 [Tmr Svc] WiFi
module initialized.
1 532 [Tmr Svc] Device Certificate (DER), size = 402
2 537 [Tmr Svc] Device Certificate (PEM), size = 600
-----BEGIN CERTIFICATE-----
MIIBjjCCATSgAwIBAgILAglQvgEhzCJbATkwCgYIKoZIzj0EAwIwTzELMAkGA1UE
BhMCTkwxHjAcBgNVBAoMFVNUTWljcm9lbGVjdHJvbmljcyBudjEgMB4GA1UEAwwX
U1RNIFNUU0FGRS1BIFBST0QgQ0EgMDEwIBcNMjAwMjI2MDAwMDAwWhgPMjA1MDAy
MjYwMDAwMDBaMEYxCzAJBgNVBAYTAkZSMRswGQYDVQQKDBJTVE1pY3JvZWxlY3Ry
b25pY3MxGjAYBgNVBAMMEVNUU0FGRS1BMTEwIEVWQUwyMFkwEwYHKoZIzj0CAQYI
KoZIzj0DAQcDQgAEv/XwIjVwhq0S9R1fCeQj8QXr6y3AcXMJIFOtV2GpGhxAkseK
QeIe2tMoAkzwwmDdixmFwT/pJuHYvZu6IY6n4TAKBggqhkjOPQQDAgNIADBFAiBq
1p9SL6sAXB1zKsgX9Pr68tKDjKbb2ZZTPcSQ5cU9oAIhAIWMVkv4wIL02v8JXzRN
HSRb1zUmb840Eo6c2rJKPG6a
-----END CERTIFICATE-----
3 595 [Tmr Svc] WiFi Firmware Version C3.5.2.5.STM.
```

Step 2. Sign-in to or create an AWS account.

Set the required user, access rights and policies for the multi-account registration mechanism. Note that the multi-account registration relieves from creating and provisioning the IoT device credentials. For this specific point, refer to step 5. below. Possible references are:

– The *Setting up your AWS account and permissions* section of the *FreeRTOS™ User Guide* on Amazon™ website

– The *Getting started with AWS IoT Core* section of the *AWS IoT Developer Guide*

Step 3. Create an IoT *thing* policy.

This policy is called *"my_iot_policy"* in the next steps. Users having used AWS IoT Core™ in the past (for instance with X-CUBE-AWS v1.x) can reuse their *thing* policy.

Step 4. Install and setup the AWS CLI.

In addition to the `default` section, set the `profile adminuser` section in `~/.aws/credentials` with

– `region`
– `aws_access_key_id`
– `aws_secret_access_key`

Users with personal AWS accounts given the required access rights may simply copy the [**default**] settings to the [**profile adminuser**] section.

Step 5. Register the device.

– Register the X.509 certificate copied from the device console:

```
aws iot register-certificate-without-ca --certificate-pem file://
my_extracted_cert.pem --status ACTIVE
```

Note the contents of the `certificateArn` field that is returned by the command, called *"my_device_cert_arn"* in the next steps. Its format is:

```
arn:aws:iot:<my_region>:<my_account_id>:cert/<my_extracted_cert_id>
```

– Create the *thing*:

```
aws iot create-thing --thing-name my_thing_name
```

– Empower the *thing* by granting its certificate with the access rights defined in the *thing* policy:

```
aws iot attach-policy --policy-name "my_iot_policy" --target
"my_device_cert_arn"
```

```
aws iot attach-thing-principal --thing-name my_thing_name --principal
my_device_cert_arn
```

– Retrieve the address of the IoT Core endpoint:

```
aws iot describe-endpoint --endpoint-type iot:Data-ATS
```

It is called *"my_endpoint_name"* in the next steps in the User application configuration section. Its format is:

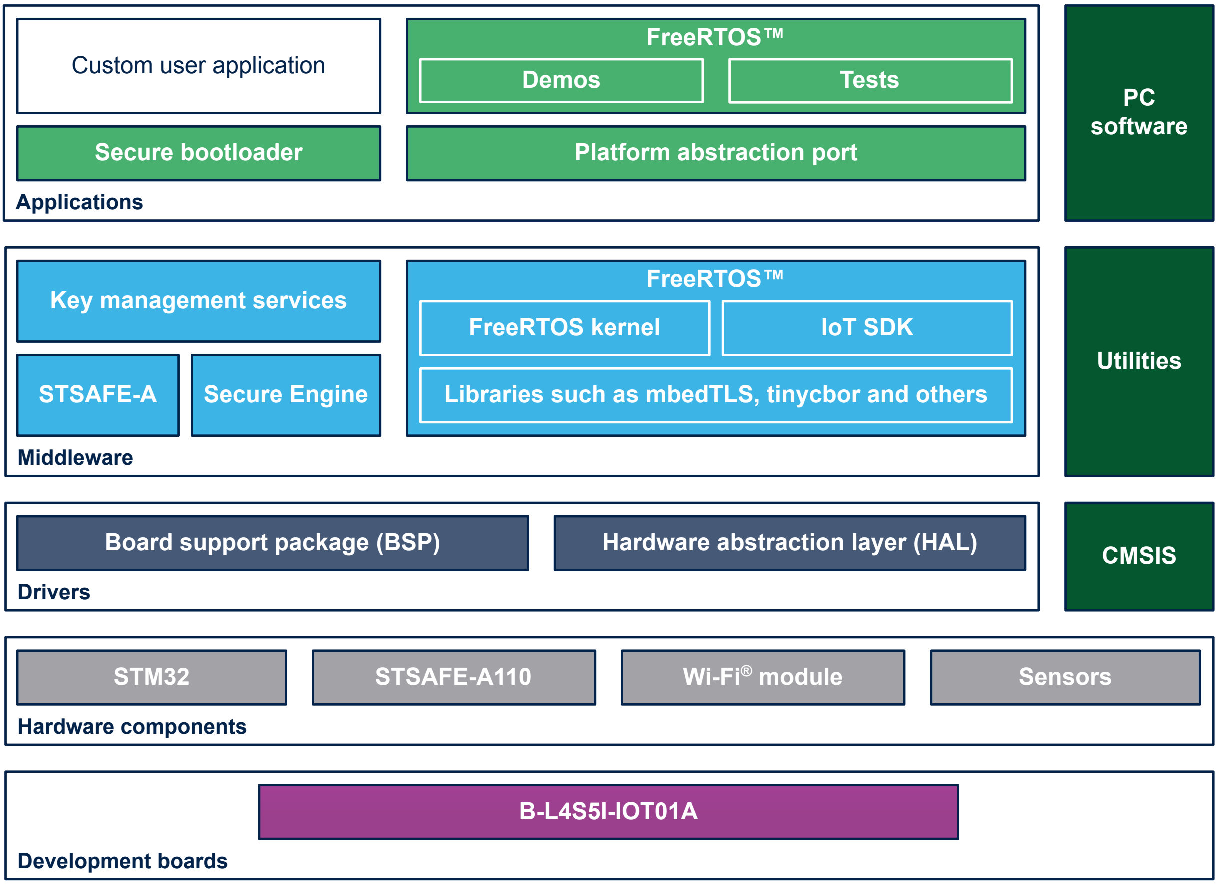
`<account-specific_prefix>-ats.iot.<my_region>.amazonaws.com`.

3 Package description

3.1 Logical software architecture

The top-level architecture of the X-CUBE-AWS Expansion Package is shown in Figure 2.

Figure 2. X-CUBE-AWS software architecture



The Expansion Package provides a FreeRTOS™ software distribution for STM32Cube. It is composed of:

- **FreeRTOS™ standard user applications** (*aws_demos* and *aws_tests*) and their platform abstraction port to the B-L4S5I-IOT01A board by means of the STM32L4 Series HAL and ISM43362 eS-WiFi driver.
- **FreeRTOS™ and its internal dependencies**.
- **STM32Cube HAL**: this driver layer provides a generic multi-instance simple set of APIs (application programming interfaces) to interact with upper layers (application, libraries and stacks). It is composed of generic and extension APIs. It is directly built around a generic architecture and allows the layers that are built upon, such as the middleware layer, to implement their functionalities without dependencies on the specific hardware configuration for a given microcontroller unit (MCU). This structure improves the library code reusability and guarantees an easy portability onto other devices. It includes:
  - STM32L4 Series HAL
- **Board support package (BSP) layer**: the software package must support the peripherals on the STM32 boards apart from the MCU. This software is included in the board support package. This is a limited set of APIs, which provides a programming interface for certain board-specific peripherals such as the LED and user button. It includes:
  - Low-layer driver for the Inventek ISM43362 eS-WiFi module
  - Sensor drivers for the B-L4S5I-IOT01A board (not used by the applications provided)

- **Secure bootloader, key management and image state management application** derived from the X-CUBE-SBSFU Expansion Package, relying on its companion middleware components and on-board STSAFE-A110 component.

The software is provided as a `.zip` archive containing source-code.

The following integrated development environments are supported:

- IAR Systems - IAR Embedded Workbench® (EWARM), version 8.32.3 or higher
- STMicroelectronics - STM32CubeIDE, version 1.3.0 or higher

3.2 Folder structure

3.2.1 STM32Cube view

Figure 3 presents the top folder structure of the X-CUBE-AWS Expansion Package. Figure 4, Figure 5, and Figure 6 further detail the top folder contents.

Figure 3. Top folders

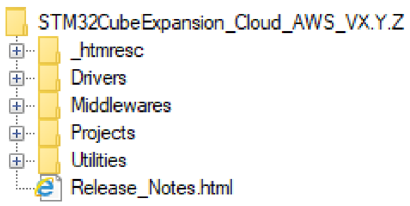


Figure 4. Drivers folder

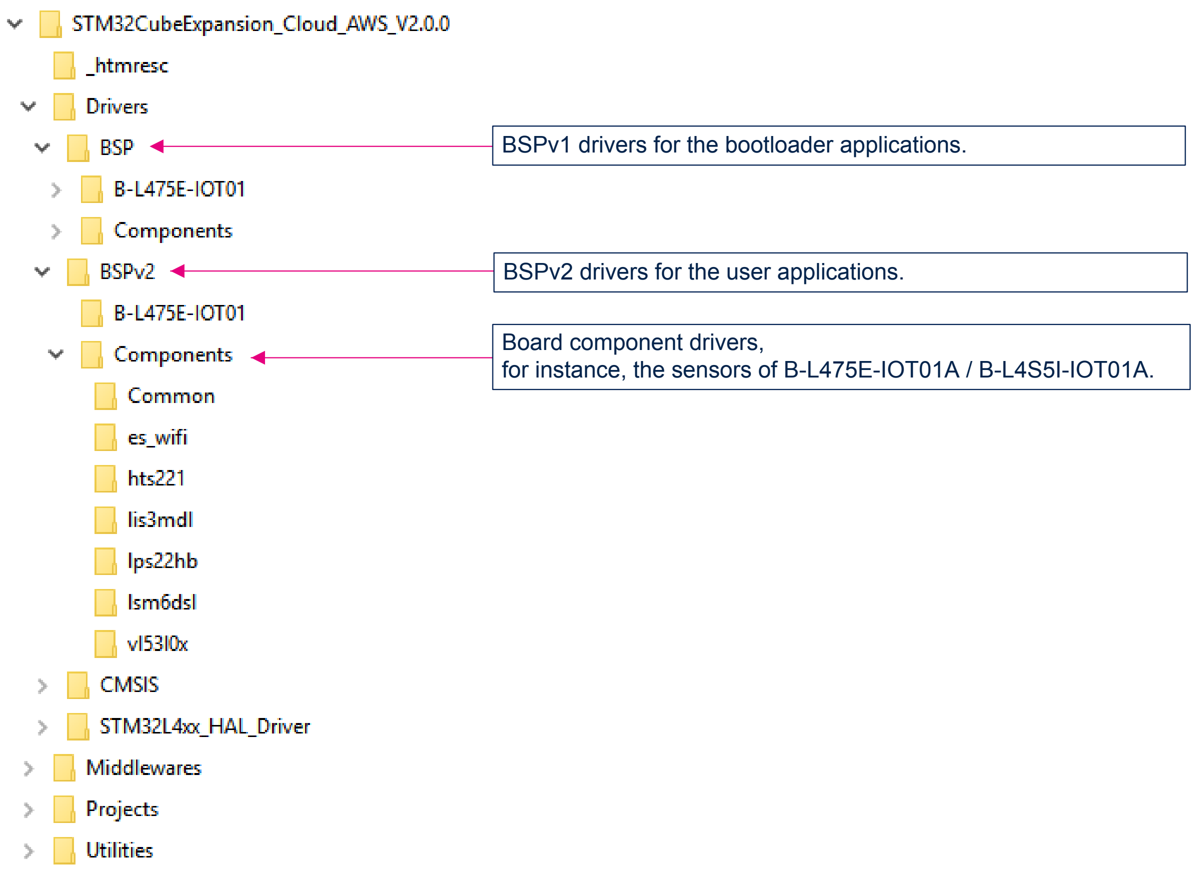


Figure 5. Middlewares folder

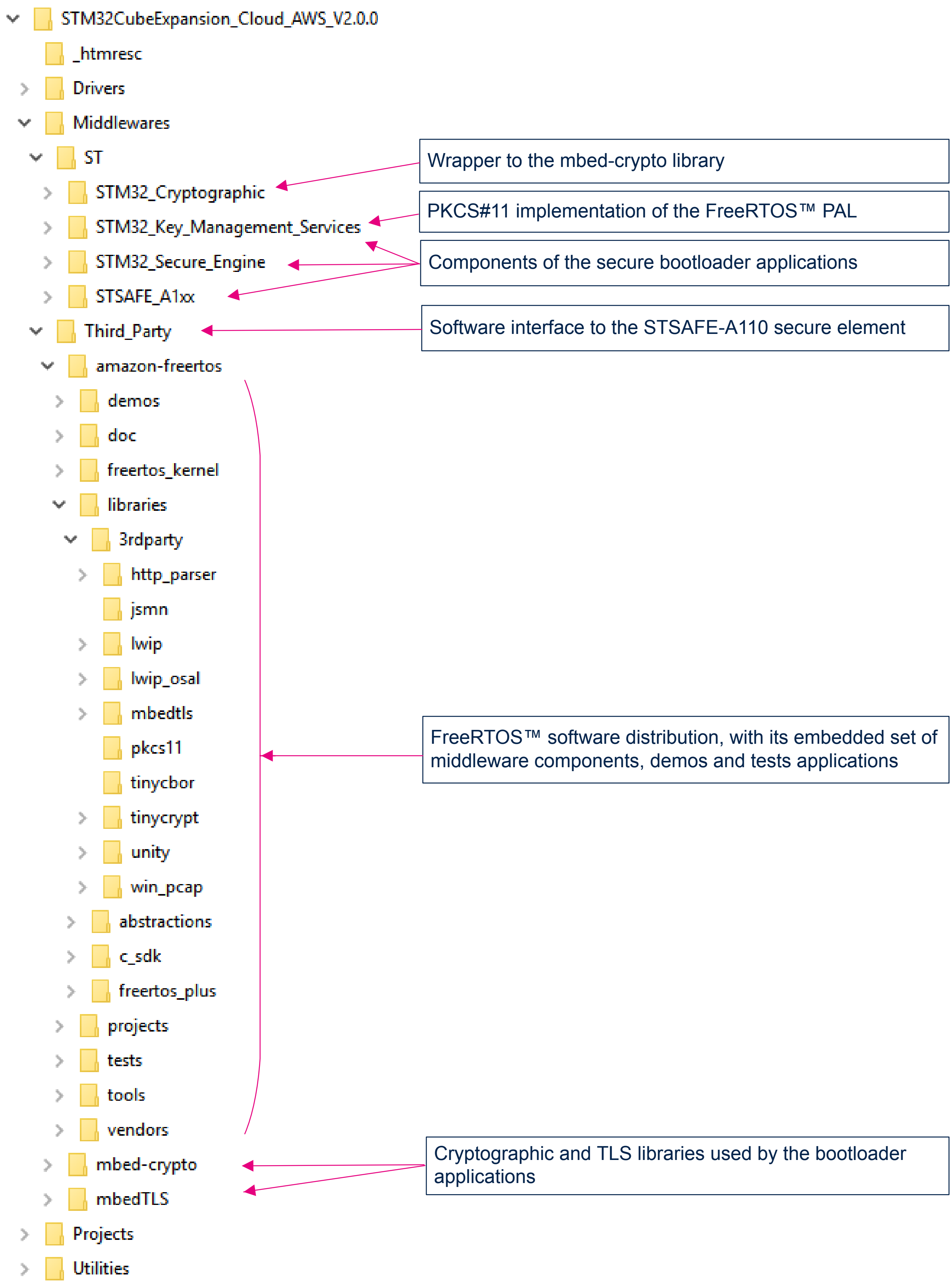
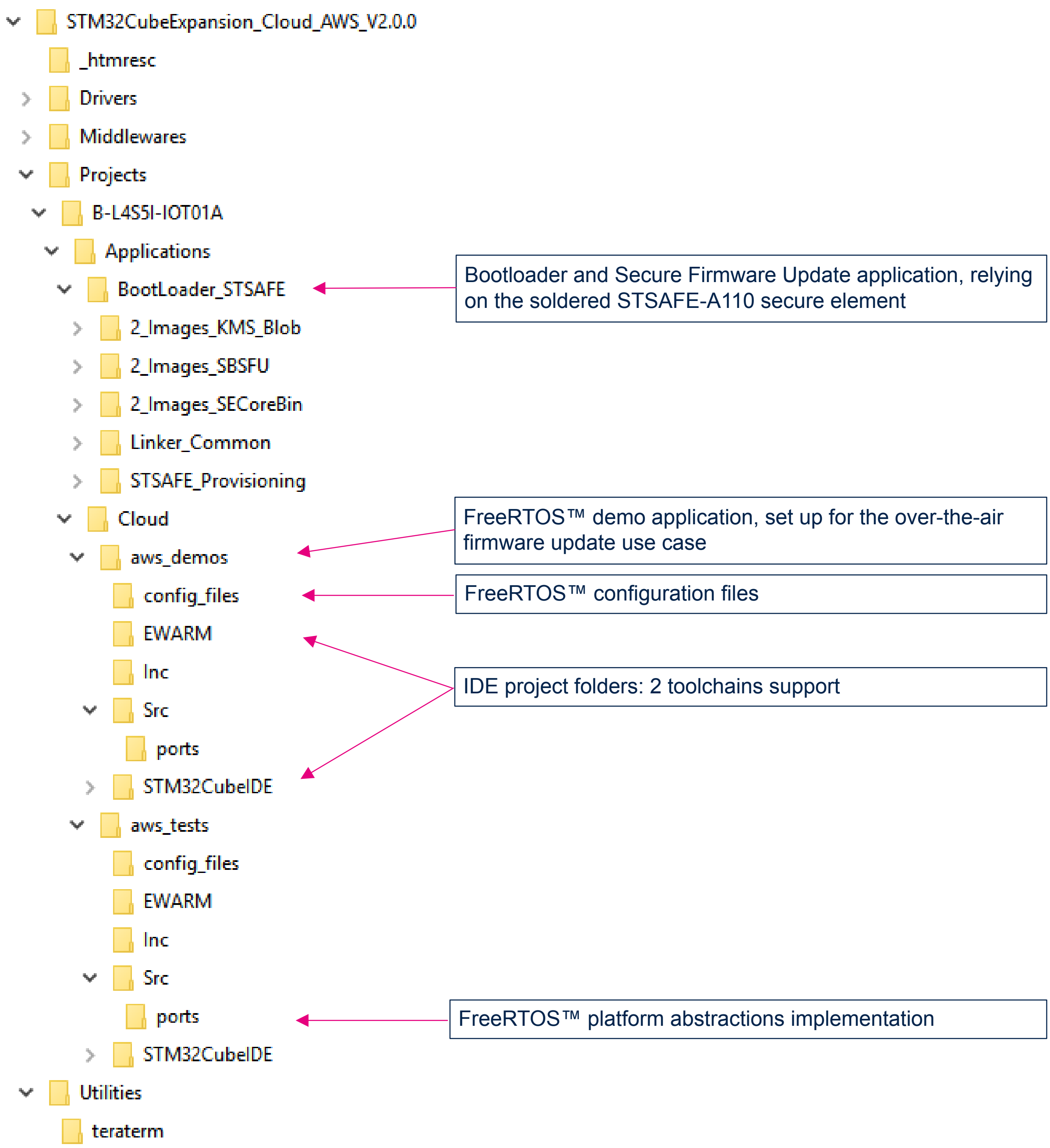


Figure 6. Projects and Utilities folders



The user applications *aws_demos* and *aws_tests* provide an implementation of the following FreeRTOS™ porting abstractions:

- `configPRINT_STRING()`
- Wi-Fi®
- TCP/IP
- Secure Sockets
- PKCS#11
- TLS
- MQTT
- HTTPS
- Over-the-air (OTA) updates

The mbedTLS user configuration is also overloaded for OTA and STSAFE-A110.

3.2.2 FreeRTOS™ view

If for some reason the user needs to adopt the FreeRTOS™ folder tree (for instance cloned from github), the recommended setup is to copy `STM32CubeExpansion_Cloud_AWS_V2.x.y/*` contents into the `/vendors/st` folder and remove `/vendors/st/Middlewares/Third_Party/amazon-freertos` to avoid source code duplication.

The IAR Embedded Workbench® projects of the provided user applications can be easily adapted to the folder structure by changing the `AFR_DIR` variable in `Projects/<board_name>/Applications/Cloud/<application_name>/EWARM/Project.custom_argvars` from `$PROJ_DIR$\..\..\..\..\..\..\Middlewares\Third_Party\amazon-freertos` to `$PROJ_DIR$\..\..\..\..\..\..\..\..`.

The STM32CubeIDE projects may be modified in an equivalent way by substituting the paths in the `.project` and `.cproject` files.

4 Hardware and software environment setup

4.1 Install STM32CubeProgrammer

The post-build of the user application requires that STM32CubeProgrammer (STM32CubeProg) is installed in `C:\Program Files\STMicroelectronics\STM32Cube\STM32CubeProgrammer`. The version is specified in the package release notes.

4.2 Virtual terminal setup

A serial terminal is required to:

- Extract the device certificate
- Monitor the application status

The example in this document is illustrated with the use of Tera Term. Any other similar tool can be used instead.

When the board is used for the first time, it must be programmed with connection string data:

- Determine the STM32 ST-LINK Virtual COM port used on the PC for the Discovery board. On a Windows® PC, open the *Device Manager*.
- Open a serial terminal on the PC and connect it to the above Virtual COM port.

A Tera Term initialization script is provided in the package utility directory (refer to Figure 1); this script sets the correct parameters. To use it, open Tera Term, select [**Setup**] and then [**Restore setup**].

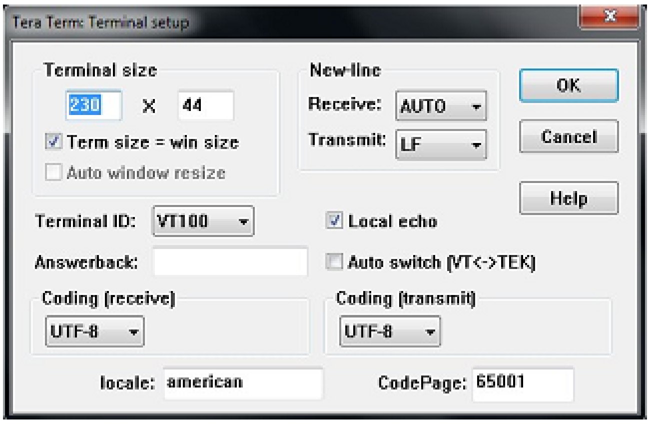
Note: The information provided below can be used to configure the UART terminal as an alternative to using the Tera Term initialization script.

Terminal setup

Terminal setup is illustrated in Figure 7. The screenshot shows the *Terminal setup* and the *New-line* recommended parameters.

The serial terminal *New-line* transmit configuration must be set to `LineFeed` (`\n` or `LF`) in order to allow copy-paste from UNIX® type text files. The selection of the *Local echo* option makes copy-paste results visible on the console.

Figure 7. Terminal setup



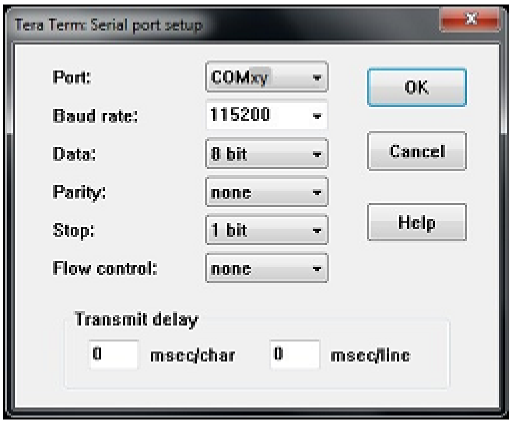
Serial port setup

The serial port must be configured with:

- COM port number
- 115200 baud rate
- 8-bit data
- No parity
- 1 stop bit
- No flow control

Serial port setup is illustrated in Figure 8.

Figure 8. Serial port setup



Once the UART terminal and the serial port are set up, press the board reset button (black). Follow the indications on the UART terminal to upload Wi-Fi® and cloud configuration data. These data remain in the Flash memory and are reused the next time the board boots.

4.3 Programming a firmware image to the STM32 board

Several options are available:

1. Copy (or drag and drop) the `.bin` file to the USB mass storage mount point created when the STM32 board is connected to the computer. This is typically `DIS_L4IOT`, or `/media/DIS_L4IOT` on Linux®.
2. Program the STM32 board directly by means of one of the supported IDEs, STM32 ST-Link Utility (STSW-LINK004), or STM32CubeProgrammer (STM32CubeProg).

If the application does not start automatically after the programming, the board must be reset (either with the IDE, STM32 ST-LINK Utility, STM32CubeProgrammer, or black reset button).

5 Applications

5.1 Secure bootloader

5.1.1 Overview

The pre-integrated bootloader allows the update of the user application (initially, one of the standard FreeRTOS™ user applications: *aws_demos* or *aws_test*), adding new features, and correcting potential issues. This is performed in a secure way, which prevents any unauthorized update.

The secure bootloader enforces hardware security mechanisms on STM32. It guarantees a unique entry point after reset, ensures immutable boot code, enforces security check and performs firmware image verification (authenticity and integrity) before execution.

It takes advantage of hardware protection mechanisms present in STM32 devices:

- RDP-L2: read data protection (disables external access, protects boot options)
- WRP/PCROP: write data protection (protects code and keys from Flash dump, protects trusted code)
- MPU: execution allowed in a chain of trust
- Firewall: protects Flash memory and RAM at runtime (secure enclave for critical operations)

The secure bootloader is a standalone executable. It is delivered in the package both as a pre-built executable file, and as source files, allowing advanced users to rebuild it with different settings.

Caution: The delivered pre-compiled bootloader does not enforce security, so that the user can still plug a debugger and debug the application. It must not be used in a production context.

Pre-compiled bootloader settings:

- Dual-image mode
- Enable local loader
- Secure IP turned off
- X.509 ECDSA_SHA256 asymmetric authentication
- No firmware encryption

The dual-image mode enables safe image update, with firmware image backup and rollback capabilities. The Flash memory is split in two areas named Slot #0 and Slot #1. The Slot #0 area contains the active firmware (firmware header + firmware). The Slot #1 area can be written a downloaded firmware (firmware header + encrypted firmware) to be decrypted and installed at next reboot. A specific Flash memory area is used to swap the content of Slot #0 and Slot #1 during the installation process at boot time. Using those two slots, firmware update supports a rollback mechanism if an error happens at first execution of a new installed firmware.

The bootloader integration is done in a seamless way, so that the user can keep using the IDE as used to, when programming the board or debugging.

By contrast to the usual build flow (compile/link/program/debug), specific pre- and post-build phases are added to the sample projects:

- The post-build phase combines the bootloader with the application, and overwrites the application executable so that it can be programmed and run as usual.
- The pre-build phase deletes the `.elf` file to force the link and post-build, even if the user project sources have not changed. It prevents post-build dependencies issues with STM32CubeIDE.

5.1.2 Application boot

The bootloader runs first. It enforces security and checks in Slot #1 if new firmware must be installed.

- If no new firmware must be installed, it starts the already installed application
- If new firmware must be installed, it decrypts if needed, and checks it before installing and running it

Bootloader messages are prefixed with `[SBOOT]`.

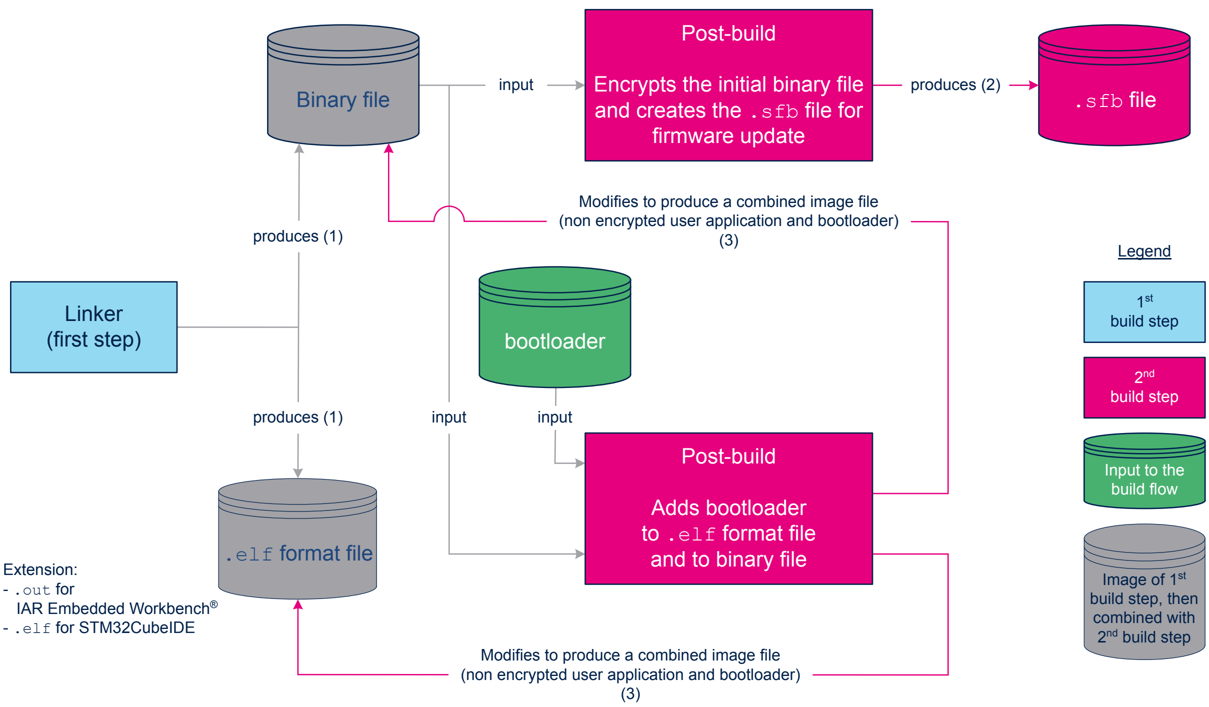
In the log below, the bootloader does not find an application to install from Slot #1. Therefore, it checks the firmware image in Slot #0, and runs it.

```
= [SBOOT] System Security Check successfully passed. Starting...
= [FWIMG] Slot #0 @: 8105000 / Slot #1 @: 8036000 / Swap @: 81d5000


======================================================================
=              (C) COPYRIGHT 2017 STMicroelectronics                 =
=                                                                    =
=              Secure Boot and Secure Firmware Update                =
======================================================================


= [SBOOT] STATE: WARNING: SECURE ENGINE INITIALIZATION WITH FACTORY DEFAULT VALUES!
= [SBOOT] STATE: CHECK STATUS ON RESET
          INFO: A Reboot has been triggered by a Software reset!
          Consecutive Boot on error counter = 0
          INFO: Last execution detected error was:No error. Success.
= [SBOOT] STATE: CHECK NEW FIRMWARE TO DOWNLOAD
= [SBOOT] STATE: CHECK KMS BLOB TO INSTALL
= [SBOOT] STATE: CHECK USER FW STATUS
= [SBOOT] LOADING CERTS FROM SECURE ENGINEOK
= [SBOOT] Verifying the Certificate chain... OK
= [SBOOT] Verify Header Signature... OK
          A valid FW is installed in the active slot - version: 1
= [SBOOT] STATE: VERIFY USER FW SIGNATURE
= [SBOOT] CHECKING IMAGE STATE
=         SFU_IMG_CheckImageState Image State = 1
= [SBOOT] IMAGE STATE OK
= [SBOOT] STATE: EXECUTE USER FIRMWARE0 524 [Tmr Svc] WiFi module initialized.
```

5.1.3 Building the whole firmware image

Figure 9 describes the flow for building binary images.

Figure 9. Image build flow



The source files are compiled and linked as usual, which produces a binary file and an `.elf` format file. After the link, a post-build script is run.

A file with the `.sfb` extension is created, which contains the standalone user application, optionally encrypted, and prefixed with meta data, ready for being downloaded and written at runtime to the firmware update slot.

The script outputs modified `.elf` and raw binary files, which combine the non-encrypted bootloader and the user application.

Detail of output files built

The combined image file (raw binary and `.elf` format) contains both the bootloader and user application. The user application is placed in the executable slot in a non-encrypted form. The file location depends on the IDE:

- IAR Embedded Workbench®

  `Project/<board_name>/Applications/Cloud/<app_name>/EWARM/<board_name>/Exe/<board_name>.out`

  `Project/<board_name>/Applications/Cloud/<app_name>/EWARM/<board_name>/<board_name>_AWS.bin`
- STM32CubeIDE

  `Project/<board_name>/Applications/Cloud/<app_name>/STM32CubeIDE/<board_name>/Debug/<board_name>_<app_name>.elf`

  `Project/<board_name>/Applications/Cloud/<app_name>/STM32CubeIDE/<board_name>/Debug/<board_name>_<app_name>.bin`

The `.sfb` file packs the firmware header and firmware image of the user application. This file is the one used when performing firmware update. Its location depends on the IDE:

- IAR Embedded Workbench®

  `Project/<board_name>/Applications/Cloud/<app_name>/EWARM/PostBuild /<board_name>_<app_name>.sfb`
- STM32CubeIDE

  `Project/<board_name>/Applications/Cloud/<app_name>/STM32CubeIDE/PostBuild/<board_name>_<app_name>.sfb`

The post-processing log file is useful to analyze the possible post-build issues. The most common issue is due to an incorrect path to the STM32CubeProgrammer (STM32CubeProg) tool. The file location depends on the IDE:

- IAR Embedded Workbench®

  `Project/<board_name>/Applications/Cloud/<app_name>/EWARM/output.txt`
- STM32CubeIDE

  `Project/<board_name>/Applications/Cloud/<app_name>/STM32CubeIDE/output.txt`

Post-processing log file example:

```
Loading cert: C:\STM32CubeExpansion_Cloud_AWS_V2.x.x\Projects\B-L4S5I-IOT01A\Applications
\BootLoader_STSAFE\2_Images_SECoreBin\EWARM\\\..\\..\\2_Images_SBSFU\\Certs\\sbsfu_fs_crt.der
Loading cert: C:\STM32CubeExpansion_Cloud_AWS_V2.x.x\Projects\B-L4S5I-IOT01A\Applications
\BootLoader_STSAFE\2_Images_SECoreBin\EWARM\\\..\\..\\2_Images_SBSFU\\Certs\\sbsfu_i2_crt.der
adding leaf cert of length 597
adding intermediate cert of length 498
Adding padding: 537
Loading cert: C:\STM32CubeExpansion_Cloud_AWS_V2.x.x\Projects\B-L4S5I-IOT01A\Applications
\BootLoader_STSAFE\2_Images_SECoreBin\EWARM\\\..\\..\\2_Images_SBSFU\\Certs\\sbsfu_fs_crt.der
Loading cert: C:\STM32CubeExpansion_Cloud_AWS_V2.x.x\Projects\B-L4S5I-IOT01A\Applications
\BootLoader_STSAFE\2_Images_SECoreBin\EWARM\\\..\\..\\2_Images_SBSFU\\Certs\\sbsfu_i2_crt.der
adding leaf cert of length 597
adding intermediate cert of length 498
Adding padding: 537
number of segment :1
number of segment :4
0x80001bc
0x801a5d9
0x801bdd4
Merging
SBSFU Base = 0x8000000
Writing header = 0x8105000
APPLI Base = 0x8105800
Writing to C:\STM32CubeExpansion_Cloud_AWS_V2.x.x\Projects\B-L4S5I-IOT01A\Applications\Cloud
\aws_demos\EWARM\\PostBuild\\\\SBSFU_B-L4S5I-IOT01_aws_demos.bin 1351616
"Generating the global elf file (SBSFU and userApp)"
      -------------------------------------------------------------------
                        STM32CubeProgrammer v2.4.0
      -------------------------------------------------------------------

Warning: The ELF file will be overwritten
ELF file modified successfully
        1 file(s) copied.
```

5.1.4 Rebuilding the bootloader

The bootloader is based on the technology of the X-CUBE-SBSFU Expansion Package. X-CUBE-AWS contains some sub-modules of X-CUBE-SBSFU:

- `Project/<board_name>/Applications/BootLoader_STSAFE/2_Images_SBSFU`
- `Project/<board_name>/Applications/BootLoader_STSAFE/2_Images_SECoreBin`
- `Project/<board_name>/Applications/BootLoader_STSAFE/Linker_Common`

Refer to the release note in the X-CUBE-AWS Expansion Package for information about the related X-CUBE-SBSFU version.

The X-CUBE-SBSFU sub-module usage is as follows:

SECorebin contains the Secure Engine Core sources, a protected environment, where all critical data and operations can be managed in a secure way.

SBSFU implements the Secure Boot and Secure Firmware Update with the support of the Secure Engine Core.

Linker_Common contains the linker files with the definition of the different Slot #0 and Slot #1 areas. The user application is linked against Slot #0 definition.

The original X-CUBE-SBSFU package is slightly modified to support the FreeRTOS™ user applications (OTA update image state management, offloading of PKCS#11 services to the STSAFE-A110 component) and to better integrate with the IDEs. Post-script templates are adapted to help with IDE integration.

Updating the bootloader implies to rebuild, **in this order**:

1. The Secure Engine library. The project is located in the `2_Images_SE_CoreBin` folder.

2. The Secure Boot / Secure Firmware Update executable. The result is called *"bootloader"* in this document. Depending on the IDE, it is located in:
   – IAR Embedded Workbench®
     `Project/<board_name>/Applications/Bootloader_STSAFE/2_Images_SBSFU/EWARM/<boardname>Exe/Project.out`
   – STM32CubeIDE
     `Project/<board_name>/Applications/Bootloader_STSAFE/2_Images_SBSFU/STM32CubeIDE/<board_name>_2_Images_SBSFU/Debug/SBSFU.elf`

Rebuilding the bootloader is required if the bootloader configuration or some linker script files are changed.

The configuration is defined by several files and is based on C preprocessor statements:

- `2_Images_SBSFU/SBSFU/App/app_sfu.h` for SBSFU settings
- `2_Images_SECoreBin/Inc/se_crypto_config.h` for the cryptography settings

The current bootloader is configured as follows:

- `SECBOOT_ECCDSA_WITH_AES128_CBC_SHA256`
- `SFU_DEBUG_MODE`
- `SECBOOT_DISABLE_SECURITY_IPS`

The secure firmware image is encrypted, but the hardware protections are not enforced. For instance, the JTAG link is on, so that debugging remains possible. Read the documentation of the X-CUBE-SBSFU Expansion Package for more information.

Programming the user application

From a user perspective, the application gets programmed as usual. Nevertheless, when security is enforced by the bootloader, it may be necessary to reprogram the Option Bytes to clear some protections and revert to RDP-L0 before reprogramming the Flash memory. This can be achieved with the STM32CubeProgrammer (STM32CubeProg) or STM32 ST-LINK Utility (STSW-LINK004) tools.

Debugging the application

The debugger retrieves the debug information from the user application `.elf` file (*aws_demos* or *aws_tests* in the present case). It has no access to the bootloader symbols. The debugger places a breakpoint on the `main()` function of the user application.

Upon reset:

- In IAR Embedded Workbench®, the debugger starts the application at address 0x0800 0000 so that the bootloader is executed. For this purpose, IAR Embedded Workbench® is given an extra option: [**Debugger**]>[**extra options**]>[**command line option**] `--drv_vector_table_base=0x0800 0000`
- The STM32CubeIDE debugger requires a modification of the `.elf` file to be able to start at address 0x0800 0000. This modification is performed automatically at the post-build stage of the project (this is specific to STM32CubeIDE). A tool named `bigelftuner.exe` changes the entry point of the global `.elf` file (combining the bootloader and the application) and sets this entry point to address 0x0800 0000 to start the bootloader. Still, the debugger places a breakpoint on the `main()` function of the user application.

5.1.5 Firmware update

The FreeRTOS™ OTA Agent running in the user application enables the AWS IoT Core™ OTA Service to deploy remotely a new user application version.

OTA Agent and firmware image state

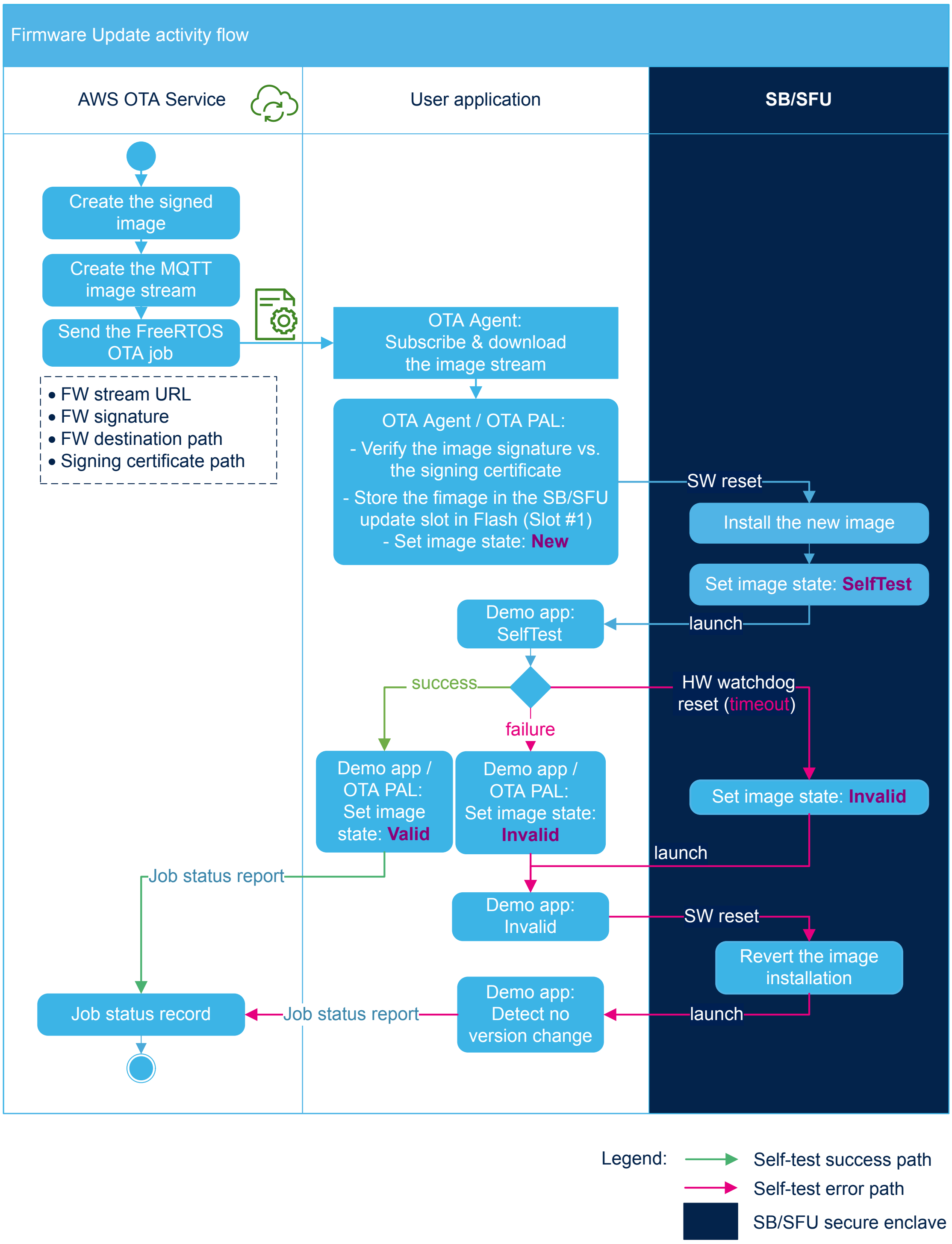
The bootloader implements the management of the firmware image states to be compliant with the OTA Agent library (refer to the OTA Agent library user guide in FreeRTOS™ documentation).

A downloaded firmware image is received with its status set to *"New"*. Once the bootloader has installed the image, the status is updated to *"Self Test"* and the new firmware image is booted.

Then, it is up to the user application to set the firmware image state to *"Accepted"* or *"Rejected"*. If the status is *"Rejected"* or if a reset occurs while the image is still in *"Self Test"* state, a rollback is performed to the previous firmware image (the one that downloaded the image under validation).

The activity flow is summarized in Figure 10.

Figure 10. OTA firmware update activity flow



Step-by-step OTA update

Refer to Section 5.3 Running aws_demos: the MQTT OTA firmware update demonstration.

5.2 User configuration

5.2.1 Bootloader application configuration

By default, the secure bootloader is configured so that the security protections of the MCU are not enforced, and it remains possible to attach a debugger.

Refer to Section 5.1.1 Overview and `Projects/<board_name>/Applications/Cloud/aws_demos/bootloader_readme.txt`.

5.2.2 User application configuration

Once the registration described in Section 2.2 Account configuration, device registration, device provisioning is completed, set the credentials in the *aws_demos* configuration file `Middlewares/Third_Party/amazon-freertos/demos/include/aws_clientcredentials.h`:

- `clientcredentialMQTT_BROKER_ENDPOINT` is *"my_endpoint_name"*
- `clientcredentialIOT_THING_NAME` is *"my_thing_name"*
- `clientcredentialWIFI_SSID` is the WLAN name
- `clientcredentialWIFI_PASSWORD` is the WLAN password
- `clientcredentialWIFI_SECURITY` is the WLAN security mode

5.3 Running *aws_demos*: the MQTT OTA firmware update demonstration

1. Re-build the application with the new configuration, program it, and launch it.
   – *aws_demos* successively
      ◦ connects to the endpoint over TCP/IP and Wi-Fi®
      ◦ authenticates itself through TLS by means of its pre-provisioned device certificate
      ◦ enters the MQTT wait loop, pending on the reception of an OTA firmware update job
2. In order to test OTA update, further configuration is required:
   a. Create a code signing certificate and profile on the AWS console (once for all) See the *Creating a code-signing certificate for the FreeRTOS Windows simulator* page of the FreeRTOS™ user guide for generating and registering your own ECDSA code signing certificate.
   b. Copy the code signing certificate string to the `pcClientCertificatePem[]` static array in the OTA PAL (`Projects/<board_name>/Applications/Cloud/aws_demos/Src/ports/aws_ota_pal.c`).

      Important: This code signing certificate is **NOT** the device certificate (*"my_device_cert_arn"*) previously used for the device registration.
   c. Build the application, program, and reset the board.
3. Prepare the application update file and upload it to AWS
   a. Increment the application version in `aws_application_version.h`. This is mandatory to avoid that the update is rejected by the demo self-test.
   b. Build the application, but do **NOT** program it to the board.
   c. Upload the resulting `<toolchain_name>/PostBuild/<board_name>_aws_demos.sfb` file to a versioned Amazon S3 bucket listed in the IAM role for OTA update job.
4. Create a FreeRTOS™ OTA update job from the AWS console ([**IoT Core**]>[**Manage**]>[**Jobs**]>[**Create**]) and select:
   – the *thing* to update: `my_thing_name`
   – the MQTT protocol for image transfer (HTTP is not supported)
   – [**Sign a new firmware for me**]
   – the code signing profile
   – the `.sfb` firmware file, referenced from the S3 bucket where it is uploaded
   – any non-empty destination pathname (such as `firmware.bin`)
   – the role for OTA update jobs, which gives access to the S3 buckets and to the IoT Core services
   – and finally choose a unique job ID.

The application then automatically:

- receives and handles the job request
- downloads the `.sfb` file and stores it into the Slot #0 region of the system Flash memory
- verifies the integrity and the authenticity of the `.sfb` file against the file signature attached to the job description, and of the AWS code signing certificate provisioned in the OTA PAL. If the file signature verification fails (this message is displayed on the device console: `[prvPAL_CloseFile] ERROR - Failed to pass sig-sha256-ecdsa signature verification`), the OTA update job is aborted and reported FAILED to the AWS OTA update service.
- resets the MCU and lets the secure bootloader detect the new `.sfb` in Slot #0, verify the integrity and the authenticity of the new user application against the secure bootloader certificate, install it into Slot #1, and reset the MCU again
- launches the new application version, which then performs the self-test and informs the OTA update service of the update success. In case of self-test error, the user application update is rejected and the previous application version is restored. If the new application version cannot complete the self-test within about 90 seconds, a timer expiration resets the MCU, the secure bootloader reverts to the previous application version, resets the MCU again, and the OTA update job is reported FAILED upon reconnection.

6 References and documentation

6.1 References

STMicroelectronics documents providing complementary information about the topics presented in this user manual are available from STMicroelectronics website at *www.st.com*.

- *Getting started with the X-CUBE-SBSFU STM32Cube Expansion Package* user manual (UM2262)
- *Integration guide for the X-CUBE-SBSFU STM32Cube Expansion Package* application note (AN5056)
- *STSAFE-A110 generic sample profile description* application note (AN5435)

6.2 Acronyms, abbreviations and definitions

Table 1. Acronyms, abbreviations and definitions

Term	Definition
API	Application programming interface
AWS	Amazon Web Services®(1)
CA	Certificate authority
CLI	Command-line interface
HAL	Hardware abstraction layer
IAM	Identity and access management
IDE	Integrated development environment
IoT	Internet of Things
JSON	JavaScript Object Notation
MQTT	Message queuing telemetry transport
OTA	Over-the-air (firmware update)
PAL	Platform abstraction layer
PKCS#11	Public-key cryptography standard
RAM	Random access memory
RNG	Random number generator
ROM	Read-only memory
SB	Secure Boot
SFU	Secure Firmware Update
SPI	Serial peripheral interface
TLS	Transport layer security
USB	Universal serial bus
X.509	Public key certificates format standard

1. *Amazon is a trademark of Amazon in the United States and/or other countries.*

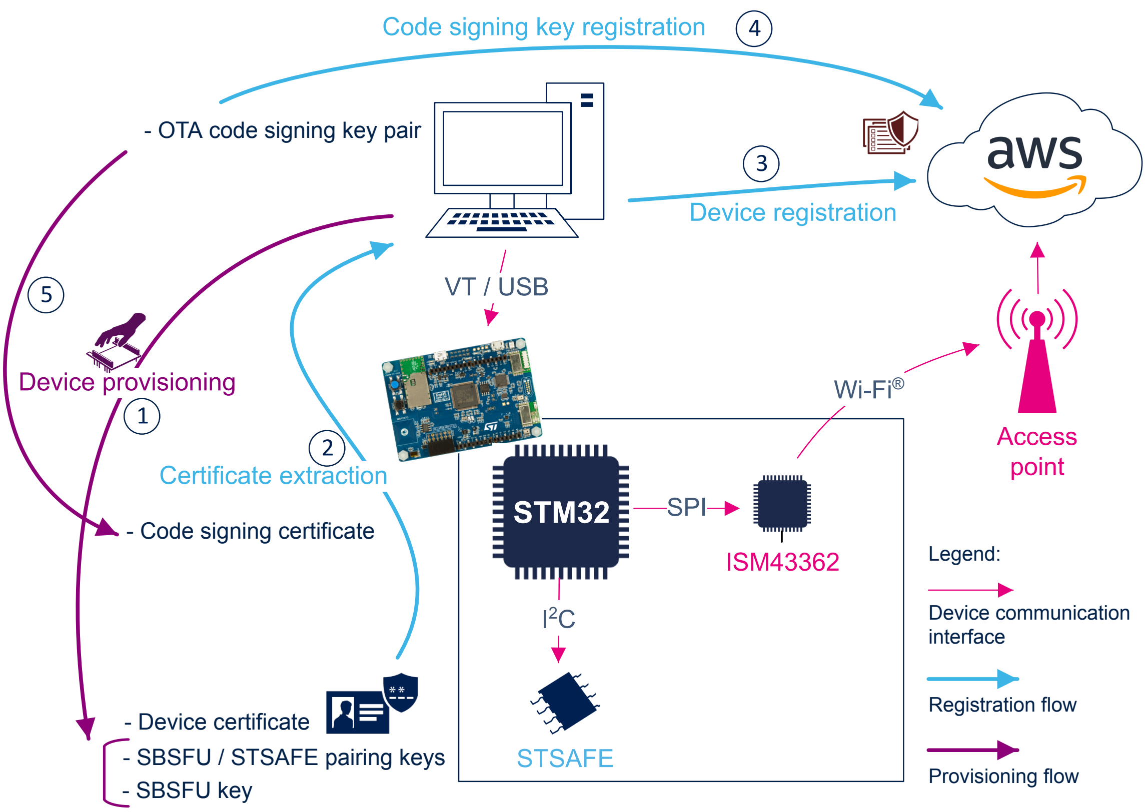
Appendix A Board specificities

A.1 B-L4S5I-IOT01A Discovery kit

A.1.1 Provisioning

B-L4S5I-IOT01A is specific in that it provides a unique device certificate provisioned in the soldered STSAFE-A110 Secure Element at production time. The system and provisioning flow is depicted in Figure 11.

Figure 11. B-L4S5I-IOT01A system overview



A.1.2 GPIO settings

The user applications GPIO settings is provided in Figure 12.

The bootloader GPIO settings are not shown because they belong to a different application for instance for addressing the STSAFE-A110 Secure Element.

Figure 12. B-L4S5I-IOT01A GPIO settings

Pin Name	Signal on Pin	GPIO output level	GPIO mode	GPIO Pull-up/Pull-down	Maximum output speed	User Label
PA9	USART1_TX	n/a	Alternate Function Push Pull	Pull-up	Medium	
PA10	USART1_RX	n/a	Alternate Function Push Pull	No pull-up and no pull-down	Medium	
PE1	n/a	n/a	External Interrupt Mode with Rising edge trigger detection	No pull-up and no pull-down	n/a	ES_WIFI_DATA_READY
PE0	n/a	High	Output Push Pull	No pull-up and no pull-down	Medium	ES_WIFI_NSS
PE8	n/a	Low	Output Push Pull	No pull-up and no pull-down	Low	ES_WIFI_RESET
PB13	n/a	Low	Output Push Pull	No pull-up and no pull-down	Low	ES_WIFI_WAKE_UP
PC11	SPI3_MISO	n/a	Alternate Function Push Pull	No pull-up and no pull-down	Medium	SPI3_MISO
PC12	SPI3_MOSI	n/a	Alternate Function Push Pull	No pull-up and no pull-down	Medium	SPI3_MOSI
PC10	SPI3_SCK	n/a	Alternate Function Push Pull	No pull-up and no pull-down	Medium	SPI3_SCK
PC13	n/a	n/a	External Interrupt Mode with Rising edge trigger detection	No pull-up and no pull-down	n/a	USER_BUTTON
PB14	n/a	Low	Output Push Pull	No pull-up and no pull-down	Low	USER_LED2

A.1.3 Security

In addition to the sensitive cryptographic data stored in the STSAFE-A110, the alternate entropy source of the mbedTLS library is mapped to the STSAFE-A110 random number generator (RNG) through the PKCS#11 interface and the host RNG is not used.

A.1.4 Network connectivity

The FreeRTOS™ SecureSockets platform abstraction layer (PAL) is ported to the mbedTLS library and to the `es-wifi` component driver. It gives access to the ISM43362 module, belonging to the Inventek eS-WiFi family, which exposes a socket-level TCP/IP interface to the host through AT commands.

The hardware interface of this module in summarized in Table 2.

Table 2. Inventek ISM43362 module hardware interface

Name	User label	Comment
ISM43362_RST	ES_WIFI_RESET	Active low. The module after power-up or reset raises the CMD/DATA READY pin to signal that the first Data Phase has started. The CMD/ DATA READY pin is mapped to the ISM43362_DRDY_EXTI1 STM32 MCU pin.
ISM43362_BOOT0	PB12 (unused)	Enable the micro bootloader. Set to 0 by default.
ISM43362_WAKEUP	ES_WIFI_WAKE_UP	Seen from the module, the wakeup pin is an external interrupt pin that on the rising edge causes the module to exit stop mode. It is an edge-triggered input.
ISM43362_SPI3_CSN	ES_WIFI_NSS	The STM32 host must set this output at low to initiate a communication with the module.
ISM43362_DRDY_EXTI1	ES_WIFI_DATA_READY	Input GPIO, interrupt mode when rising The module sets this pin high when ready to communicate.
INTERNAL_SPI3_SCK	SPI3_SCK	Mode SPI3 Alternate Function, push-pull SPI interface to read and write data to the module.
INTERNAL_SPI3_MISO	SPI3_MISO	-
INTERNAL_SPI3_MOSI	SPI3_MOSI	-

A.1.5 Sensors

The sensors present on the board are not used by the FreeRTOS™ standard applications provided.

A.1.6 Memory mapping and footprint

The figures presented in Table 3 and Table 4 are computed from the IAR Embedded Workbench® linker configuration and output files of the *SBSFU* and *aws_demos* applications of the v2.0.0 package. The unused heap size is returned by FreeRTOS™ `xPortGetMinimumEverFreeHeapSize()`.

Table 3. ROM footprint of the OTA demo

Area	Reserved (Kbytes)	Used (Kbytes)
Bootloader	215	183
Slot #0	748	183 (*aws_demos*)
Slot #1	748	185
Swap	44	44

Table 4. **RAM footprint of the OTA demo**

Area	Reserved (Kbytes)	Linked (Kbytes)	Used (Kbytes)
Bootloader	192	48	-
UserApp	384	226 (*aws_demos*)	91 (*aws_demos* has 135 Kbytes of unused heap)

A.1.7 Running the application

- Ensure that JP8 is open, JP5, JP6 and JP7 are closed, JP4 is set to 5V_ST_LINK
- Connect a USB Type-A or USB Type-C® to Micro-B cable from the board connector USB ST-LINK CN7 to a personal computer
- LED 6 (ST-LINK COM - bi color) must be lit (red) and LED 5 (5 V power - green) must also be lit

Revision history

Table 5. Document revision history

Date	Version	Changes
29-Mar-2017	1	Initial release.
2-Jul-2019	2	Document entirely updated for: • Support of the Secure Firmware Update using XCUBE-SBSFU • Integration of X-CUBE-CELLULAR and Connectivity middleware with the support of LTE Cat M1/NB modem with 2G fallback • Connection to STMicroelectronics AWS web dashboard
10-Aug-2020	3	Entire document updated after X-CUBE-AWS v2.x major update, replacing the IoT C SDK with FreeRTOS™.
23-Sep-2020	4	Updated the ISM43362_BOOT0 entry in Table 2. Inventek ISM43362 module hardware interface. Updated Figure 2. X-CUBE-AWS software architecture.

Contents

List of tables

List of figures

IMPORTANT NOTICE – PLEASE READ CAREFULLY

STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST’s terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers’ products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, please refer to www.st.com/trademarks. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2020 STMicroelectronics – All rights reserved