AN12980
KW38 - Integrating the OTAP Client Service into a Bluetooth LE Central Device

Rev. 0 — 11/2020 Application Note

Contents

1 Introduction

The Over The Air Programming (OTAP) NXP's custom Bluetooth LE service provides the developers a solution to upgrade the software that the MCU contains. It removes the need of cables between the device to be upgraded (OTAP client) and the device that contains the new software (OTAP server).

The best way to take advantage of the OTAP service is to integrate it into the Bluetooth LE application. In that way, you can reprogram the device as many times as required.

This document is intended for developers who want to be familiar with the OTAP software.

2 OTAP client software

OTAP memory management during the update process describes the actual implementation of the OTAP client software included in the SDK package for FRDM-KW38. Advantages of the OTAP service integration explains the importance of integrating OTAP client software into your application, and the expected results.

2.1 OTAP memory management during the update process

1. The KW38 Flash is partitioned into:
   - One 256 KB Program Flash array (P-Flash) divided into 2 KB sectors with a flash address range from `0x0000_0000` to `0x0003_FFFF`.
   - One 256 KB FlexNVM array divided in 2 KB sectors with address range from `0x1000_0000` to `0x1003_FFFF`.
   - Alias memory with address range from `0x0004_0000` to `0x0007_FFFF`. Writing or reading at the Alias range address modifies or returns the FlexNVM content respectively.

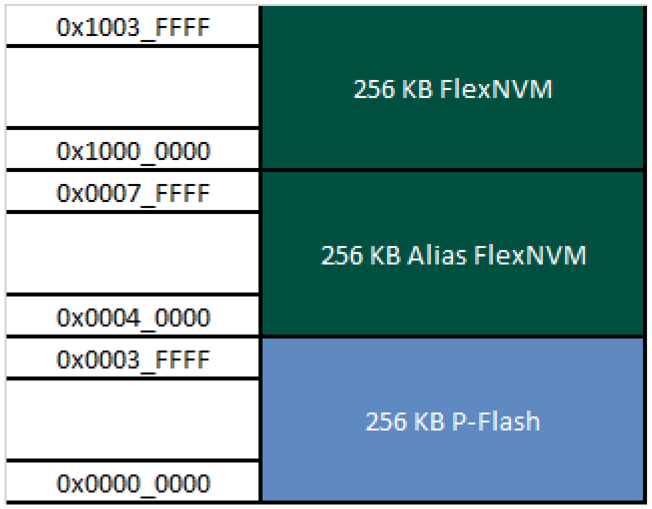


Figure 1. MCU on-chip memory

2. The OTAP application splits the flash into two independent parts, the OTAP bootloader and the OTAP client.
   - The OTAP bootloader verifies if there is a new image available in the OTAP client to reprogram the device.
   - The OTAP client software provides the Bluetooth LE custom service needed to communicate the OTAP client device with the OTAP server that contains the new image file.

   Therefore, the OTAP client device needs to be programmed twice, first with the OTAP bootloader, and then with the Bluetooth LE application supporting OTAP client. The mechanism is created to have two different software coexisting in the same device and store each one in different memory regions. This is implemented by the linker file. In the KW38 device, the bootloader application has reserved an 8 KB slot of memory from `0x0000_0000` to `0x0000_1FFF`, thus the rest of the memory is reserved, among other things, by the OTAP client application.

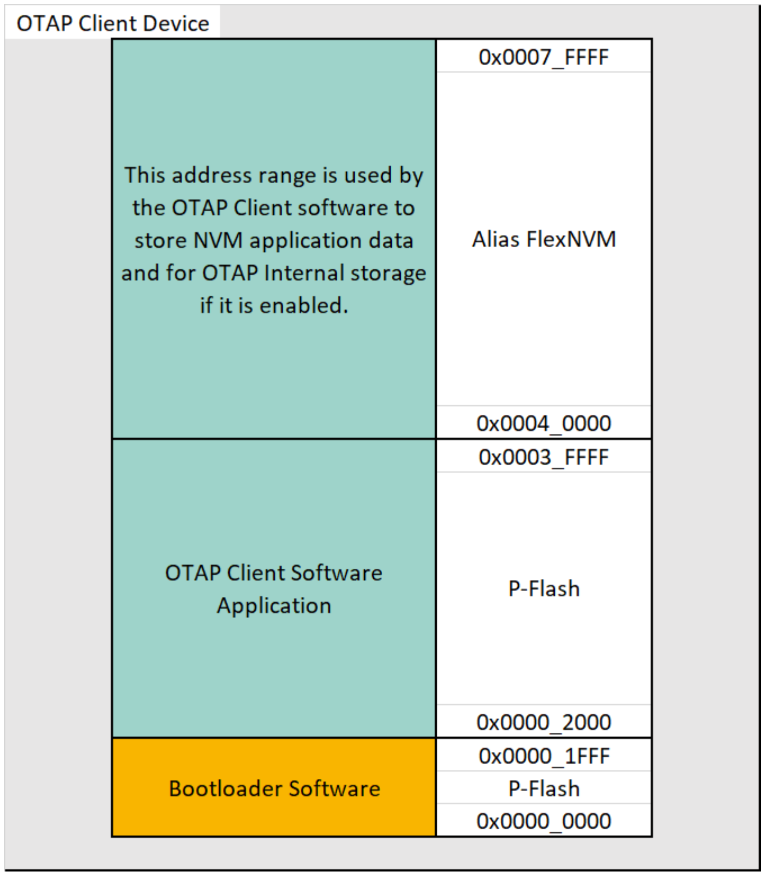

OTAP Client Device
This address range is used by the OTAP Client software to store NVM application data and for OTAP Internal storage if it is enabled.
0x0007_FFFF
Alias FlexNVM
0x0004_0000
0x0003_FFFF
OTAP Client Software Application
P-Flash
0x0000_2000
0x0000_1FFF
Bootloader Software
P-Flash
0x0000_0000

Figure 2. OTAP client software

3. When generating the new image file for the OTAP client device, the developer needs to specify that the code will be stored with an offset of 8 KB since the first addresses must be reserved for the bootloader, making use of the linker script. The new application should contain the Bootloader Flags at the corresponding address to work properly.

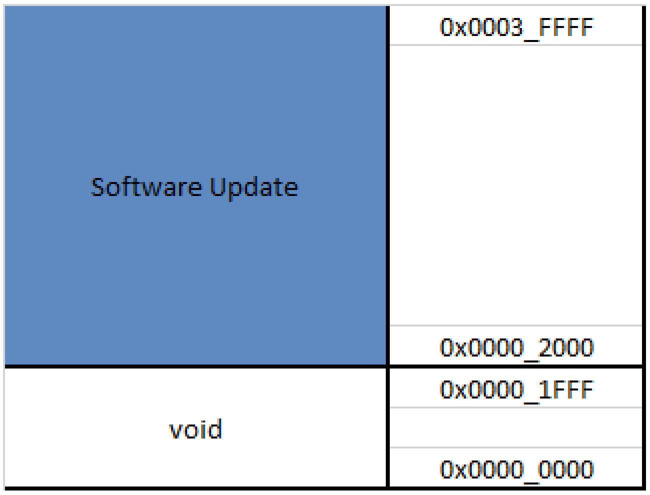


Figure 3. Software update

4. At the connection state, the OTAP server sends the image packets (known as chunks) to the OTAP client via Bluetooth LE. The OTAP client device can store these chunks, at the external SPI flash (only available on the FRDM-KW38 board) or the On-Chip FlexNVM memory. The destination of the code is selectable in the OTAP client software.

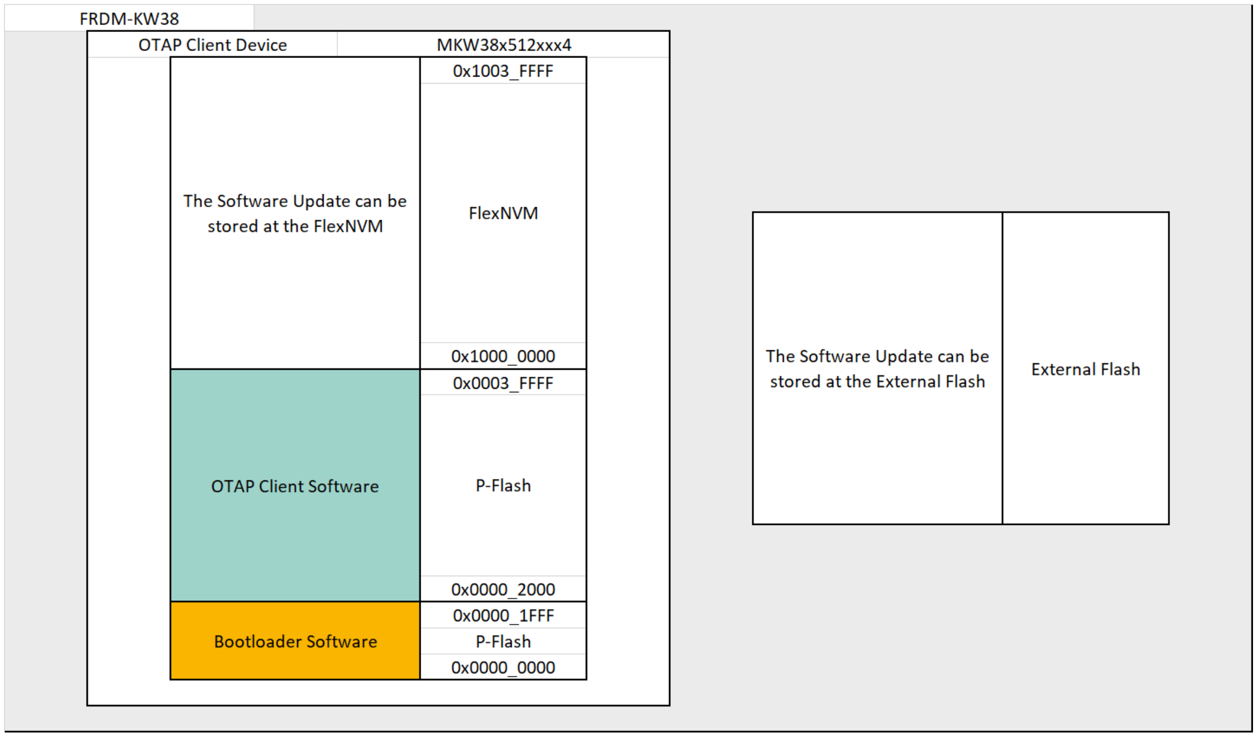


Figure 4. Storage of the software update

5. When the transfer of the image has finished and all chunks were sent from the OTAP server to the OTAP client, the OTAP client software writes information, such as the source of the image update, external flash or FlexNVM, in a portion of memory known as Bootloader Flags, and then resets the MCU to execute the OTAP bootloader code. The OTAP bootloader reads the Bootloader Flags to get the information needed to program the device and triggers a command to reprogram the MCU with the new application. This is shown in the figure below.

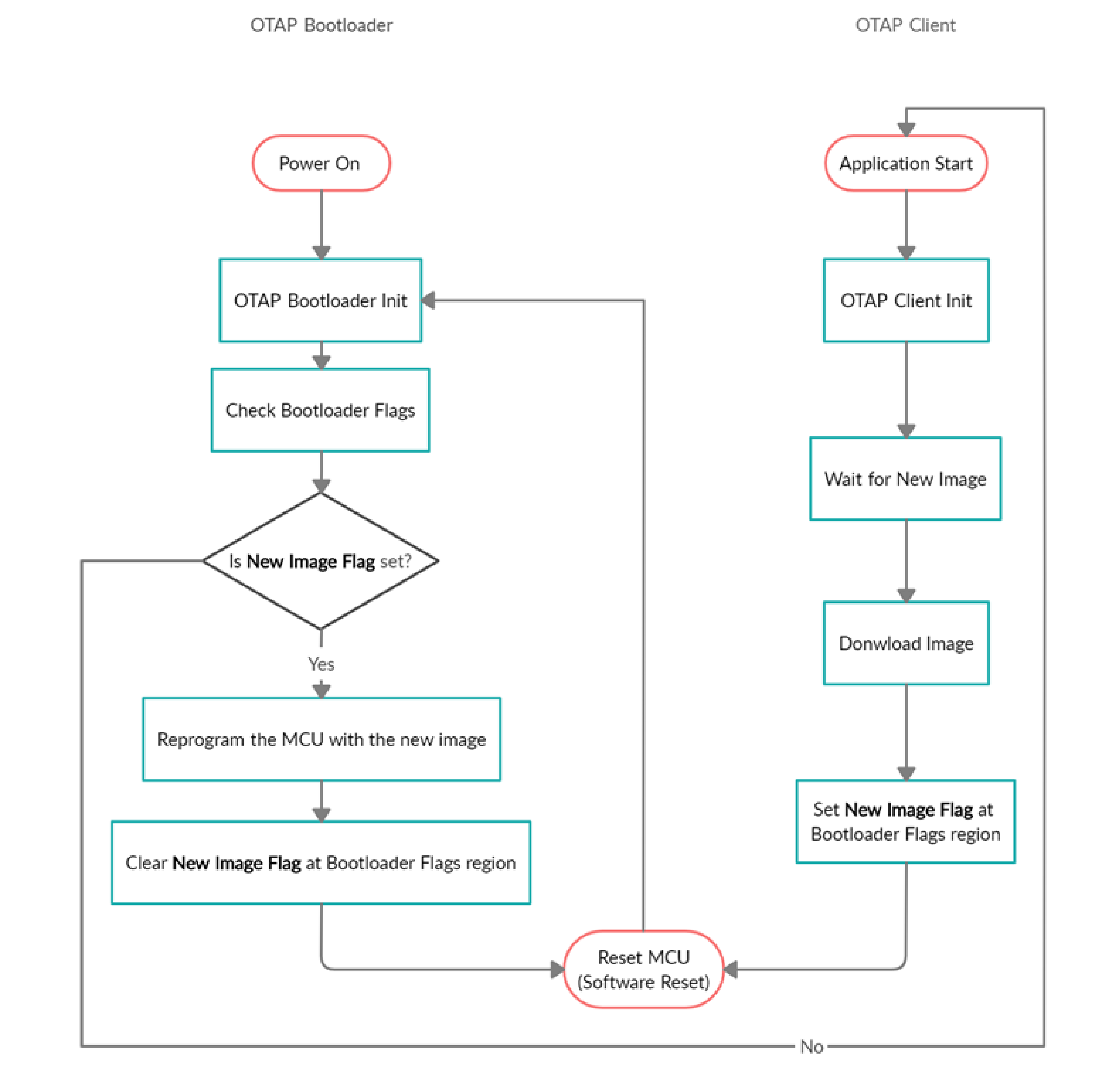

OTAP Bootloader
OTAP Client
Power On
OTAP Bootloader Init
Check Bootloader Flags
Is **New Image Flag** set?
Yes
Reprogram the MCU with the new image
Clear **New Image Flag** at Bootloader Flags region
Reset MCU (Software Reset)
No
Application Start
OTAP Client Init
Wait for New Image
Donwload Image
Set **New Image Flag** at Bootloader Flags region

Figure 5. Simplified flow diagram of OTAP software

6. Because the new application was built with an offset of 8 KB, the OTAP bootloader programs the device starting from the `0x0000_2000` address and the OTAP client application is overwritten by the new image. Then the OTAP bootloader triggers a command to start the execution of the new image. If the new image does not contain the OTAP service included, the device is not able to be programmed again due to the lack of OTAP functionality. For more description, see Advantages of the OTAP service integration.

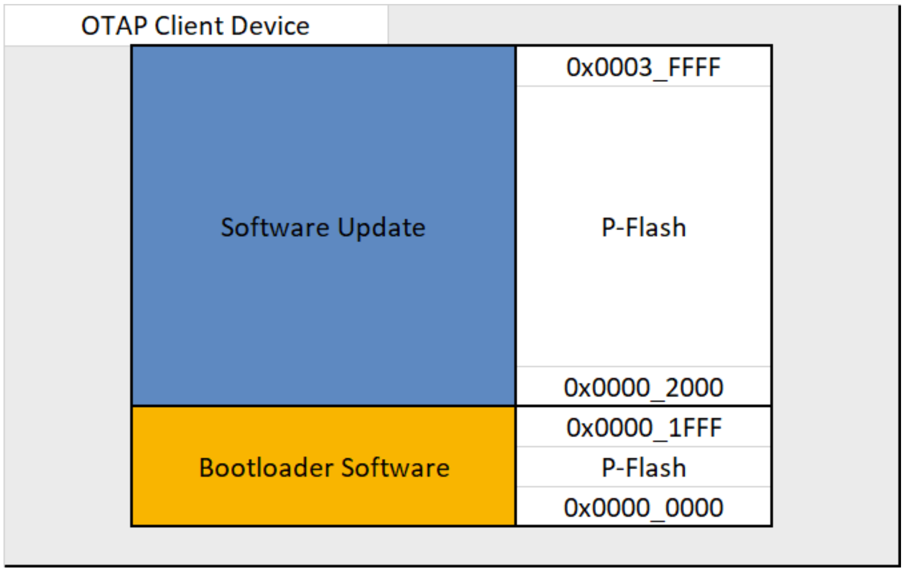


Figure 6. Memory content at the end of the software update process

NOTE

In practice, the boundary created between the OTAP client software and the software update addresses when the internal storage is enabled is not placed exactly in the boundary of the P-Flash and FlexNVM memory regions. These values might change with linker settings. You can inspect the effective memory addresses in your project.

2.2 Advantages of the OTAP service integration

As explained in OTAP memory management during the update process, the OTAP client software is a single-programming demo application. Supposing that an OTAP client device is programmed with the OTAP client software, this device requests an update, for example, a Temperature Collector (Temp Coll). The image that the OTAP server will send to the OTAP client must be the Temp Coll. After the reprogramming process the device that was the OTAP client, now, has turned into a Temperature Collector. The Temp Coll does not have the capabilities to communicate with the OTAP server and request for another update. But if the Temp Coll image had included the OTAP client service as well, the device would have the possibility to request another software update, for example, a modified Wireless UART example with OTAP Service. Due to the WU software already includes the OTAP client, the device can request another software update from the OTAP server. That way, the developer can continue upgrading the software many times as needed. In other words, to be able to upgrade the software on the OTAP client device in the future, the application sent over the air should support OTAP service.

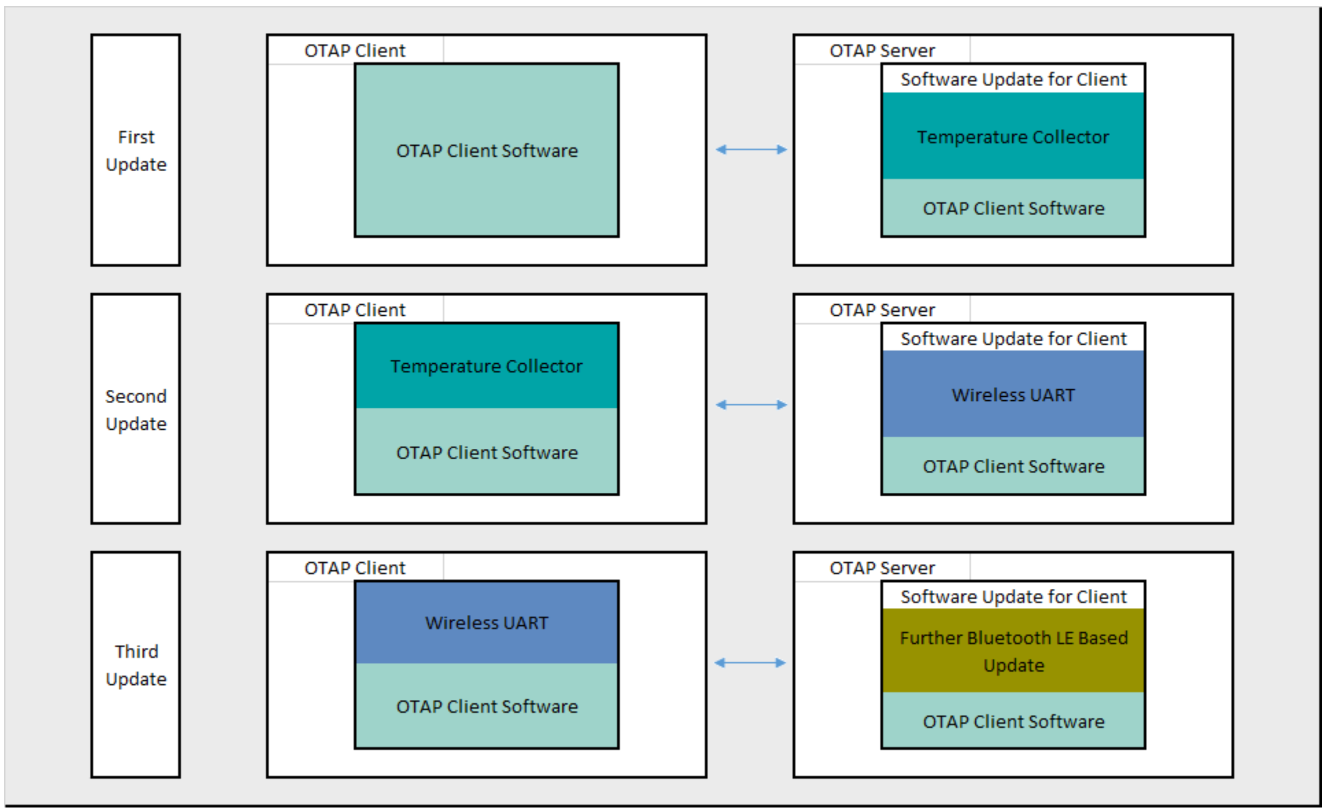


Figure 7. OTAP integration functionality example

This application note is intended as guidance to add the OTAP service to a Bluetooth LE application.

3 Prerequisites

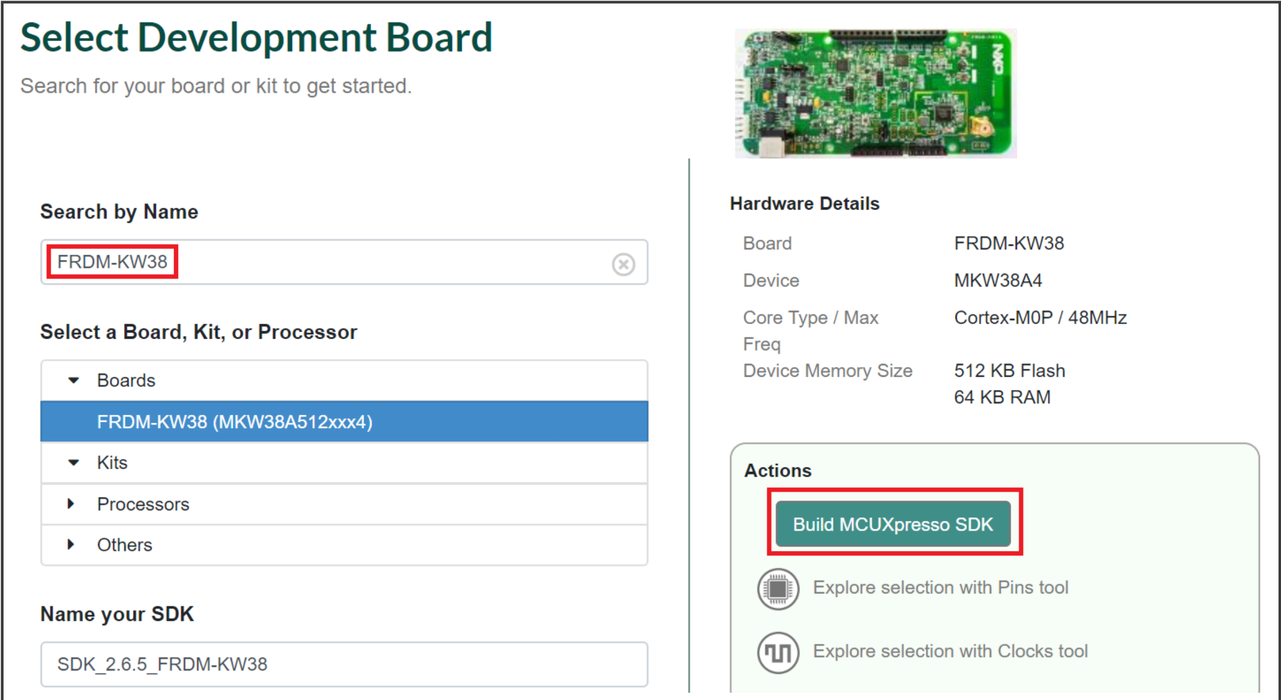
This document is provided together with a functional demo of the OTAP service integration. The example is based on the Temp Coll project, available in the FRDM-KW38 SDK package and developed on the MCUXpresso IDE platform. The following are required to complete the implementation of the Temp Coll - OTAP integration demo.

- MCUXpresso IDE v11.0.0 or later
- FRDM-KW38 SDK
- Temp Coll – OTAP demo package
- FRDM-KW38 board
- A smartphone with IoT Toolbox NXP app, available for Android and iOS.

3.1 Downloading and installing the software development kit

This chapter provides all the steps needed to download the SDK (Software Development Kit) for the FRDM-KW38 used as a starting point.

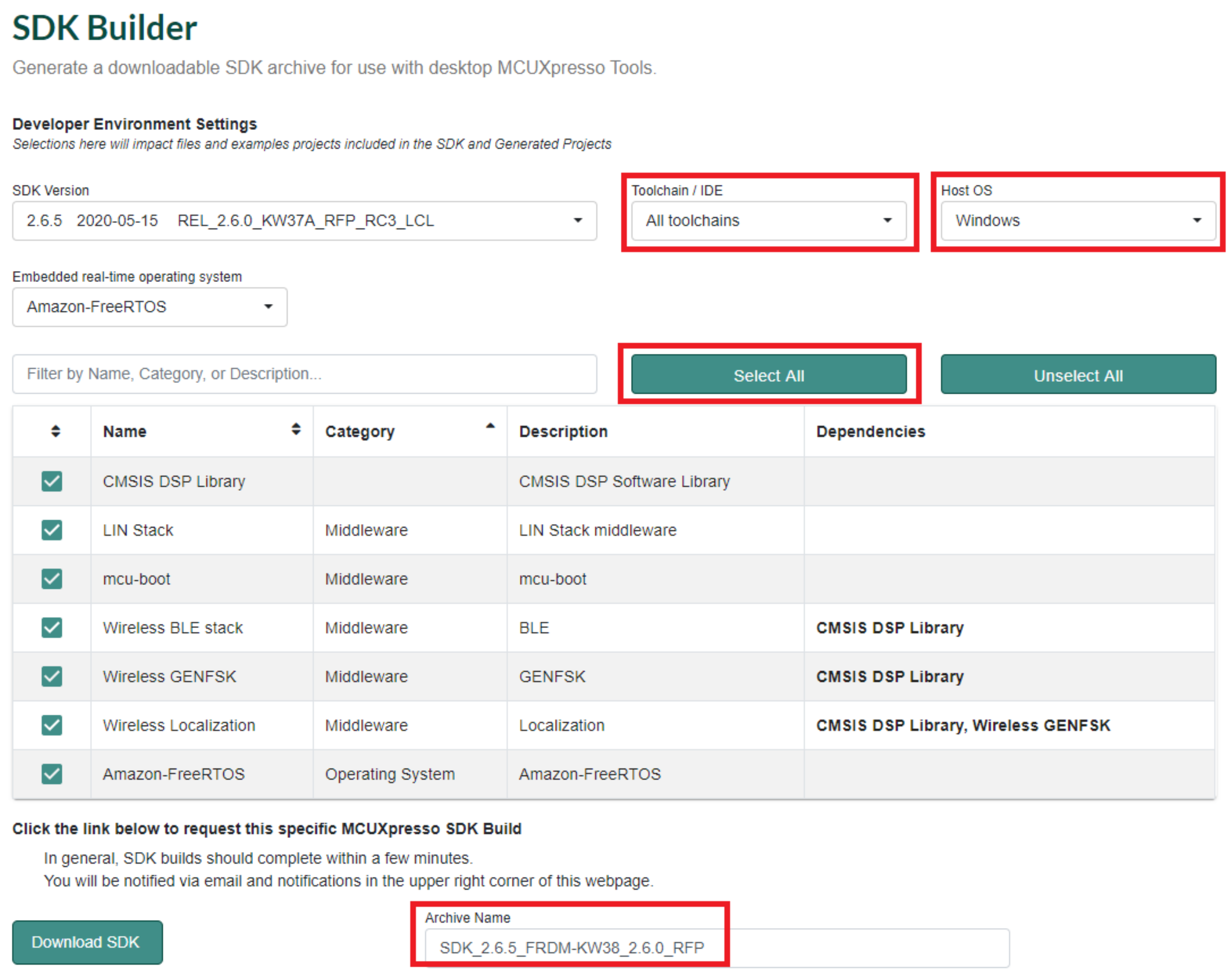
1. Navigate to the MCUXpresso website.
2. Click **Select Development Board**. Log in with your registered account.
3. In the **Search by Name** field, search for **FRDM-KW38**. Then click the suggested board and click **Build MCUXpresso SDK**.


Select Development Board
Search for your board or kit to get started.
Search by Name
FRDM-KW38
Select a Board, Kit, or Processor
Boards
FRDM-KW38 (MKW38A512xxx4)
Kits
Processors
Others
Name your SDK
SDK_2.6.5_FRDM-KW38
Hardware Details
Actions
Build MCUXpresso SDK
Explore selection with Pins tool
Explore selection with Clocks tool

Board	FRDM-KW38
Device	MKW38A4
Core Type / Max Freq	Cortex-M0P / 48MHz
Device Memory Size	512 KB Flash 64 KB RAM

Figure 8. Building the FRDM-KW38 SDK package

4. Select the IDE in the **Toolchain/IDE** combo box. Select the supported OS. Click the **Select All** button to download all components and provide the name to identify the package in your MCUXpresso Dashboard.



SDK Builder

Generate a downloadable SDK archive for use with desktop MCUXpresso Tools.

Developer Environment Settings

Selections here will impact files and examples projects included in the SDK and Generated Projects

SDK Version: 2.6.5 2020-05-15 REL_2.6.0_KW37A_RFP_RC3_LCL

Toolchain / IDE: All toolchains

Host OS: Windows

Embedded real-time operating system: Amazon-FreeRTOS

	Name	Category	Description	Dependencies
✓	CMSIS DSP Library		CMSIS DSP Software Library	
✓	LIN Stack	Middleware	LIN Stack middleware	
✓	mcu-boot	Middleware	mcu-boot	
✓	Wireless BLE stack	Middleware	BLE	**CMSIS DSP Library**
✓	Wireless GENFSK	Middleware	GENFSK	**CMSIS DSP Library**
✓	Wireless Localization	Middleware	Localization	**CMSIS DSP Library, Wireless GENFSK**
✓	Amazon-FreeRTOS	Operating System	Amazon-FreeRTOS	

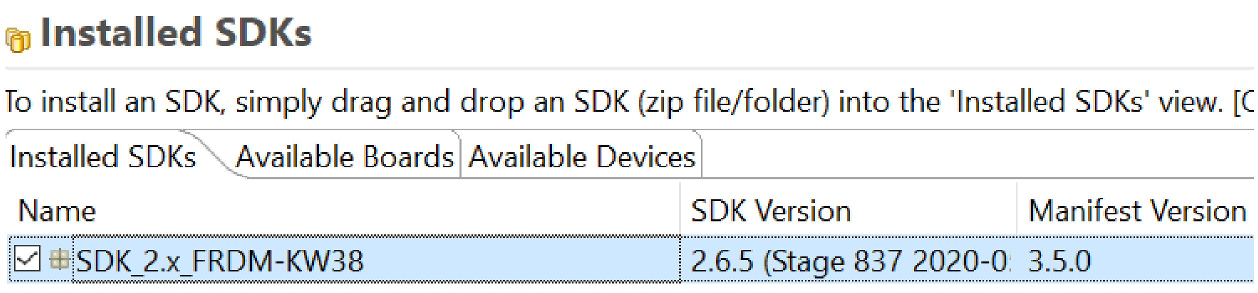
Click the link below to request this specific MCUXpresso SDK Build

In general, SDK builds should complete within a few minutes.
You will be notified via email and notifications in the upper right corner of this webpage.

Archive Name: SDK_2.6.5_FRDM-KW38_2.6.0_RFP

Figure 9. Customizing the installation settings

5. Click **Download SDK** and it will take a few minutes until the system gets the package into your account on the MCUXpresso web page. Read and accept the license agreement. The SDK download starts automatically on your PC.
6. Open MCUXpresso IDE. Drag and drop the FRDM-KW38 SDK zip in the **Installed SDK's** list.



Installed SDKs

To install an SDK, simply drag and drop an SDK (zip file/folder) into the 'Installed SDKs' view. [C

Name	SDK Version	Manifest Version
✓ SDK_2.x_FRDM-KW38	2.6.5 (Stage 837 2020-0	3.5.0

Figure 10. Importing SDK package to MCUXpresso IDE

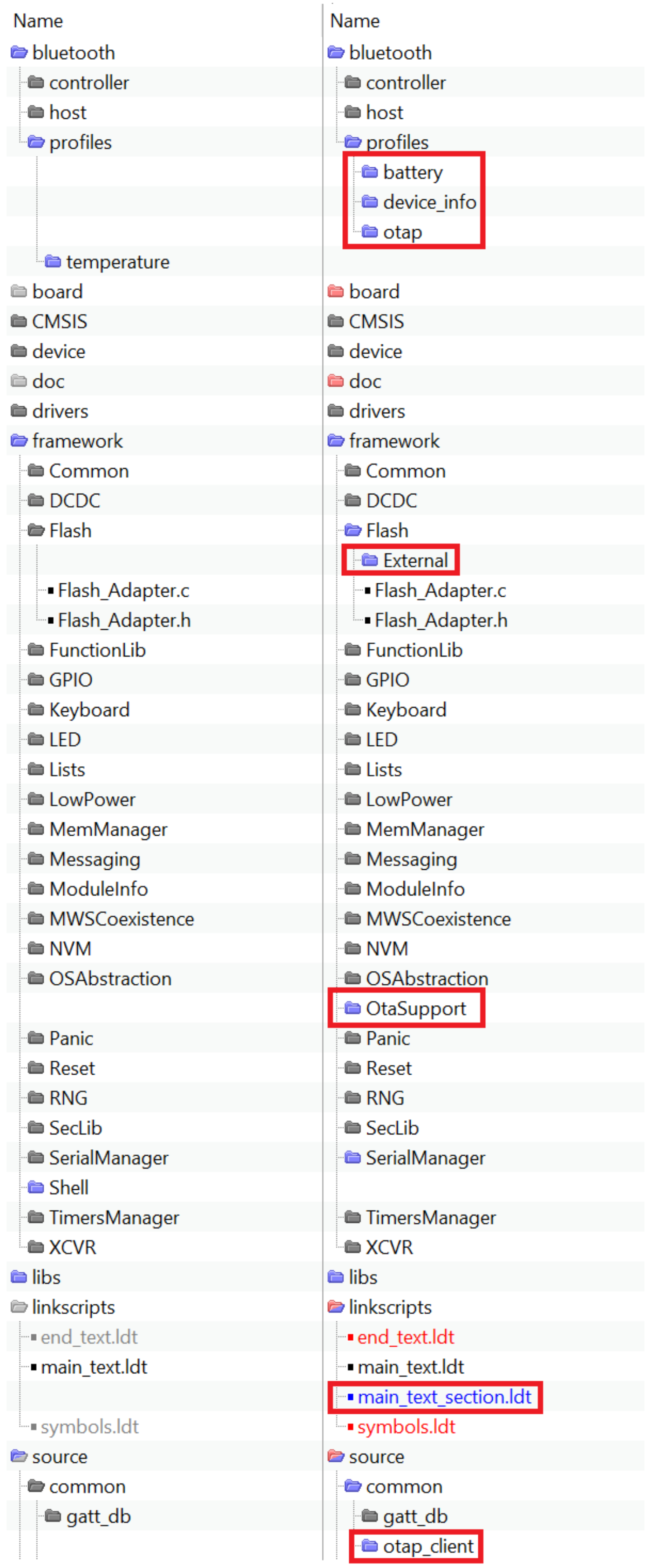
Now, you have downloaded and installed the SDK package for the FRDM-KW38 board.

4 Customizing a based Bluetooth LE demo to integrate the OTAP service

The following steps describe the process of customizing a Bluetooth LE demo imported from the SDK to integrate the OTAP service into it. This guide uses a Temp Coll project as a starting point, so some steps may differ for another Bluetooth LE SDK example.

4.1 Importing the OTAP Bluetooth LE service and framework software into the Temp Coll project

To integrate the OTAP client service in your application, you will need to import additional software that is not included in other SDK examples by default. Hence, the first step consists in to make a comparison between your project and the OTAP client SDK project to locate which files you will need to merge in your project to support this service in your application. A comparison between the Temp Coll (left) and the OTAP client (right) is shown in Figure 11. Files and folders highlighted in red are part of the OTAP client software, but not in the Temp Coll. Consequently, we need to incorporate these files in our Temp Coll example to add the OTAP feature in this project. If you are interested in adding OTAP to other Bluetooth LE SDK projects or in your custom Bluetooth LE project, you need to look for the missing files and incorporate them following the same methodology described in this example.



```
Name                          Name
bluetooth                     bluetooth
    controller                    controller
    host                          host
    profiles                      profiles
                                      battery
                                      device_info
                                      otap
        temperature
board                         board
CMSIS                         CMSIS
device                        device
doc                           doc
drivers                       drivers
framework                     framework
    Common                        Common
    DCDC                          DCDC
    Flash                         Flash
                                      External
        Flash_Adapter.c               Flash_Adapter.c
        Flash_Adapter.h               Flash_Adapter.h
    FunctionLib                   FunctionLib
    GPIO                          GPIO
    Keyboard                      Keyboard
    LED                           LED
    Lists                         Lists
    LowPower                      LowPower
    MemManager                    MemManager
    Messaging                     Messaging
    ModuleInfo                    ModuleInfo
    MWSCoexistence                MWSCoexistence
    NVM                           NVM
    OSAbstraction                 OSAbstraction
                                  OtaSupport
    Panic                         Panic
    Reset                         Reset
    RNG                           RNG
    SecLib                        SecLib
    SerialManager                 SerialManager
    Shell
    TimersManager                 TimersManager
    XCVR                          XCVR
libs                          libs
linkscripts                   linkscripts
    end_text.ldt                  end_text.ldt
    main_text.ldt                 main_text.ldt
                                  main_text_section.ldt
    symbols.ldt                   symbols.ldt
source                        source
    common                        common
        gatt_db                       gatt_db
                                      otap_client
```

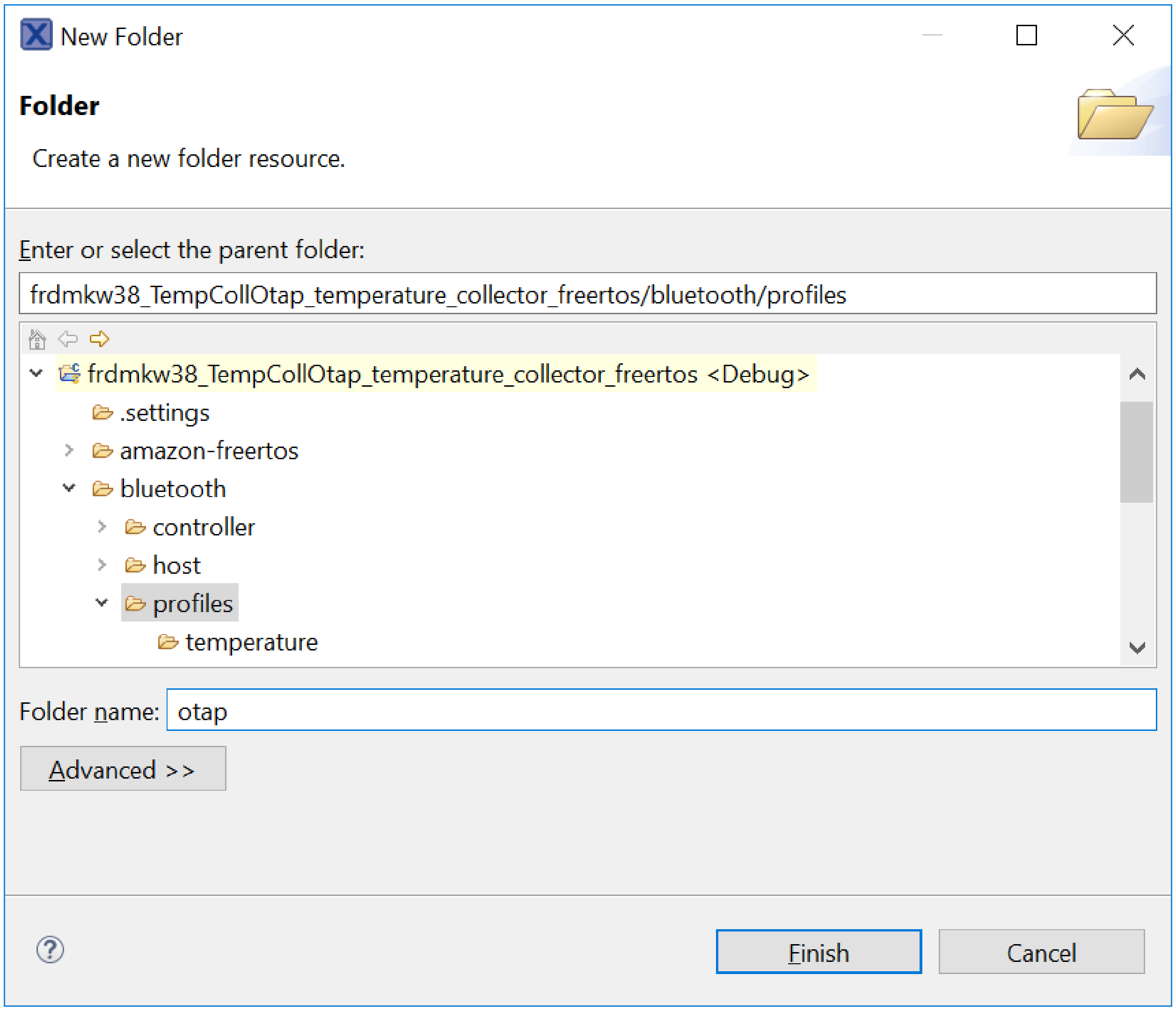
Figure 11. Source tree comparison

The folders and files, which are in OTAP but not in Temp Coll, must be imported in your Temp Coll project. For example, in Figure 11, the following are required to be imported:

- bluetooth -> profiles -> battery
- bluetooth -> profiles -> device_info
- bluetooth -> profiles -> otap
- framework -> Flash -> External
- framework ->OtaSupport
- framework -> SerialManager -> source -> SPI_Adapter
- source -> common -> otap_client
- linkscripts -> main_text_section.ldt

To include these folders and source files in your project, perform the following steps.

1. Expand the **bluetooth** and **framework** folders in your workspace. Select the folder needed for updates and click the right mouse button. Select **New -> Folder**. The **Folder** window appears to provide the same name as the missing folder in the source directory, as shown in Figure 12.


New Folder

Folder

Create a new folder resource.

Enter or select the parent folder:

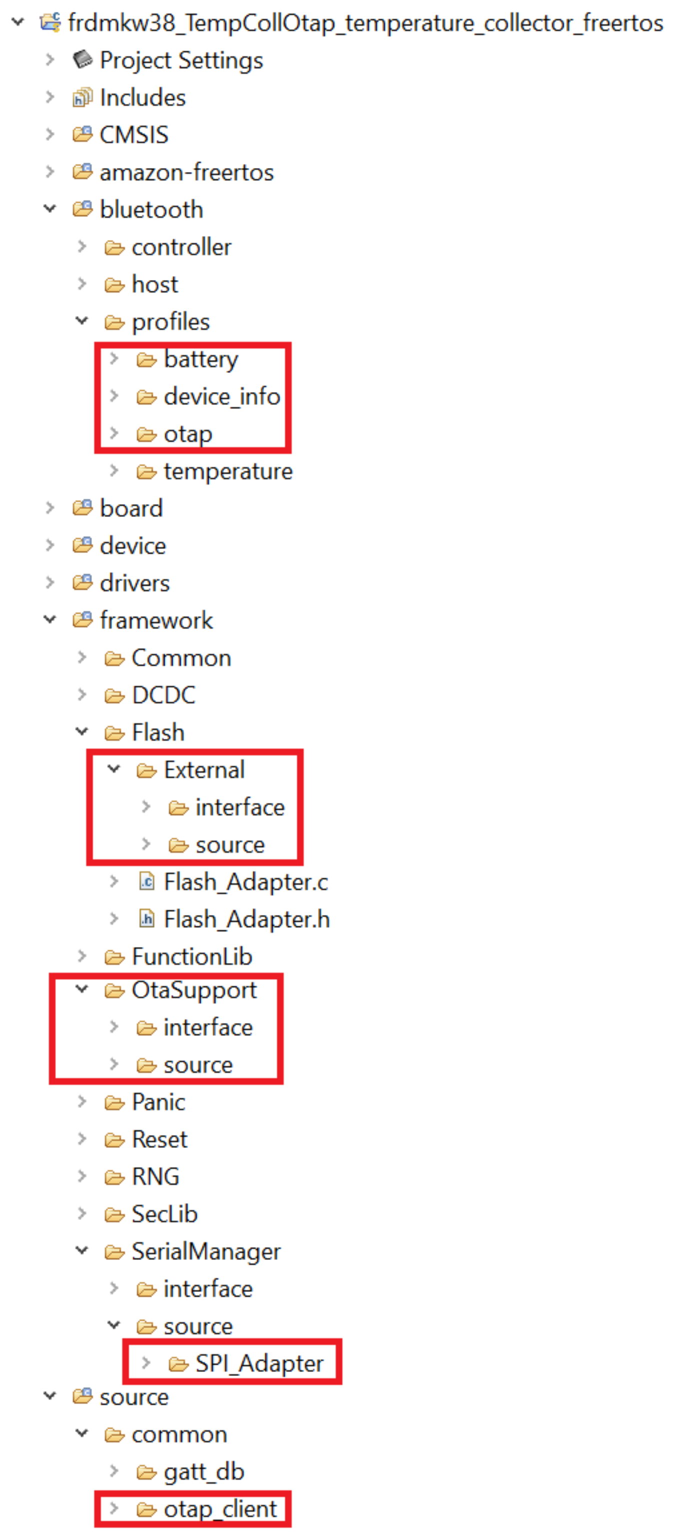
frdmkw38_TempCollOtap_temperature_collector_freertos/bluetooth/profiles

```
frdmkw38_TempCollOtap_temperature_collector_freertos <Debug>
    .settings
    amazon-freertos
    bluetooth
        controller
        host
        profiles
            temperature
```

Folder name: otap

Figure 12. Creating the Bluetooth and Framework folders

2. Repeat Step 1 for the left folders. The result must look similar as shown in Figure 13.



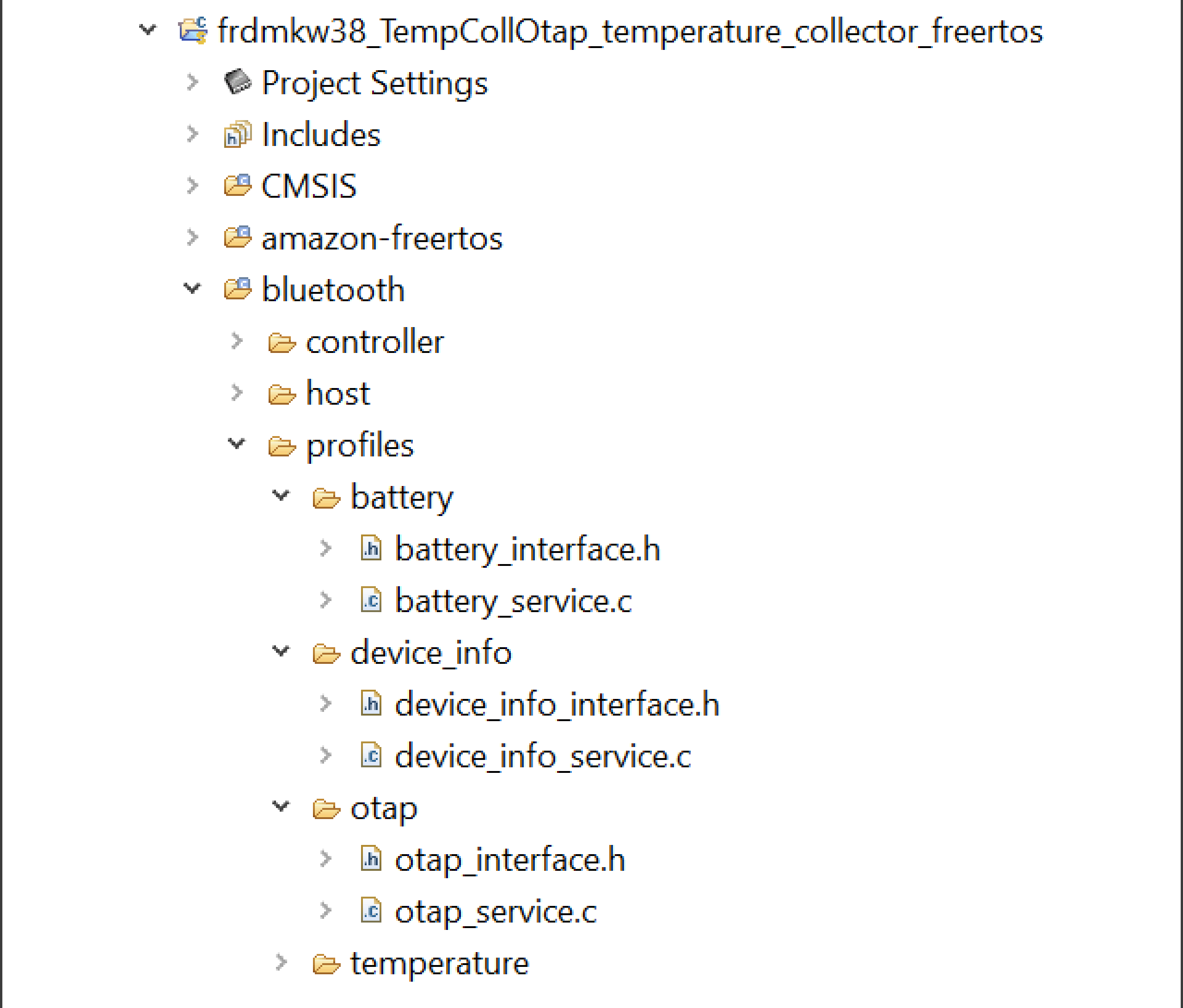
```
frdmkw38_TempCollOtap_temperature_collector_freertos
  Project Settings
  Includes
  CMSIS
  amazon-freertos
  bluetooth
    controller
    host
    profiles
      battery
      device_info
      otap
      temperature
  board
  device
  drivers
  framework
    Common
    DCDC
    Flash
      External
        interface
        source
      Flash_Adapter.c
      Flash_Adapter.h
    FunctionLib
    OtaSupport
      interface
      source
    Panic
    Reset
    RNG
    SecLib
    SerialManager
      interface
      source
        SPI_Adapter
  source
    common
      gatt_db
      otap_client
```

Figure 13. Temp Coll directory updated

3. Copy the files inside all the recently created folders from the OTAP client and save it into your project. Ensure that all the files are in the same folder from the Temp Coll side. For this example, these files are listed as below.

   - `battery_interface.h` and `battery_interface.c` in the **bluetooth -> profile -> battery** folder.

- `device_info_interface.h` and `device_info_service.c` in the **bluetooth** -> **profile** -> **device_info** folder.
- `otap_interface.h` and `otap_service.c` in the **bluetooth** -> **profiles** -> **otap** folder.
- `Eeprom.h` in the **framework** -> **Flash** -> **External** -> **Interface** folder.
- `Eeprom` source files in the **framework** -> **Flash** -> **External** -> **Source** folder.
- `OtaSupport.h` in the **framework** -> **OtaSupport** -> **Interface** folder.
- `OtaSupport.c` in the **framework** -> **OtaSupport** -> **Source** folder.
- `SPI_Serial_Adapter.h` and `SPI_Serial_Adapter.c` in the **framework** -> **SerialManager** -> **source** -> **SPI_Adapter** folder.
- `main_text_section.ldt` in **linkscripts** folder.
- `otap_client.h` and `otap_client.c` in the **source** -> **common** -> **otap_client** folder.

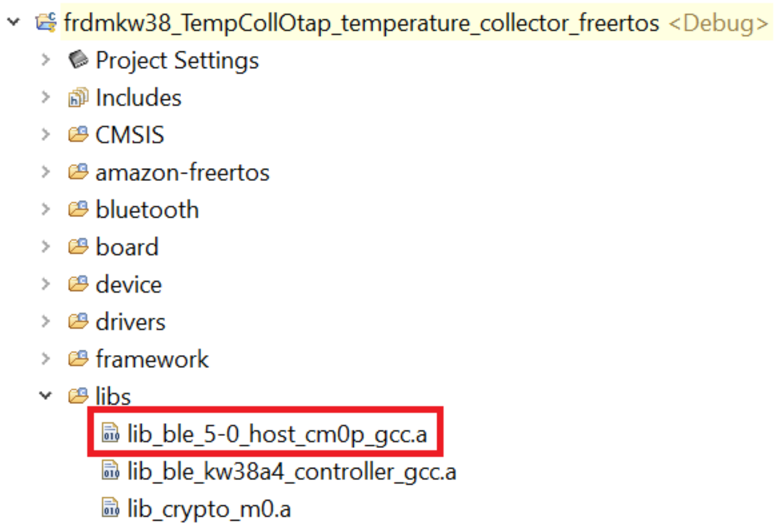


```
frdmkw38_TempCollOtap_temperature_collector_freertos
  Project Settings
  Includes
  CMSIS
  amazon-freertos
  bluetooth
    controller
    host
    profiles
      battery
        battery_interface.h
        battery_service.c
      device_info
        device_info_interface.h
        device_info_service.c
      otap
        otap_interface.h
        otap_service.c
      temperature
```

Figure 14. OTAP files integrated into the Temp Coll project

4. Replace `lib_ble_5-0_host_central_cm0p_gcc.a`, included in your project in libs folder, with the `lib_ble_5-0_host_cm0p_gcc.a` library located in *<SDK_path>\middleware\wireless\bluetooth\host\lib*.

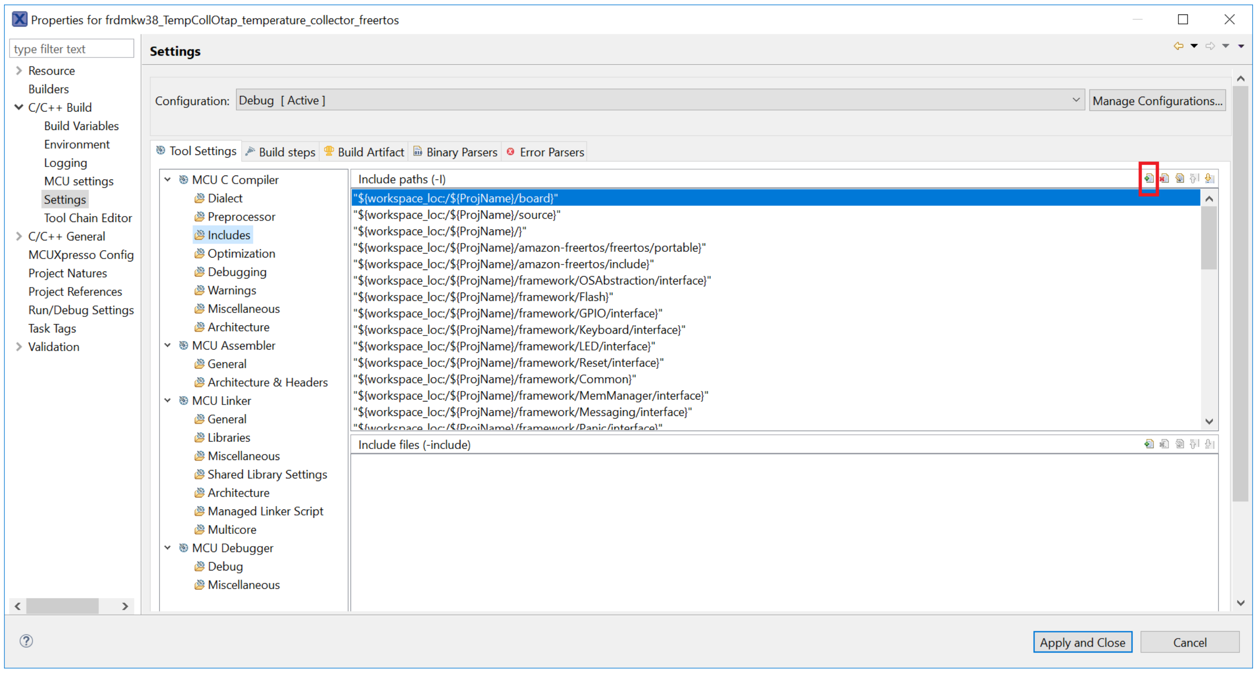
You can simply drag and drop the new library on the workspace and remove the original library file. To remove the old library, right-click on the file and select **Delete**.



```
frdmkw38_TempCollOtap_temperature_collector_freertos <Debug>
  Project Settings
  Includes
  CMSIS
  amazon-freertos
  bluetooth
  board
  device
  drivers
  framework
  libs
    lib_ble_5-0_host_cm0p_gcc.a
    lib_ble_kw38a4_controller_gcc.a
    lib_crypto_m0.a
```

Figure 15. Updating the Bluetooth LE library

5. Navigate to **Project** -> **Properties** in MCUXpresso IDE. Go to **C/C++ Build** -> **Settings** -> **Tool Settings** -> **MCU C Compiler** -> **Includes**. Click the icon next to the **Include paths** textbox, as shown in Figure 16. In the new window that appears, click the **Workspace** button.



Properties for frdmkw38_TempCollOtap_temperature_collector_freertos

Settings

Configuration: Debug [Active]

Include paths (-I)

```
"${workspace_loc:/${ProjName}/board}"
"${workspace_loc:/${ProjName}/source}"
"${workspace_loc:/${ProjName}/}"
"${workspace_loc:/${ProjName}/amazon-freertos/freertos/portable}"
"${workspace_loc:/${ProjName}/amazon-freertos/include}"
"${workspace_loc:/${ProjName}/framework/OSAbstraction/interface}"
"${workspace_loc:/${ProjName}/framework/Flash}"
"${workspace_loc:/${ProjName}/framework/GPIO/interface}"
"${workspace_loc:/${ProjName}/framework/Keyboard/interface}"
"${workspace_loc:/${ProjName}/framework/LED/interface}"
"${workspace_loc:/${ProjName}/framework/Reset/interface}"
"${workspace_loc:/${ProjName}/framework/Common}"
"${workspace_loc:/${ProjName}/framework/MemManager/interface}"
"${workspace_loc:/${ProjName}/framework/Messaging/interface}"
"${workspace_loc:/${ProjName}/framework/Panic/interface}"
```

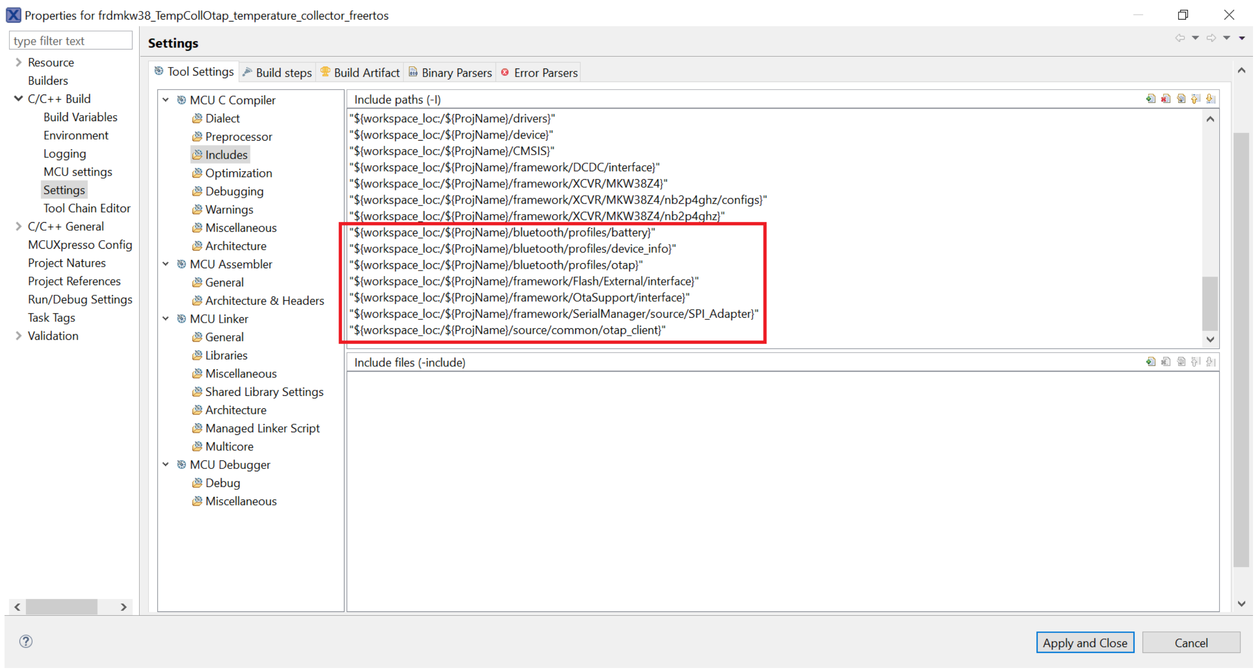
Include files (-include)

Figure 16. Include paths perspective

6. Deploy your directory tree in the folder selection window. Select the following folders:
   - **bluetooth** -> **profiles** -> **battery**
   - **bluetooth** -> **profiles** -> **device_info**

- bluetooth -> profiles -> otap
- framework -> Flash -> External -> Interface
- framework -> OtaSupport -> Interface
- framework -> SerialManager -> source -> SPI_Adapter
- source -> common -> otap_client

Ensure that these paths were imported onto the **Include paths** view.



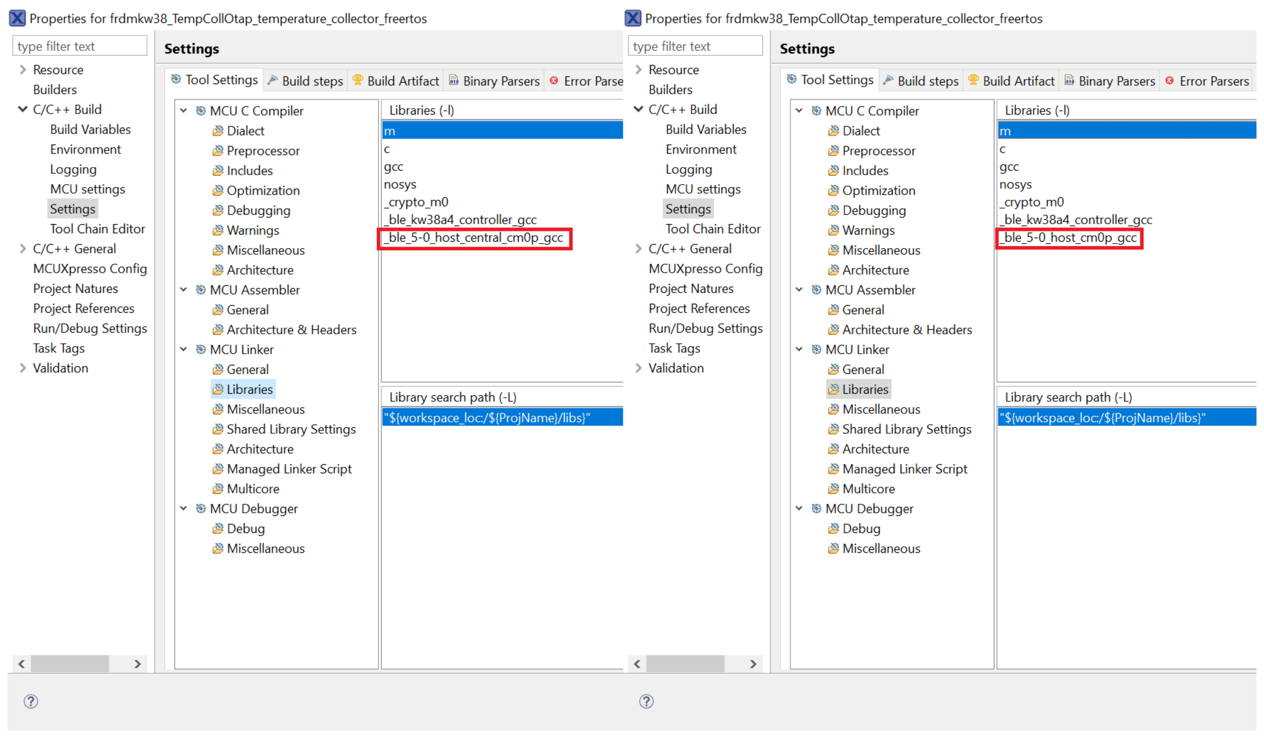
Include paths (-I)

```
"${workspace_loc:/${ProjName}/drivers}"
"${workspace_loc:/${ProjName}/device}"
"${workspace_loc:/${ProjName}/CMSIS}"
"${workspace_loc:/${ProjName}/framework/DCDC/interface}"
"${workspace_loc:/${ProjName}/framework/XCVR/MKW38Z4}"
"${workspace_loc:/${ProjName}/framework/XCVR/MKW38Z4/nb2p4ghz/configs}"
"${workspace_loc:/${ProjName}/framework/XCVR/MKW38Z4/nb2p4ghz}"
"${workspace_loc:/${ProjName}/bluetooth/profiles/battery}"
"${workspace_loc:/${ProjName}/bluetooth/profiles/device_info}"
"${workspace_loc:/${ProjName}/bluetooth/profiles/otap}"
"${workspace_loc:/${ProjName}/framework/Flash/External/interface}"
"${workspace_loc:/${ProjName}/framework/OtaSupport/interface}"
"${workspace_loc:/${ProjName}/framework/SerialManager/source/SPI_Adapter}"
"${workspace_loc:/${ProjName}/source/common/otap_client}"
```

Include files (-include)

Figure 17. Including the OTAP folders in the project paths

7. Open the **MCU Linker -> Libraries** view. Remove the `_ble_5-0_host_central_cm0p_gcc` library and replace it with the `_ble_5-0_host_cm0p_gcc` library, as shown in Figure 18. Then, click **OK** to save the changes.



Libraries (-l)

```
m
c
gcc
nosys
_crypto_m0
_ble_kw38a4_controller_gcc
_ble_5-0_host_central_cm0p_gcc
```

Library search path (-L)

```
"${workspace_loc:/${ProjName}/libs}"
```

Libraries (-l)

```
m
c
gcc
nosys
_crypto_m0
_ble_kw38a4_controller_gcc
_ble_5-0_host_cm0p_gcc
```

Library search path (-L)

```
"${workspace_loc:/${ProjName}/libs}"
```

Figure 18. Updating the Bluetooth LE library path

Now, you have included the OTAP client Bluetooth and Framework services in the Temperature Collector project.

4.2 Main modifications in the source files

Once you have included the OTAP client folders and files in your custom project, inspect the differences between the source files of the OTAP client and your Bluetooth LE application and add the code needed to integrate the service. The following sections explain the main aspects that you should focus on.

4.2.1 pin_mux.h and pin_mux.c

`pin_mux.c` and `pin_mux.h` files contain the pin initialization routines, which are located at the board folder in your project. As the OTAP client uses the SPI protocol to download the software update on the external flash, when the external storage method is selected, the following code must be added, which is the initialization of the pins for this module:

- `pin_mux.h`

```
void BOARD_InitSPI(void);
```

- `pin_mux.c`

```
void BOARD_InitSPI(void)
{
    /* Port C Clock Gate Control: Clock enabled */
    CLOCK_EnableClock(kCLOCK_PortC);
    /* PORTC16 (pin 45) is configured as SPI0_SCK */
    PORT_SetPinMux(PORTC, 16U, kPORT_MuxAlt2);
    /* PORTC17 (pin 46) is configured as SPI0_SOUT */
    PORT_SetPinMux(PORTC, 17U, kPORT_MuxAlt2);
    /* PORTC18 (pin 47) is configured as SPI0_SIN */
    PORT_SetPinMux(PORTC, 18U, kPORT_MuxAlt2);
    /* PORTC19 (pin 48) is configured as SPI0_PCS0 */
    PORT_SetPinMux(PORTC, 19U, kPORT_MuxAlt2);
}
```

4.2.2 app_preinclude.h

The *app_preinclude.h* file contains many preprocessor directives that configure some functionalities of the project, such as low power enablement, DCDC configuration, Bluetooth LE security definitions, and the hardware configuration macros. The OTAP client software requires some definitions that are not included for other Bluetooth LE SDK projects. The software update must include the following definitions:

- `gEepromType_d`
- `gEepromParams_WriteAlignment_c`
- `gOtapClientAtt_d`

The OTAP Temp Coll demo, sets the following values:

1. **`gEepromType_d`**: It defines the storage method between the AT45DB041E external flash on the FRDM-KW38 board, the default value, or the FlexNVM on-chip memory. You can also select from the list of EEPROM devices in the *Eeprom.h* header file at *framework/Flash/External/Interface*, for custom boards.

```
/* Specifies the type of EEPROM available on the target board */
#define gEepromType_d           gEepromDevice_AT45DB041E_c
```

2. **`gEepromParams_WriteAlignment`**: It defines the offset of the software update for programming. Do not modify the default value.

```
/* Eeprom Write alignment for Bootloader flags. */
#define gEepromParams_WriteAlignment_c  8
```

3. **`gOtapClientAtt_d`**: It sets the ATT transference method for OTA updates. It must be set to **1** for own purpose.

```
#define gOtapClientAtt_d  1
```

4.2.3 app_config.c

The *app_config.c* source file contains some structures that configure the advertising and scanning parameters and data. It also contains the access security requirements for each service in the device.

The advertising data announces the list of services that the Bluetooth LE advertiser device, Temp Coll – OTAP, contains. This information is used by the Bluetooth LE scanner, to filter out the advertiser devices that do not contain the services required. Hence, you must include the OTAP client service in the advertising data, to announce to the OTAP server the availability of this service.

The following code must be included in this file to prepare the advertising data:

```
/* Default Advertising Parameters. Values can be changed at runtime
    to align with profile requirements */
#define gGapAdvertisingInterval_050ms_c 0x0050
#define gGapAdvertisingInterval_100ms_c 0x00A0
#define gGapAdvertisingInterval_125ms_c 0x00C8
#define gGapAdvertisingInterval_250ms_c 0x0190
#define gGapAdvertisingInterval_500ms_c 0x0320
{
    /* minInterval */ gGapAdvertisingInterval_050ms_c,
    /* maxInterval */ gGapAdvertisingInterval_100ms_c,
    /* advertisingType */ gAdvConnectableUndirected_c,
    /* addressType */ gBleAddrTypePublic_c,
    /* directedAddressType */ gBleAddrTypePublic_c,
    /* directedAddress */ {0, 0, 0, 0, 0, 0},
    /* channelMap */ (gapAdvertisingChannelMapFlags_t) (gGapAdvertisingChannelMapDefault_c),
    /* filterPolicy */ gProcessAll_c
};
/* Scanning and Advertising Data */
static const uint8_t adData0[1] = { (gapAdTypeFlags_t)(gLeGeneralDiscoverableMode_c |
gBrEdrNotSupported_c) };
static const uint8_t adData1[] = { 0xE0, 0x1C, 0x4B, 0x5E, 0x1E, 0xEB, 0xA1, 0x5C, 0xEE, 0xF4, 0x5E,
0xBA, 0x50, 0x55, 0xFF, 0x01};
static const gapAdStructure_t advScanStruct[3] = {
  {
    .length = NumberOfElements(adData0) + 1,
    .adType = gAdFlags_c,
    .aData = (uint8_t *)adData0
  },
  {
    .length = NumberOfElements(adData1) + 1,
    .adType = gAdComplete128bitServiceList_c,
    .aData = (uint8_t *)adData1
  },
  {
    .length = 8 + 1,
    .adType = gAdShortenedLocalName_c,
    .aData = (uint8_t*)"NXP_OTAT"
  }
};
gapAdvertisingData_t gAppAdvertisingData =
{
    NumberOfElements(advScanStruct),
    (void *)advScanStruct
};
gapScanResponseData_t gAppScanRspData =
{
    0,
    NULL
};
```

Additionally, you need to add the access security requirements for the OTAP service, including the `gapServiceSecurityRequirements_t` struct. You can customize these parameters for your purpose. The Temp Coll – OTAP demo sets the following parameters:

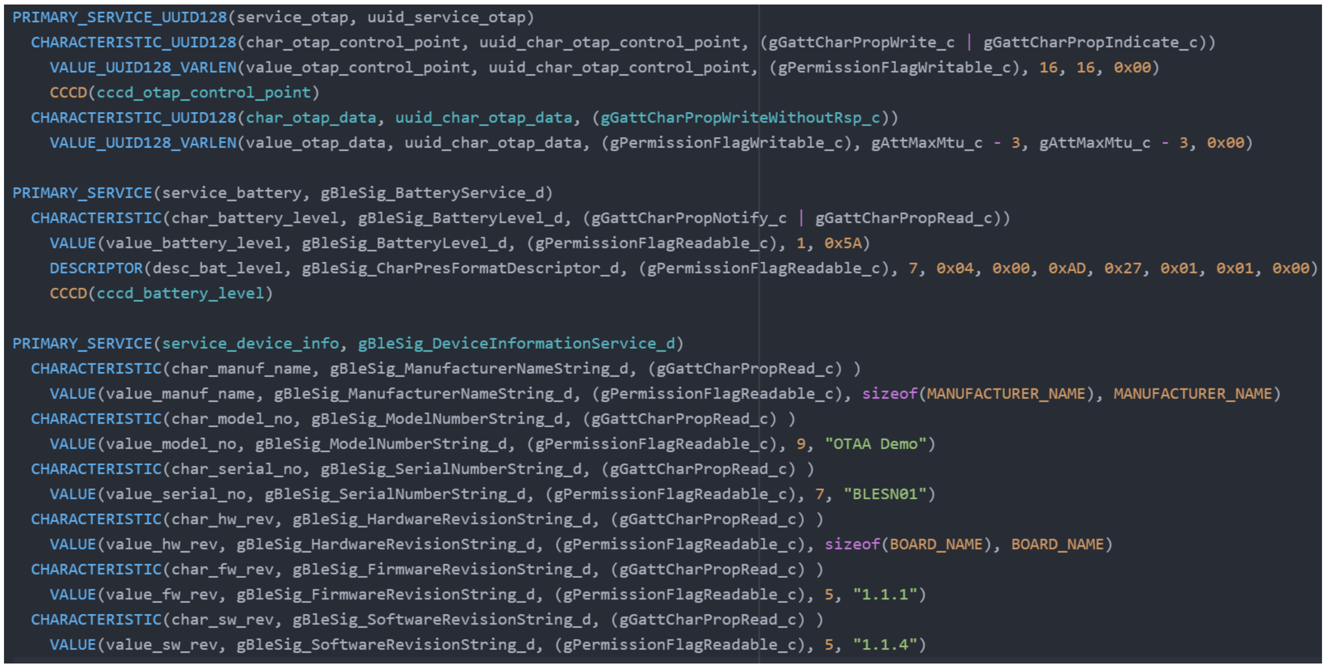
```
static const gapServiceSecurityRequirements_t serviceSecurity[3] = {
  {
    .requirements = {
        .securityModeLevel = gSecurityMode_1_Level_3_c,
        .authorization = FALSE,
        .minimumEncryptionKeySize = gDefaultEncryptionKeySize_d
    },
    .serviceHandle = (uint16_t)service_otap
  },
  {
    .requirements = {
        .securityModeLevel = gSecurityMode_1_Level_3_c,
        .authorization = FALSE,
        .minimumEncryptionKeySize = gDefaultEncryptionKeySize_d
    },
    .serviceHandle = (uint16_t)service_battery
  },
  {
    .requirements = {
        .securityModeLevel = gSecurityMode_1_Level_3_c,
        .authorization = FALSE,
        .minimumEncryptionKeySize = gDefaultEncryptionKeySize_d
    },
    .serviceHandle = (uint16_t)service_device_info
  }
};
```

Last modification is to register all services into the `deviceSecurityRequirements` struct. See the following portion of code:

```
gapDeviceSecurityRequirements_t deviceSecurityRequirements = {
    .pMasterSecurityRequirements = (void*)&masterSecurity,
    .cNumServices = 3,
    .aServiceSecurityRequirements = (void*)&serviceSecurity
};
```

4.2.4 gatt_db.h and gatt_uuid128.h

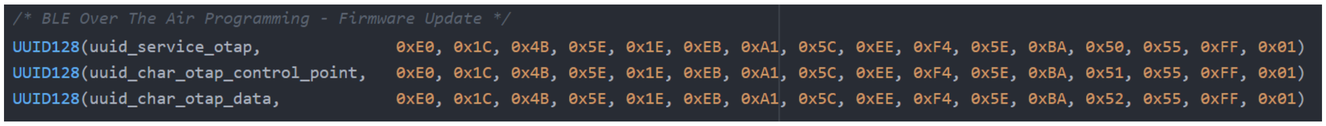
The *gatt_db.h* header file contains the list of attributes, which shapes the profile of the Temp Coll-OTAP device. The most important step of this guide is to include the list of the OTAP client attributes into the device's database. It is recommended to open the OTAP client SDK example and your Bluetooth LE demo to compare both GATT databases, and include the list of attributes missing in your project. Figure 19 shows the OTAP client portion of the database that must be included in the Temp Coll project.



```
PRIMARY_SERVICE_UUID128(service_otap, uuid_service_otap)
  CHARACTERISTIC_UUID128(char_otap_control_point, uuid_char_otap_control_point, (gGattCharPropWrite_c | gGattCharPropIndicate_c))
    VALUE_UUID128_VARLEN(value_otap_control_point, uuid_char_otap_control_point, (gPermissionFlagWritable_c), 16, 16, 0x00)
    CCCD(cccd_otap_control_point)
  CHARACTERISTIC_UUID128(char_otap_data, uuid_char_otap_data, (gGattCharPropWriteWithoutRsp_c))
    VALUE_UUID128_VARLEN(value_otap_data, uuid_char_otap_data, (gPermissionFlagWritable_c), gAttMaxMtu_c - 3, gAttMaxMtu_c - 3, 0x00)

PRIMARY_SERVICE(service_battery, gBleSig_BatteryService_d)
  CHARACTERISTIC(char_battery_level, gBleSig_BatteryLevel_d, (gGattCharPropNotify_c | gGattCharPropRead_c))
    VALUE(value_battery_level, gBleSig_BatteryLevel_d, (gPermissionFlagReadable_c), 1, 0x5A)
    DESCRIPTOR(desc_bat_level, gBleSig_CharPresFormatDescriptor_d, (gPermissionFlagReadable_c), 7, 0x04, 0x00, 0xAD, 0x27, 0x01, 0x01, 0x00)
    CCCD(cccd_battery_level)

PRIMARY_SERVICE(service_device_info, gBleSig_DeviceInformationService_d)
  CHARACTERISTIC(char_manuf_name, gBleSig_ManufacturerNameString_d, (gGattCharPropRead_c) )
    VALUE(value_manuf_name, gBleSig_ManufacturerNameString_d, (gPermissionFlagReadable_c), sizeof(MANUFACTURER_NAME), MANUFACTURER_NAME)
  CHARACTERISTIC(char_model_no, gBleSig_ModelNumberString_d, (gGattCharPropRead_c) )
    VALUE(value_model_no, gBleSig_ModelNumberString_d, (gPermissionFlagReadable_c), 9, "OTAA Demo")
  CHARACTERISTIC(char_serial_no, gBleSig_SerialNumberString_d, (gGattCharPropRead_c) )
    VALUE(value_serial_no, gBleSig_SerialNumberString_d, (gPermissionFlagReadable_c), 7, "BLESN01")
  CHARACTERISTIC(char_hw_rev, gBleSig_HardwareRevisionString_d, (gGattCharPropRead_c) )
    VALUE(value_hw_rev, gBleSig_HardwareRevisionString_d, (gPermissionFlagReadable_c), sizeof(BOARD_NAME), BOARD_NAME)
  CHARACTERISTIC(char_fw_rev, gBleSig_FirmwareRevisionString_d, (gGattCharPropRead_c) )
    VALUE(value_fw_rev, gBleSig_FirmwareRevisionString_d, (gPermissionFlagReadable_c), 5, "1.1.1")
  CHARACTERISTIC(char_sw_rev, gBleSig_SoftwareRevisionString_d, (gGattCharPropRead_c) )
    VALUE(value_sw_rev, gBleSig_SoftwareRevisionString_d, (gPermissionFlagReadable_c), 5, "1.1.4")
```

Figure 19. OTAP client service

The *gatt_uuid128.h* header file contains all the *custom* UUID definitions and its assignation. OTAP service and its characteristics need to be specified by the developer as a 128 – UUID in this file. Figure 20 shows how to implement the 128 – UUID assignation for the OTAP service.



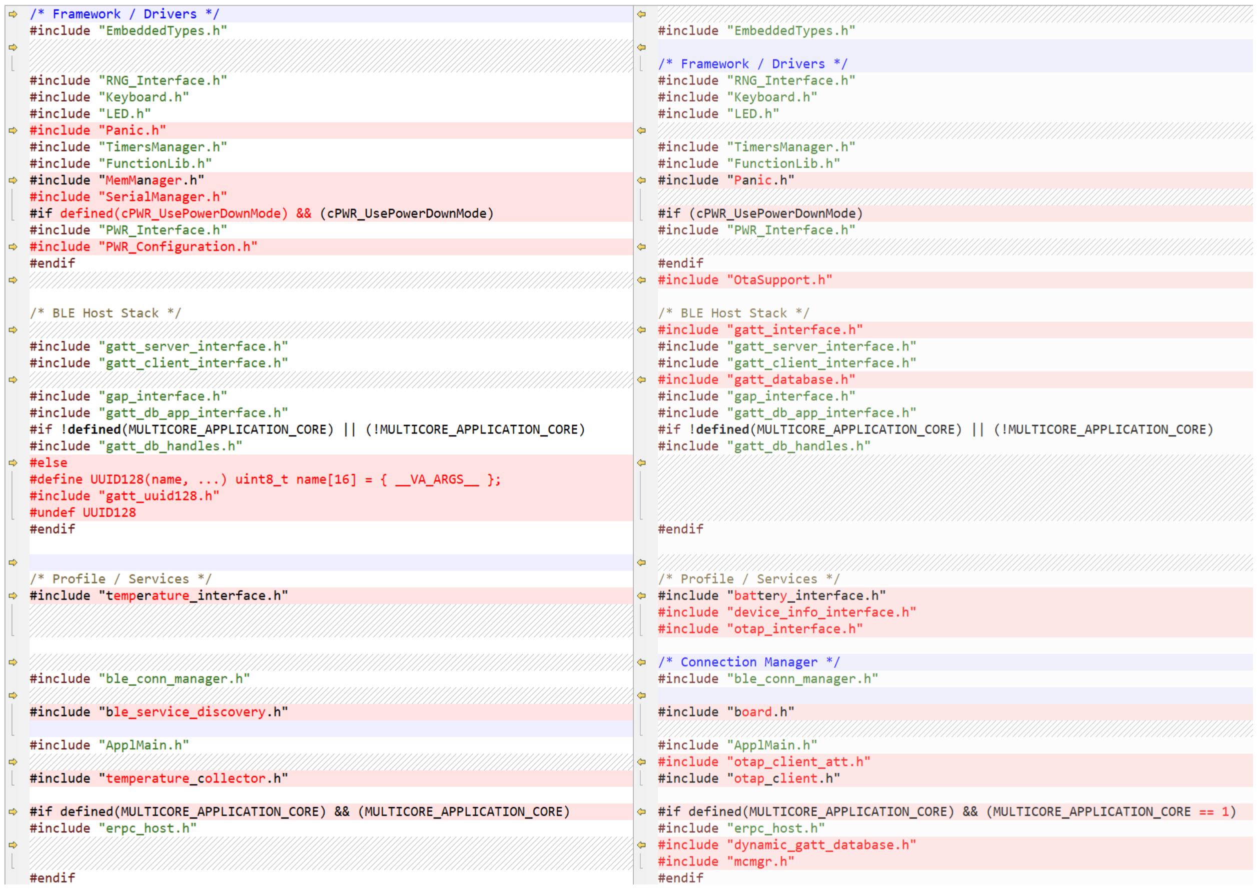
```
/* BLE Over The Air Programming - Firmware Update */
UUID128(uuid_service_otap,                 0xE0, 0x1C, 0x4B, 0x5E, 0x1E, 0xEB, 0xA1, 0x5C, 0xEE, 0xF4, 0x5E, 0xBA, 0x50, 0x55, 0xFF, 0x01)
UUID128(uuid_char_otap_control_point,      0xE0, 0x1C, 0x4B, 0x5E, 0x1E, 0xEB, 0xA1, 0x5C, 0xEE, 0xF4, 0x5E, 0xBA, 0x51, 0x55, 0xFF, 0x01)
UUID128(uuid_char_otap_data,               0xE0, 0x1C, 0x4B, 0x5E, 0x1E, 0xEB, 0xA1, 0x5C, 0xEE, 0xF4, 0x5E, 0xBA, 0x52, 0x55, 0xFF, 0x01)
```

Figure 20. Temp Coll – OTAP 128 – UUID definitions

4.2.5 temperature_collector.h and temperature_collector.c

The *temperature_collector.c* file is the main source file at the application level. Here are managed all the procedures that the device performs, before, during and after to create a connection. The following steps are the main changes to integrate the OTAP service.

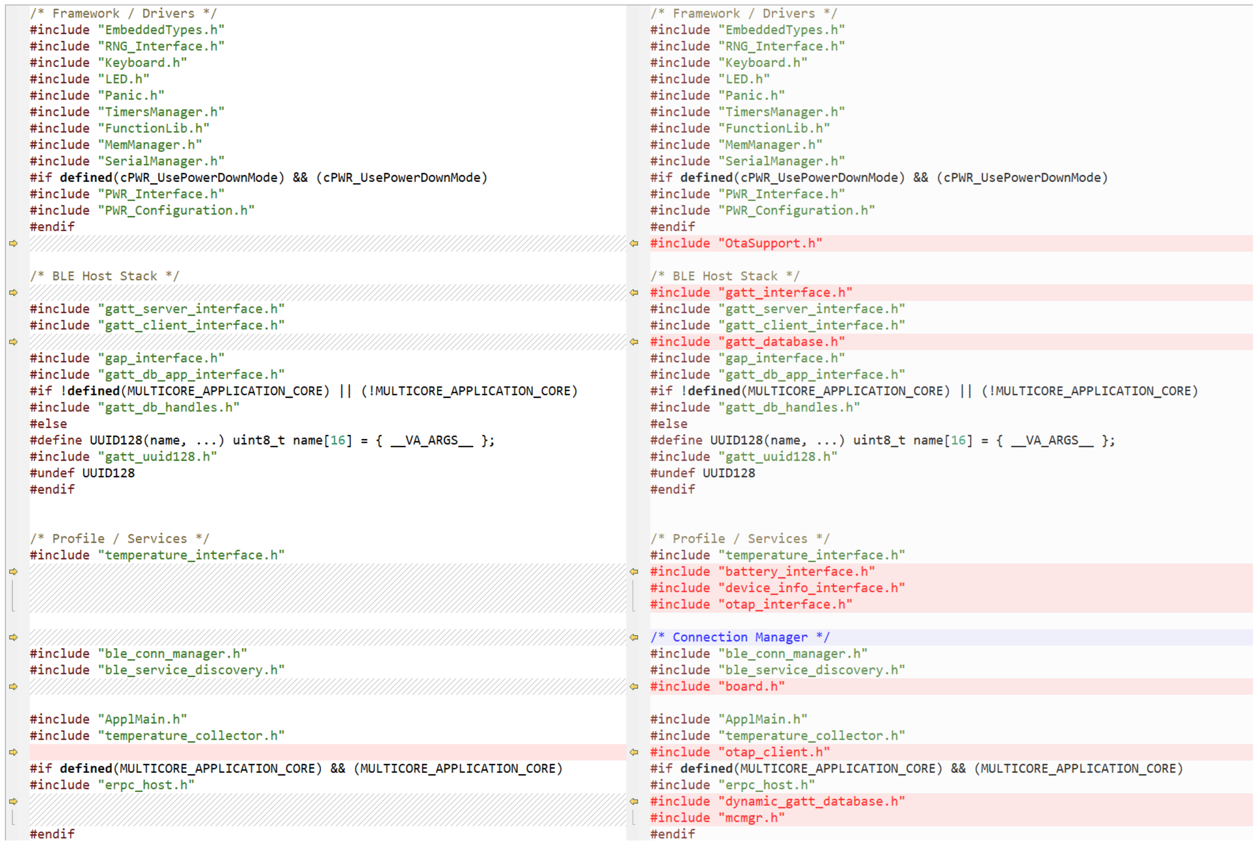
1. Merge the missing `#include` preprocessor directives to reference the OTAP files on your project in *temperature_collector.c* file, except the `#include` statement for the `otap_client_att.h` file. Figure 21 shows the comparison between Temp Coll (left) and OTAP client (right) application files. This step depends on your software as it might share different files than this example. The results are similar as depicted in Figure 22, before (Temp Coll left) and after (Temp Coll – OTAP right).



```
/* Framework / Drivers */
#include "EmbeddedTypes.h"

#include "RNG_Interface.h"
#include "Keyboard.h"
#include "LED.h"
#include "Panic.h"
#include "TimersManager.h"
#include "FunctionLib.h"
#include "MemManager.h"
#include "SerialManager.h"
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
#include "PWR_Interface.h"
#include "PWR_Configuration.h"
#endif

/* BLE Host Stack */
#include "gatt_server_interface.h"
#include "gatt_client_interface.h"
#include "gap_interface.h"
#include "gatt_db_app_interface.h"
#if !defined(MULTICORE_APPLICATION_CORE) || (!MULTICORE_APPLICATION_CORE)
#include "gatt_db_handles.h"
#else
#define UUID128(name, ...) uint8_t name[16] = { __VA_ARGS__ };
#include "gatt_uuid128.h"
#undef UUID128
#endif

/* Profile / Services */
#include "temperature_interface.h"

#include "ble_conn_manager.h"
#include "ble_service_discovery.h"

#include "ApplMain.h"
#include "temperature_collector.h"

#if defined(MULTICORE_APPLICATION_CORE) && (MULTICORE_APPLICATION_CORE)
#include "erpc_host.h"

#endif
```

```
#include "EmbeddedTypes.h"

/* Framework / Drivers */
#include "RNG_Interface.h"
#include "Keyboard.h"
#include "LED.h"

#include "TimersManager.h"
#include "FunctionLib.h"
#include "Panic.h"

#if (cPWR_UsePowerDownMode)
#include "PWR_Interface.h"

#endif
#include "OtaSupport.h"

/* BLE Host Stack */
#include "gatt_interface.h"
#include "gatt_server_interface.h"
#include "gatt_client_interface.h"
#include "gatt_database.h"
#include "gap_interface.h"
#include "gatt_db_app_interface.h"
#if !defined(MULTICORE_APPLICATION_CORE) || (!MULTICORE_APPLICATION_CORE)
#include "gatt_db_handles.h"

#endif

/* Profile / Services */
#include "battery_interface.h"
#include "device_info_interface.h"
#include "otap_interface.h"

/* Connection Manager */
#include "ble_conn_manager.h"

#include "board.h"

#include "ApplMain.h"
#include "otap_client_att.h"
#include "otap_client.h"

#if defined(MULTICORE_APPLICATION_CORE) && (MULTICORE_APPLICATION_CORE == 1)
#include "erpc_host.h"
#include "dynamic_gatt_database.h"
#include "mcmgr.h"
#endif
```

Figure 21. Comparison between Temp Coll (left) and OTAP (right) include directives

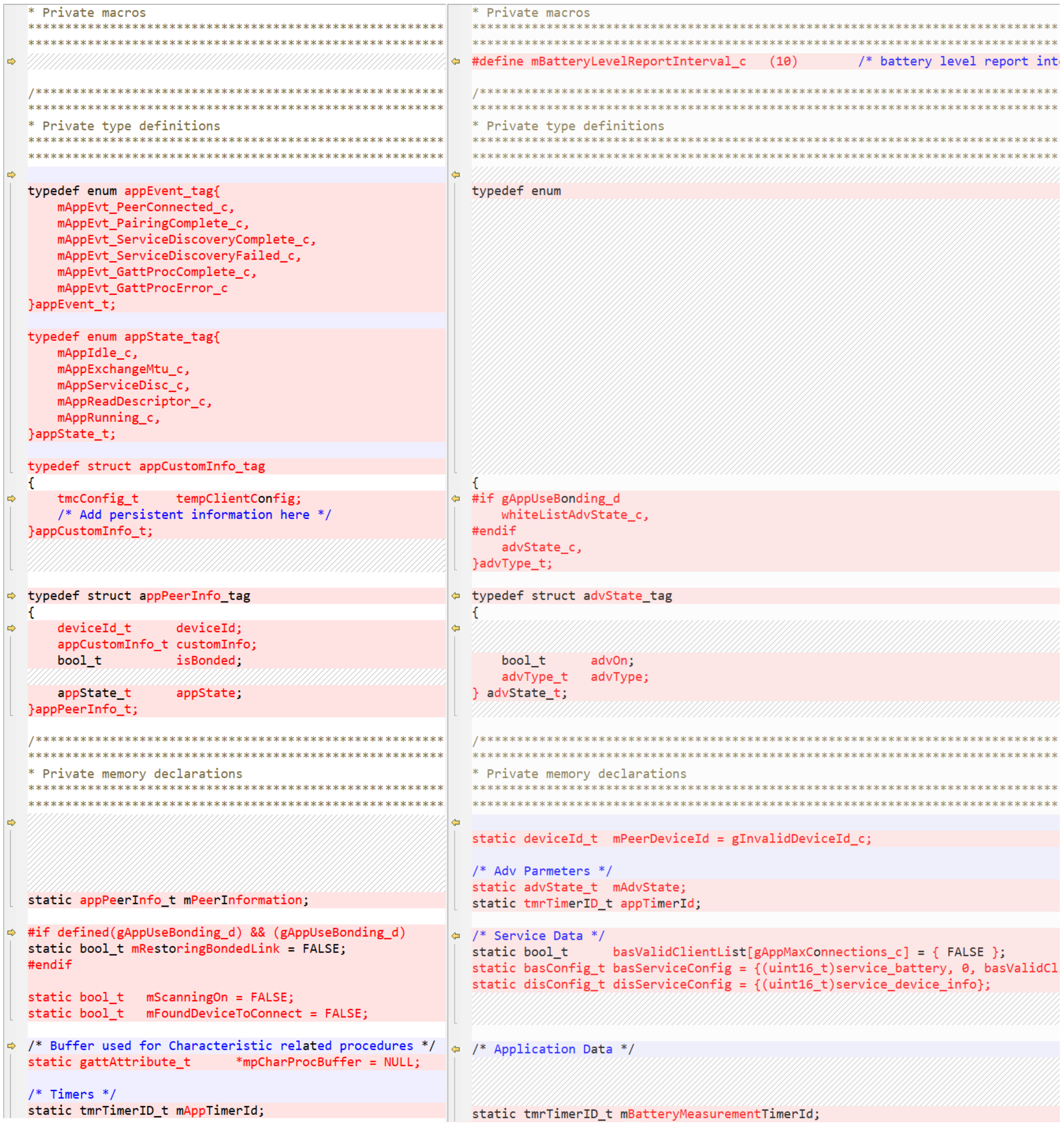


```
/* Framework / Drivers */
#include "EmbeddedTypes.h"
#include "RNG_Interface.h"
#include "Keyboard.h"
#include "LED.h"
#include "Panic.h"
#include "TimersManager.h"
#include "FunctionLib.h"
#include "MemManager.h"
#include "SerialManager.h"
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
#include "PWR_Interface.h"
#include "PWR_Configuration.h"
#endif

/* BLE Host Stack */
#include "gatt_server_interface.h"
#include "gatt_client_interface.h"
#include "gap_interface.h"
#include "gatt_db_app_interface.h"
#if !defined(MULTICORE_APPLICATION_CORE) || (!MULTICORE_APPLICATION_CORE)
#include "gatt_db_handles.h"
#else
#define UUID128(name, ...) uint8_t name[16] = { __VA_ARGS__ };
#include "gatt_uuid128.h"
#undef UUID128
#endif

/* Profile / Services */
#include "temperature_interface.h"

#include "ble_conn_manager.h"
#include "ble_service_discovery.h"

#include "ApplMain.h"
#include "temperature_collector.h"

#if defined(MULTICORE_APPLICATION_CORE) && (MULTICORE_APPLICATION_CORE)
#include "erpc_host.h"

#endif
```

```
/* Framework / Drivers */
#include "EmbeddedTypes.h"
#include "RNG_Interface.h"
#include "Keyboard.h"
#include "LED.h"
#include "Panic.h"
#include "TimersManager.h"
#include "FunctionLib.h"
#include "MemManager.h"
#include "SerialManager.h"
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
#include "PWR_Interface.h"
#include "PWR_Configuration.h"
#endif
#include "OtaSupport.h"

/* BLE Host Stack */
#include "gatt_interface.h"
#include "gatt_server_interface.h"
#include "gatt_client_interface.h"
#include "gatt_database.h"
#include "gap_interface.h"
#include "gatt_db_app_interface.h"
#if !defined(MULTICORE_APPLICATION_CORE) || (!MULTICORE_APPLICATION_CORE)
#include "gatt_db_handles.h"
#else
#define UUID128(name, ...) uint8_t name[16] = { __VA_ARGS__ };
#include "gatt_uuid128.h"
#undef UUID128
#endif

/* Profile / Services */
#include "temperature_interface.h"
#include "battery_interface.h"
#include "device_info_interface.h"
#include "otap_interface.h"

/* Connection Manager */
#include "ble_conn_manager.h"
#include "ble_service_discovery.h"
#include "board.h"

#include "ApplMain.h"
#include "temperature_collector.h"
#include "otap_client.h"
#if defined(MULTICORE_APPLICATION_CORE) && (MULTICORE_APPLICATION_CORE)
#include "erpc_host.h"
#include "dynamic_gatt_database.h"
#include "mcmgr.h"
#endif
```

Figure 22. Merging the OTAP directives into the project, before (Temp Coll left), after (Temp Coll OTAP)

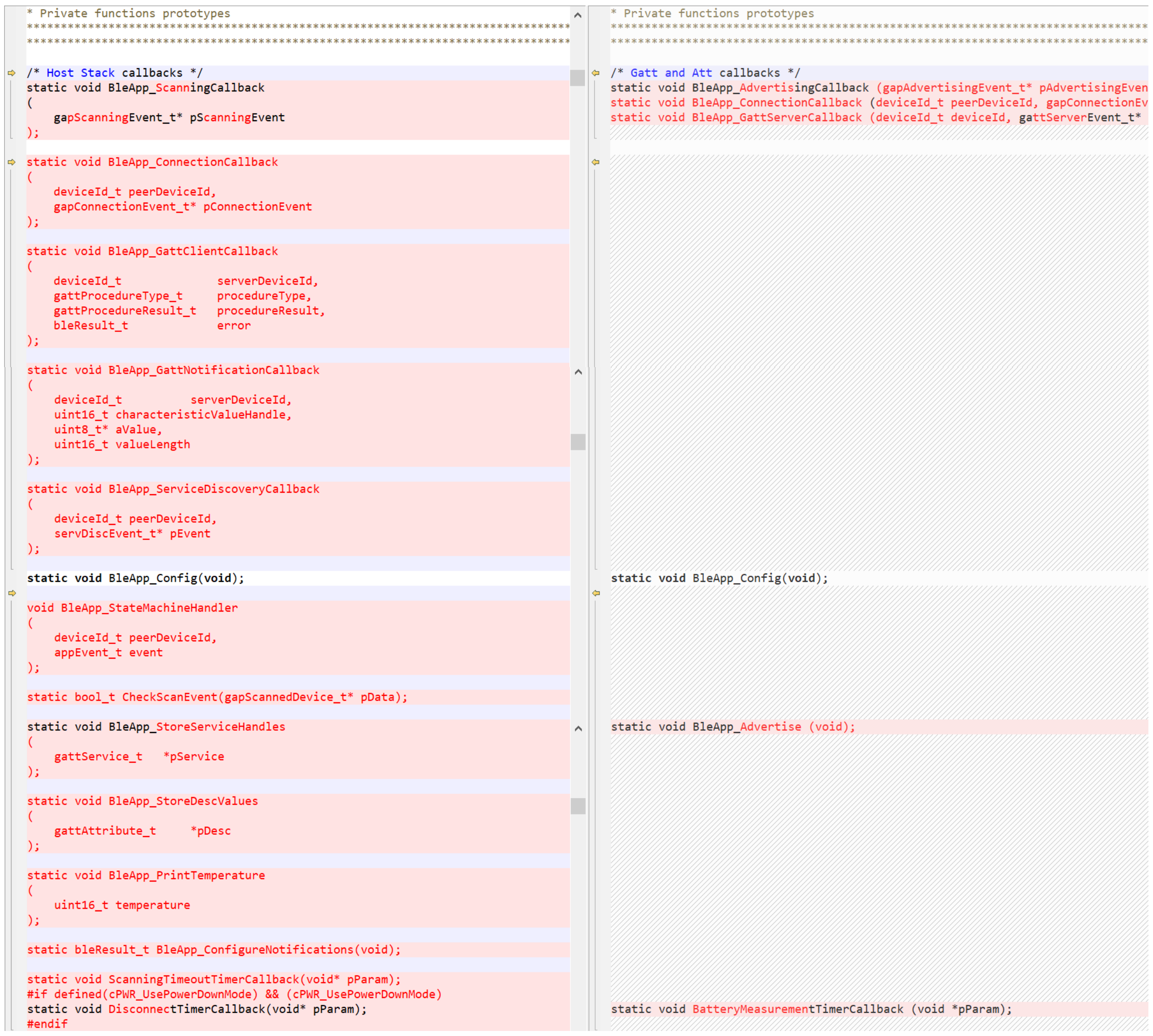
2. Add the function prototypes and global variables that are used by the OTAP client software. Figure 23 and Figure 24 show the comparison between Temp Coll (left) and OTAP (right). As mentioned in Step 1, this might depend on your application. For this example, you can skip merging the `appTimerId` variable in your Temperature Collector project, as this is used in the OTAP client to create an instance of a timer that will not implement in this example. Also, it is required to create another variable: `static gapRole_t mGapRole`. This variable will be used to switch between central and peripheral GAP roles as the OTAP Client device needs to be the Bluetooth LE peripheral to advertise this service and communicate with the OTAP Server. In other words, your KW38 device will be the Bluetooth LE Central device while it is the Temp Coll and will be the Bluetooth LE Peripheral device while it is the OTAP Client. The results are similar as depicted in Figure 25 and Figure 26.



```
* Private macros
************************************************************
************************************************************


/***********************************************************
************************************************************
* Private type definitions
************************************************************
************************************************************

typedef enum appEvent_tag{
    mAppEvt_PeerConnected_c,
    mAppEvt_PairingComplete_c,
    mAppEvt_ServiceDiscoveryComplete_c,
    mAppEvt_ServiceDiscoveryFailed_c,
    mAppEvt_GattProcComplete_c,
    mAppEvt_GattProcError_c
}appEvent_t;

typedef enum appState_tag{
    mAppIdle_c,
    mAppExchangeMtu_c,
    mAppServiceDisc_c,
    mAppReadDescriptor_c,
    mAppRunning_c,
}appState_t;

typedef struct appCustomInfo_tag
{
    tmcConfig_t     tempClientConfig;
    /* Add persistent information here */
}appCustomInfo_t;

typedef struct appPeerInfo_tag
{
    deviceId_t      deviceId;
    appCustomInfo_t customInfo;
    bool_t          isBonded;

    appState_t      appState;
}appPeerInfo_t;

/***********************************************************
************************************************************
* Private memory declarations
************************************************************
************************************************************

static appPeerInfo_t mPeerInformation;

#if defined(gAppUseBonding_d) && (gAppUseBonding_d)
static bool_t mRestoringBondedLink = FALSE;
#endif

static bool_t   mScanningOn = FALSE;
static bool_t   mFoundDeviceToConnect = FALSE;

/* Buffer used for Characteristic related procedures */
static gattAttribute_t      *mpCharProcBuffer = NULL;

/* Timers */
static tmrTimerID_t mAppTimerId;
```

```
* Private macros
************************************************************************************
************************************************************************************
#define mBatteryLevelReportInterval_c   (10)        /* battery level report int

/***********************************************************************************
************************************************************************************
* Private type definitions
************************************************************************************
************************************************************************************

typedef enum
{
#if gAppUseBonding_d
    whiteListAdvState_c,
#endif
    advState_c,
}advType_t;

typedef struct advState_tag
{

    bool_t      advOn;
    advType_t   advType;
} advState_t;

/***********************************************************************************
************************************************************************************
* Private memory declarations
************************************************************************************
************************************************************************************

static deviceId_t  mPeerDeviceId = gInvalidDeviceId_c;

/* Adv Parmeters */
static advState_t  mAdvState;
static tmrTimerID_t appTimerId;

/* Service Data */
static bool_t      basValidClientList[gAppMaxConnections_c] = { FALSE };
static basConfig_t basServiceConfig = {(uint16_t)service_battery, 0, basValidCl
static disConfig_t disServiceConfig = {(uint16_t)service_device_info};

/* Application Data */

static tmrTimerID_t mBatteryMeasurementTimerId;
```

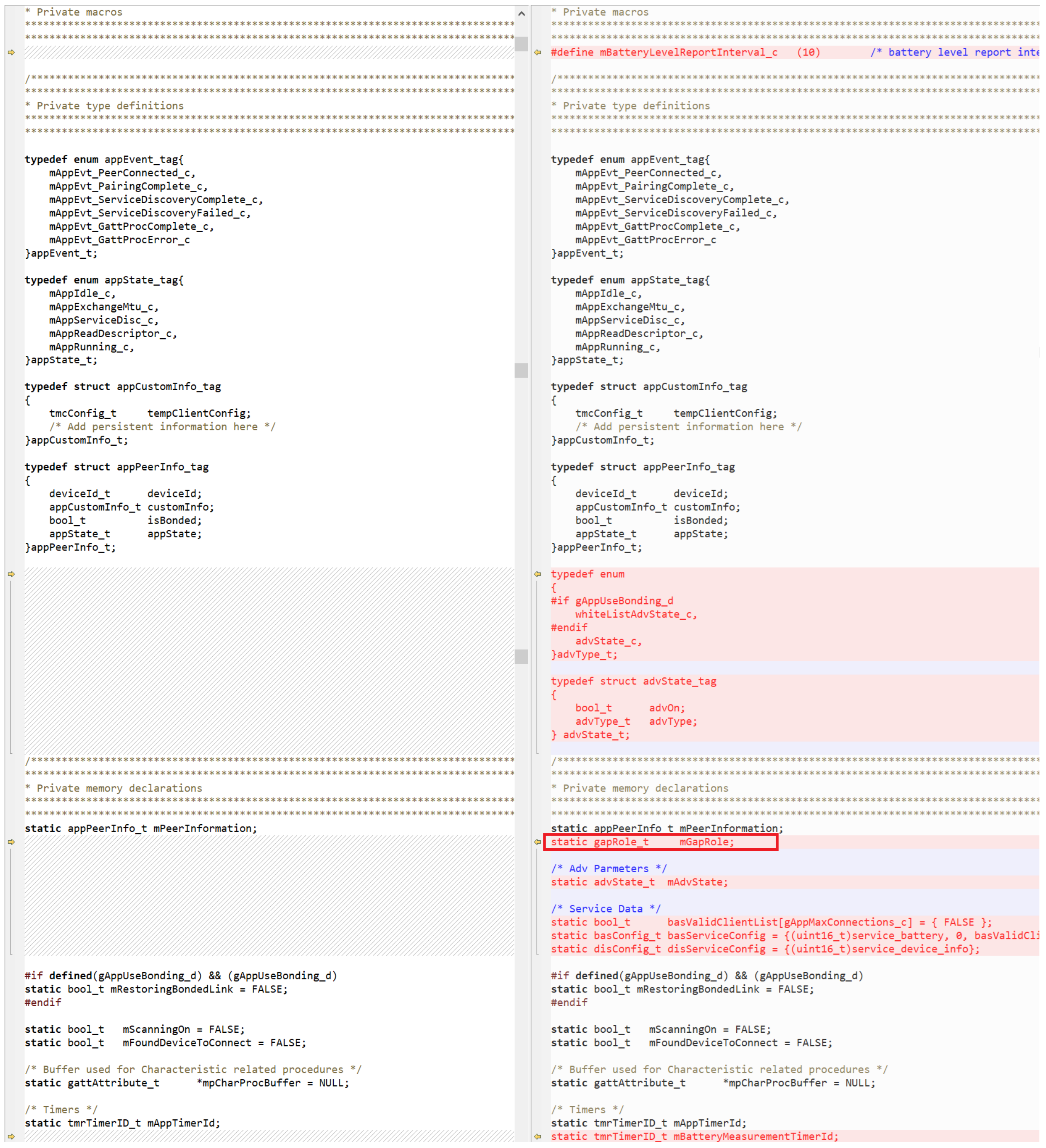
Figure 23. Comparison between Temp Coll (left) and OTAP (right) prototypes (1)



```
* Private functions prototypes
********************************************************************************
********************************************************************************

/* Host Stack callbacks */
static void BleApp_ScanningCallback
(
    gapScanningEvent_t* pScanningEvent
);

static void BleApp_ConnectionCallback
(
    deviceId_t peerDeviceId,
    gapConnectionEvent_t* pConnectionEvent
);

static void BleApp_GattClientCallback
(
    deviceId_t              serverDeviceId,
    gattProcedureType_t     procedureType,
    gattProcedureResult_t   procedureResult,
    bleResult_t             error
);

static void BleApp_GattNotificationCallback
(
    deviceId_t          serverDeviceId,
    uint16_t characteristicValueHandle,
    uint8_t* aValue,
    uint16_t valueLength
);

static void BleApp_ServiceDiscoveryCallback
(
    deviceId_t peerDeviceId,
    servDiscEvent_t* pEvent
);

static void BleApp_Config(void);

void BleApp_StateMachineHandler
(
    deviceId_t peerDeviceId,
    appEvent_t event
);

static bool_t CheckScanEvent(gapScannedDevice_t* pData);

static void BleApp_StoreServiceHandles
(
    gattService_t   *pService
);

static void BleApp_StoreDescValues
(
    gattAttribute_t     *pDesc
);

static void BleApp_PrintTemperature
(
    uint16_t temperature
);

static bleResult_t BleApp_ConfigureNotifications(void);

static void ScanningTimeoutTimerCallback(void* pParam);
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
static void DisconnectTimerCallback(void* pParam);
#endif
```

```
* Private functions prototypes
********************************************************************************
********************************************************************************

/* Gatt and Att callbacks */
static void BleApp_AdvertisingCallback (gapAdvertisingEvent_t* pAdvertisingEven
static void BleApp_ConnectionCallback (deviceId_t peerDeviceId, gapConnectionEv
static void BleApp_GattServerCallback (deviceId_t deviceId, gattServerEvent_t*

static void BleApp_Config(void);

static void BleApp_Advertise (void);

static void BatteryMeasurementTimerCallback (void *pParam);
```

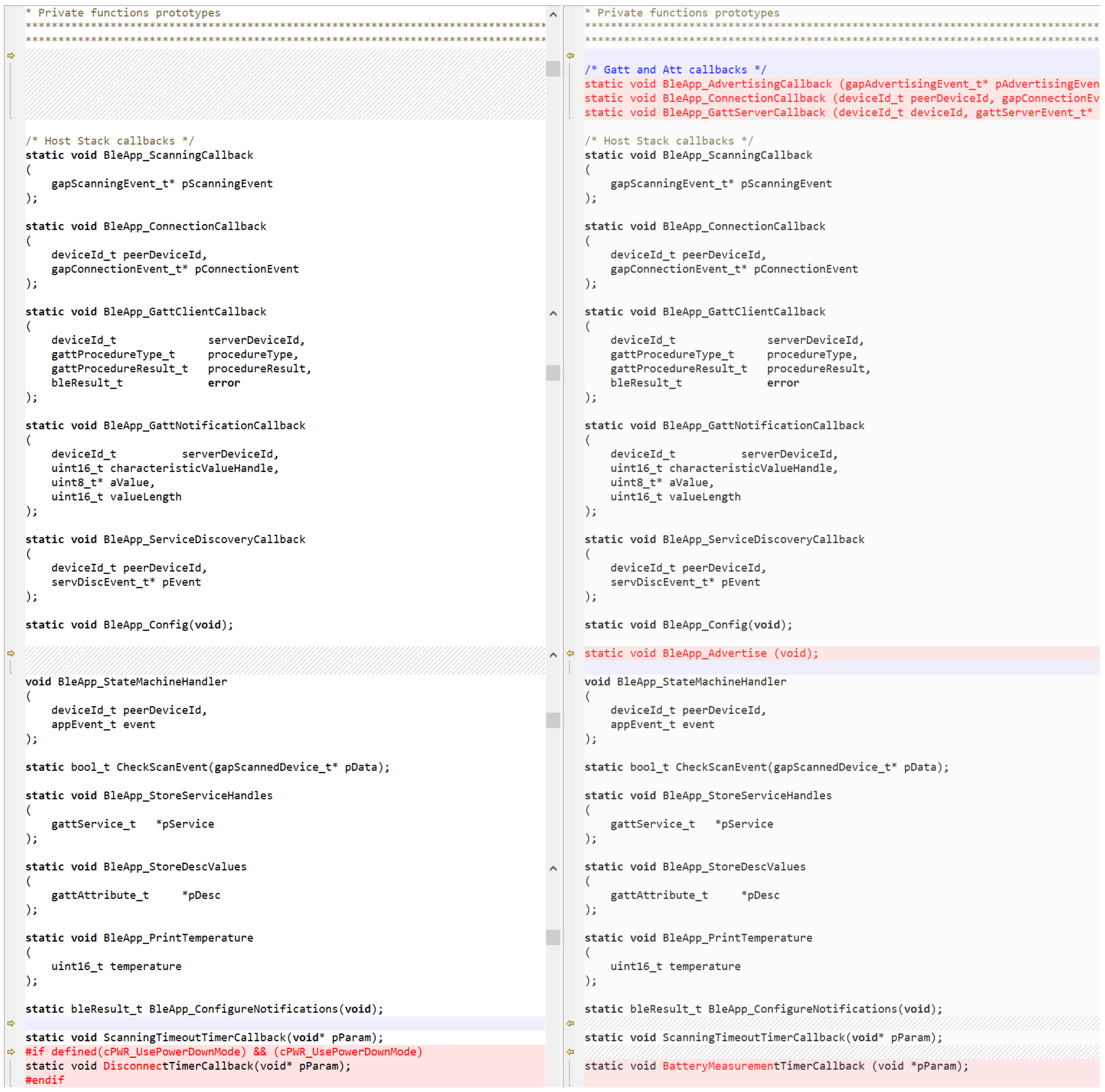
Figure 24. Comparison between Temp Coll (left) and OTAP (right) prototypes (2)



```
* Private macros
********************************************************************************
********************************************************************************

/*******************************************************************************
********************************************************************************
* Private type definitions
********************************************************************************
********************************************************************************

typedef enum appEvent_tag{
    mAppEvt_PeerConnected_c,
    mAppEvt_PairingComplete_c,
    mAppEvt_ServiceDiscoveryComplete_c,
    mAppEvt_ServiceDiscoveryFailed_c,
    mAppEvt_GattProcComplete_c,
    mAppEvt_GattProcError_c
}appEvent_t;

typedef enum appState_tag{
    mAppIdle_c,
    mAppExchangeMtu_c,
    mAppServiceDisc_c,
    mAppReadDescriptor_c,
    mAppRunning_c,
}appState_t;

typedef struct appCustomInfo_tag
{
    tmcConfig_t     tempClientConfig;
    /* Add persistent information here */
}appCustomInfo_t;

typedef struct appPeerInfo_tag
{
    deviceId_t      deviceId;
    appCustomInfo_t customInfo;
    bool_t          isBonded;
    appState_t      appState;
}appPeerInfo_t;

/*******************************************************************************
********************************************************************************
* Private memory declarations
********************************************************************************
********************************************************************************
static appPeerInfo_t mPeerInformation;

#if defined(gAppUseBonding_d) && (gAppUseBonding_d)
static bool_t mRestoringBondedLink = FALSE;
#endif

static bool_t   mScanningOn = FALSE;
static bool_t   mFoundDeviceToConnect = FALSE;

/* Buffer used for Characteristic related procedures */
static gattAttribute_t      *mpCharProcBuffer = NULL;

/* Timers */
static tmrTimerID_t mAppTimerId;
```

```
* Private macros
********************************************************************************
********************************************************************************
#define mBatteryLevelReportInterval_c   (10)        /* battery level report inte

/*******************************************************************************
********************************************************************************
* Private type definitions
********************************************************************************
********************************************************************************

typedef enum appEvent_tag{
    mAppEvt_PeerConnected_c,
    mAppEvt_PairingComplete_c,
    mAppEvt_ServiceDiscoveryComplete_c,
    mAppEvt_ServiceDiscoveryFailed_c,
    mAppEvt_GattProcComplete_c,
    mAppEvt_GattProcError_c
}appEvent_t;

typedef enum appState_tag{
    mAppIdle_c,
    mAppExchangeMtu_c,
    mAppServiceDisc_c,
    mAppReadDescriptor_c,
    mAppRunning_c,
}appState_t;

typedef struct appCustomInfo_tag
{
    tmcConfig_t     tempClientConfig;
    /* Add persistent information here */
}appCustomInfo_t;

typedef struct appPeerInfo_tag
{
    deviceId_t      deviceId;
    appCustomInfo_t customInfo;
    bool_t          isBonded;
    appState_t      appState;
}appPeerInfo_t;

typedef enum
{
#if gAppUseBonding_d
    whiteListAdvState_c,
#endif
    advState_c,
}advType_t;

typedef struct advState_tag
{
    bool_t      advOn;
    advType_t   advType;
} advState_t;

/*******************************************************************************
********************************************************************************
* Private memory declarations
********************************************************************************
********************************************************************************
static appPeerInfo_t mPeerInformation;
static gapRole_t     mGapRole;

/* Adv Parmeters */
static advState_t  mAdvState;

/* Service Data */
static bool_t      basValidClientList[gAppMaxConnections_c] = { FALSE };
static basConfig_t basServiceConfig = {(uint16_t)service_battery, 0, basValidCli
static disConfig_t disServiceConfig = {(uint16_t)service_device_info};

#if defined(gAppUseBonding_d) && (gAppUseBonding_d)
static bool_t mRestoringBondedLink = FALSE;
#endif

static bool_t   mScanningOn = FALSE;
static bool_t   mFoundDeviceToConnect = FALSE;

/* Buffer used for Characteristic related procedures */
static gattAttribute_t      *mpCharProcBuffer = NULL;

/* Timers */
static tmrTimerID_t mAppTimerId;
static tmrTimerID_t mBatteryMeasurementTimerId;
```

Figure 25. Merging the variables into the project: before (Temp Coll left) and after (Temp Coll - OTAP) (1)



```
* Private functions prototypes
*******************************************************************************
*******************************************************************************

/* Host Stack callbacks */
static void BleApp_ScanningCallback
(
    gapScanningEvent_t* pScanningEvent
);

static void BleApp_ConnectionCallback
(
    deviceId_t peerDeviceId,
    gapConnectionEvent_t* pConnectionEvent
);

static void BleApp_GattClientCallback
(
    deviceId_t              serverDeviceId,
    gattProcedureType_t     procedureType,
    gattProcedureResult_t   procedureResult,
    bleResult_t             error
);

static void BleApp_GattNotificationCallback
(
    deviceId_t          serverDeviceId,
    uint16_t characteristicValueHandle,
    uint8_t* aValue,
    uint16_t valueLength
);

static void BleApp_ServiceDiscoveryCallback
(
    deviceId_t peerDeviceId,
    servDiscEvent_t* pEvent
);

static void BleApp_Config(void);

void BleApp_StateMachineHandler
(
    deviceId_t peerDeviceId,
    appEvent_t event
);

static bool_t CheckScanEvent(gapScannedDevice_t* pData);

static void BleApp_StoreServiceHandles
(
    gattService_t   *pService
);

static void BleApp_StoreDescValues
(
    gattAttribute_t     *pDesc
);

static void BleApp_PrintTemperature
(
    uint16_t temperature
);

static bleResult_t BleApp_ConfigureNotifications(void);

static void ScanningTimeoutTimerCallback(void* pParam);
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
static void DisconnectTimerCallback(void* pParam);
#endif
```

```
* Private functions prototypes
*******************************************************************************
*******************************************************************************

/* Gatt and Att callbacks */
static void BleApp_AdvertisingCallback (gapAdvertisingEvent_t* pAdvertisingEven
static void BleApp_ConnectionCallback (deviceId_t peerDeviceId, gapConnectionEv
static void BleApp_GattServerCallback (deviceId_t deviceId, gattServerEvent_t*

/* Host Stack callbacks */
static void BleApp_ScanningCallback
(
    gapScanningEvent_t* pScanningEvent
);

static void BleApp_ConnectionCallback
(
    deviceId_t peerDeviceId,
    gapConnectionEvent_t* pConnectionEvent
);

static void BleApp_GattClientCallback
(
    deviceId_t              serverDeviceId,
    gattProcedureType_t     procedureType,
    gattProcedureResult_t   procedureResult,
    bleResult_t             error
);

static void BleApp_GattNotificationCallback
(
    deviceId_t          serverDeviceId,
    uint16_t characteristicValueHandle,
    uint8_t* aValue,
    uint16_t valueLength
);

static void BleApp_ServiceDiscoveryCallback
(
    deviceId_t peerDeviceId,
    servDiscEvent_t* pEvent
);

static void BleApp_Config(void);

static void BleApp_Advertise (void);
void BleApp_StateMachineHandler
(
    deviceId_t peerDeviceId,
    appEvent_t event
);

static bool_t CheckScanEvent(gapScannedDevice_t* pData);

static void BleApp_StoreServiceHandles
(
    gattService_t   *pService
);

static void BleApp_StoreDescValues
(
    gattAttribute_t     *pDesc
);

static void BleApp_PrintTemperature
(
    uint16_t temperature
);

static bleResult_t BleApp_ConfigureNotifications(void);

static void ScanningTimeoutTimerCallback(void* pParam);

static void BatteryMeasurementTimerCallback (void *pParam);
```

Figure 26. Merging the variables into the project: before (Temp Coll left) and after (Temp Coll - OTAP) (2)

3. Locate the `BleApp_Init` function. You can add in this function, driver initialization API's for the application. The Temp Coll does not support the Battery Service while the OTAP Client does, so you must call the `BOARD_InitAdc` function. See the following portion of code:

```
void BleApp_Init(void)
{
    /* Initialize application support for drivers */
    BOARD_InitAdc();
#if (defined(KW37A4_SERIES) || defined(KW37Z4_SERIES) || defined(KW38A4_SERIES) ||
defined(KW38Z4_SERIES) || defined(KW39A4_SERIES))
    /* Get the serial interface in use */
    gAppSerMgrIf = BOARD_GetSerialManagerInterface();
#else
    SerialManager_Init();
    Serial_InitInterface(&gAppSerMgrIf, APP_SERIAL_INTERFACE_TYPE,
APP_SERIAL_INTERFACE_INSTANCE);
    Serial_SetBaudRate(gAppSerMgrIf, APP_SERIAL_INTERFACE_SPEED);
#endif
#if defined(MULTICORE_APPLICATION_CORE) && (MULTICORE_APPLICATION_CORE)
    /* Init eRPC host */
    init_erpc_host();
#endif
}
```

4. Locate the `BleApp_Start` function. This function is used to start the scanning. Modify it as follows to start scanning or advertising depending on the `gapRole` variable and change the `BleApp_Start` prototype at *temperature_collector.h* by **`void BleApp_Start`** `(gapRole_t gapRole)` file, to match with the new function.

```
void BleApp_Start(gapRole_t gapRole)
{
    switch (gapRole)
    {
        case gGapCentral_c:
        {
            if (!mScanningOn)
            {
                gPairingParameters.localIoCapabilities = gIoKeyboardDisplay_c;
                /* Stop advertising, Start scanning */
                if (mAdvState.advOn)
                {
                    (void)Gap_StopAdvertising();
                }
                (void)App_StartScanning(&gScanParams, BleApp_ScanningCallback,
gGapDuplicateFilteringEnable_c, gGapScanContinuously_d, gGapScanPeriodicDisabled_d);
            }
        }
        break;
        case gGapPeripheral_c:
        {
            if (mPeerInformation.deviceId == gInvalidDeviceId_c)
            {
            /* Device is not connected and not advertising*/
            if (!mAdvState.advOn)
            {
#if gAppUseBonding_d
                if (gcBondedDevices > 0)
                {
                    mAdvState.advType = whiteListAdvState_c;
                }
                else
                {
#endif
                    mAdvState.advType = advState_c;
#if gAppUseBonding_d
                }
#endif
                gPairingParameters.localIoCapabilities = gIoDisplayOnly_c;
                /* Stop scanning, Start advertising */
                if(mScanningOn)
                {
                    (void)Gap_StopScanning();
                }
                BleApp_Advertise();
            }
            }
        }
        break;
        default:
        {
            /* No action required */
        }
        break;
    }
}
```

5. Locate the `BleApp_HandleKeys` function. This is executed each time that you press a switch on the FRDM-KW38 board. It must be modified to change the GAP role of the device when the user presses a switch button, allowing to move from Temp Coll to OTAP Client and return to Tempe Coll if it is desired.

```
void BleApp_HandleKeys(key_event_t events)
{
    switch (events)
    {
        /* Start on button press if low-power is disabled */
        case gKBD_EventPressPB1_c:
        {
            BleApp_Start(mGapRole);
            break;
        }
        /* Disconnect on long button press */
        case gKBD_EventLongPB1_c:
        {
            if (mPeerInformation.deviceId != gInvalidDeviceId_c)
            {
                (void)Gap_Disconnect(mPeerInformation.deviceId);
            }
            break;
        }
        /* Toggle Gap Role */
        case gKBD_EventPressPB2_c: /* Fall-through */
        case gKBD_EventLongPB2_c: /* Fall-through */
        {
        if(mGapRole == gGapCentral_c)
        {
            mGapRole = gGapPeripheral_c;
        }
        else
        {
            mGapRole = gGapCentral_c;
        }
        break;
        }
        default:
        {
            ; /* No action required */
            break;
        }
    }
}
```

6. Locate the `BleApp_GenericCallback` function. Include the handling of `gAdvertisingParametersSetupComplete_`, `gAdvertisingDataSetupComplete_c`, and `gAdvertisingSetupFailed_c` events.

```
void BleApp_GenericCallback (gapGenericEvent_t* pGenericEvent)
{
    /* Call BLE Conn Manager */
    BleConnManager_GenericEvent(pGenericEvent);
    switch (pGenericEvent->eventType)
    {
        case gInitializationComplete_c:
        {
            BleApp_Config();
        }
    break;
    case gAdvertisingParametersSetupComplete_c:
    {
        (void)Gap_SetAdvertisingData(&gAppAdvertisingData, &gAppScanRspData);
    }
    break;
    case gAdvertisingDataSetupComplete_c:
    {
        (void)App_StartAdvertising(BleApp_AdvertisingCallback, BleApp_ConnectionCallback);
    }
    break;
    case gAdvertisingSetupFailed_c:
    {
        panic(0,0,0,0);
    }
    break;
#if defined(gAppPrintLePhyEvent_c) && (gAppPrintLePhyEvent_c)
    case gLePhyEvent_c:
    {
        if(pGenericEvent->eventData.phyEvent.phyEventType == gPhyUpdateComplete_c )
        {
            AppPrintLePhyEvent(&pGenericEvent->eventData.phyEvent);
        }
        }
        break;
#endif
        default:
        {
        ; /* No action required */
        }
        break;
    }
}
```

7. Locate the `BleApp_Config` function. The `BleApp_Config` function configures the initial GAP role of the device, with the default value that Temp Coll – OTAP is GAP Central, registers the notifiable attributes, prepares the services built on the database, and allocates some application timers. Register the `BleApp_GattServerCallback` defines an initial GAP role for the device, including the `OtapClient_Config` and `Dis_Start` functions to initialize these services and allocate a timer for the battery measurements. The result should look as the following example.

```
static void BleApp_Config(void)
{
    /* Configure as GAP Central */
    BleConnManager_GapCommonConfig();
    /* Register for callbacks*/
    (void)App_RegisterGattServerCallback(BleApp_GattServerCallback);
    (void)App_RegisterGattClientProcedureCallback(BleApp_GattClientCallback);
    (void)App_RegisterGattClientNotificationCallback(BleApp_GattNotificationCallback);
    BleServDisc_RegisterCallback(BleApp_ServiceDiscoveryCallback);
    /* By default, always start node as GAP central */
    mGapRole = gGapCentral_c;
    /* Initialize private variables */
    mPeerInformation.appState = mAppIdle_c;
    mPeerInformation.deviceId = gInvalidDeviceId_c;
    mScanningOn = FALSE;
    mAdvState.advOn = FALSE;
    mFoundDeviceToConnect = FALSE;
    /* Start services */
    basServiceConfig.batteryLevel = BOARD_GetBatteryLevel();
    (void)Bas_Start(&basServiceConfig);
    (void)Dis_Start(&disServiceConfig);
    if (OtapClient_Config() == FALSE)
    {
        /* An error occurred in configuring the OTAP Client */
        panic(0,0,0,0);
    }
    /* Allocate scan timeout timer */
    mAppTimerId = TMR_AllocateTimer();
    mBatteryMeasurementTimerId = TMR_AllocateTimer();
    AppPrintString("\r\nPress SW2 to change the role. Press SW3 to connect either to a
Temperature Sensor or OTAP Server\r\n");
}
```

8. Include after `BleApp_Config`, the `BleApp_Advertise` function:

```
static void BleApp_Advertise(void)
{
    switch (mAdvState.advType)
    {
#if gAppUseBonding_d
        case whiteListAdvState_c:
        {
            gAdvParams.filterPolicy = gProcessWhiteListOnly_c;
        }
        break;
#endif
        case advState_c:
        {
            gAdvParams.filterPolicy = gProcessAll_c;
        }
        break;
        default:
            ; /* For MISRA compliance */
        break;
    }
    /* Set advertising parameters*/
    (void)Gap_SetAdvertisingParameters(&gAdvParams);
}
```

9. Include after `BleApp_ScanningCallback`, the `BleApp_AdvertisingCallback` function:

```
static void BleApp_AdvertisingCallback (gapAdvertisingEvent_t* pAdvertisingEvent)
{
    switch (pAdvertisingEvent->eventType)
    {
        case gAdvertisingStateChanged_c:
        {
            mAdvState.advOn = !mAdvState.advOn;
            if(mAdvState.advOn)
            {
                AppPrintString("\r\nAdvertising...\r\n");
                LED_StopFlashingAllLeds();
                Led2Flashing();
            }
        }
        break;
        case gAdvertisingCommandFailed_c:
        {
            Led2On();
            panic(0,0,0,0);
        }
        break;
        default:
            ; /* For MISRA compliance */
        break;
    }
}
```

10. Locate the `BleApp_ConnectionCallback` function. The connection callback is triggered whenever a connection event happens, such as a connection or disconnection. Modify this callback to handle the OTAP service as follows:

```
static void BleApp_ConnectionCallback (deviceId_t peerDeviceId, gapConnectionEvent_t*
pConnectionEvent)
{
    if(mGapRole == gGapCentral_c)
    {
        /* Connection Manager to handle Host Stack interactions */
        BleConnManager_GapCentralEvent(peerDeviceId, pConnectionEvent);
    }
    else
    {
        /* Connection Manager to handle Host Stack interactions */
        BleConnManager_GapPeripheralEvent(peerDeviceId, pConnectionEvent);;
    }
    switch (pConnectionEvent->eventType)
    {
        case gConnEvtConnected_c:
        {
        mAdvState.advOn = FALSE;
        /* Subscribe client */
        (void)Bas_Subscribe(&basServiceConfig, peerDeviceId);
        (void)OtapCS_Subscribe(peerDeviceId);
        /* Update UI */
        LED_StopFlashingAllLeds();
        Led3On();
        AppPrintString("\r\nConnected!\r\n");
        mPeerInformation.deviceId = peerDeviceId;
        mPeerInformation.isBonded = FALSE;
        /* Set low power mode */
#if defined(cPWR_UsePowerDownMode) && (cPWR_UsePowerDownMode)
        /* Device does not need to sleep until some information is exchanged with the peer. */
        PWR_DisallowDeviceToSleep();
#endif
        if(!TMR_IsTimerActive(mBatteryMeasurementTimerId))
        {
            /* Start battery measurements */
            (void)TMR_StartLowPowerTimer(mBatteryMeasurementTimerId,
gTmrLowPowerIntervalMillisTimer_c,
                TmrSeconds(mBatteryLevelReportInterval_c),
BatteryMeasurementTimerCallback, NULL);
        }
        if(mGapRole == gGapCentral_c)
        {
#if defined(gAppUseBonding_d) && (gAppUseBonding_d)
        (void)Gap_CheckIfBonded(peerDeviceId, &mPeerInformation.isBonded, NULL);
        if ((mPeerInformation.isBonded) &&
            (gBleSuccess_c == Gap_LoadCustomPeerInformation(peerDeviceId,
                (void*) &mPeerInformation.customInfo, 0, sizeof (appCustomInfo_t))))
        {
            mRestoringBondedLink = TRUE;
            /* Restored custom connection information. Encrypt link */
            (void)Gap_EncryptLink(peerDeviceId);
        }
#endif
        BleApp_StateMachineHandler(mPeerInformation.deviceId, mAppEvt_PeerConnected_c);
        }
        if(mGapRole == gGapPeripheral_c)
        {
            /* Handle OTAP connection event */
            OtapClient_HandleConnectionEvent (peerDeviceId);
        }
    }
    break;
    case gConnEvtDisconnected_c:
    {
        /* Unsubscribe client */
        (void)Bas_Unsubscribe(&basServiceConfig, peerDeviceId);
        (void)OtapCS_Unsubscribe();
        mPeerInformation.deviceId = gInvalidDeviceId_c;
        mPeerInformation.appState = mAppIdle_c;
        TMR_StopTimer(mBatteryMeasurementTimerId);
        if(mGapRole == gGapPeripheral_c)
        {
            /* Handle OTAP disconnection event */
            OtapClient_HandleDisconnectionEvent(peerDeviceId);
        }
        /* Reset Service Discovery to be sure*/
        BleServDisc_Stop(peerDeviceId);
        /* Update UI */
        AppPrintString("\r\nDisconnected!\r\n");
        LED_TurnOffAllLeds();
        LED_StartFlash(LED_ALL);
    }
    break;
#if gAppUsePairing_d
    case gConnEvtPairingComplete_c:
    {
        /* Notify state machine handler on pairing complete */
        if (pConnectionEvent->eventData.pairingCompleteEvent.pairingSuccessful)
        {
        BleApp_StateMachineHandler(mPeerInformation.deviceId, mAppEvt_PairingComplete_c);
        }
    }
    break;
```

```
#if defined(gAppUseBonding_d) && (gAppUseBonding_d)
        case gConnEvtEncryptionChanged_c:
        {
            if( pConnectionEvent->eventData.encryptionChangedEvent.newEncryptionState )
            {
                if( mRestoringBondedLink )
                {
                    /* Try to enable temperature notifications, disconnect on failure */
                    if( gBleSuccess_c != BleApp_ConfigureNotifications() )
                    {
                        (void)Gap_Disconnect(peerDeviceId);
                    }
                else
                {
                    mRestoringBondedLink = FALSE;
                }
            }
        }
    }
    break;
    case gConnEvtAuthenticationRejected_c:
    {
        /* Start Pairing Procedure */
        (void)Gap_Pair(peerDeviceId, &gPairingParameters);
    }
    break;
#endif /* gAppUseBonding_d */
#endif /* gAppUsePairing_d */
    default:
        ; /* No action required */
    break;
    }
}
```

11. Develop the `BleApp_GattServerCallback` function. It manages all the incoming communications from the client devices. Add the GATT server events that need to be handled by the OTAP client software. See the following example.

```
static void BleApp_GattServerCallback (deviceId_t deviceId, gattServerEvent_t* pServerEvent)
{
    switch (pServerEvent->eventType)
    {
        case gEvtMtuChanged_c:
        {
            OtapClient_AttMtuChanged (deviceId,
                pServerEvent->eventData.mtuChangedEvent.newMtu);
        }
        break;
        case gEvtCharacteristicCccdWritten_c:
        {
            OtapClient_CccdWritten (deviceId,
                pServerEvent->eventData.charCccdWrittenEvent.handle,
                pServerEvent->eventData.charCccdWrittenEvent.newCccd);
        }
        break;
        case gEvtAttributeWritten_c:
        {
            OtapClient_AttributeWritten (deviceId,
                pServerEvent->eventData.attributeWrittenEvent.handle,
                pServerEvent->eventData.attributeWrittenEvent.cValueLength,
                pServerEvent->eventData.attributeWrittenEvent.aValue);
        }
        break;
        case gEvtAttributeWrittenWithoutResponse_c:
        {
            OtapClient_AttributeWrittenWithoutResponse (deviceId,
                pServerEvent->eventData.attributeWrittenEvent.handle,
                pServerEvent->eventData.attributeWrittenEvent.cValueLength,
                pServerEvent->eventData.attributeWrittenEvent.aValue);
        }
        break;
        case gEvtHandleValueConfirmation_c:
        {
            OtapClient_HandleValueConfirmation (deviceId);
        }
        break;
        case gEvtError_c:
        {
            attErrorCode_t attError = (attErrorCode_t) (pServerEvent-
>eventData.procedureError.error & 0xFF);
            if (attError == gAttErrCodeInsufficientEncryption_c ||
                attError == gAttErrCodeInsufficientAuthorization_c ||
                attError == gAttErrCodeInsufficientAuthentication_c)
        {
#if gAppUsePairing_d
#if gAppUseBonding_d
                bool_t isBonded = FALSE;
                /* Check if the devices are bonded and if this is true than the bond may have
                * been lost on the peer device or the security properties may not be sufficient.
                * In this case try to restart pairing and bonding. */
                if (gBleSuccess_c == Gap_CheckIfBonded(deviceId, &isBonded, NULL) &&
                    TRUE == isBonded)
#endif /* gAppUseBonding_d */
                {
                    (void)Gap_SendSlaveSecurityRequest(deviceId, &gPairingParameters);
                }
#endif /* gAppUsePairing_d */
                }
            }
        break;
            default:
                ; /* For MISRA compliance */
            break;
    }
}
```

12. Include the timer callback for the battery service:

```
static void BatteryMeasurementTimerCallback(void * pParam)
{
    basServiceConfig.batteryLevel = BOARD_GetBatteryLevel();
    (void)Bas_RecordBatteryMeasurement(&basServiceConfig);
}
```

Now, you have integrated the OTAP Client code into the Temp Coll.

NOTE

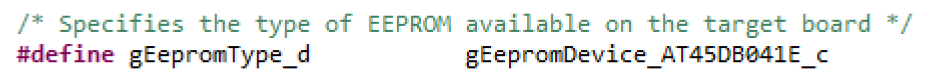
The example provided with this application note removes all references related to low power support in the *temperature_collector.c*, except the `PWR_DisallowDeviceToSleep` function at `BleApp_ConnectionCallback`. The `DisconnectTimerCallback` and its associated timer instance and it changes the state machine of the RGB LED. These changes are not listed in the steps above since they are not relevant for this application note.

4.3 Modifications in project settings and storage configurations

The OTAP client software included in the SDK package contains some linker configurations to generate the application offset needed for the OTAP Bootloader software and split the flash memory in accord of the storage method desired. Such configurations are not part of the Temp Coll demo, so it should be included to integrate the OTAP on the application. Follow the next steps to set the project settings and the storage configurations.

1. Open the *app_preinclude.h* file located in the source folder of the project.
   - To configure the software for external flash storage method, set the `gEepromType` defination to `gEepromDevice_AT45DB041E_c`.
   - To use the internal flash storage method, set the `gEepromType` defination to `gEepromDevice_InternalFlash_c`.

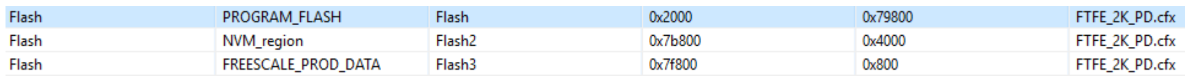
   For more details about storage methods, see OTAP memory management during the update process.



```
/* Specifies the type of EEPROM available on the target board */
#define gEepromType_d            gEepromDevice_AT45DB041E_c
```

Figure 27. Configuring the storage method at the preinclude file

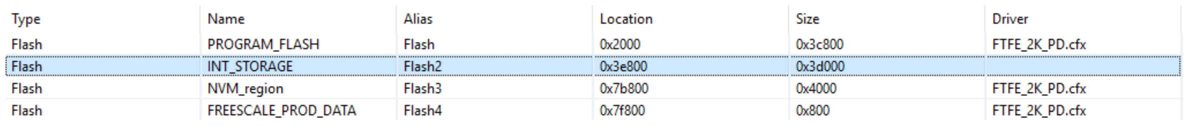
2. Navigate to **Project** -> **Properties** in MCUXpresso IDE. Go to **C/C++ Build** -> **MCU settings**.
   a. To select external flash storage method, as shown in Figure 28, configure the fields in the **Memory details** pane. This is the default storage method for the Tempertaure Collector - OTAP software.



Flash	PROGRAM_FLASH	Flash	0x2000	0x79800	FTFE_2K_PD.cfx
Flash	NVM_region	Flash2	0x7b800	0x4000	FTFE_2K_PD.cfx
Flash	FREESCALE_PROD_DATA	Flash3	0x7f800	0x800	FTFE_2K_PD.cfx

Figure 28. Configuring external storage method

   b. To select internal flash storage method, as shown in Figure 29, configure the fields in the **Memory details** pane.



Type	Name	Alias	Location	Size	Driver
Flash	PROGRAM_FLASH	Flash	0x2000	0x3c800	FTFE_2K_PD.cfx
Flash	INT_STORAGE	Flash2	0x3e800	0x3d000	
Flash	NVM_region	Flash3	0x7b800	0x4000	FTFE_2K_PD.cfx
Flash	FREESCALE_PROD_DATA	Flash4	0x7f800	0x800	FTFE_2K_PD.cfx

Figure 29. Configuring internal storage method

3. Clean and build the project.

Now, you have finally integrated the OTAP service on the Bluetooth LE based application.

5 Testing the Temp Coll-OTAP demo

The test case example, designed to demonstrate the OTAP integration in Testing the Temp Coll-OTAP software, makes use of the following software:

- OTAP Client SDK software, programmed in the FRDM-KW38 board.
- An SREC software update of the Temp Coll-OTAP example.

- An SREC software update of the Temp Coll SDK example.

The following sections explain how to build the software required for the testing case proposed by this document. However, users can decide which software or steps are not relevant to their application.

5.1 Preparing the OTAP client SDK software

1. Attach your FRDM-KW38 board on the PC.
2. Open MCUXpresso IDE.

   In the **Quickstart Panel** view, click **Import SDK example(s)**.

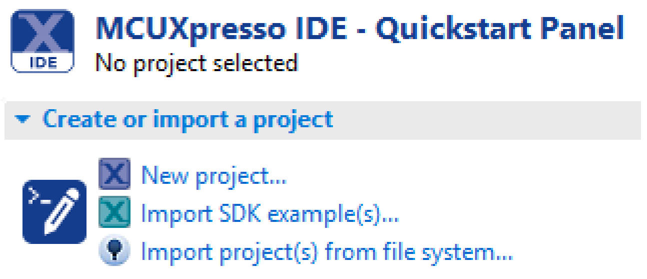
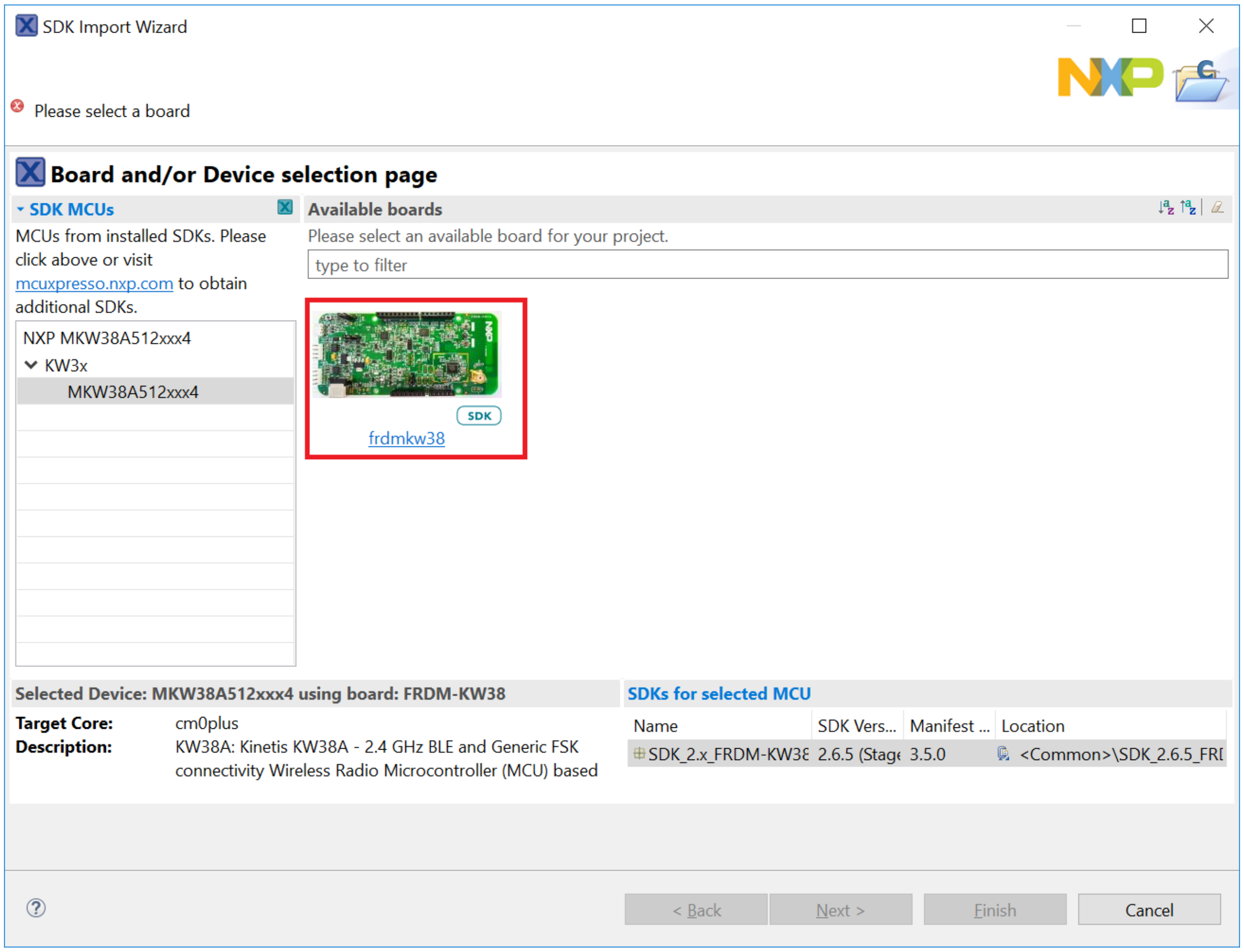

MCUXpresso IDE - Quickstart Panel
No project selected
Create or import a project
New project...
Import SDK example(s)...
Import project(s) from file system...

Figure 30. Quickstart panel perspective

3. Click twice on the **frdmkw38** icon.



Please select a board

Board and/or Device selection page

SDK MCUs

MCUs from installed SDKs. Please click above or visit mcuxpresso.nxp.com to obtain additional SDKs.

NXP MKW38A512xxx4
KW3x
MKW38A512xxx4

Available boards

Please select an available board for your project.

type to filter

frdmkw38

Selected Device: MKW38A512xxx4 using board: FRDM-KW38

Target Core: cm0plus

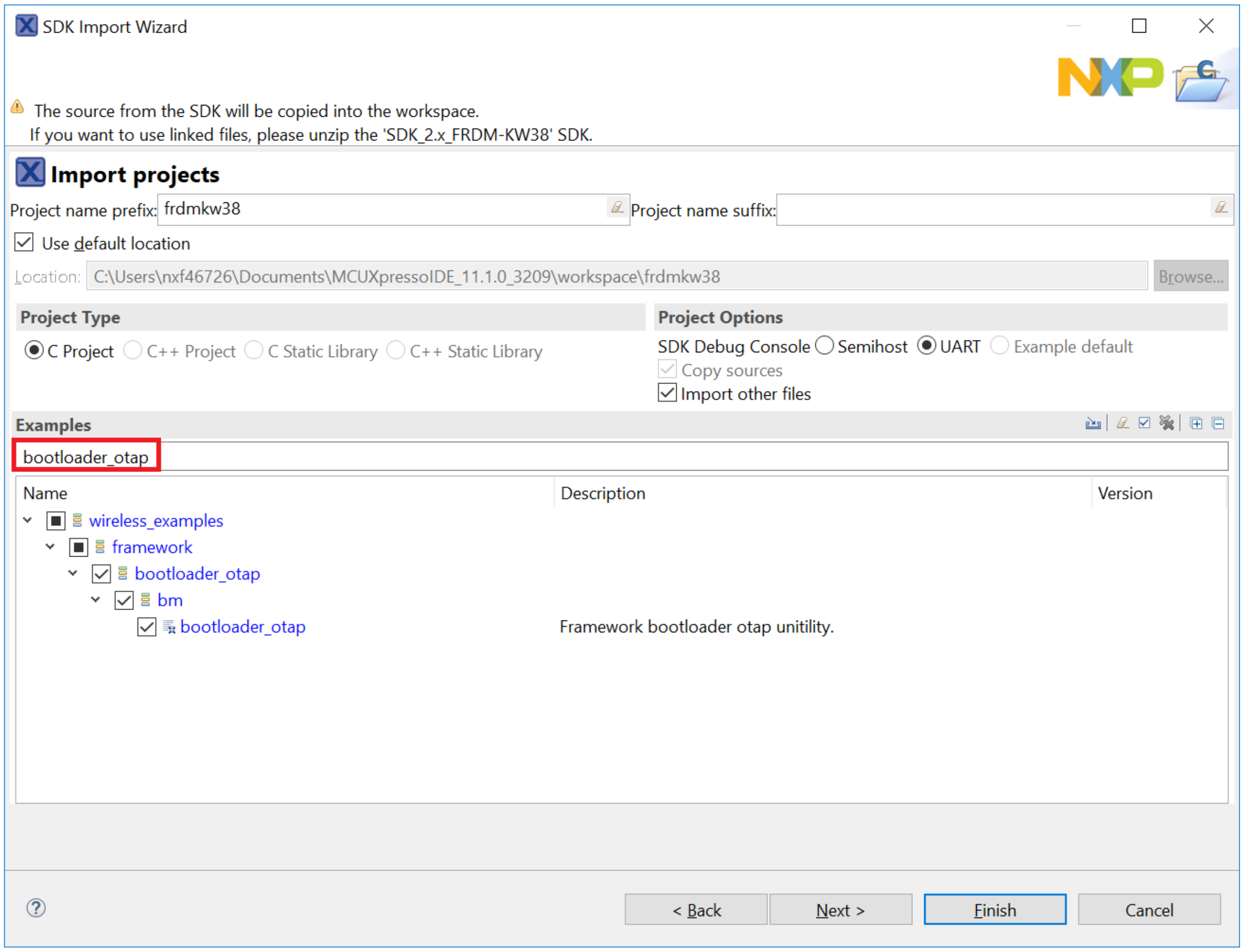
Description: KW38A: Kinetis KW38A - 2.4 GHz BLE and Generic FSK connectivity Wireless Radio Microcontroller (MCU) based

SDKs for selected MCU

Name	SDK Vers...	Manifest ...	Location
SDK_2.x_FRDM-KW3ε	2.6.5 (Stage	3.5.0	<Common>\SDK_2.6.5_FRI

Figure 31. Device selection perspective

4. In the **Examples** text field, type **bootloader_otap** and click **wireless_examples** -> **framework** -> **bootloader_otap** -> **bm**. Click **Finish**.
5. Flash the *bootloader_otap* project (OTAP Bootloader project) in your FRDM-KW38 board.



The source from the SDK will be copied into the workspace.
If you want to use linked files, please unzip the 'SDK_2.x_FRDM-KW38' SDK.

Project name prefix: frdmkw38 Project name suffix:

[✓] Use default location

Location: C:\Users\nxf46726\Documents\MCUXpressoIDE_11.1.0_3209\workspace\frdmkw38

Project Type: [● C Project] C++ Project C Static Library C++ Static Library

Project Options: SDK Debug Console Semihost [● UART] Example default

[✓] Copy sources

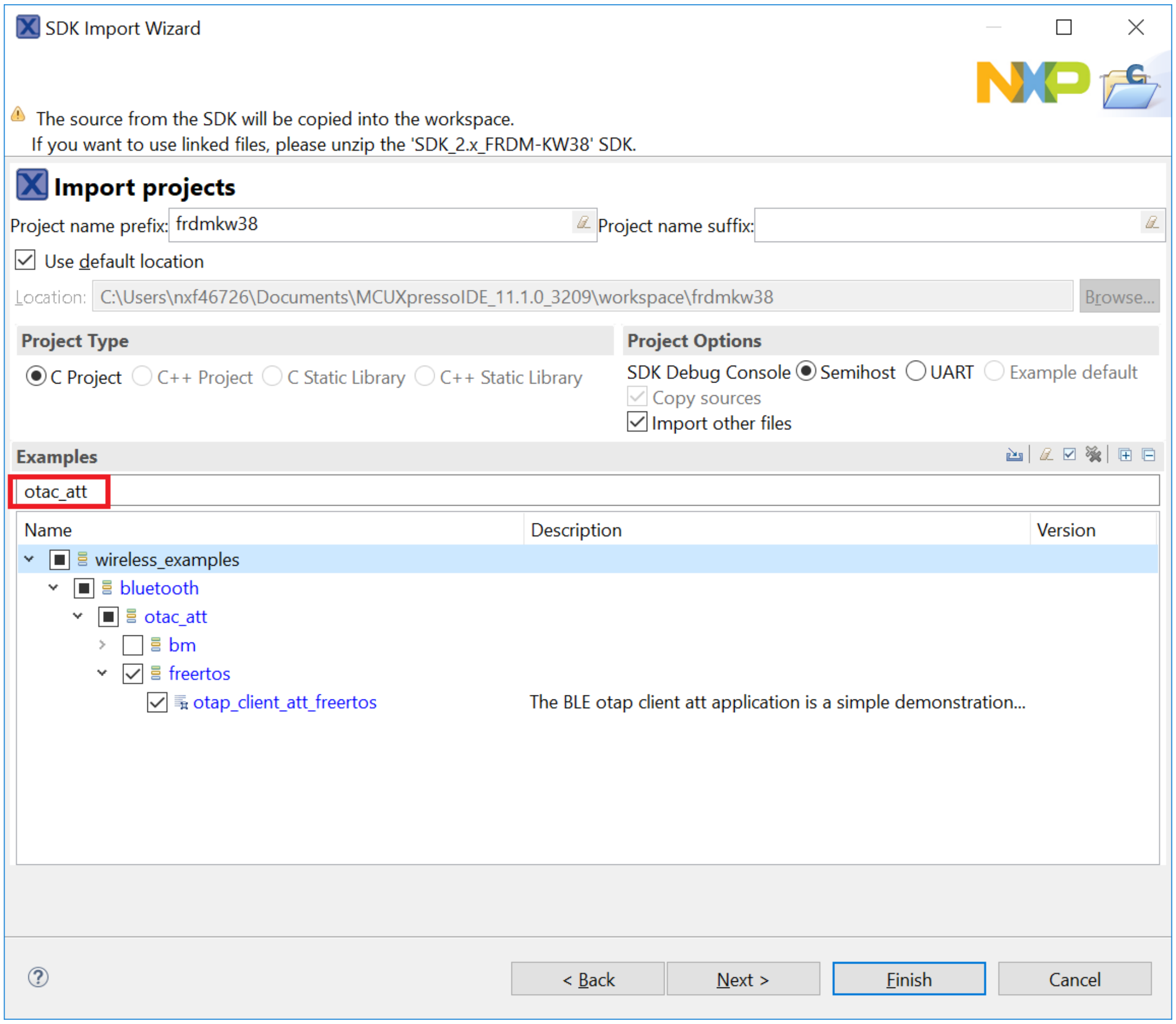
[✓] Import other files

Examples: bootloader_otap

Name	Description	Version
wireless_examples		
framework		
[✓] bootloader_otap		
[✓] bm		
[✓] bootloader_otap	Framework bootloader otap unitility.	

Figure 32. Importing the OTAP Bootloader project on the workspace

6. Repeat 2 to 4 to import the *otac_att* project. It is located in **wireless_examples** -> **bluetooth** -> **otac_att** -> **freertos**.


SDK Import Wizard

The source from the SDK will be copied into the workspace.
If you want to use linked files, please unzip the 'SDK_2.x_FRDM-KW38' SDK.

Import projects

Project name prefix: frdmkw38 Project name suffix:

☑ Use default location

Location: C:\Users\nxf46726\Documents\MCUXpressoIDE_11.1.0_3209\workspace\frdmkw38

Project Type: [✓ C Project] C++ Project C Static Library C++ Static Library

Project Options: SDK Debug Console [✓ Semihost] UART Example default; ☑ Copy sources; ☑ Import other files

Examples: otac_att

Name	Description	Version
wireless_examples		
bluetooth		
otac_att		
☐ bm		
☑ freertos		
☑ otap_client_att_freertos	The BLE otap client att application is a simple demonstration...	

Figure 33. Importing the OTAP client project on the workspace

7. Set the storage configurations for the *otac_att* project, OTAP client project.
   a. Open the *app_preinclude.h* file located in the source folder of the project:
      - To select the software for external flash storage method, set the **gEepromType** definition to **gEepromDevice_AT45DB041E_c**.
      - To select the internal flash storage method, On-chip FlexNVM memory, set **gEepromType** definition to **gEepromDevice_InternalFlash_c**.

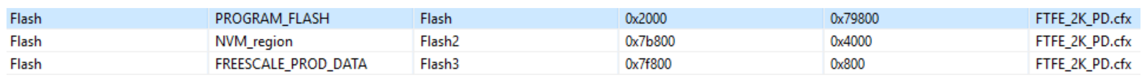
```
/* Specifies the type of EEPROM available on the target board */
#define gEepromType_d           gEepromDevice_AT45DB041E_c
```

Figure 34. Configuring the storage method at the preinclude file

   For more details about storage methods, see OTAP memory management during the update process.

   b. Navigate to **Project** -> **Properties** in MCUXpresso IDE. Go to **C/C++ Build** -> **MCU settings** -> **Memory details** perspective.

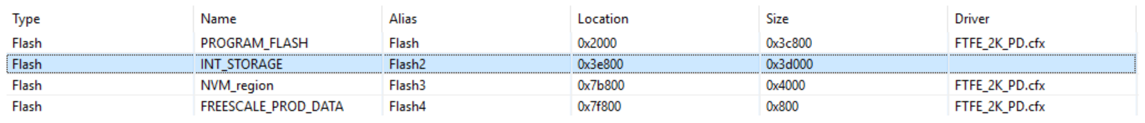
- To select external flash storage method, as shown in Figure 35, configure the fields in the **Memory details** pane.



Flash	PROGRAM_FLASH	Flash	0x2000	0x79800	FTFE_2K_PD.cfx
Flash	NVM_region	Flash2	0x7b800	0x4000	FTFE_2K_PD.cfx
Flash	FREESCALE_PROD_DATA	Flash3	0x7f800	0x800	FTFE_2K_PD.cfx

Figure 35. Configuring external storage method

- To select internal flash storage method, as shown in Figure 36, configure the fields in the **Memory details** pane.



Type	Name	Alias	Location	Size	Driver
Flash	PROGRAM_FLASH	Flash	0x2000	0x3c800	FTFE_2K_PD.cfx
Flash	INT_STORAGE	Flash2	0x3e800	0x3d000	
Flash	NVM_region	Flash3	0x7b800	0x4000	FTFE_2K_PD.cfx
Flash	FREESCALE_PROD_DATA	Flash4	0x7f800	0x800	FTFE_2K_PD.cfx

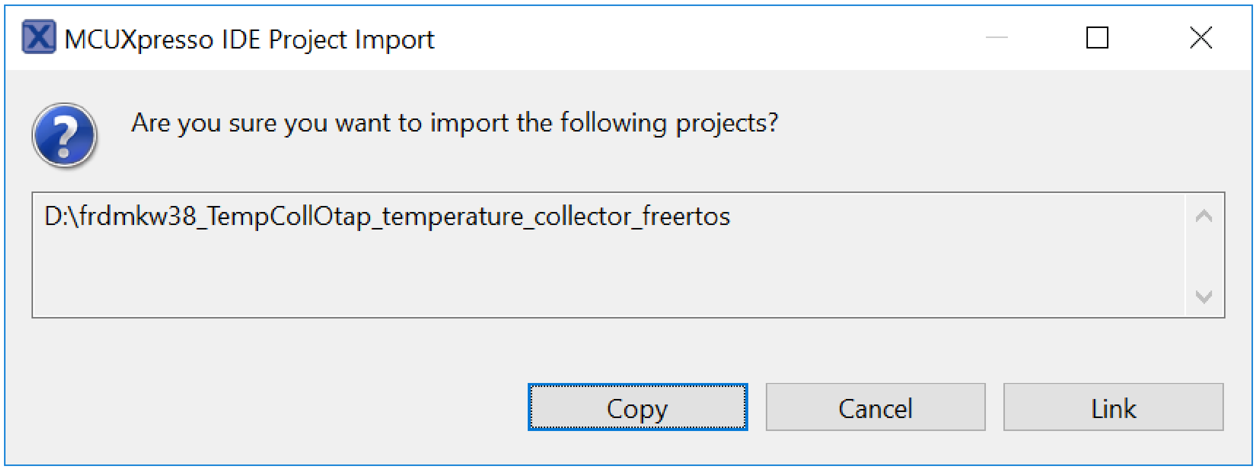
Figure 36. Configuring internal storage method

8. Clean and build the project. Flash the project on the **FRDM-KW38** board.

Now, you have programmed and configured the OTAP client software on your board. You can communicate to a server and request for a software update.

5.2 Creating a Temp Coll - OTAP S - record image to update the software

1. Install the Temp Coll-OTAP demo provided with this document in your MCUXpresso IDE. You can drag and drop the project from your installation path to the MCUXpresso workspace. A warning message appears, as shown in Figure 37. click the **Copy** button to clone the original example.



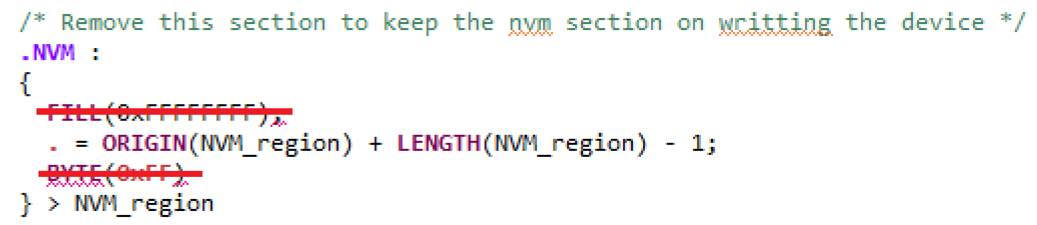
MCUXpresso IDE Project Import

Are you sure you want to import the following projects?

D:\frdmkw38_TempCollOtap_temperature_collector_freertos

Figure 37. Importing the Temp Coll-OTAP demo on the MCUXpresso workspace

2. Open the `end_text.ldt` linker script located at the linkscripts folder in the workspace. Locate the section placement and remove the **FILL** and **BYTE** statements, as shown in Figure 38. This step is needed only to build the SREC image file to reprogram the device.



```
/* Remove this section to keep the nvm section on writting the device */
.NVM :
{
  ~~FILL(0xFFFFFFFF);~~
  . = ORIGIN(NVM_region) + LENGTH(NVM_region) - 1;
  ~~BYTE(0xFF)~~
} > NVM_region
```

Figure 38. Preparing the linker file

3. Clean and build the project.
4. Deploy the **Binaries** icon in the workspace. Right-click the *.axf* file and select **Binary Utilities** -> **Create S-Record**. The S-Record file will be saved at the **Debug** folder in the workspace with the *.s19* extension.

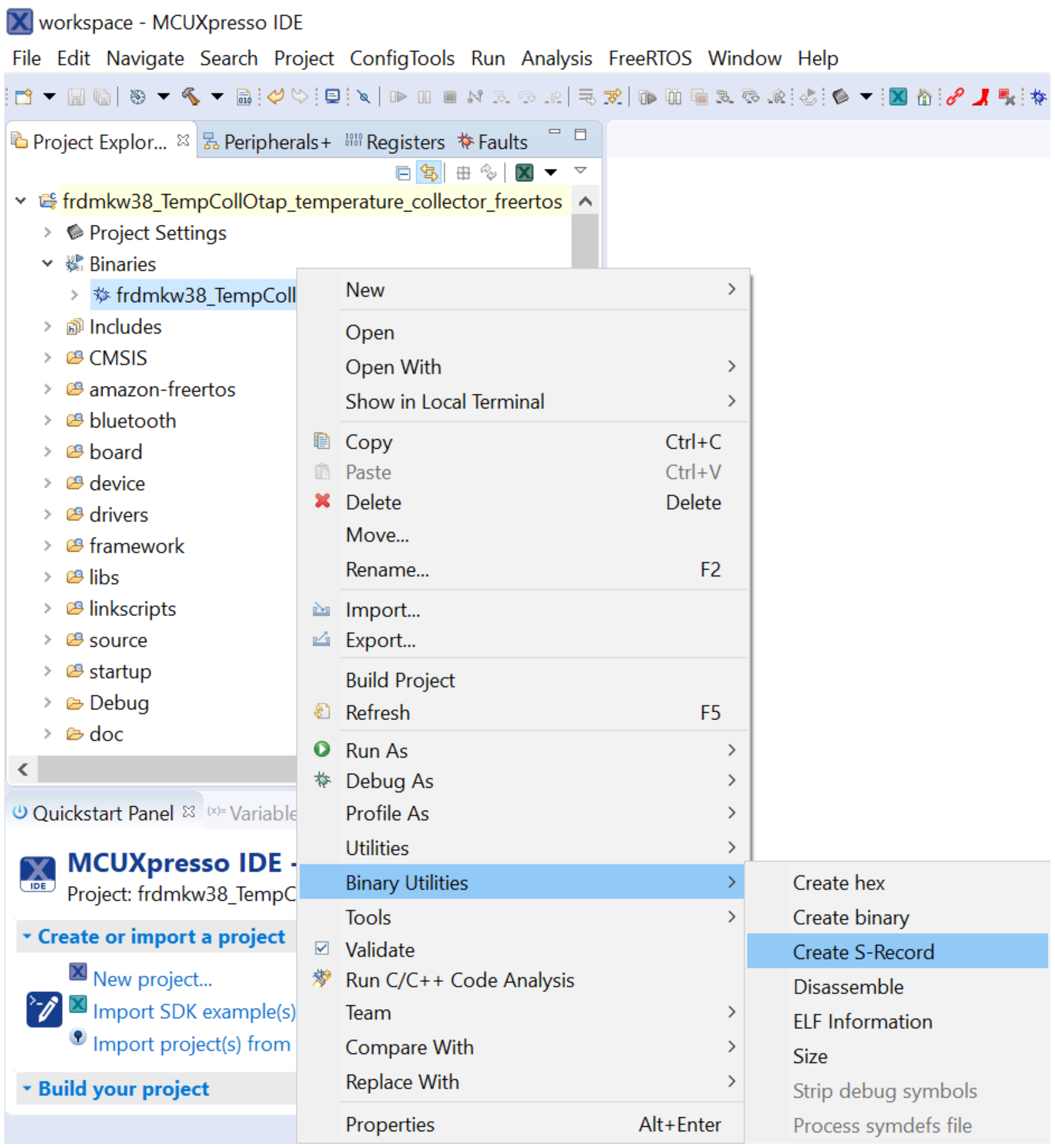
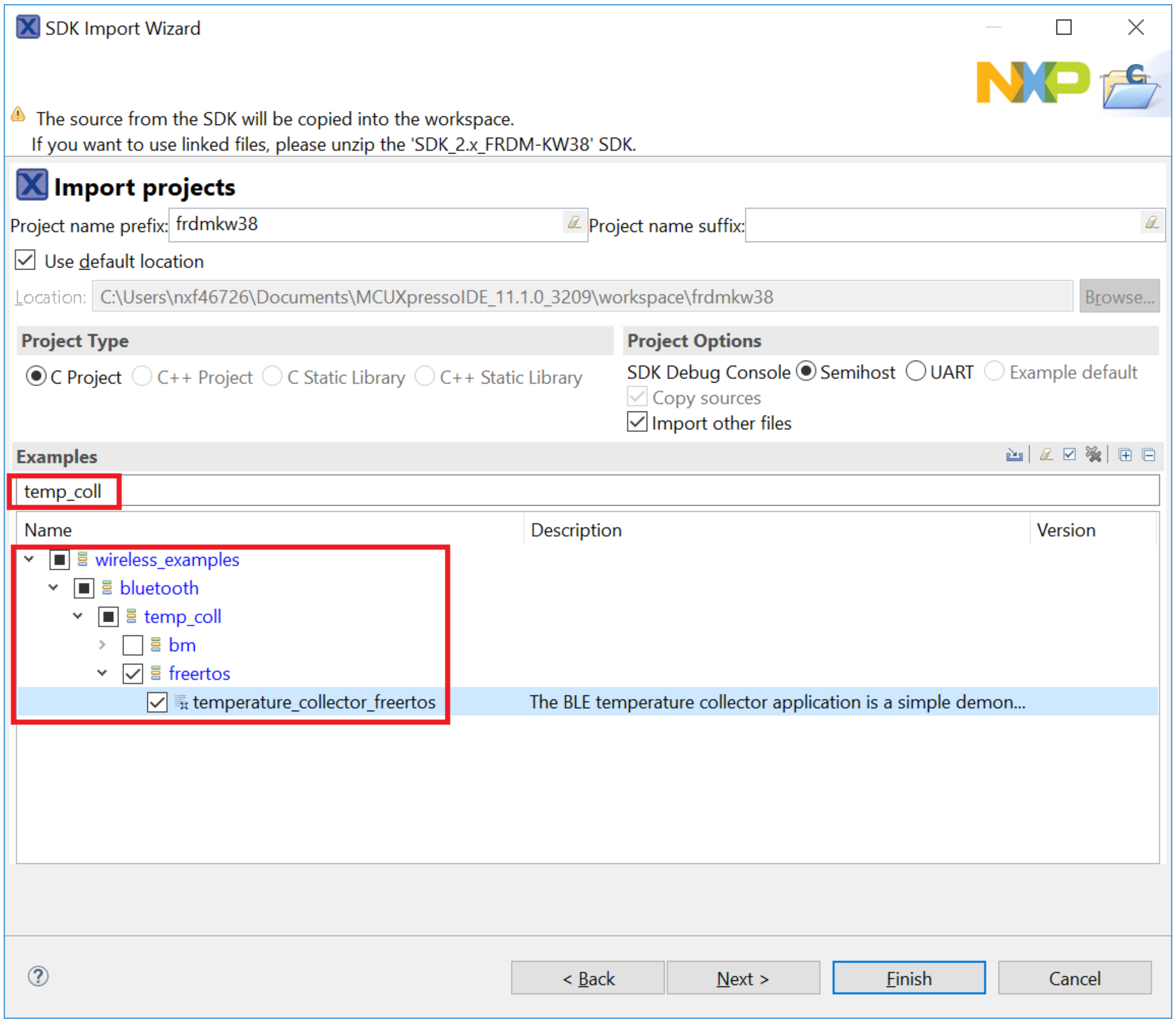


Figure 39. Creating the SREC file

5. Save this file in a known location on your smartphone.

5.3 Creating a Temp Coll S-Record image to update the software

1. Open MCUXpresso IDE. In the **Quickstart Panel** view, click the **Import SDK example(s)**, and the device selection perspective will appear. Click twice on the **frdmkw38** icon.
2. In the **Examples** text box, type **temp_coll** and select **wireless_examples** -> **bluetooth** -> **temp_coll** ->**freertos**. Click **Finish**.


SDK Import Wizard

The source from the SDK will be copied into the workspace.
If you want to use linked files, please unzip the 'SDK_2.x_FRDM-KW38' SDK.

Import projects

Project name prefix: frdmkw38 Project name suffix:

[✓] Use default location

Location: C:\Users\nxf46726\Documents\MCUXpressoIDE_11.1.0_3209\workspace\frdmkw38

Project Type: [● C Project] ○ C++ Project ○ C Static Library ○ C++ Static Library

Project Options: SDK Debug Console [● Semihost] ○ UART ○ Example default

[✓] Copy sources

[✓] Import other files

Examples: temp_coll

Name	Description	Version
wireless_examples		
bluetooth		
temp_coll		
bm		
[✓] freertos		
[✓] temperature_collector_freertos	The BLE temperature collector application is a simple demon...	

Figure 40. Importing the Temp Coll project on the workspace

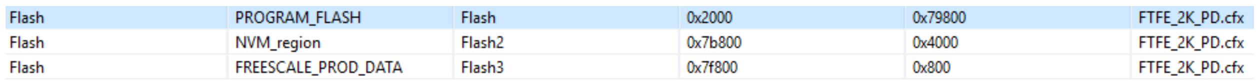
3. Open the *app_preinclude.h* file under the source folder at the MCUXpresso workspace. Locate the `cPWR_UsePowerDownMode` macro and change its value to zero. This step is not mandatory, but it is useful at running time to confirm whenever the software update has been successfully programmed by the OTAP bootloader.

```
/* Enable/Disable PowerDown functionality in PwrLib */
#define cPWR_UsePowerDownMode          0
```

4. Define `gEepromType_d` as internal flash storage in the **Board Configuration** section of the *app_preinclude.h* file. This is a dummy definition needed to place the Bootloader Flags in the proper address, so this will not affect the storage method chosen when you programmed previously the OTAP Client software in the MCU.

```
/* Specifies the type of EEPROM available on the target board */
#define gEepromType_d          gEepromDevice_InternalFlash_c
```

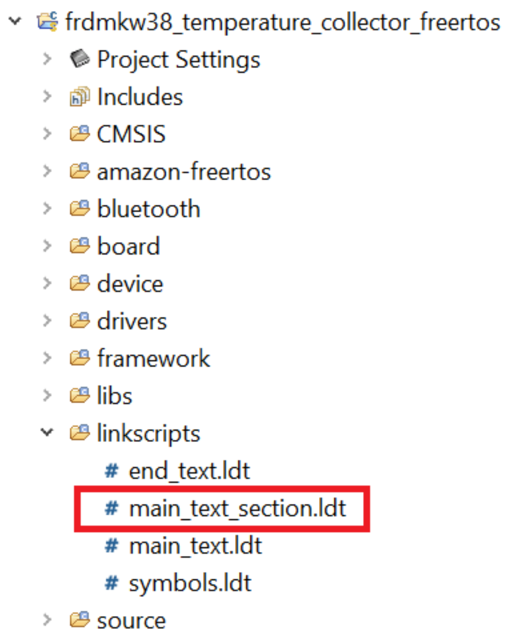
5. Navigate to **Project** -> **Properties** -> **C/C++ Build** -> **MCU settings**. Configure **PROGRAM_FLASH**, **NVM_region**, and **FREESCALE_PROD_DATA** fields and save the changes.



Flash	PROGRAM_FLASH	Flash	0x2000	0x79800	FTFE_2K_PD.cfx
Flash	NVM_region	Flash2	0x7b800	0x4000	FTFE_2K_PD.cfx
Flash	FREESCALE_PROD_DATA	Flash3	0x7f800	0x800	FTFE_2K_PD.cfx

Figure 41. Configuring the memory layout

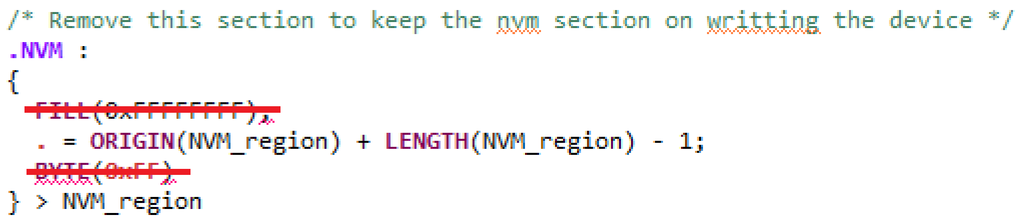
6. Navigate to the workspace. Locate the *linkscripts* folder and include into it the `main_text_section.ldt` linker script. You can copy and paste from the OTAP client SDK example.



```
frdmkw38_temperature_collector_freertos
  Project Settings
  Includes
  CMSIS
  amazon-freertos
  bluetooth
  board
  device
  drivers
  framework
  libs
  linkscripts
    end_text.ldt
    main_text_section.ldt
    main_text.ldt
    symbols.ldt
  source
```

Figure 42. Importing linker scripts

7. Open the `end_text.ldt` linker script located at the linkscripts folder in the workspace. Locate the section placement and remove the **FILL** and **BYTE** statements, as shown in Figure 43.



```
/* Remove this section to keep the nvm section on writting the device */
.NVM :
{
  ~~FILL(0xFFFFFFFF);~~
  . = ORIGIN(NVM_region) + LENGTH(NVM_region) - 1;
  ~~BYTE(0xFF)~~
} > NVM_region
```

Figure 43. Preparing the linker file

8. Include the *OtaSupport* folder and its files in the *framework* folder. Include the *External* folder and its files in the *framework->Flash* folder. This step can be done in the same way as explained in Importing the OTAP Bluetooth LE service and framework software into the Temp Coll project.
9. Clean and build the project.
10. Deploy the **Binaries** icon in the workspace. Right-click the *.axf* file and select **Binary Utilities** -> **Create S-Record**. The S-Record file will be saved at the *Debug* folder in the workspace with the *.s19* extension.
11. Save this file in a known location on your smartphone.

5.4 Testing the Temp Coll-OTAP software

Figure 44 exemplifies the testing case of this section. The FRDM-KW38 contains the OTAP client software. The OTAP client will request a software update from the OTAP server, the smartphone. This software image is the Temp Coll-OTAP demo. At this point, the FRDM-KW38 has been updated and can handle all the incoming communication from a Temperature Sensor Example or the OTAP server.

To demonstrate that you can continue updating the software of the KW38 device, you can connect the Temp Coll-OTAP to an OTAP server and request a software update that only contains the Temp Coll example. From this point, you cannot continue updating the software since the OTAP service was not included in the last software upgrade, demonstrating the importance of including OTAP in the software update sent over the air.

This example was designed to understand the key points of the OTAP integration. However, the main purpose of this application note is to create software updates that include the OTAP service and continue upgrading and improving the KW38 device.

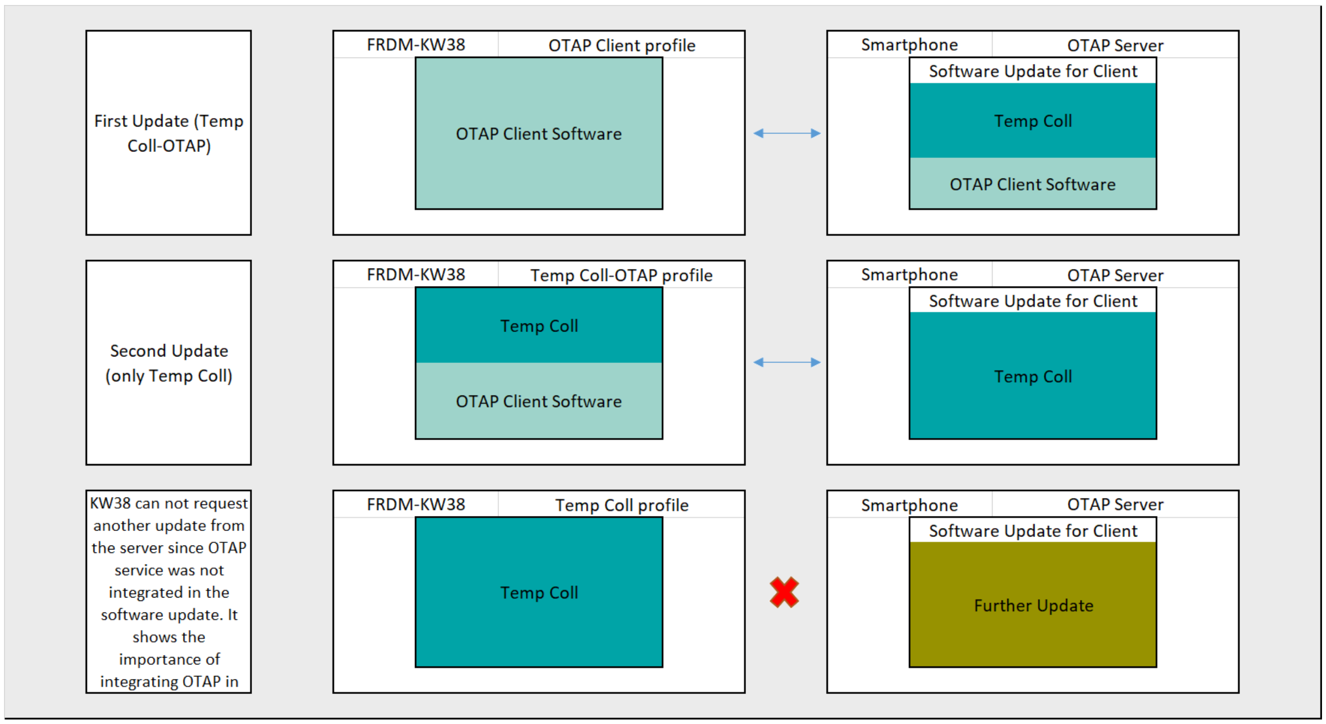

First Update (Temp Coll-OTAP)
FRDM-KW38
OTAP Client profile
OTAP Client Software
Smartphone
OTAP Server
Software Update for Client
Temp Coll
OTAP Client Software
Second Update (only Temp Coll)
FRDM-KW38
Temp Coll-OTAP profile
Temp Coll
OTAP Client Software
Smartphone
OTAP Server
Software Update for Client
Temp Coll
KW38 can not request another update from the server since OTAP service was not integrated in the software update. It shows the importance of integrating OTAP in
FRDM-KW38
Temp Coll profile
Temp Coll
Smartphone
OTAP Server
Software Update for Client
Further Update

Figure 44. Proposed test

1. Open the IoT Toolbox App and select the OTAP demo. Click the **SCAN** to start scanning for a suitable advertiser.

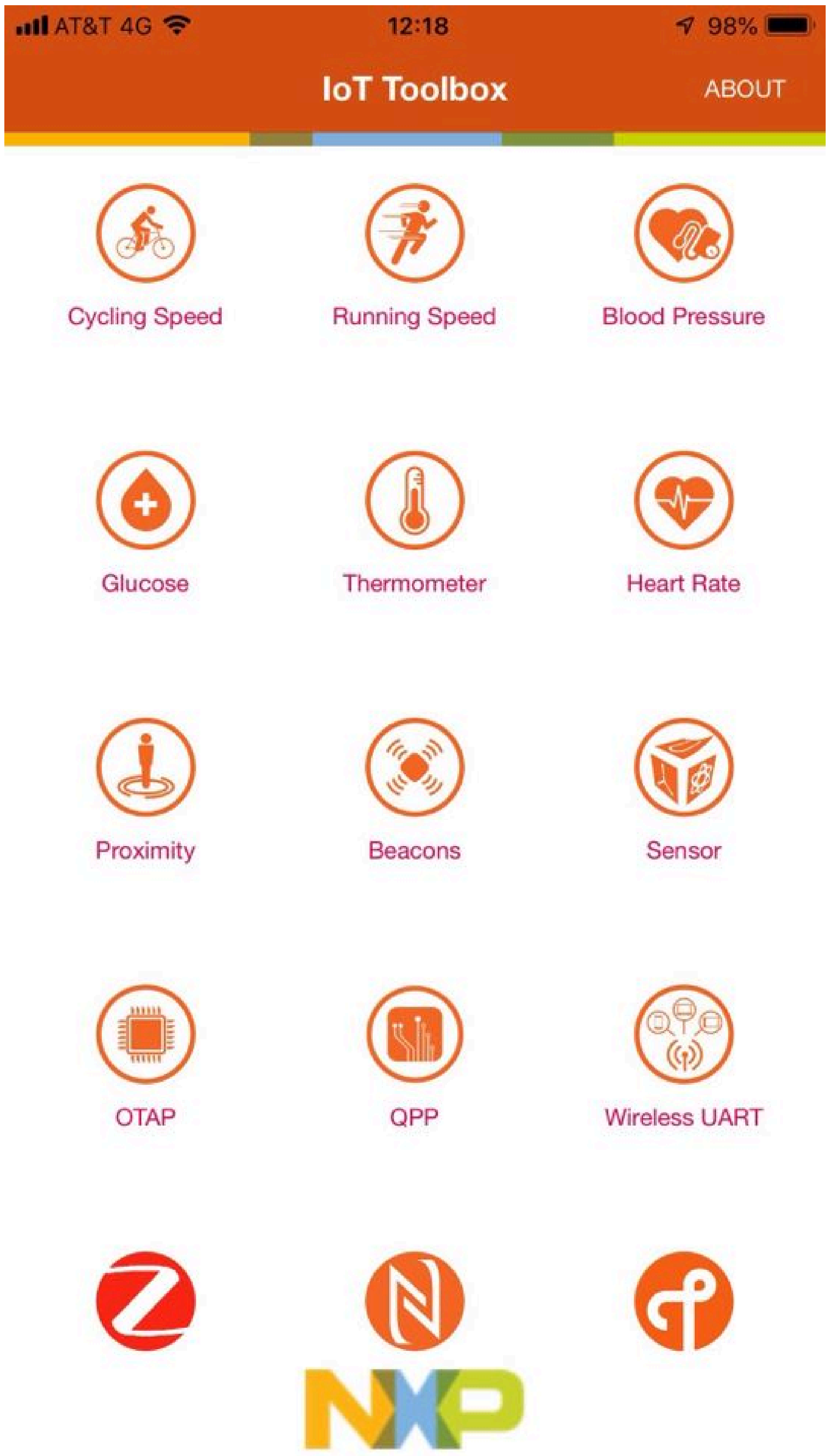


Figure 45. IoT Toolbox interface

2. Press the ADV button, SW2, on the FRDM-KW38 board to start advertising.
3. Create a connection with the NXP_OTAA device. Then, the OTAP interface will be displayed on your smartphone.

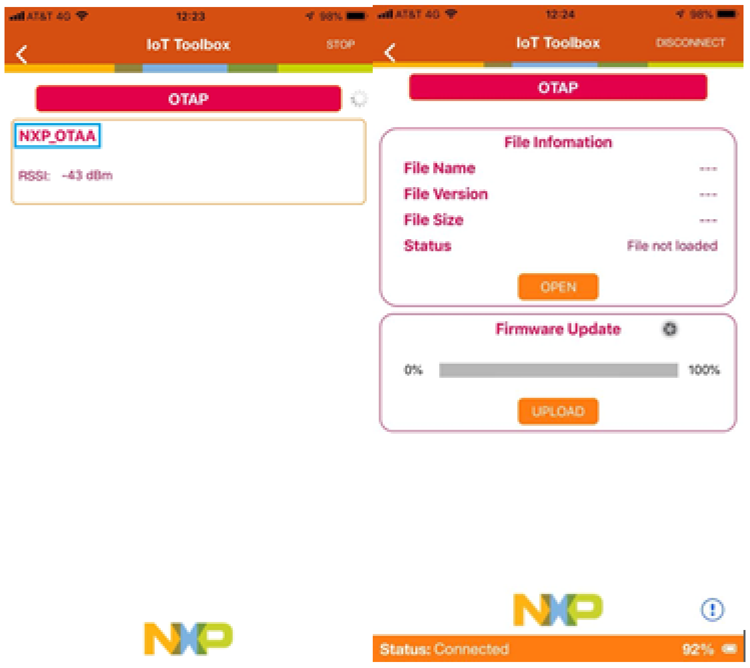
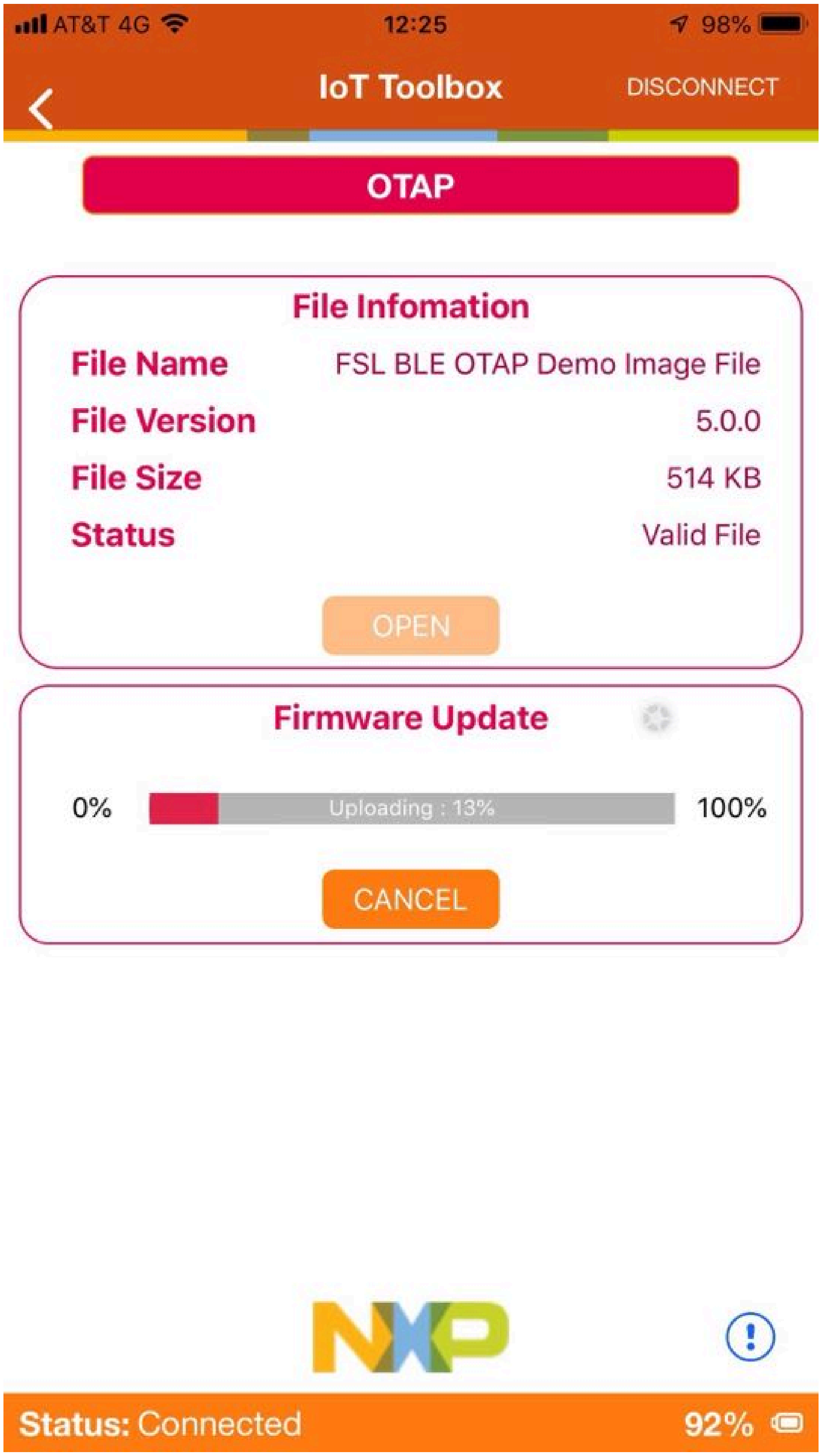


Figure 46. Connecting the OTAP client and the OTAP server

4. Click the Open button and search for the Temp Coll-OTAP SREC file.
5. Click the Upload button to start the transfer. Wait for the transfer to be completed until the confirmation message is displayed.


AT&T 4G 12:25 98%

IoT Toolbox

DISCONNECT

OTAP

File Infomation

File Name	FSL BLE OTAP Demo Image File
File Version	5.0.0
File Size	514 KB
Status	Valid File

OPEN

Firmware Update

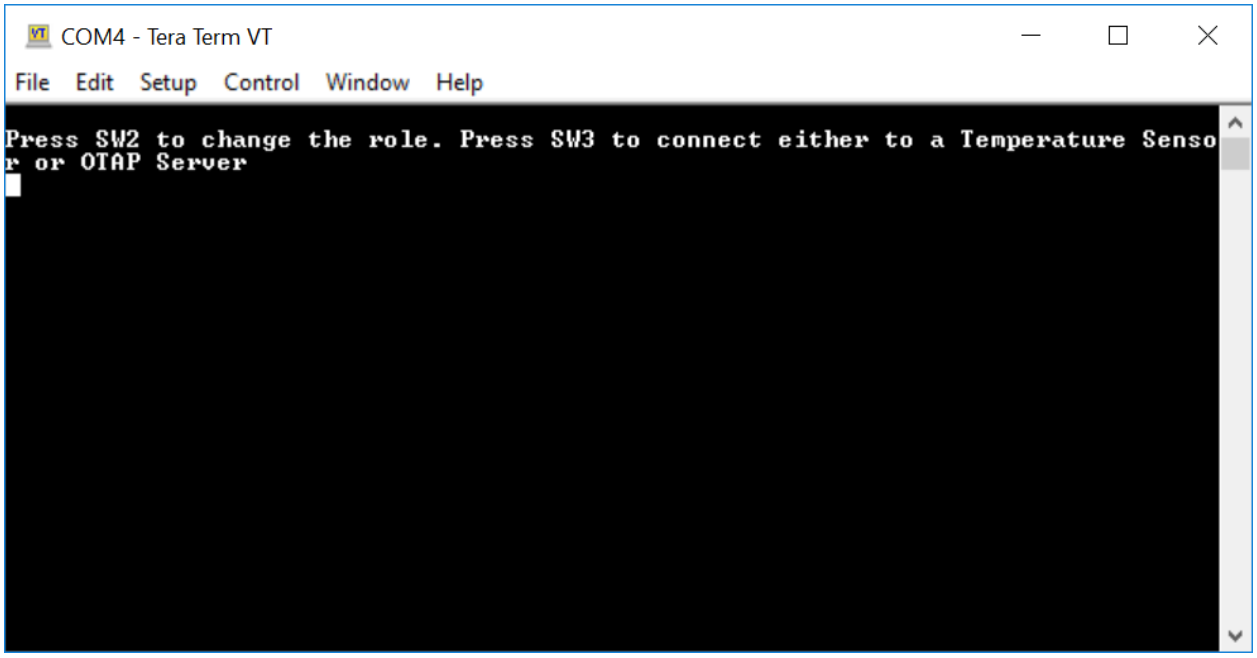
0% Uploading : 13% 100%

CANCEL

Status: Connected 92%

Figure 47. Updating the OTAP client to Temp Coll-OTAP

6. Connect your FRDM-KW38 with any serial terminal software. Wait for few seconds until the OTAP bootloader has finished programming the new image. The Temp Coll-OTAP application will start automatically, when the RGB LED will blink, and a welcome message will be displayed on the serial terminal.



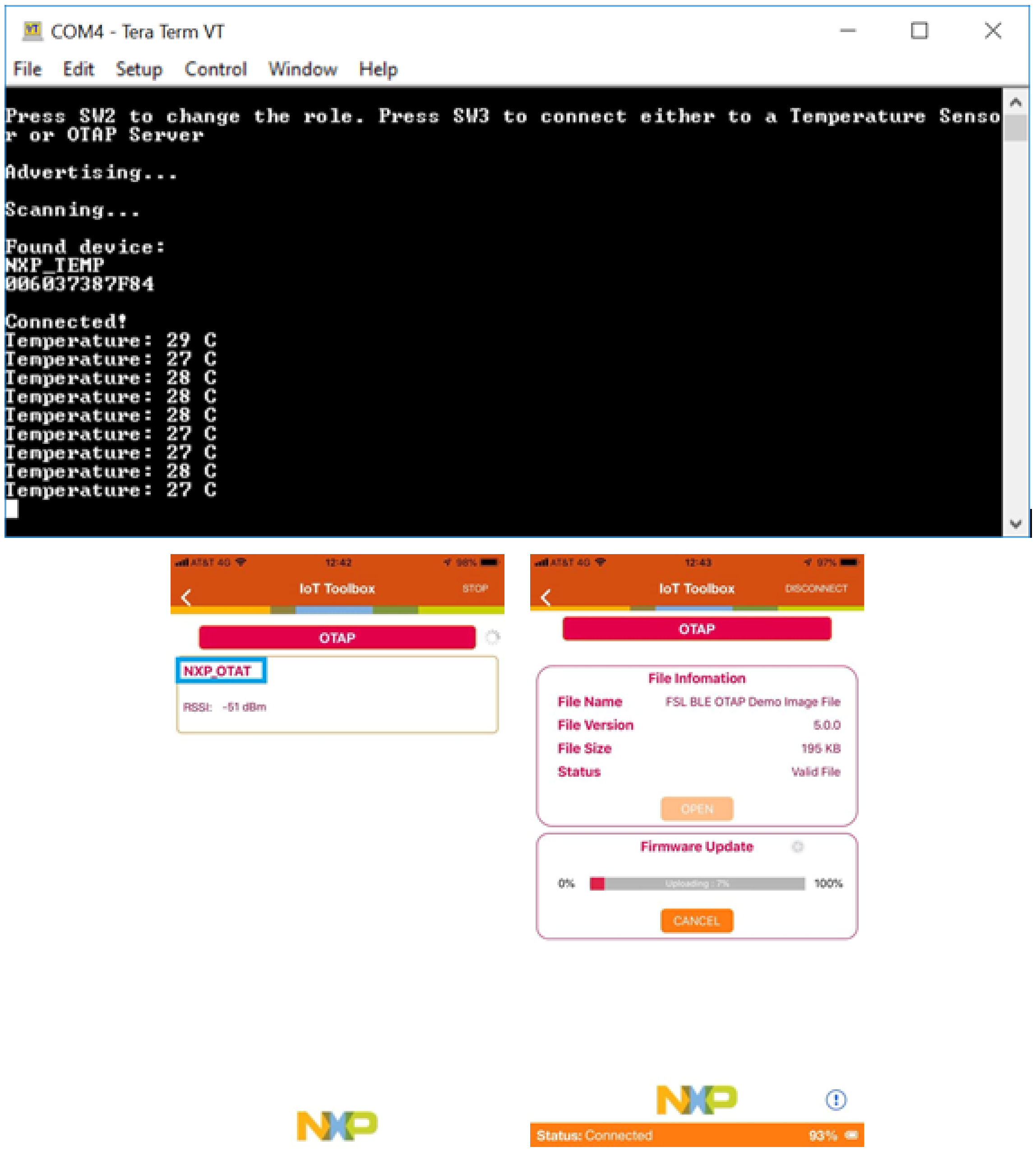
```
Press SW2 to change the role. Press SW3 to connect either to a Temperature Senso
r or OTAP Server
```

Figure 48. Welcome message Temp Coll-OTAP software

7. At this point, the KW38 is programmed with the Temperature Collector, OTAP software. It can establish a connection and interact with either an OTAP Server, acting as a peripheral device (the smartphone running IoT Toolbox) or a Temperature Sensor, as the central device. The **SW2** button on the FRDM KW38 board changes the GAP role of the device, while **SW3** is used to start scanning or advertising depending on the GAP role selected. To connect with a Temperature Sensor, select the GAP Central role with SW2 and start scanning with SW3, the RGB will blink blue when it is scanning.

   You can program the Temperature Sensor SDK example on another FRDM-KW38 board, configuring the preinclude file to disable low power `cPWR_UsePowerDownMode = 0`, and disabling `gAppUseBonding_d = 0` and `gAppUsePairing_d = 0`. This example is located at **wireless_examples -> bluetooth -> temp_sens**.

   To connect with OTAP Server, IoT Toolbox app, select the GAP Peripheral role using the **SW2** button and start advertising with **SW3**, the RGB will blink in red when it is advertising. While the device is advertising, it will be named as **NXP_OTAT**.



```
Press SW2 to change the role. Press SW3 to connect either to a Temperature Senso
r or OTAP Server

Advertising...

Scanning...

Found device:
NXP_TEMP
006037387F84

Connected!
Temperature: 29 C
Temperature: 27 C
Temperature: 28 C
Temperature: 28 C
Temperature: 28 C
Temperature: 27 C
Temperature: 27 C
Temperature: 28 C
Temperature: 27 C
```

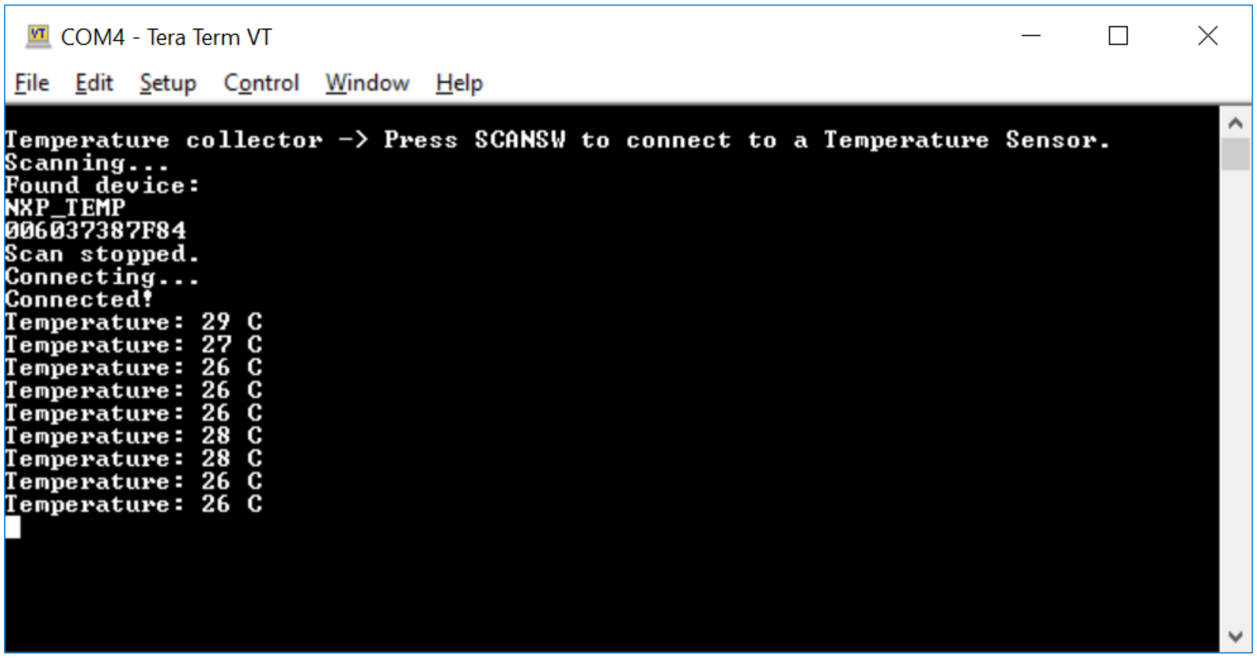
File Infomation

File Name	FSL BLE OTAP Demo Image File
File Version	5.0.0
File Size	195 KB
Status	Valid File

Figure 49. Temp Coll-OTAP device detected by both applications

8. Connect the Temp Coll-OTAP device with the OTAP smartphone application, when the RGB will be ON in green. Update the software using the **Temp Coll** SREC file using the OTAP service.

9. Press the **SCAN** button, **SW2**, on the FRDM-KW38 board to start scanning. Connect the device with a temperature sensor and verify that it works as expected. Now, you can't continue updating the software, as OTAP service was not added to the software update. This demonstrates the importance of integrating OTAP in the software update.



```
Temperature collector -> Press SCANSW to connect to a Temperature Sensor.
Scanning...
Found device:
NXP_TEMP
006037387F84
Scan stopped.
Connecting...
Connected!
Temperature: 29 C
Temperature: 27 C
Temperature: 26 C
Temperature: 26 C
Temperature: 26 C
Temperature: 28 C
Temperature: 28 C
Temperature: 26 C
Temperature: 26 C
```

Figure 50. Temp Coll device connected

Date of release: 11/2020
Document identifier: AN12980