

Bluetooth® Low Energy Demo Applications

User's Guide



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Chapter 1

Introduction

This document describes the Bluetooth® Low Energy stack enablement for the NXP development platforms. The initial chapters start with a presentation of the hardware and toolchain requirements.

Chapter 5 describes the demo applications that can be found in the software development kit. It presents the profiles and services implemented and how to interact with them.

Chapter 2

Bluetooth Low Energy

The Software Development Package provides a Bluetooth Low Energy v5.0-compliant host stack and controller implementation with a set of GATT-based profiles and services implemented on top. To demonstrate the device functionality, the following demo applications are implemented.

- Bluetooth LE Relay Proxy
- Bluetooth LE Shell App
- IPv6 Node and Router (KW41 Platforms)
- OTAP Client and Server
- HID Device (Mouse) and HID Host
- Low Power Temperature Sensor and Collector
- Wireless UART demo application
- Proximity Reporter
- Alert Notification Server
- Heart Rate Sensor
- Blood Pressure Sensor
- Glucose Sensor
- Health Thermometer
- Cycling Speed and Cadence Sensor
- Cycling Power Sensor
- Running Speed and Cadence Sensor
- Beacon Application
- Wireless Power Transfer Receiving and Transmitting Units (KW41 and KW3x Platforms)
- Private Profile Client and Server
- ANCS Client
- Bluetooth LE FSCI Black Box
- HCI Black Box
- Pulse Oximeter Sensor
- Location and Navigation Server
- Location and Navigation Client
- Hybrid Bluetooth LE and Generic FSK advertising demo application

Chapter 3

Hardware Configurations

3.1 Hardware requirements

The NXP Bluetooth LE demo applications are designed to run on any of these supported platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN908XCDK
- FRDM-KW36

3.2 Toolchain requirements

The Bluetooth Low Energy Stack demo applications were compiled and tested with IAR Embedded Workbench for Arm® and MCUXpresso. It is recommended to use one of these tools.

3.3 Freedom FRDM-KW41Z Platform

FRDM-KW41Z Freedom platform is based on the KW41Z wireless, dual-mode SoC, which incorporates an Arm® Cortex®-M0+ core and can be configured to operate at various frequencies, up to 48 MHz. It has 512 KB of Flash and 128 KB of SRAM. A figure representing the platform is shown below. For detailed information about the platform, see the appropriate board user's guide.

The platform features a composite USB device called OpenSDA which serves as debugger interface and as a USB-to-serial converter via a virtual COM port application. Several firmware images can be programmed on the OpenSDA device, such as:

- developer.mbed.org/handbook/CMSIS-DAP
- segger.com/opensda.html
- www.pemicro.com/opensda

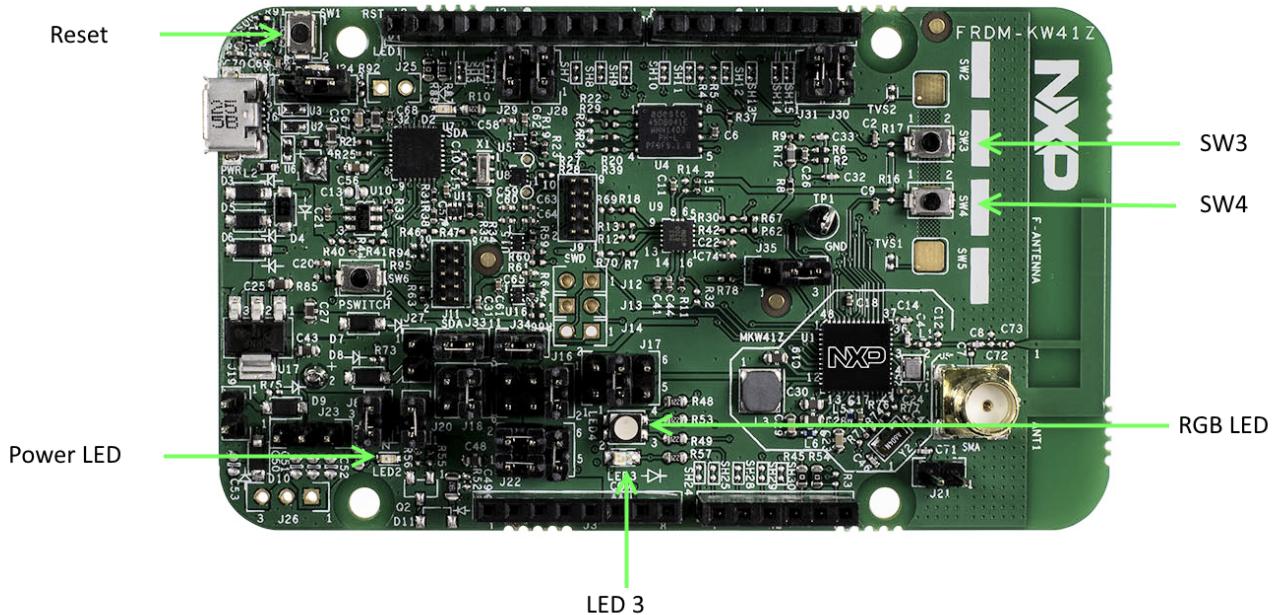


Figure 1. Freedom FRDM-KW41Z platform

3.4 USB-KW41Z platform

The USB-KW41Z board is mainly targeted for sniffer applications. It is based on the same KW41Z wireless, dual mode SoC. A figure representing the platform is shown below. For detailed information about the board, see the appropriate board user's guide.

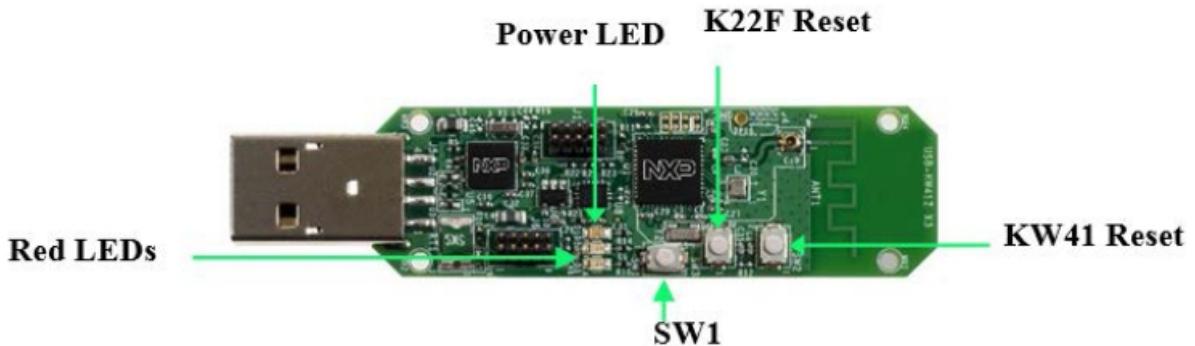


Figure 2. USB-KW41Z platform

3.5 QN9080CDK platform

QN9080CDK platform is based on the QN9080CDK Bluetooth Low Power SoC, which incorporates an Arm® Cortex®-M4F core and can be configured to operate at various frequencies, up to 32 MHz. It has 512 KB of Flash and 128 KB of SRAM. A figure representing the platform is shown below. For detailed information about the platform, see the appropriate board user's guide.

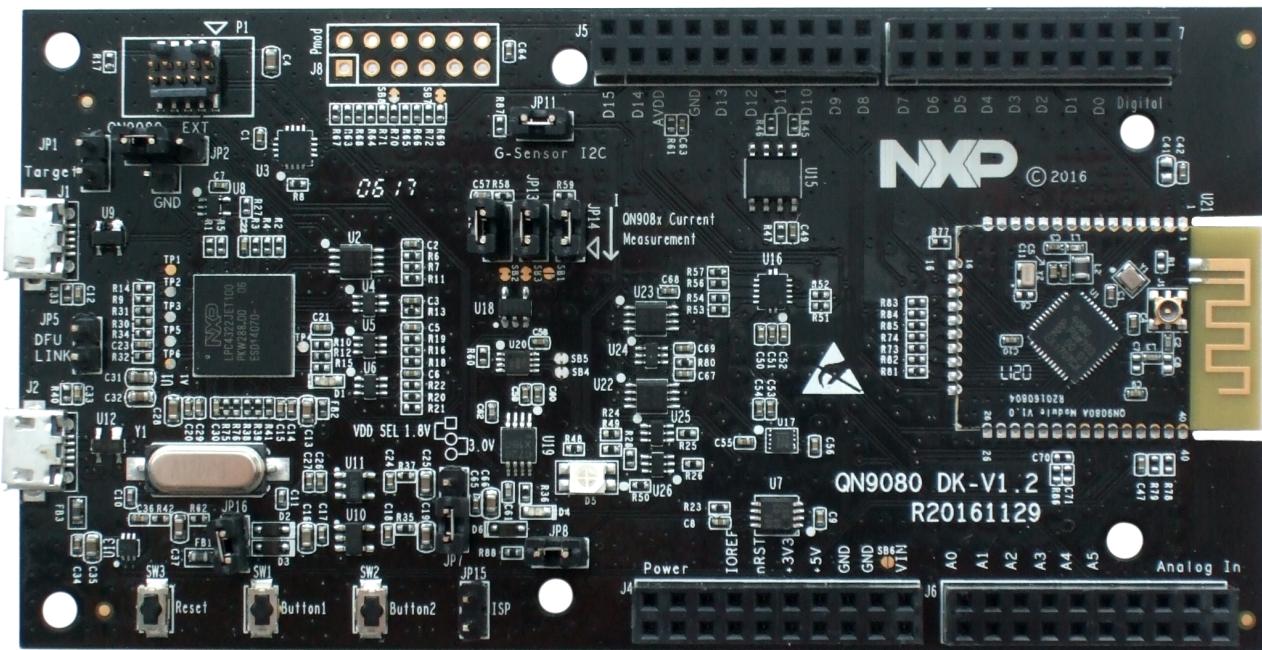


Figure 3. QN9080CDK platform

3.6 Freedom FRDM-KW36 platform

FRDM-KW36 Freedom platform is based on the KW36 SoC which incorporates an Arm® Cortex®-M0+ core and enables Bluetooth Low Energy and Generic FSK. It can be configured to operate at various frequencies, up to 48 MHz and it has 256 KB of on-chip Flash and 64 KB of SRAM. The Bluetooth LE transceiver supports up to 8 concurrent connections in any master/slave combination. A figure representing the platform is shown below. For detailed information about the platform, see the appropriate board user's guide.

The platform features a composite USB device called OpenSDA which serves as debugger interface and as a USB-to-serial converter via a virtual COM port application.

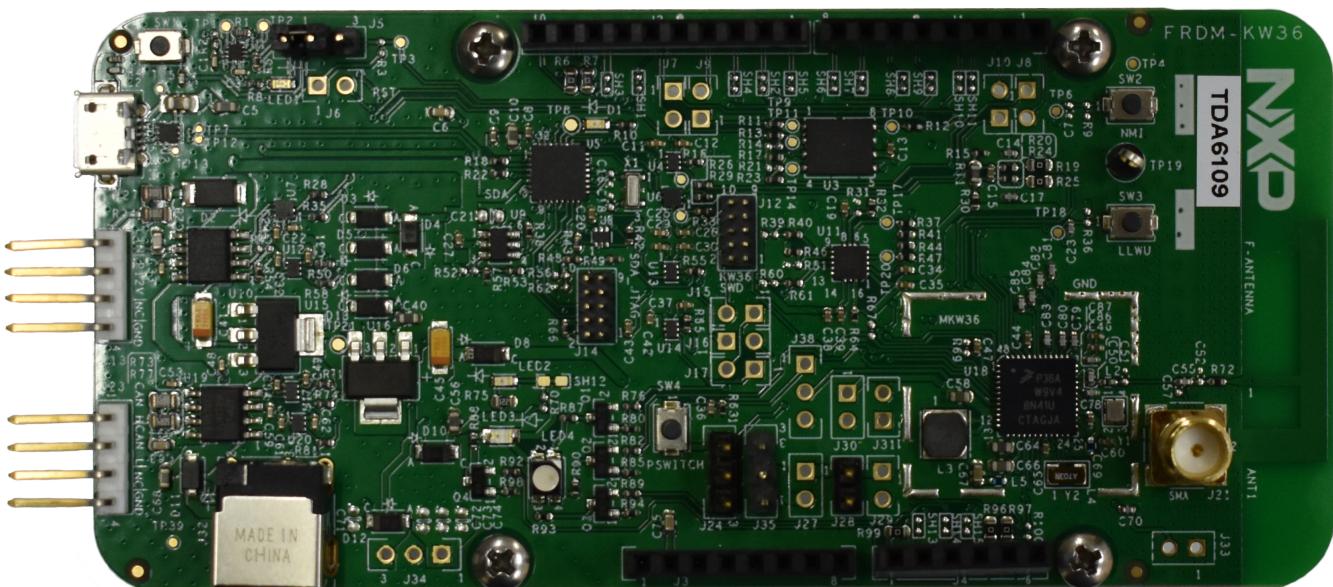


Figure 4. FRDM-KW36 platform

Chapter 4

Build and Run a Bluetooth LE Example Application

To open, build and run any example application, see the corresponding board Bluetooth Low Energy Quick Start Guide document.

4.1 User Interface

The demo applications that implement the Battery Service expose the current battery level, as measured on the board, through the Battery Level characteristic. The value represents a percentage between 0 and 100. The value can be read from the device from a connected GATT client.

The demo applications that implement the Device Information Service expose different information regarding the current software, hardware, and firmware revisions. These values are used as an example and can be modified by the user when developing their product. The values can be read from the device from a connected GATT client.

4.2 Security

The examples that enable pairing always generates a default passkey of 999999 that has to be entered on the central device, in most cases a smartphone or tablet.

4.3 Testing Devices

To demonstrate the profile functionality, most of the scenarios require one of the supported platform and a Bluetooth Low Energy capable central device, usually a smartphone or a tablet that runs a compatible Bluetooth LE application.

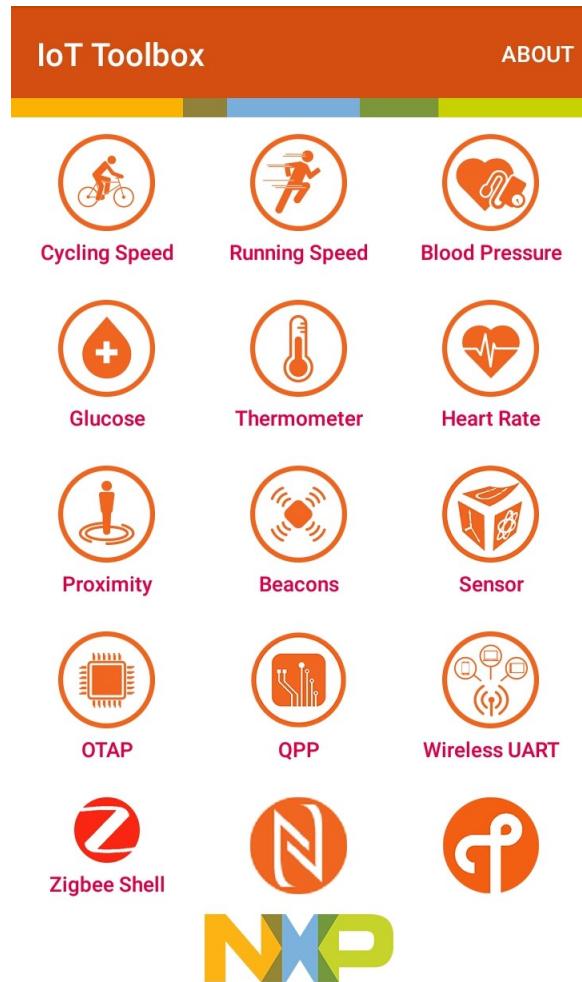


Figure 5. IoT Toolbox

The recommended application is the IoT Toolbox, which can be installed on Apple® iOS or Android™ OS handheld devices that support Bluetooth Low Energy. The application can be found on [iTunes](#) or [Google playstore](#).

Other demos can be run by using two platforms, one for the peripheral and one for the central role, for example IPv6 Node and Router, Low Power Temperature Sensor and Collector, Wireless UART, OTAP Client and Server, HID Host and Device.

To provide feedback and additional interaction, some examples make use of a shell console via the virtual COM port. To access the device, open a serial port terminal and connect it to the platform as shown in the figures below. For this example, Tera Term VT and a FRDM-KW41Z were used. The communication parameters are 115200 and 8N1.

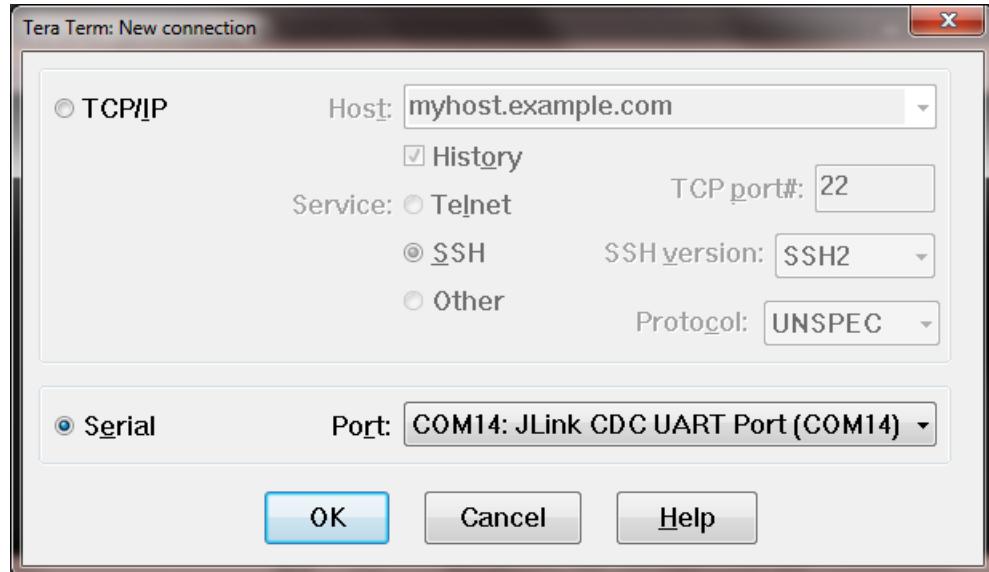


Figure 6. Tera Term – mbed serial port

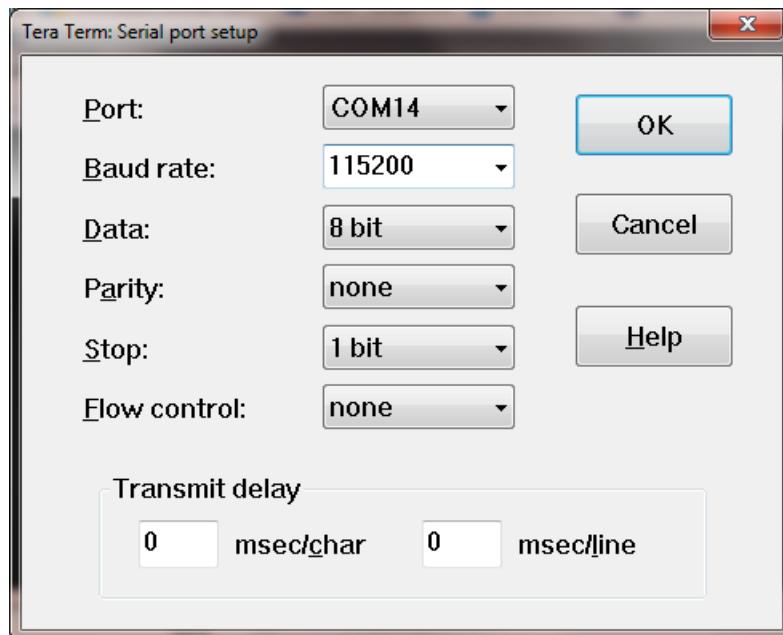


Figure 7. Tera Term – mbed serial port configuration

The start screen is displayed after the board is reset.

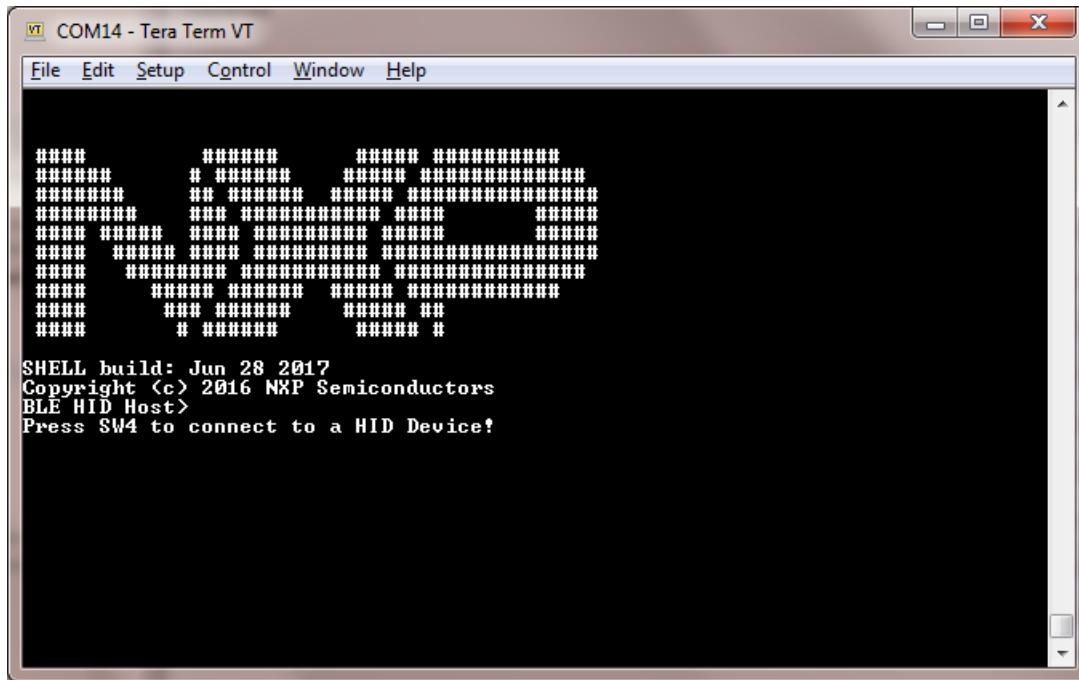


Figure 8. Tera Term – console start

4.4 Time client devices

Some applications implement the Current Time Service. To enable this feature, define gAppUseTimeService_d in the app_preinclude.h file as 1. If the Time Client is enabled, the device must synchronize with a Time Server to update its internal date/time to the current date/time. The Time Client synchronizes with a phone if you connect the device to it (pairing and bonding must be active).

Chapter 5

Bluetooth LE Stack and Demo Applications

5.1 Heart rate sensor

This section describes the implemented profiles and services, user interactions, and testing methods for the Heart Rate Sensor application.

5.1.1 Implemented Profile and Services

The Heart Rate Sensor application implements a GATT server and the following profile and services.

- Heart Rate Profile v1.0
- Heart Rate Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters the GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications, the sensor starts sending heart rate measurements every second.

5.1.2 Supported platforms

The Heart Rate Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.1.3 User interface

After flashing the board, the sensor is put in deep sleep (all LEDs are off). Also, any attached debugger will lose its connection. The application default configuration enables low power, which disables LED support. The user can manually change this and enable LED support, otherwise all subsequent LED behavior references shall be ignored. To wake up and start advertising, press the ADVSW button. When in GAP Discoverable Mode, the CONNLED is on. When the central node connects to the peripheral, the CONNLED remains solid. The heart rate measurement values are generated randomly in the interval 40 to 200 bpm. The heart rate value format is set to 8 bits and the contact status is on.

See details below for hardware references.

Table 1. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED4
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW3	LED3

5.1.4 Usage

The Heart Rate Sensor can be connected to any Bluetooth® Smart Ready products available on the market.

To make the Heart Rate Sensor visible, press the ADVSW button to start sending advertisements. The sensor name “NXP_HRS” shows on the device when its scanning is active. If configured, the sensor notifies the application with heart rate measurements every second. Also, the battery level and various device information is exposed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.

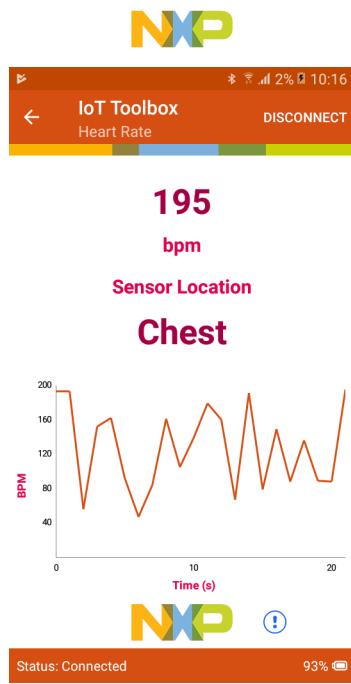
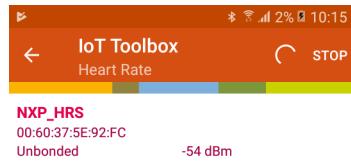


Figure 9. IoT Toolbox Heart Rate Monitor Demo

5.2 Beacon

This section presents the user interactions and testing methods for the Beacon application.

5.2.1 Supported platforms

The Beacon application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.2.2 Advertising data

The beacons are non-connectable advertising packets that are sent on the three advertising channels. The latter contains the following fields.

- Company Identifier (2 bytes): 0x0025 (NXP ID as defined by the Bluetooth SIG).
- Beacon Identifier (1 byte): 0xBC (Allows identifying an NXP Beacon alongside with Company Identifier).
- UUID (16 bytes): Beacon sensor unique identifier.
- A (2 bytes): Beacon application data.
- B (2 bytes): Beacon application data.
- C (2 bytes): Beacon application data.
- RSSI at 1m (1 byte): Allows distance-based applications.

By default, the UUID value is a random value based on the unique identifier of the board.

5.2.3 User interface

After flashing the board, the beacon application starts advertising. When in GAP Discoverable Mode, CONNLED is flashing. Hold the ADVSW button pressed for 2-3 seconds anytime to stop advertising. In idle mode, all LEDs are flashing. To restart advertising, press the ADVSW button.

See details below for hardware references.

Table 2. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.2.4 Usage

The beacon can be tested with any Bluetooth® Smart Ready products available on the market. The IoT Toolbox can also be used to showcase the profile functionality, as shown in the image below.

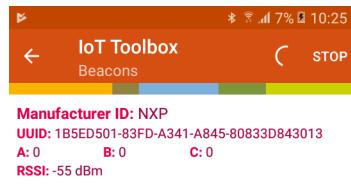


Figure 10. IoT Toolbox Beacon Demo

5.3 Blood pressure sensor

This section describes implemented profiles and services, user interactions, and testing methods for the Blood Pressure Sensor application.

5.3.1 Implemented profile and services

The Blood Pressure Sensor application implements a GATT server and the following profile and services.

- Blood Pressure Profile v1.0
- Blood Pressure Service v1.0
- Battery Service v1.0
- Device Information Service v1.1
- Current Time Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications or indications, the sensor starts sending intermediate cuff pressure and blood pressure measurements. In a 5 second interval, the sensor sends 5 events (4 notifications with the intermediate cuff pressure measurement and one indication with the blood pressure measurement).

5.3.2 Supported platforms

The Blood Pressure Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.3.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button.

When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

The blood and cuff pressure measurement values are generated randomly on the device.

See details below for hardware references.

Table 3. Hardware references

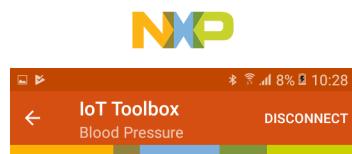
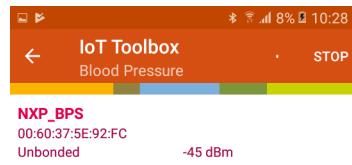
Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.3.4 Usage

The blood pressure sensor can be connected to any Bluetooth® Smart Ready products available on the market.

To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_BPS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the 2 devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect.

If configured, the sensor notifies the application with intermediate cuff pressure each second and blood pressure measurements every 5 seconds. Also, the battery level and various device information is exposed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.



Systolic 122.0 kPa

Diastolic 83.0 kPa

Mean AP 96.0 kPa

Pulse Rate
93.0
bpm

Time & Date
00:00:29 2016 - 01 - 01



Figure 11. IoT Toolbox Blood Pressure Demo

5.4 Glucose Sensor

This section describes implemented profiles and services, user interactions, and testing methods for the Glucose Sensor application.

5.4.1 Implemented profile and services

The Glucose Sensor application implements a GATT server and the following profile and services.

- Glucose Profile v1.0
- Glucose Service v1.0
- Battery Service v1.0

- Device Information Service v1.1
- Current Time Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications, the sensor can send glucose measurements. The latest three measurements are stored on the sensor device and can be retrieved by the collector.

5.4.2 Supported platforms

The Glucose Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.4.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode. When in connection, pressing the ADVSW button triggers a new glucose measurement. The glucose measurement values are generated randomly on the device.

See details below for hardware references.

Table 4. Hardware references

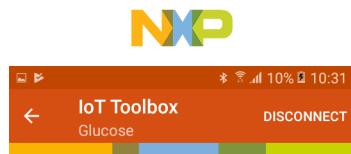
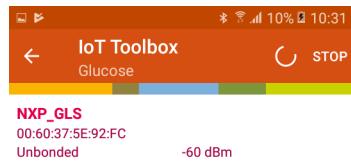
Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.4.4 Usage

The glucose sensor can be connected to any Bluetooth® Smart Ready products available on the market.

To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_GLS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the two devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect.

If notifications are configured, the sensor sends the data to the collector when ADVSW button is pressed for less than 1 second. The measurement data is stored on the sensor. Also, the battery level and various device information is displayed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.



Glucose	Timestamp
2738.74 mg/dl	00:10 2016 - 01 - 01

◀ ▶



Figure 12. IoT Toolbox Glucose Sensor Demo

5.5 Proximity Reporter

This section describes the implemented profiles and services, user interactions and testing methods for the Proximity Reporter application.

5.5.1 Implemented profile and services

The Proximity Reporter application implements a GATT server and the following profile and services.

- Proximity Profile v1.0.1
- Immediate Alert Service v1.0
- TX Power Service v1.0

- Link Loss Service v1.0.1
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect.

The Immediate Alert Service shows the alert level control point. GATT clients can trigger an alert on the device. The TX Power Service exposes the TX Power level that is read from the Bluetooth LE controller. The Link Loss Service exposes a configurable alert level. When the radio link with the central node is suddenly lost, the configured alert is triggered on the reporter node.

5.5.2 Supported platforms

The Proximity Reporter application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.5.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

When a mild alert is triggered on the reporter, RGB LED starts flashing blue. When a high alert is triggered on the reporter, both RGB LED starts flashing green.

See details below for hardware references.

Table 5. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.5.4 Usage

The proximity reporter can be connected to any Bluetooth® Smart Ready products available on the market. To make the sensor visible, press ADVSW to start advertising which causes CONNLED to start flashing. The sensor name "NXP_PXR" shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the two devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect. When a link loss is detected or when an alert is written on the control point, the user interface exposes the alert level on the RGB LED as stated previously.

Also, the battery level and various device information is displayed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.

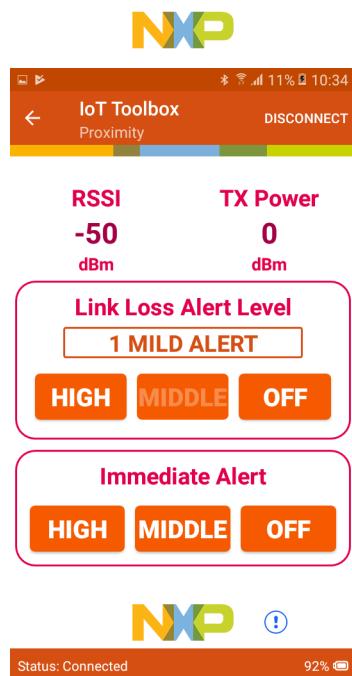
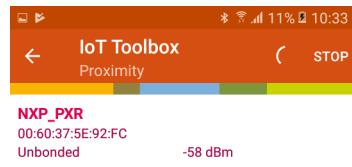


Figure 13. IoT Toolbox Proximity Reporter Demo

5.6 HID Device (Mouse)

This section describes implemented profiles and services, user interactions, and testing methods for the HID mouse application.

5.6.1 Implemented profiles and services

The HID Device application implements a GATT server and the following profile and services.

- HID over GATT Profile v1.0
- Human Interface Device Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. Security on the services and bonding is enabled on this device.

When the GATT client configures notification, the application starts sending HID reports every two seconds with the movement of the MOUSE_STEP. The demo moves the cursor in a square pattern between AXIS_MIN and AXIS_MAX. The report contains 3 bytes, one for button status, one for X axis, and one for Y axis. The report descriptor matches the example in chapter E.10 from the USB Device Class Definition for Human Interface Devices (USB HID Specification), Version 1.11.

5.6.2 Supported platforms

The HID Device application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.6.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

See details below for hardware references.

Table 6. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.6.4 Usage

The HID mouse can be connected to any Bluetooth Smart Ready products available on the market that supports HID devices or to another supported platform running the HID Host example (setup steps detailed in the HID Host section).

To make the HID mouse visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_HID” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the 2 devices. When prompted to enter the pin, type the 999999 passkey.

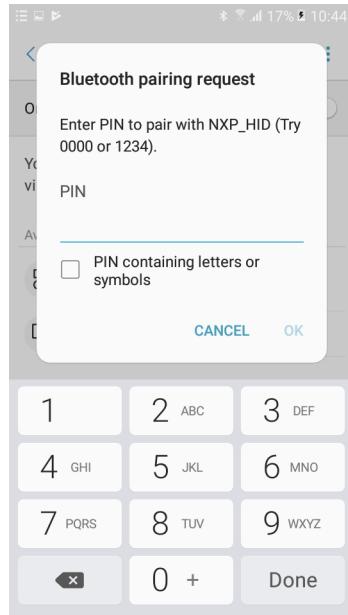


Figure 14. Enter PIN prompt on Android platform

When configured, the HID mouse starts sending HID report, which is configured as explained above, with notifications every 100 milliseconds. The mouse cursor shows a square pattern movement on the screen.

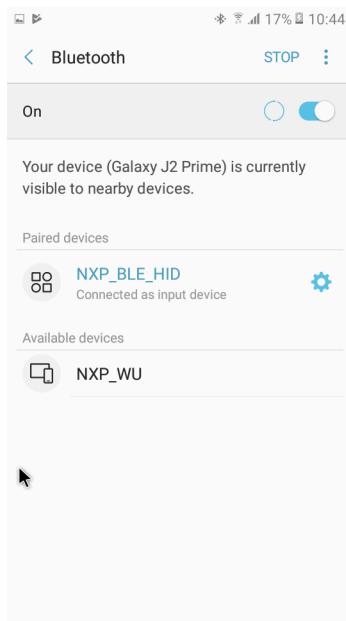


Figure 15. HID Mouse detected by Android platform

5.7 HID Host

This section presents the implemented profiles and services, user interactions, and testing methods for the HID Host application.

5.7.1 Implemented profiles and services

The HID Host application implements a GATT client or server for the following profile and service.

- HID over GATT Profile v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP central node. It enters the GAP Limited Discovery Procedure and searches for HID devices to connect to. After connecting with the peripheral, it configures notifications and displays the received HID reports on a terminal connected to the UART port. The application uses pairing with bonding by default. When connected with the HID Device application, it sends the 999999 passcode to the host stack by default.

5.7.2 Supported platforms

The HID Host application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.7.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the SCANSW button pressed for 2-3 seconds. The node then re-enters GAP Limited Discovery Procedure.

See details below for hardware references.

Table 7. Hardware references

Platform	SCANSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.7.4 Usage

The application is built to work only with the HID Device application presented in the previous subchapter and it supports up to 2 peripherals connected at the same time.

1. Open a serial port terminal and connect it to board, in the same manner described in section 5.1.3. The start screen is displayed after the board is reset.
2. Press the SCANSW button on the HID Host board to start scanning for devices. Do the same on the HID device board to make it enter discoverable mode. The host connects with the board after it sees it advertise the HID service, connects to it, and configures report notifications. The device then starts sending HID reports, as shown below.

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect.

5.8.2 Supported platforms

The Private Profile Server application is supported by the following platforms:

- QN9080CDK

5.8.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

See details below for hardware references.

Table 8. Hardware references

Platform	ADVSW	CONNLED
QN9080CDK	BUTTON1	D5-RED

5.8.4 Usage

The Private Profile Server can be connected to any supported platforms running Private Profile Client application.

To make the Private Profile Server visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The device is visible with the name "NXP_QPP". A solid CONNLED indicates a successful connection between 2 devices.

The Private Profile is a custom service that implements two custom characteristic:

- Rx Characteristic (UUID: d44bc439-abfd-45a2-b575-925416129600), used to write data to the server
- Tx Characteristic (UUID: d44bc439-abfd-45a2-b575-925416129601), used to get data from the server through notifications

When in connection and if notifications are configured, the Private Profile Server starts sending data every 100 milliseconds through GATT instant value notifications. If the client starts writing the Rx characteristic, the value length received will be monitored in the data Rx callback. Every 10 seconds, a throughput statistics is made and Tx/Rx results are printed on the serial interface.

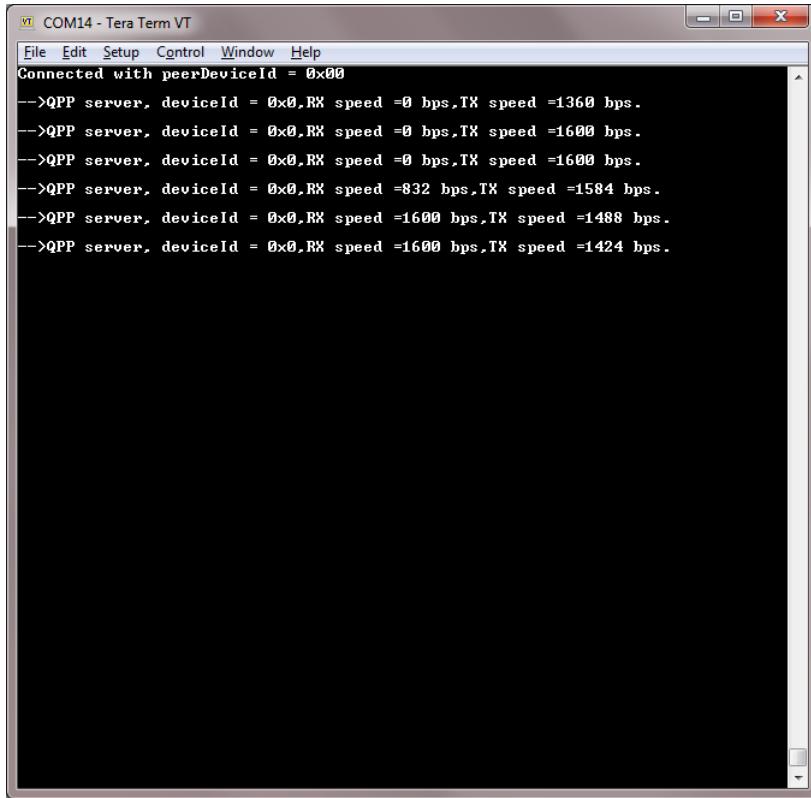


Figure 18. Private Profile Server – Output Console

5.9 Private Profile Client

This section describes the implemented profiles and services, user interactions, and testing methods for the Private Profile Client application.

5.9.1 Implemented profiles and services

The Private Profile Client application implements a GATT client or server for the following profile and service.

- Private Profile (UUID: 0000fee9-0000-1000-8000-00805f9b34fb)
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP central node. It enters the GAP Limited Discovery Procedure and searches for Private Profile servers to connect to. After connecting with the peripheral, it configures notifications and monitors the data received through notifications.

5.9.2 Supported platforms

The Private Profile Client application is supported by the following platforms:

- QN9080CDK

5.9.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns

solid. To disconnect the node, hold the SCANSW button pressed for 2-3 seconds. The node then re-enters GAP Limited Discovery Procedure.

See details below for hardware references.

Table 9. Hardware references

Platform	SCANSW	CONNLED	SENDSW
QN9080CDK	BUTTON1	D5-RED	BUTTON2

5.9.4 Usage

The application is built to work only with the Private Profile Server application presented in the previous subchapter.

1. Open a serial port terminal and connect it to board, in the same manner described in section 5.1.3. The start screen is displayed after the board is reset.
2. Press the SCANSW button on the Private Profile Client board to start scanning for devices. Press the ADVSW button on the Private Profile Server board to make it enter discoverable mode. The client connects to the server after it sees it advertise the Private Profile Service. The client then configures notifications and monitors data received through notifications.
3. If the user wants to also send data from the client to the server, after pressing SENDSW, the client starts writing the Rx characteristic every 100 milliseconds.

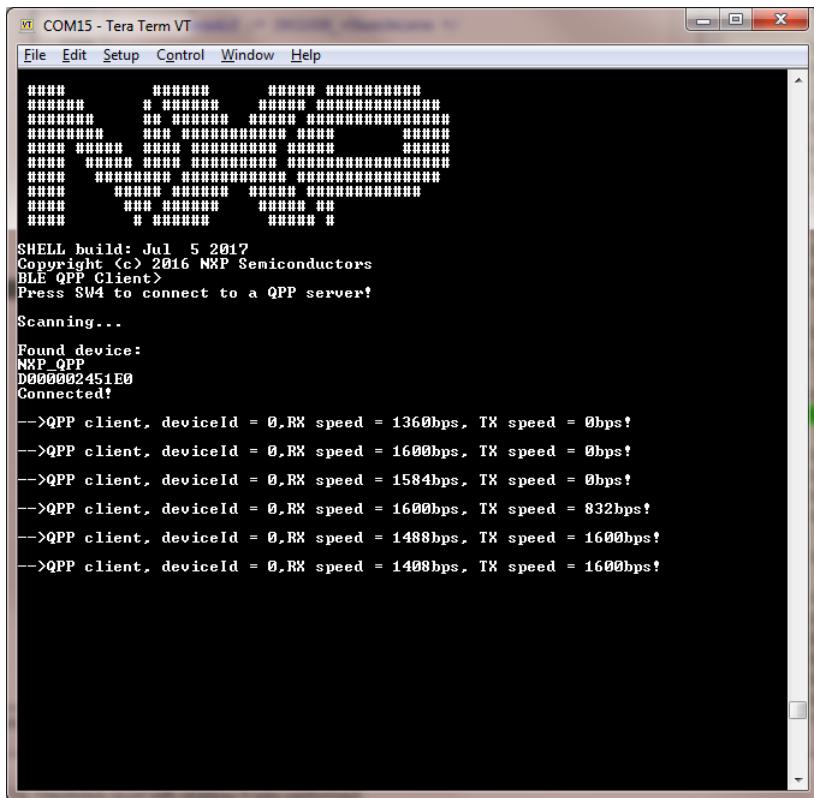


Figure 19. Private Profile Client – Output Console

5.10 Cycling Speed and Cadence Sensor

This section describes the implemented profiles and services, user interactions, and testing methods for the Cycling Speed and Cadence Sensor application.

5.10.1 Implemented profiles and services

The Cycling Speed and Cadence application implements a GATT server and the following profile and services.

- Cycling Speed and Cadence Profile v1.0
- Cycling Speed and Cadence Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications, the sensor starts sending speed and cadence measurements. The measurement values are generated randomly on the device.

5.10.2 Supported platforms

The Cycling Speed and Cadence Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.10.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode

See details below for hardware references.

Table 10. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.10.4 Usage

The sensor can be connected to any Bluetooth Smart Ready products available on the market. To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name "NXP_CSCS" shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the 2 devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect.

If configured, the sensor notifies the application with speed and cadence measurements every second. Also, the battery level and various device information is exposed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.

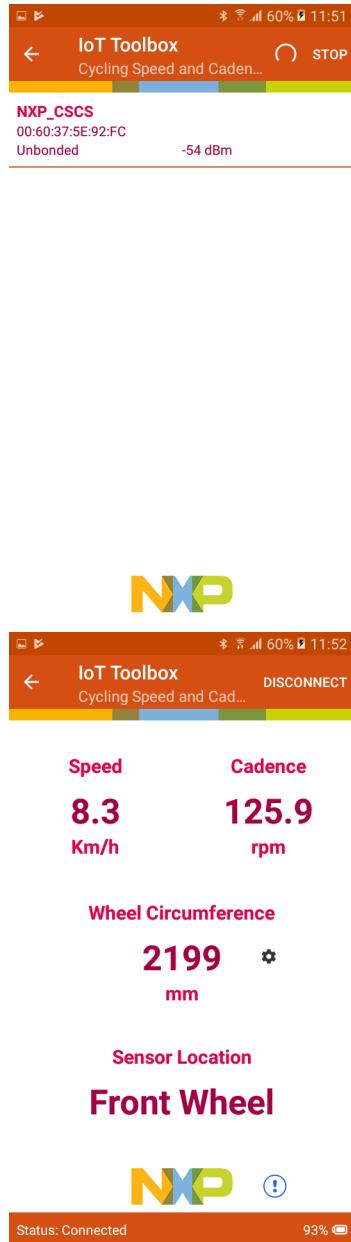


Figure 20. IoT Toolbox Cycling Speed and Cadence Sensor Demo

5.11 Cycling Power Sensor

This section presents the implemented profiles and services, user interactions, and testing methods for the Cycling Power Sensor application.

5.11.1 Implemented profiles and services

The Cycling Power Sensor application implements a GATT server and the following profile and services.

- Cycling Power Profile v1.0
- Cycling Power Service v1.0
- Battery Service v1.0

- Device Information Service v1.1
- Current Time Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications and/or indications, the sensor starts sending power measurements. The measurement values are generated randomly on the device.

5.11.2 Supported platforms

The Cycling Power Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.11.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

Because all the fields in the power measurement cannot fit into one single ATT frame, the user can toggle the optional fields by pressing the TOGSW button.

See details below for hardware references.

Table 11. Hardware references

Platform	ADVSW	CONNLED	TOGSW
FRDM-KW41Z	SW4	LED3	SW3
QN9080CDK	BUTTON1	D5-RED	BUTTON2
FRDM-KW36	SW2	LED3	SW3

5.11.4 Usage

The sensor can be connected to any Bluetooth Smart Ready products available on the market. To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_CPS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the 2 devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect. If configured, the sensor notifies the application with power measurements. Also, the battery level and various device information is displayed for reading.

To demonstrate profile functionality, any bike application (from Health & Fitness category) can be installed on Apple iOS or Android OS handheld devices that support Bluetooth Low Energy.

5.12 Running Speed and Cadence Sensor

This section describes the implemented profiles and services, user interactions, and testing methods for the Running Speed and Cadence Sensor application.

5.12.1 Implemented profiles and services

The Running Speed and Cadence application implements a GATT server and the following profile and services.

- Running Speed and Cadence Profile v1.0
- Running Speed and Cadence Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications, the sensor starts sending speed and cadence measurements. The measurement values are generated randomly on the device.

5.12.2 Supported platforms

The Running Speed and Cadence Sensor application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.12.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

When the node is connected, the user can toggle the running status (running/walking) by pressing the TOGSW button. When the status is set to “walking” the RGB LED turns solid. When the status is set to “running”, the RGB LED is not lit.

See details below for hardware references.

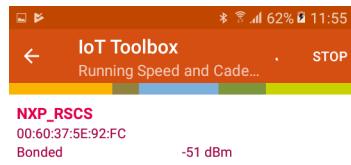
Table 12. Hardware references

Platform	ADVSW	CONNLED	TOGSW
FRDM-KW41Z	SW4	LED3	SW3
QN9080CDK	BUTTON1	D5-RED	BUTTON2
FRDM-KW36	SW2	LED3	SW3

5.12.4 Usage

The sensor can be connected to any Bluetooth® Smart Ready products available on the market. To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_RSCS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the two devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect.

If configured, the sensor notifies the application with speed and cadence measurements every second. Also, the battery level and various device information are exposed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.



Speed Cadence
10.8 **60**
 Km/h rmp

Run

Stride Length 0.22 m
 Total Distance 10 m

Sensor Location

Top Of Shoe



Status: Connected 93%

Figure 21. IoT Toolbox Running Speed and Cadence Demo

5.13 Health Thermometer

This section presents the implemented profiles and services, user interactions, and testing methods for the Health Thermometer application.

5.13.1 Implemented profiles and services

The Health Thermometer application implements a GATT server and the following profile and services.

- Health Thermometer Profile v1.0
- Health Thermometer Service v1.0
- Battery Service v1.0

- Device Information Service v1.1
- Current Time Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications or indications, the sensor starts sending intermediate temperature and temperature measurements.

In a 5 second interval, the sensor sends 5 events (4 notifications with the intermediate temperature and one indication with the temperature measurement). The intermediate temperature and temperature measurements are generated randomly on the device.

5.13.2 Supported platforms

The Health Thermometer application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.13.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press ADVSW. When in GAP Discoverable Mode CONNLED is flashing. When the central node connects to the peripheral CONNLED turns solid. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect. The node re-enters the GAP Discoverable Mode.

See details below for hardware references.

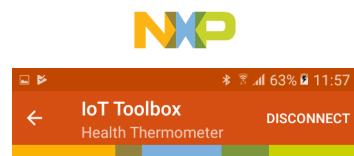
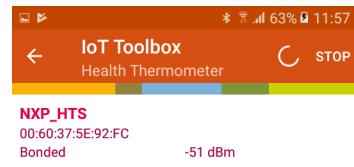
Table 13. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.13.4 Usage

The sensor can be connected to any Bluetooth® Smart Ready products available on the market. To make the sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_HTS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the two devices. Hold the ADVSW button pressed for 2-3 seconds anytime to initiate disconnect.

If configured, the sensor notifies the application with temperature measurements. Also, the battery level and various device information are exposed for reading. The IoT Toolbox can be used to showcase the profile functionality, as shown in the image below.



Temperature
38.0 °C

Sensor Location
Armpit



Figure 22. IoT Toolbox Health Thermometer Demo

5.14 Low Power Temperature Sensor and Collector

This section describes the implemented profiles and services, user interactions, and testing methods for the temperature sensor application.

5.14.1 Implemented profiles and services

The Temperature Sensor application implements a GATT server, a custom profile and the following services.

- Temperature Service (UUID: 01ff0200-ba5e-f4ee-5ca1-eb1e5e4b1ce0)
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect and configure notifications for the temperature value.

The Temperature service is a custom service that implements the Temperature characteristic (UUID: 0x2A6E) with a Characteristic Presentation Format descriptor (UUID: 0x2904), both defined by the Bluetooth SIG.

The Temperature Collector application implements a GATT client or server for the following profile and services.

- Temperature Service (UUID: 01ff0200-ba5e-f4ee-5ca1-eb1e5e4b1ce0)
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP central node. It enters GAP Limited Discovery Procedure and searches for sensor devices to pair with. After pairing with the peripheral, it configures notifications and displays temperature values on a terminal connected to the UART port.

Both application uses pairing with bonding by default. When connected with the Low Power Temperature Sensor application, the collector sends the 999999 passcode to the host stack by default.

5.14.2 Supported platforms

The Temperature Sensor and Collector applications are supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

NOTE

On FRDM-KW36 and FRDM-KW38, deep-sleep modes 5 and 8 are used by default.

5.14.3 User interface

After flashing the board, both nodes enter cPWR_DeepSleepMode deep-sleep mode (3 - LLS or 5 - VLLS). The application default configuration enables low power which disables LED support. The user can manually change this and enable LED support, else all subsequent LED behavior references are ignored. All LEDs are off. When the node is awake and communicating, CONNLED is on. To wake up the node press the WAKESW button.

See details below for hardware references.

Table 14. Hardware references

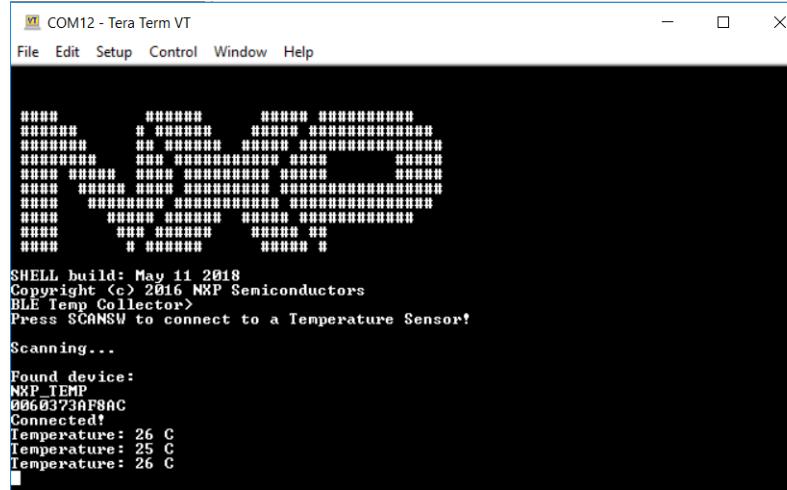
Platform	WAKESW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW3	LED3

5.14.4 Usage

The setup requires two supported platforms, one for the temperature sensor and one for the temperature collector.

1. Open a serial port terminal and connect it to the temperature collector board, in the same manner as described in 5.1.3. The start screen is displayed after the board is reset. At first the LEDs are off on both devices.

2. To start advertising on the sensor, press the WAKESW button and CONNLED lights up. The sensor enters into the gAppDeepSleepMode_c deep-sleep mode (1 - LLS or 8 - VLLS), which means that the MCU wakes up on any packet from the Link layer, in this case the connect request. If no connection is established in an interval of 30 seconds, the sensor stops advertising and enters into the cPWR_DeepSleepMode again. CONNLED turns off.
3. To start scanning on the collector, press the WAKESW button and CONNLED lights up. The device wakes up, enters into the cPWR_DeepSleepMode deep-sleep mode 6, scans and connects to a compatible sensor device. If no connection is established within 10 seconds, the collector stops scanning and enters deep-sleep mode (for QN9090/K32W061 is deep sleep mode 3) again. CONNLED turns off.
4. If the collector connects to a sensor node, it bonds (if no bond was previously made), does service discovery (only the first time it connects with the sensor) and configures notification and waits for notifications from the sensor for 5 seconds. If no data is sent, the node disconnects and re-enters cPWR_DeepSleepMode. The sensor exits low power and sends a notification with the value of the temperature read through an ADC from the thermistor, if present, or random generated if not.



The screenshot shows a terminal window titled "COM12 - Tera Term VT". The window has a menu bar with "File", "Edit", "Setup", "Control", "Window", and "Help". Below the menu is a scrollable text area. The text displays a logo consisting of a grid of symbols, followed by the text:
SHELL build: May 11 2018
Copyright <> 2016 NXP Semiconductors
BLE Temp Collector>
Press SCANSW to connect to a Temperature Sensor!
Scanning...
Found device:
NXP TEMP
00E0373A8AC
Connected!
Temperature: 26 C
Temperature: 25 C
Temperature: 26 C

Figure 23. Tera Term – Output Console on Temperature Collector

5. Subsequent key pressing triggers other notifications for the collector. If no key is pressed in an interval of 5 seconds, the sensor node disconnects and re-enters cPWR_DeepSleepMode.

5.15 IPv6 Router and Node (KW41 Platforms)

For information about the IPv6 Node and Router applications, see the *Bluetooth® Low Energy Transport for IPv6 Datagrams* (document BLEIP6UG).

5.16 Alert Notification Server

This section describes the implemented profiles and services, user interactions, and testing methods for the Alert Notification Server application.

5.16.1 Implemented profile and services

The Alert Notification application implements a GATT client or server for the following profile and services.

- Alert Notification Profile v1.0
- Alert Notification Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

- Current Time Service v1.1
- Next DST Change Service v1.0
- Reference Time Update Service v1.0

The application behaves as a GAP central node. It enters the GAP Limited Discovery Procedure and searches for Alert Notification Clients or Time Clients to connect to. After connecting with the peripheral, it waits for notifications to be configured.

5.16.2 Supported platforms

The Alert Notification Server application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.16.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the SCANSW button pressed for 2-3 seconds. The node then re-enters GAP Limited Discovery Procedure.

When in connection and if notifications are configured, pressing the ALERTSW button triggers a new alert notification (“New mail”) to be sent to the GATT client and adjusts the time of the device by +1 hour. Holding the ALERTSW button for 2-3 seconds triggers a new unread alert status notification (missed call) to be sent to the same GATT client.

See details below for hardware references.

Table 15. Hardware references

Platform	SCANSW	CONNLED	ALERTSW
FRDM-KW41Z	SW4	LED3	SW3
QN9080CDK	BUTTON1	D5-RED	BUTTON2
FRDM-KW36	SW2	LED3	SW3

5.16.4 Usage

The application can be tested against the Profile Tuning Suite (PTS) black-box testing tool from the Bluetooth SIG.

5.17 Wireless UART

This section describes the implemented profiles and services, user interactions, and testing methods for the Wireless UART application.

5.17.1 Implemented profile and services

The Wireless UART application implements both the GATT client and server for the custom Wireless UART profile and services.

- Wireless UART Service (UUID: 01ff0100-ba5e-f4ee-5ca1-eb1e5e4b1ce0)
- Battery Service v1.0
- Device Information Service v1.1

The Wireless UART service is a custom service that implements a custom writable ASCII Char characteristic (UUID: 01ff0101-ba5e-f4ee-5ca1-eb1e5e4b1ce0) that holds the character written by the peer device.

The application behaves at first as a GAP central node. It enters GAP Limited Discovery Procedure and searches for other Wireless UART devices to connect. If the node fails to find any peripherals within seconds, it changes its role to a GAP peripheral. It enters GAP General Discoverable Mode and waits for a GAP central node to connect.

5.17.2 Supported platforms

The Wireless UART application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.17.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure of GAP General Discoverable Mode, CONNLED is flashing. When the node connects to a peer device, CONNLED turns solid. To disconnect the node, hold the SCANSW button pressed for 2-3 seconds. The node then re-enters GAP Limited Discovery Procedure.

See details below for hardware references.

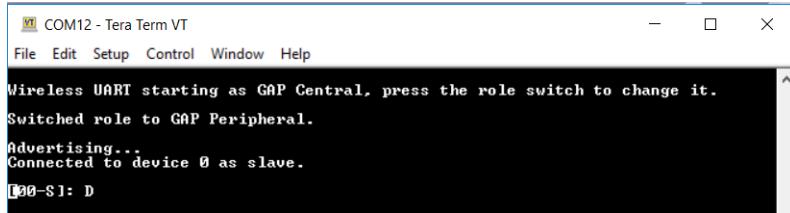
Table 16. Hardware references

Platform	SCANSW	CONNLED	ROLESW
FRDM-KW41Z	SW4	LED3	SW3
QN9080CDK	BUTTON1	D5-RED	Button2
FRDM-KW36	SW2	LED3	SW3

5.17.4 Usage

The application is built to work with another supported platform running the same example or with the Wireless UART from the IoT Toolbox application. When testing with two boards do the following.

1. Open a serial port terminal and connect them to the two boards, in the same manner described in section 5.1.3. The start screen is blank after the board is reset.
2. The application starts as a GAP central. To switch the role to a GAP peripheral, press the role switch. Depending on the role, when pressing the SCANSW, the application starts either scanning or advertising.
3. As soon as the CONNLED turns solid on both devices, the user can start writing in one of the consoles. The text appears on the other terminal, as shown in the figure below.
4. After creating a connection, the role (master or slave) is printed in the console. The role switch can be pressed again before creating a new connection.

**Figure 24. Tera Term – received text on Wireless UART**

When testing with one board and the IoT Toolbox do the following.

1. Open a serial port terminal and connect the board in the same manner described in section 5.1.3. The start screen is blank after the board is reset.
2. Press the role switch button to behave as a GAP peripheral and then press the SCANSW to start advertising. The IoT Toolbox app can then connect. Select UART instead of Console and start typing.

5.18 Bluetooth LE Shell

This section describes the functionality, user interactions, and testing methods for the Bluetooth LE Shell Application.

5.18.1 Implemented stack features

The Bluetooth LE Shell Application implements a console application that allows the user to interact with a full feature Bluetooth Low Energy stack library. It implements All GAP roles and both GATT client and server. Enabling these roles can be done using shell commands.

5.18.2 Implemented profile and services

The application implements a dynamic GATT database. The user can add services at runtime and also erase the database contents. The database is always populated with the GAP and GATT services. These services cannot be erased. The user can dynamically add the following services.

- Heart Rate Service (UUID: 0x180D)
- Battery Service (UUID: 0x180F)
- Device Information Service (UUID: 0x180A)
- Internet Support Profile Service (0x1820)

5.18.3 Supported platforms

The Bluetooth LE Shell application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.18.4 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). The interaction with the board is done entirely by using the shell commands via the serial communication terminal.

5.18.5 Usage

The application is built to work with any other Bluetooth LE device. To showcase the functionality, two platforms are used in the following setup.

1. Open a serial port terminal and connect them to the two boards, in the same manner described in section 5.1.3. The start screen is displayed after the board is reset. All LEDs are flashing on both devices.
2. Configure one of the devices as a GAP peripheral and a Heart Rate server. Change name to HRS. Start advertising on this device.

```
Kinetis Shell>gap devicename HRS
--> GATTDB Event: Attribute Written
HRS>gap advdata 1 6
--> GAP Event: Advertising data successfully set.
HRS>gap advdata 8 HRS
--> GAP Event: Advertising data successfully set.
HRS>gap advstart
--> GAP Event: Advertising started.
HRS>gattdb addservice 0x180D
--> Heart Rate
- Heart Rate Measurement Value Handle: 14
- CCCD Handle: 15
- Body Sensor Location Value Handle: 17
- Heart Rate Control Point Value Handle: 19
--> GATTDB Event: Service Added in database.
```

3. Configure the other device as a GAP central. Change name as Collector. Start scanning and connect to the HRS device by selecting the corresponding device index. In the example below, the HRS device is device number 2.

```
Kinetis Shell>gap devicename Collector
--> GATTDB Event: Attribute Written
Collector>gap scanstart
--> GAP Event: Scan started.
Collector>
--> GAP Event: Found device 0 : 880F102F500E 0 dBm
--> GAP Event: Found device 1 : NXP_CSCS 00049F000006 0 dBm
--> GAP Event: Found device 2 : HRS 00049F0000FF 0 dBm
Collector>gap connect 2
--> GAP Event: Scan stopped.
Collector>
--> GAP Event: Connected
```

4. Optionally, the devices can be paired. On the collector initiate the pairing.

```
Collector>gap pair
--> Pairing...
--> GAP Event: Passkey is 792910
```

5. On the HRS, enter the pin displayed by the collector, as shown below. If the leSecureConnectionSupported member of gPairingParameters, from app_config.c is enabled, then the PIN is not required.

```
HRS>
--> GAP Event: PIN required
```

```
HRS>gap enterpin 792910  
--> GAP Event: Device Paired.
```

6. On the Collector, start service discovery. The device discovers the GAP, GATT and Heart Rate services.

```
Collector>gatt discover -all  
--> Discovered primary services: 3  
--> Generic Access Start Handle: 1 End Handle: 7  
- Device Name Value Handle: 3  
- Appearance Value Handle: 5  
- Peripheral Preferred Connection Parameters Value Handle: 7  
--> Generic Attribute Start Handle: 8 End Handle: 11  
- Service Changed Value Handle: 10  
- Client Characteristic Configuration Descriptor Handle: 11  
--> Heart Rate Start Handle: 12 End Handle: 19  
- Heart Rate Measurement Value Handle: 14  
- Client Characteristic Configuration Descriptor Handle: 15  
- Body Sensor Location Value Handle: 17  
- Heart Rate Control Point Value Handle: 19
```

7. Configure the HRS to send notifications by writing the CCCD from the Collector. Send a GATT write command with value 1 to the CCCD handle discovered, 15.

```
Collector>gatt write 15 0x0001
```

8. Send heart rate measurement notifications from the HRS device by using the value handle obtained after adding the service in the previous step.

```
HRS>gatt notify 14
```

9. A notification appears on the Collector console.

```
Collector>  
--> GATT Event: Received Notification  
Handle: 14  
Value: B400
```

5.18.6 Throughput feature

The Bluetooth LE Shell application also has a throughput test feature which can be used to test different combinations of connection interval, payload size, and packet count to determine the best data-rate.

This feature requires two devices:

- GAP Peripheral: transmits the test packets
- GAP Central: receives the packets and display a report

All throughput related commands are grouped under the “thruput” keyword:

- thrput start tx: configures the device as a GAP Peripheral and start advertising. Once the receiving device is connected, the packet transmission will start. The packet size and count can also be specified (-s <size_value> -c <count_value>).
- thrput start rx: configures the device as a GAP Central and will start scanning. Once a transmitter device is found, it will connect to it and wait for the test to begin. The connection interval can also be configured (-ci <value>).
- thrput stop: will stop the test and disconnect the devices.

Once a connection has been established between the devices and initial throughput test end, one can start a new throughput transmission test with a new set of parameters (packet size / count).

The receiving device will generate the report if no packets were received for more 3 consecutive connection events.

The default config of the throughput test is the following:

Packet count: 1000

Payload size: 20 bytes

Connection interval (min,max): 160, 160 (200ms)

Example of a test report:

```
*****
***** TEST REPORT *****
*****

Packets received: 1000
Total bytes: 244000
Receive duration: 4162 ms
Average bitrate: 469 kbps

*****
*** END OF REPORT ***
*****
```

5.19 Over the Air Programming (OTAP)

This section describes the implemented profiles and services, user interactions, and testing methods for the Bluetooth LE OTAP application.

5.19.1 Implemented profile and services

The Bluetooth LE OTAP applications implement the GATT client and server for the custom Bluetooth LE OTAP profile and service.

- Bluetooth LE OTAP Service (UUID: 01ff5550-ba5e-f4ee-5ca1-eb1e5e4b1ce0)

The Bluetooth LE OTAP Service is a custom service which has 2 characteristics.

- OTAP Control Point Characteristic (UUID: 01ff5551-ba5e-f4ee-5ca1-eb1e5e4b1ce0). This characteristic can be written and indicated to exchange OTAP Commands between the OTAP Server and the OTAP Client. Data chunks are not transferred using this characteristic.
- OTAP Data Characteristic (UUID: 01ff5552-ba5e-f4ee-5ca1-eb1e5e4b1ce0). This characteristic can be written without response by the OTAP Server to transfer image file data chunks to the OTAP Client only when an image block transfer is requested via the ATT transfer method. Data chunks can also be transferred via the L2CAP credit based PSM channels method.

The demo runs using 4 applications: an OTAP Client embedded application, an OTAP Bootloader embedded application, an OTAP Server embedded application, and an OTAP Server PC application. The OTAP Client embedded application has two versions, an ATT version and a L2CAP version each using a different transfer method. The OTAP Bootloader and OTAP Client applications must be flashed on the same device (the program region does not overlap).

The embedded OTAP Server application is a GAP Central application which scans for devices advertising the Bluetooth LE OTAP service. After it finds one, it connects to it and configures the OTAP Control Point CCC Descriptor to receive ATT Indications from the device then it waits for OTAP commands from this device.

Once commands start arriving from the OTAP Client via ATT Indications the OTAP Server relays them via serial interface to a PC application which responds. The responses are then sent back to the OTAP Client by writing the OTAP Control Point Characteristic. The embedded OTAP Server application effectively acts as a relay between the OTAP Client to which the image is sent over the air and the OTAP Server PC application which has an OTAP image file constructed using a binary .srec image or a .bin image.

The OTAP Client is a GAP Peripheral which advertises the Bluetooth LE OTAP Service and waits for a connection from an OTAP Server. After an OTAP Server connects, the OTAP Client waits for it to write the OTAP Control Point CCCD and then starts sending commands via ATT Indications. If the OTAP Client is configured to ask the data transfer via the L2CAP CoC PSM, it registers and tries to connect a predetermined L2CAP PSM before sending any commands to the OTAP Server.

5.19.2 Supported platforms

The OTAP application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.19.3 User interface

After flashing two boards with the OTAP Server and OTAP Client applications respectively, the devices are in idle mode (all LEDs flashing). To start advertising, press the ADVSW button on the OTAP Client. To start scanning, press the SCANSW button on the OTAP Server. After the two devices connect and start exchanging commands. CONNLED becomes solid on the OTAP Server and on the OTAP Client.

After the embedded applications are flashed to the boards the OTAP Server PC application must be started. The application creates an OTAP image file using the provided executable .srec or .bin file, connects to the embedded OTAP Server via the configured serial interface and waits for commands. The application shows details about the creation of the image file and allows the configuration of the OTAP upgrade image file header. A log view is present where the interactions between the OTAP Client and the OTAP Server are shown.

Table 17. Hardware references

Platform	ADVSW	SCANSW	CONNLED
FRDM-KW41Z	SW4	SW4	LED3
QN9080CDK	BUTTON1	BUTTON1	D5-RED
FRDM-KW36	SW2	SW2	LED3

5.19.4 Usage with Test Tool for Connectivity products

This is a list of requirements.

- Test Tool for Connectivity Products 12.5.0 or newer – Test Tool on www.nxp.com
- Serial COM port drivers – these are board-specific

These are the steps to run the application.

1. Flash the OTAP Server onto a supported platform, and the OTAP Bootloader and the OTAP Client to another supported platform. Make sure the board running the OTAP Server is connected to your PC and your PC has appropriate drivers for the USB to serial device on that board.

NOTE

The OTAP Bootloader must be programmed separately into the MCU, before programming the OTAP Client application.

2. Create the application to send over the air. The executable must be provided in the .srec or .bin format. The .srec format executable can be obtained by using the IAR Output Converter and setting the output format to Motorola as shown below. The created .srec application image must be offset to begin after the Bootloader region. To offset the application copy the settings from the Linker->Config tab of the otap_client_l2cap_credit or otap_client_att example applications project properties. For more details, see the *Bluetooth LE Application Developer's Guide* (BLEADG).

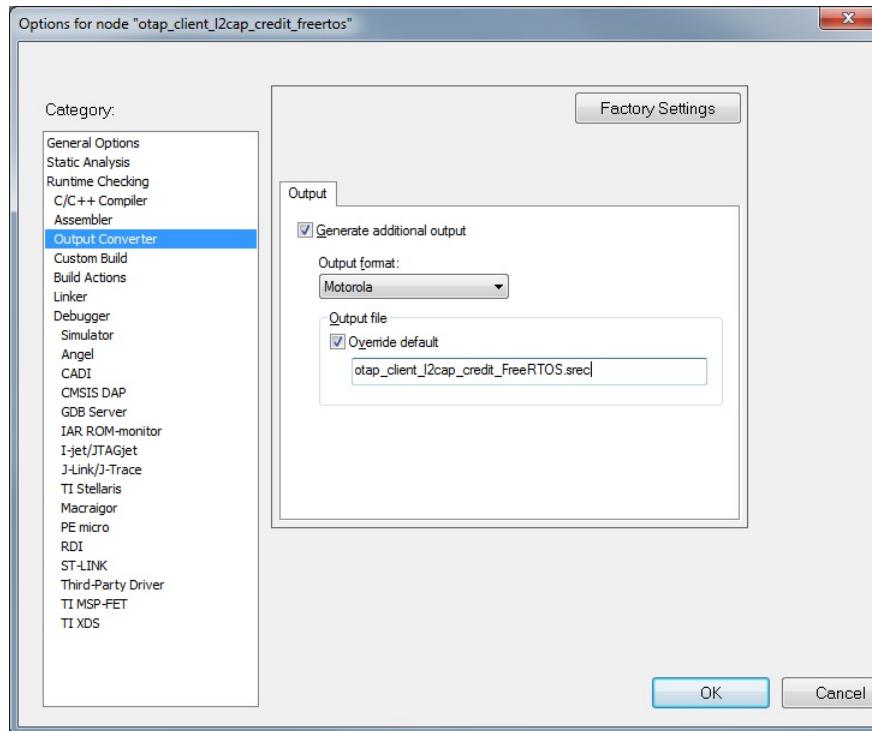


Figure 25. IAR Output Converter Dialog - .srec output

3. To obtain a .bin file from IAR select the Raw binary option in the IAR Output Converter as seen in the figure below.

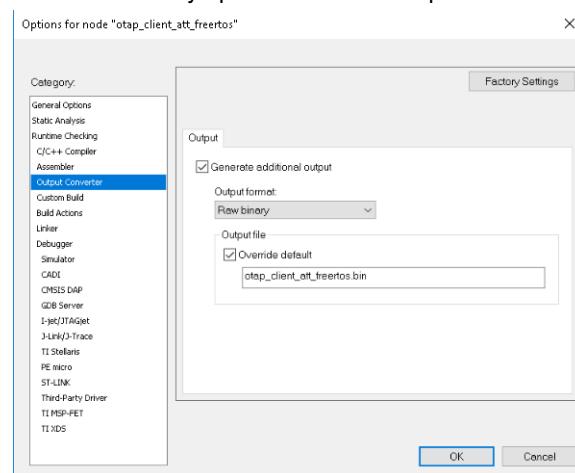


Figure 26. IAR .bin file output converter

4. To obtain a .bin file from MCUXpresso IDE go to the Project properties -> Settings -> Build steps window and press the Edit button for the Post-build steps. A Post-build steps window will show up in which the following command must be added or uncommented (by removing the '#' character at the beginning) if it is already there: arm-none-eabi-objcopy -v -

O binary "\${BuildArtifactFileName}" "\${BuildArtifactFileName}.bin". To obtain a .srec (.s19) file add or uncomment the following post-build command in the same window: arm-none-eabi-objcopy -v -O srec "\${BuildArtifactFileName}" "\${BuildArtifactFileName}.s19". This window, is shown in the figure below.

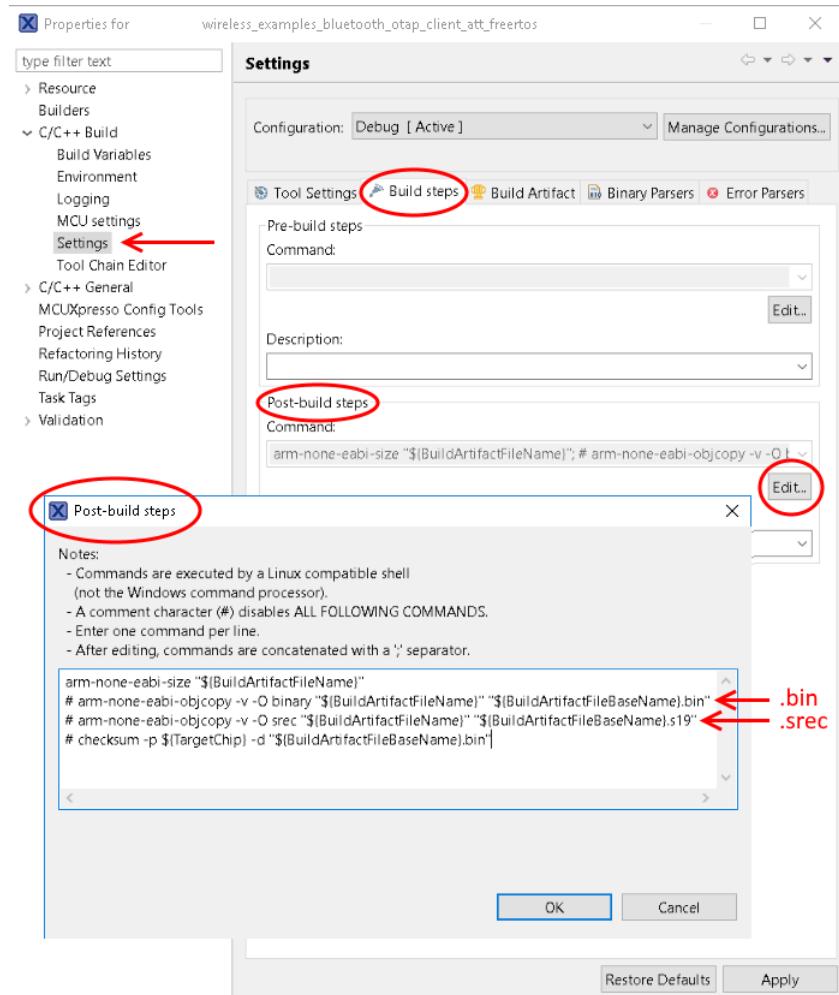


Figure 27. MCUX .bin .srec file output

- Start the Test Tool application. If you have the proper drivers installed and the OTAP Server board is connected to the PC, then its corresponding serial port shows up in the USB/UART Active devices view on the Start Page of the Test Tool software as shown below.



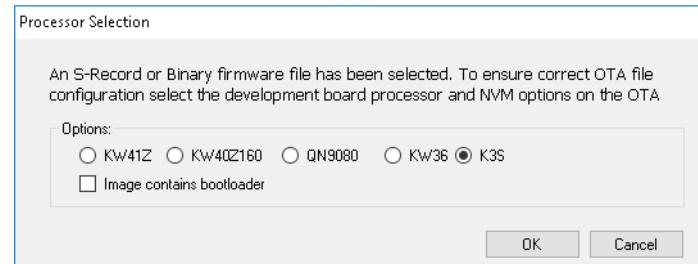
Figure 28. Test Tool Start Page - OTAP Server USB/UART

6. Go to the OTA Updates menu in Test Tool and choose the OTAP BLE option to open the Bluetooth LE over-the-air update window.

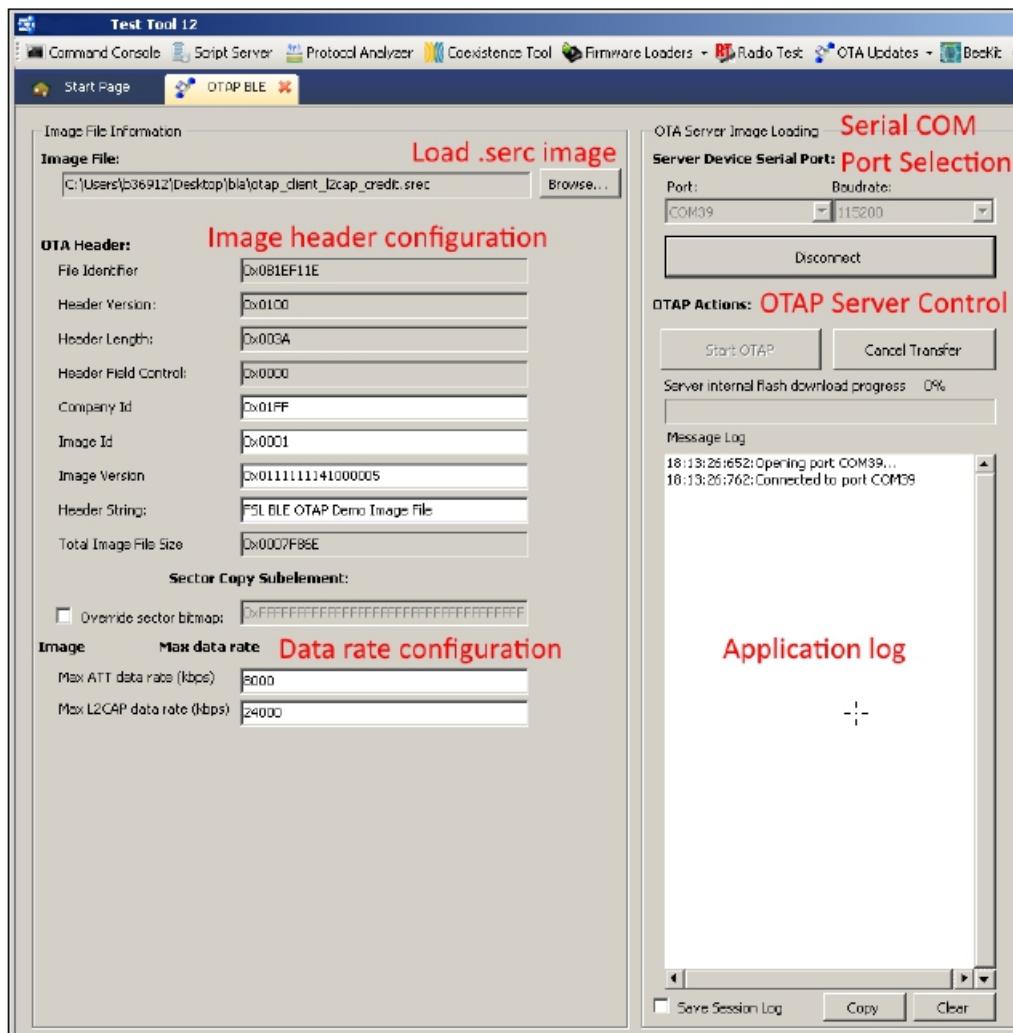


Figure 29. Test Tool OTAP Bluetooth LE

7. Load the image file into the application and configure the image file header and start the OTAP Server
 - In the Image File Information box of the OTAP Bluetooth LE application from Test Tool press the "Browse" button and go to the .srec or .bin file containing the image to be sent to the OTAP Client. The .srec or .bin file and the OTA Header configuration options from the same box is used by the application to build the OTAP Image File which is sent over-the-air. The default values of the OTA Header configuration work out of the box for the OTAP demo applications. For details about these configuration options, see the Bluetooth LE Application Developer's Guide document (BLEADG). After the .srec or .bin file is chosen a pop-up window asks to choose the target processor (this is used to correctly configure the Sector Bitmap sub-element of the OTAP Image File). Choose the correct processor and press "OK". The "Image contains bootloader" tick-box only needs to be selected for KW41Z devices.

**Figure 30. Test Tool OTAP Bluetooth LE Processor Selection**

- After the image is loaded go to the OTA Server Image Loading box, select the correct COM Port for the OTAP Server board and the default baudrate of 115200 and press the “Connect to OTAP Server Device” button. If the connection is successful then the Message Log shows this. If the image is loaded before connecting to the OTAP Server COM Port, then the application’s OTAP Server starts automatically. If the connection to the COM Port is established before the image is loaded, then the “Start OTAP” button needs to be pressed to start the application’s OTAP Server. For details, see the annotated screenshot below.

**Figure 31. Test Tool Bluetooth LE OTAP Application Overview**

- Before starting the image transfer process, the data rate must be configured for each transfer method (ATT or L2CAP CoC). The image chunks of a block are sent over the serial interface and over-the-air without waiting for confirmation and if the data rate is not configured correctly errors can appear in the transfer process which can slow

it down significantly. The optimal data rate depends on multiple factors like: distance between boards, type of antenna, performance of the RF circuitry between the radio and antenna, type and level of noise in the environment, speed of the storage medium in which the image is saved on the OTAP Client, serial driver delay between PC and OTAP Server board and other factors. If the data rate is too high, then the OTAP Client receives a new chunk before it can process the previous one and it sends an “Unexpected Chunk Sequence Number” error and restart the transfer of the current block from where it left off. If the channel is too noisy the transmitter can be flooded and some chunks may not reach the client triggering a similar type of error. The default data rate values should work for most configurations.

8. Start the embedded applications by pressing ADVSW first on the OTAP Client and then on the OTAP Server. The transfer progress and transfer-related messages and/or errors are shown in the application window. The duration of the transfer depends on the size of the image and the chosen data rate and transfer method.

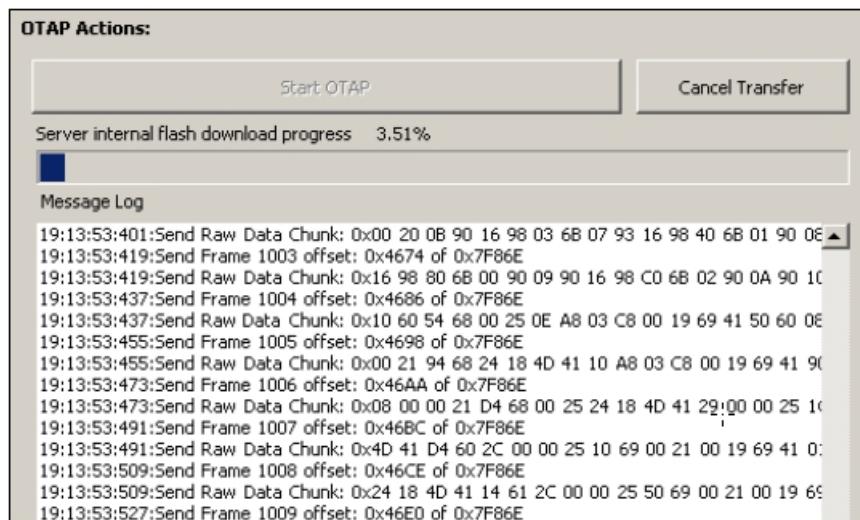


Figure 32. Test Tool OTAP Bluetooth LE Image Transfer in Progress

9. After all the blocks are sent the OTAP Client send an Image Transfer Complete command to the OTAP Server. When this command is received by the PC Application, it displays a “Sent Image with Success” message in the log window.

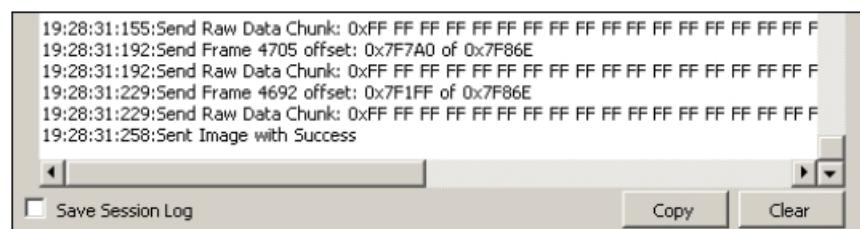


Figure 33. Test Tool OTAP Bluetooth LE Image Transfer Completed

10. After the image transfer is complete the OTAP Client triggers the bootloader and resets the MCU. The bootloader takes about 30 seconds to flash the image on the board. After this time passes the MCU resets again and runs the new image.

5.19.5 Usage with IoT Toolbox

This is the list of requirements.

- Mobile device running Android platform or iOS with hardware and software supporting Bluetooth 4.0 and later
- Kinetis Bluetooth LE Toolbox application – download from the specific application store for your device

To run the application do the following.

1. Flash the OTAP Client ATT and the OTAP Bootloader applications to a supported platform. The Kinetis Bluetooth LE Toolbox only supports the ATT OTAP Client
2. Create the application to send over the air in .srec format. Follow the instructions from the previous section on how to do this. Remember to include the Bootloader in its appropriate section in your application.
3. Start the Kinetis Bluetooth LE Toolbox application on your mobile device and start the OTAP Tool. The application starts scanning.
4. Press ADVSW on the board to start Advertising on the embedded OTAP Client application. The device should show up in the list of scanned devices. Touch the device in the scan list to connect to and the application performs service discovery and displays some information shown in the figures below.

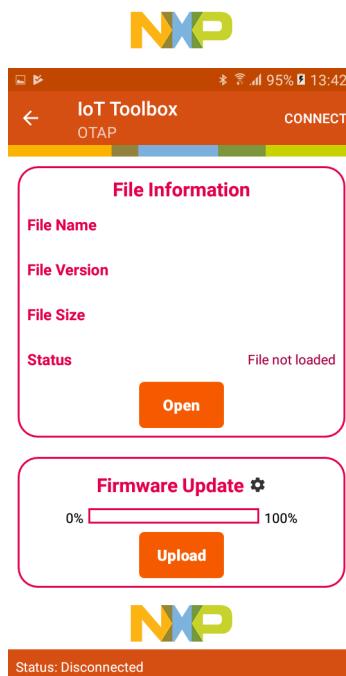
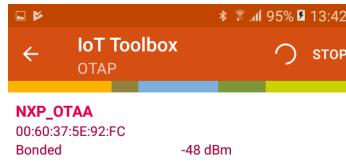


Figure 34. IoT Toolbox - OTAP Tool Scanning and Discovery

5. Press the “Open” button and load the .srec file to be sent over-the-air. Once the file is loaded some information about it is displayed. Press the “Upload” button to start the image transfer process. A progress bar is shown while the image

transfer is ongoing. The successful transfer is signaled by the progress bar reaching 100%. This is shown in the figures below.

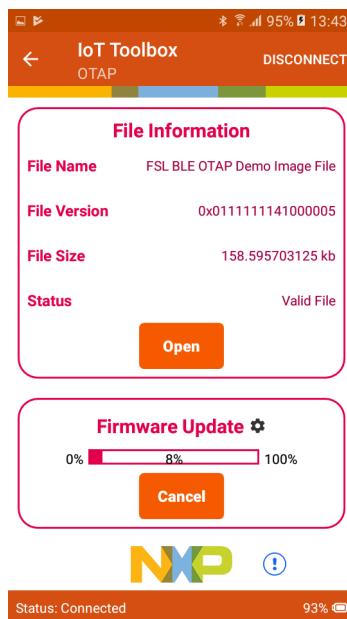


Figure 35. IoT Toolbox - OTAP Image Transfer

6. After the image transfer is complete the OTAP Client triggers the bootloader and resets the MCU. The bootloader takes about 30 seconds to flash the image on the board. After this time passes the MCU resets again and runs the new image.

5.19.6 Notes on multicore platforms and secured OTAP

The following sections describe:

- Secured OTAP for multicore platforms
- Building the image files
- Using test tool to perform secured OTAP

5.19.6.1 Secured OTAP for multicore

FRDM-K32W042 is a multicore platform equipped with two cores: an Arm Cortex-M4 core and an Arm Cortex-M0+ core. The process for performing OTA updates on this platform differs from single core platforms:

- Selective OTAP can be performed. A single OTA update can include only the M4 image, only the M0+ image or both.
- The image files (*.bin or *.srec) are encrypted and signed beforehand, resulting in a *.sbin file.

5.19.6.2 Building the image files

The image files (*.bin or *.srec) are obtained as described in section 5.19.4, with few small differences:

- When building with IAR EW, two image files are obtained, one for the *_cm4 project containing only the M4 image and one for the *_cm0p project containing only the M0+ image.
- When building with MCUXpresso IDE, a single image file is obtained, containing both the M4 and M0+ images. However, this image file is not generated by default. Refer to section 5.19.4 for how to change the post-build steps to generate a .bin or .srec file. In addition, when generating a .bin file the arm-none-eabi-objcopy command must include “—gap-fill=0xFF” as

an additional argument. This reduces the size of the image that ends up being transferred OTA since unused sections filled with 0xFF will be trimmed by Test Tool. To recap, when generating a .bin file the command should look like this:

```
arm-none-eabi-objcopy -v -O binary -gap-fill=0xFF "${BuildArtifactFileName}" "${BuildArtifactFileName}.bin"
```

- When generating a .srec file the command should be:

```
arm-none-eabi-objcopy -v -O srec "${BuildArtifactFileName}" "${BuildArtifactFileName}.srec"
```

5.19.6.3 Using the Test Tool to perform secured OTAP

- Start the Test Tool application and go to OTA Updates > OTAP Bluetooth LE.



Figure 36. Test Tool application

- Click the Browse button and select an image file. Select K3S in the Processor Selection dialogue.

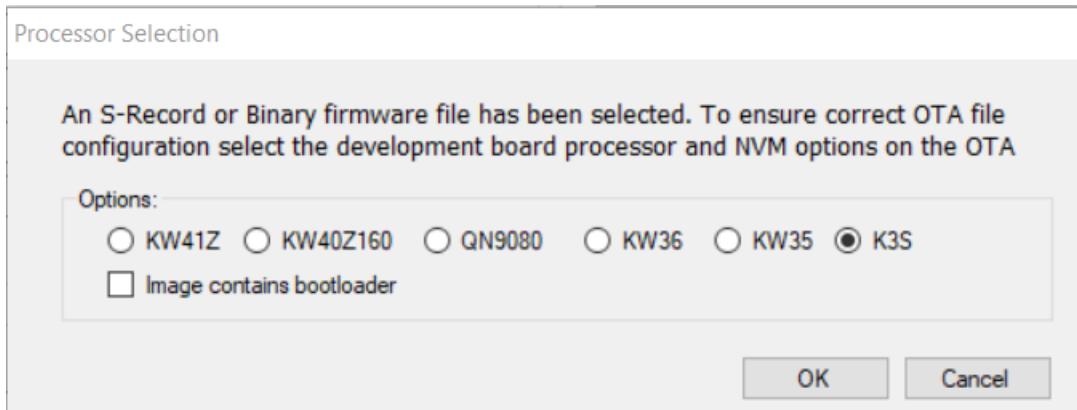
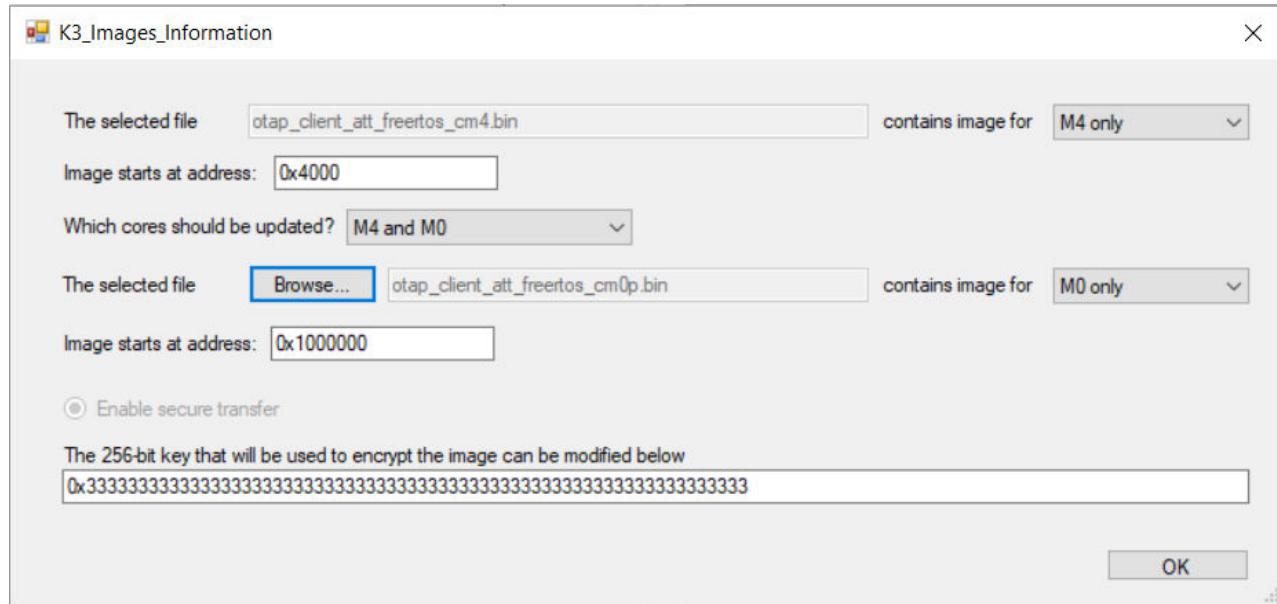
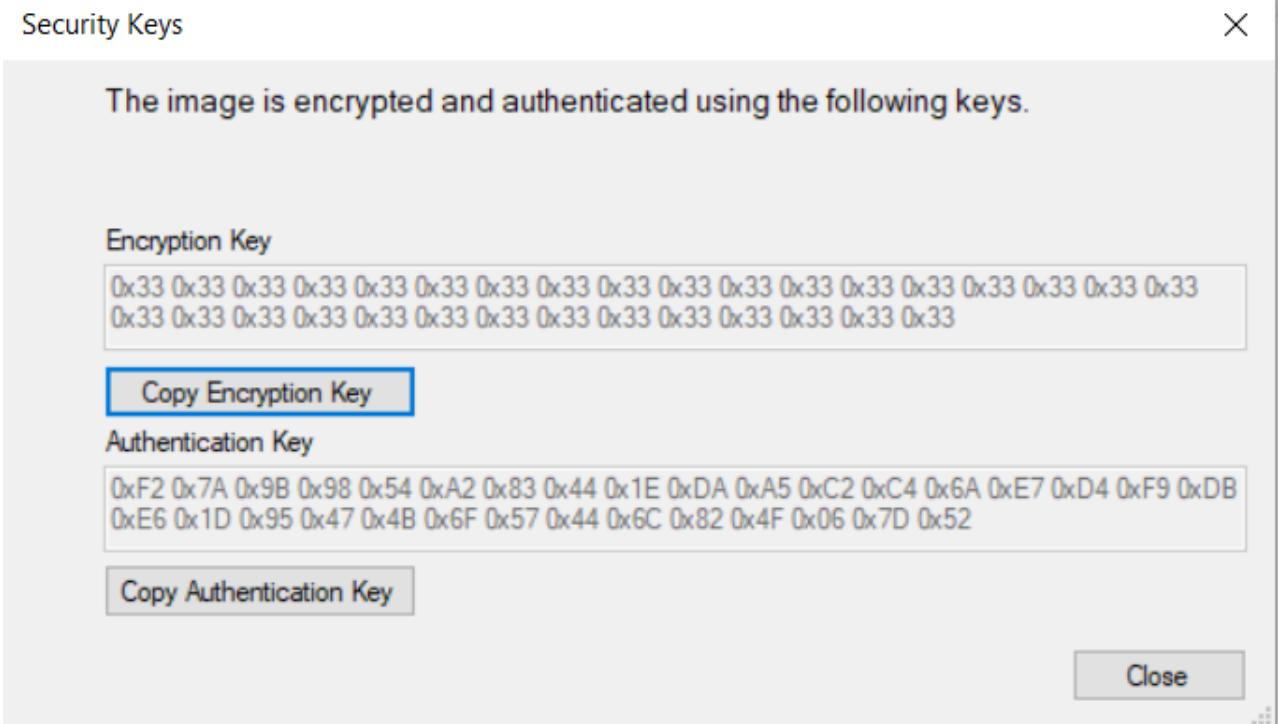


Figure 37. Processor selection

- Choose from the dropdown menu on the right side whether the file you selected contains both M4 and M0+ images, i.e. it has been generated by MCUXpresso IDE, or only the M4/M0+ image, i.e. it has been generated by IAR EW. The start address is the default one for the provided OTAP demos. If you have changed the project linker layout, pick the correct start address for the image.
- Select which core images should be updated. If the initial selected image contains only the M4 or only the M0+ image but the user wants to update both, a second Browse button appears, and the user must select the second image file. As in the previous step, the start address is the default one. In this example screenshot, a .bin file containing the M4 image file has been selected, but the user wishes to update both core images, therefore they must also select the file containing only the M0+ image.

**Figure 38. K32W032 image information**

5. Only secured OTAP is supported for K32W032. The user can overwrite the 256-bit SBKEK (Secured Boot Key Encryption Key) used to encrypt the image. The key is secret and must be shared with the client board which decrypts the image. The way to share the key is left to the user. In the demos provided, the key is hardcoded in Test Tool and in the application residing on the client board. After the client application has received the image, it will write the pre-shared SBKEK at a known location in flash where it is read by the bootloader after reset.
6. Click OK. The user is prompted to save the resulting encrypted and signed image, with a .sbin extension. After saving, a dialog box appears with the SBKEK used to encrypt the image and the RHK (Root Hash Key), which is an SHA-256 hash of the RSA public key for the certificate used to sign the image. As noted in step 5, the SBKEK must be shared with the client in a secured way. The RHK is public and is sent over-the-air as part of the OTAP process. It is also not modifiable by the user since it depends on the certificate.

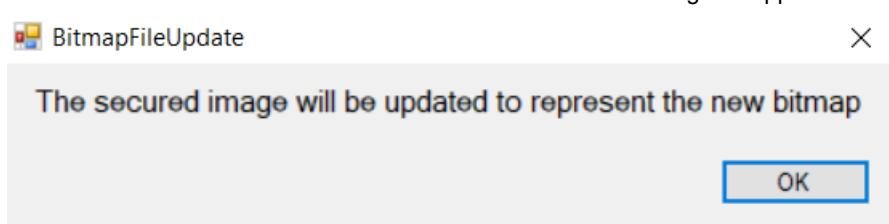
**Figure 39. Security keys****NOTE**

If the user wants to use their own certificate, they must overwrite the certificate used by Test Tool, specifically the files named cert0_noca.der.crt (root certificate) and private.pem (RSA private key) located in Secured/config inside the folder where Test Tool is installed.

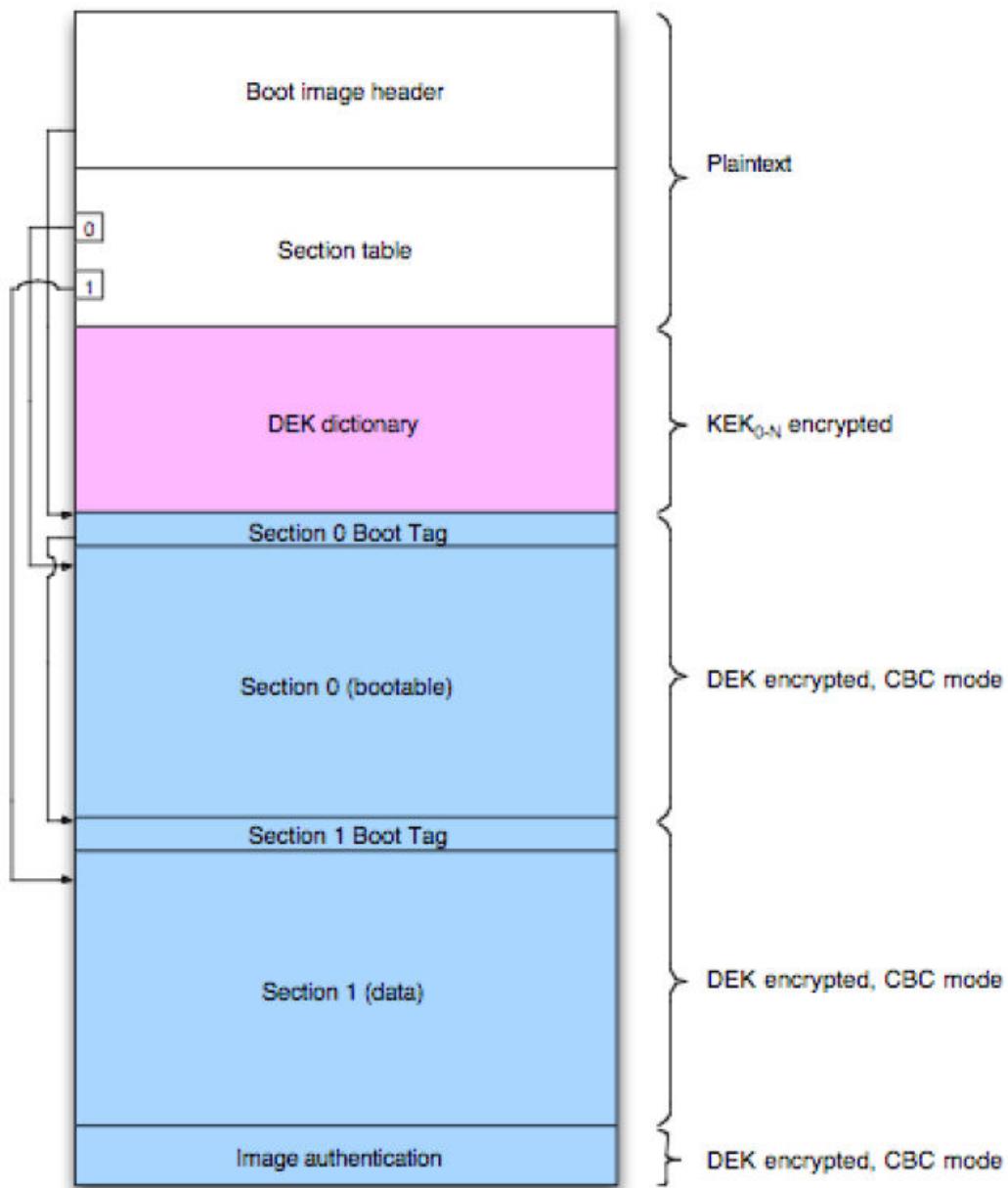
7. The sector bitmap field in the OTAP Bluetooth LE view is used to determine which sectors are erased on the client board before writing the new image. By default, the entire useful flash is erased. The bitmap looks like this:

```
0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
```

The bold bytes above represent the Non-Volatile Memory space in M0+'s flash (8 sectors * 2K for each sector = 16K of NVM). To avoid the NVM being erased, after the secured image has been created the user can change FF to 00. The secured image is recreated – the NVM is not erased on the client board. This dialog box appears.

**Figure 40. Bitmap file update****Secured image format**

After the image files have been selected and the user clicks OK to generate the .sbin, Test Tool will create the secured image in the background using calls to the elftosb executable. For full documentation see the Kinetis elftosb User's Guide. The following figure shows an overview of the .sbin file:

**Figure 41. Secured image format**

The .sbin file will begin with two plaintext sections, the boot image header and the section table. The DEK dictionary contains one or more randomly generated keys used to encrypt the useful data. These keys are wrapped by the SBKEK chosen by the user as per RFC 3394. Encrypted sections follow, and the image authentication code is at the end. The only information needed by the bootloader on the client board to successfully authenticate and decrypt the image is the two keys: SBKEK for decryption, RHK for authentication.

5.20 Hybrid (Dual-Mode) Bluetooth Low Energy Heart Rate Sensor and IEEE 802.15.4 Coordinator Demo Application (KW41 Platform)

5.20.1 Implemented profile and services

The Bluetooth LE Heart Rate Sensor implements a GATT server and the following profile and services.

- Heart Rate Profile v1.0
- Heart Rate Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When the collector configures notifications, the sensor starts sending heart rate measurements every second.

The IEEE 802.15.4 part of the application is an IEEE 802.15.4 Coordinator running in background, in parallel with the Bluetooth LE sensor application.

5.20.2 Supported platforms

The Hybrid (Dual-Mode) Bluetooth Low Energy Heart Rate Sensor and IEEE 802.15.4 Coordinator application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z

5.20.3 User interface

The IEEE 802.15.4 thread starts automatically at device startup in the role of an IEEE 802.15.4 Coordinator. It chooses the channel based on Clear Channel Assesment (CCA). No user interaction is needed.

The Bluetooth LE Heart Rate Sensor user interface is identically with the standalone one. After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, the CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button pressed for 2-3 seconds. The node then re-enters the GAP Discoverable Mode.

See details below for hardware references.

Table 18. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3

5.20.4 Testing method

The IEEE 802.15.4 Coordinator is basically a “MyWirelessApp Coordinator” demo (for more information check the 802154MPDAUG document), and responds to requests from other IEEE 802.15.4 devices (Active Scan, Association, Data Requests). Any IEEE 802.15.4 sniffer can be used to observe the over-the-air activity on the channel that the coordinator started.

At the same time, the Bluetooth LE Heart Rate Sensor part of the application runs independently based on user interaction. The Heart Rate Sensor can be connected to any Bluetooth Smart Ready product available on the market. To make the Heart Rate Sensor visible, press the ADVSW button to start sending advertisements, which causes CONNLED to start flashing. The sensor name “NXP_HYBRID_HRS” shows on the device when its scanning is active. A solid CONNLED indicates a successful connection between the 2 devices. Hold the ADVSW button pressed for 2-3 seconds anytime to get the sensor to initiate disconnect.

If configured, the sensor notifies the application with heart rate measurements every second. Also, the battery level and various device information is exposed for reading. The Kinetis Bluetooth LE Toolbox can be used to showcase the Heart Rate profile functionality.

5.21 Relay Proxy

This section describes the functionality, user interactions, and testing methods for the Bluetooth LE Relay Proxy Application.

5.21.1 Implemented stack features

The Bluetooth LE Relay Proxy implements a GAP dual-role application that allows 2 simultaneous connections, one with a GAP Peripheral and the other with a GAP Central device. It also supports both GATT client and server. When the two connections are active, the device will relay data from the GAP Peripheral to the GAP Central and vice-versa.

5.21.2 Implemented services

The device will discover services on the GAP Peripheral and clone the database locally by using the dynamic GATT database feature. The application acts afterwards as a proxy for that device and will respond to service discovery queries made by the remote GAP Central device. The application supports all services defined by the Bluetooth SIG. Connection with the GAP Peripheral that contains the database to be cloned is made based on the specified service in the following macro from app.h: gAppProxySelectService_d. By default, the application will check for GAP Peripherals that support the Heart Rate Service (0x180D).

5.21.3 Supported platforms

The Relay Proxy application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080CDK
- FRDM-KW36

5.21.4 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure, CONNLED is flashing. When the central node connects to the peripheral, CONNLED turns solid. After service discovery is done and the dynamic GATT database is created, the application enters GAP Discoverable Mode and CONNLED starts flashing. When the central node connects to the peripheral, CONNLED turns back solid. To disconnect the node from all connections, hold the SCANSW button pressed for 2-3 seconds.

See details below for hardware references.

Table 19. Hardware references

Platform	SCANSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.21.5 Usage

The application is built to work with any other two devices that implement a GAP Peripheral and a GAP Central. The out of the box example describes the Bluetooth LE Relay Proxy connecting with a Heart Rate Sensor application from the same SDK and a smartphone or a tablet running the Kinetis Bluetooth LE Toolbox application.

1. Download a Heart Rate Sensor application on a supported platform and start it as described in the previous chapter.

2. Press SCANSW on the Bluetooth LE Relay Proxy application. The node will connect with the Heart Rate Sensor and do Service Discovery. CONNLED is solid. After the database is recreated locally, the node will start advertising with the same data as the original device. CONNLED starts flashing.
3. Start Kinetis Bluetooth LE Toolbox and connect to the Bluetooth LE Relay Proxy application as with a normal Heart Rate Sensor application.
4. All GATT Read and Write operations made by the Kinetis Bluetooth LE Toolbox are relayed by the node to the initial Heart Rate Sensor. All GATT Notifications are relayed to the Kinetis Bluetooth LE Toolbox application.

5.22 Wireless Power Transfer System Receiving Unit and Transmitting Unit

This section describes the implemented profiles and services, user interactions, and testing methods for the wireless power transfer receiving unit (WPT PRU) and transmitting unit (WPT PTU).

5.22.1 Implemented profile and services

The WPT PRU and PTU applications implement a GATT server and a GATT client for the following profile and service:

- A4WP Wireless Power Transfer System specification v1.3
- Wireless Power Transfer (WPT) Service v1.3

The WPT PRU application behaves as a GAP peripheral node. It enters GAP Limited Discoverable Mode using as advertising data the WPT service UUID (0xFFFFE) and the ATT database handle corresponding to the service declaration.

The WPT PTU application behaves as a GAP central node. It scans for PRU devices by looking for the WPT Service UUID, it connects to a PRU device, performs a procedure known as device registration and allows or disallows the device to start charging. The device registration procedure should take less than 500 milliseconds and for this reason the profile uses security mode 1, level 1 and no service discovery is performed. All handles are computed using the offset handle found in the advertising data. Device charging state and other measurable values are simulated in software using random numbers (except for device temperature included in the dynamic parameters).

Both application use pairing with bonding by default. Both applications require a terminal to output application specific information. A part of the application information is provided using onboard LED's. All actions are triggered using the push-button events. The events have the following meaning:

- Short press: pressing a button and releasing it under 1 second.
- Long press: pressing a button and releasing after 1 second, but before 8 seconds are passed.
- Very long press: pressing a button and releasing it after 8 seconds.

5.22.2 Supported platforms

The Wireless Power Transfer System Receiving Unit application is supported by the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- FRDM-KW36

5.22.3 User interface

After flashing the boards, the PRU device enters a “Null” state, and the PTU enters a “Power Save” state. A short press on the ADVSW button of the PTU device simulates a device configuration and the presence of a PRU device which requires charging. For this reason, the PTU device starts a scanning procedure. A short press on the ADVSW of the PRU device simulates sufficient power to start the advertising procedure. During both scanning and advertising procedures, CONNLED will flash. If the PRU

device does not connect to the PTU for 10 seconds, the advertising is stopped and CONNLED turns off. In this case the PRU device returns to the "Null" state. After the PTU connects to the PRU, CONNLED is turned on.

After the devices connect, the PTU performs device registration and determines if it has sufficient power to charge the PRU. If registration is successful, the push-buttons events change their meaning as follows:

- Short press on the PTU device triggers another scanning procedure in case another device is supported.
- Short press on the PRU device prints the dynamic parameters in the console.
- Long press on the PTU device prints information regarding the connected devices and maximum power remaining.
- Long press on the PRU device simulates a charge complete event. After the PRU is considered charged, the PTU will disconnect from it. After disconnection, the PRU device enters in a "Boot" state and requires a very long press event to return to "Null" state.
- Very long press on the PTU device simulates an error case and disconnects all connected PRU devices.
- Very long press on the PRU device simulates power removal (taking a device outside the charge area).

If the PRU device is allowed to charge, it simulates charging by printing information in the console and by turning CHGLED on.

See details below for hardware references.

Table 20. Hardware references

Platform	ADVSW	CONNLED	CHGLED
FRDM-KW41Z	SW4	LED3	LED4
FRDM-KW36	SW2	LED3	LED4-RED

5.22.4 Usage

The setup requires two or three supported platforms, one for PTU device and one or two for PRU devices.

1. Open serial port terminals for all the platforms. The start screen is displayed after the board is reset. At first the LEDs are flashing on all devices.
2. Press ADVSW on the PTU device and on a PRU device. CONNLED should start flashing on both devices until the connection is established or until the PRU device times out.
3. After the registration procedure is finished the PTU device will display a success message and will simulate the procedure for providing power to the PRU.

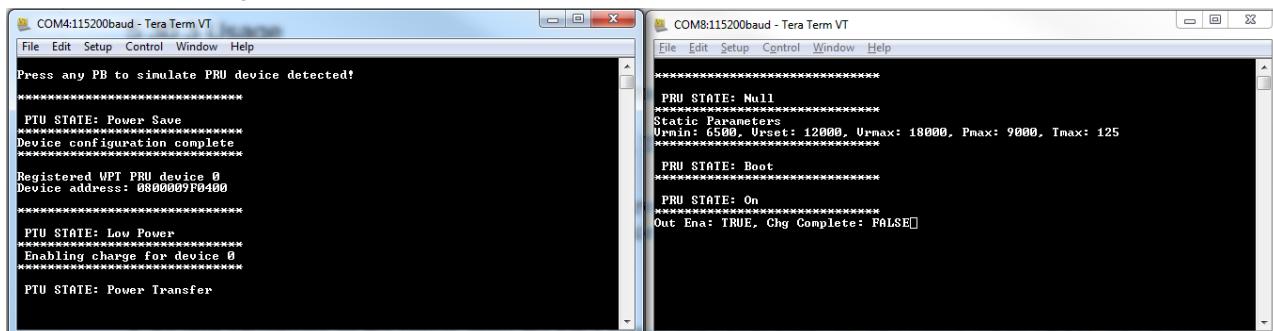


Figure 42. PTU and PRU after connecting, registering and enabling charge

4. Short press ADVSW on the PRU device again to print most recent dynamic parameters.
5. Long press on ADVSW on the PTU device to get system information.

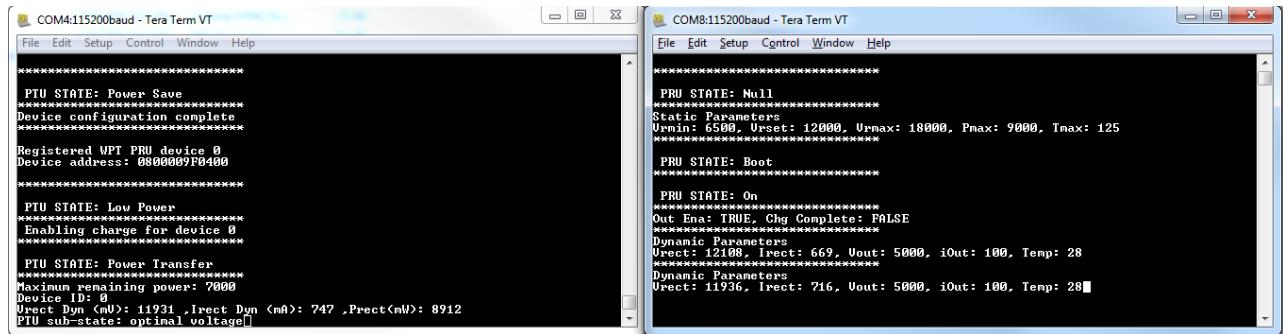


Figure 43. PTU information and PRU dynamic parameters display

- Long press ADVSW on the PRU device to simulate a charge complete event.

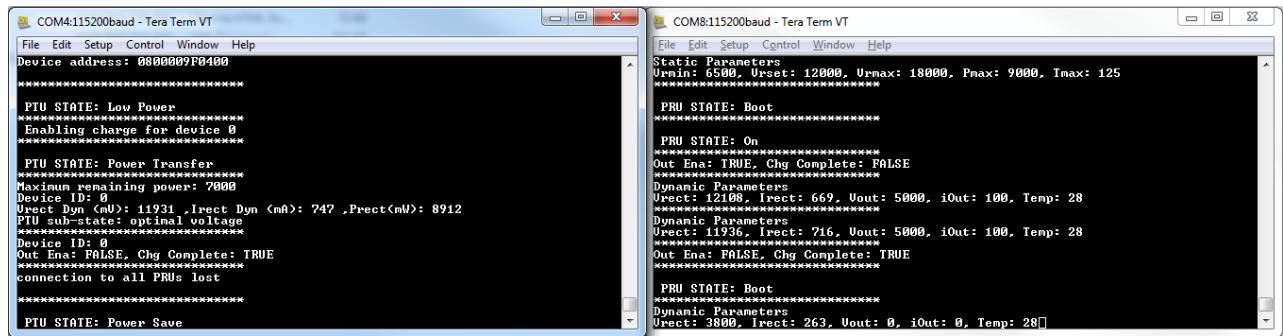


Figure 44. PRU device charged

- Very long press ADVSW on the PRU device to simulate power removed and return it into a “Null” state.

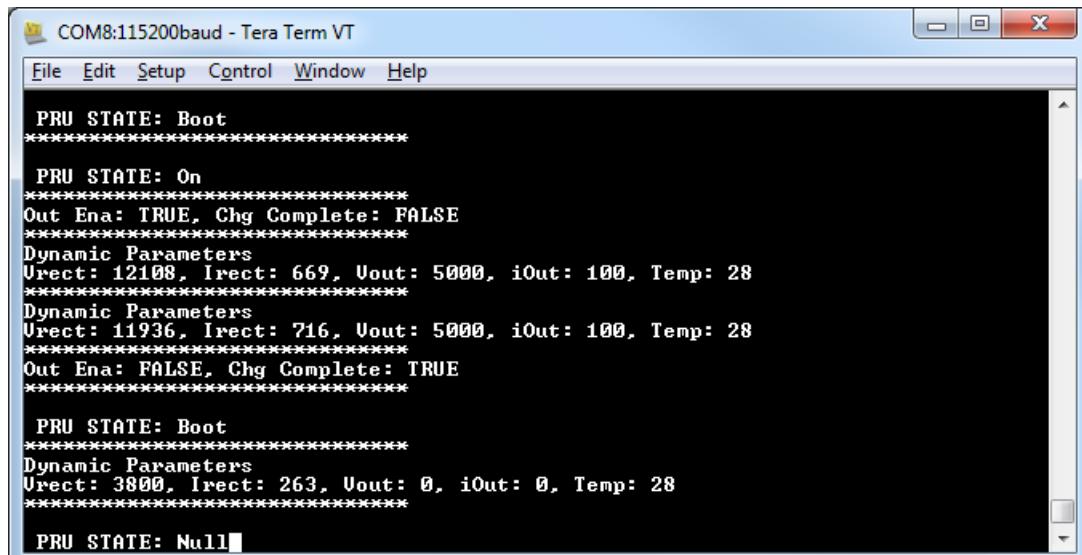


Figure 45. PRU power removed

- If a second PRU device is used, ADVSW can be short pressed on both the PTU and on the new PRU after step 3 was finished for the previous PRU. Also, to test the power sharing procedure support, the gAdjustPowerCommandSupport_d macro should be defined as TRUE on at least one of the PRU devices before flashing the firmware. If the above macro is set to TRUE a scenario is designed so that two PRU devices combined require more power than the PTU device can provide, but the PTU device attempts a power sharing procedure so that it can adjust the power draw for at least one of the PRU's.

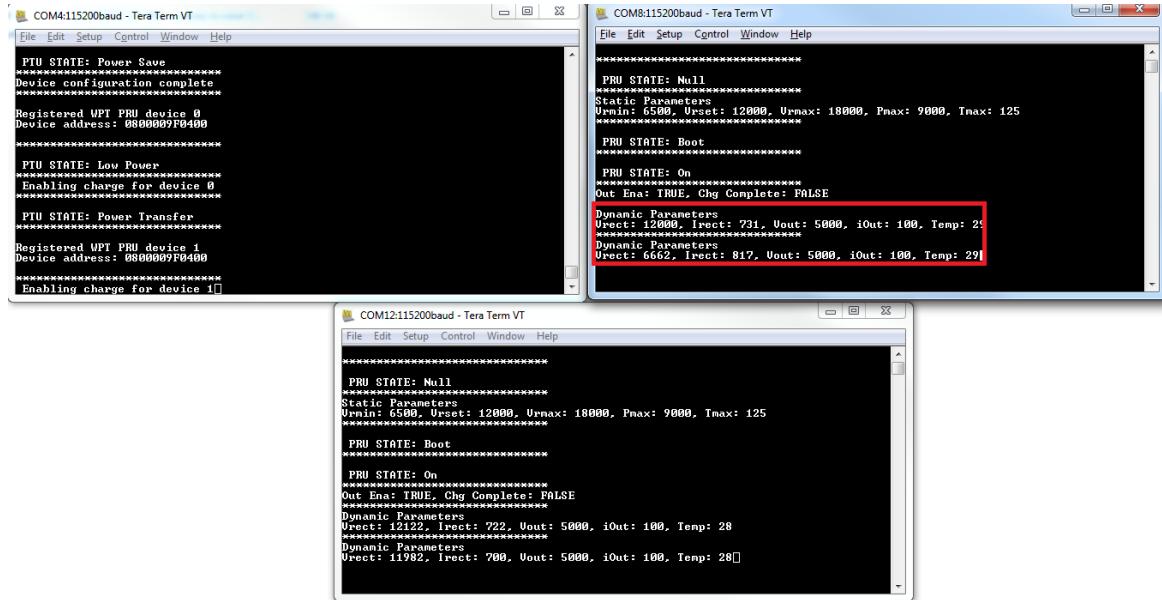


Figure 46. Power sharing support on one PRU

5.23 Hybrid (Dual-Mode) Bluetooth Low Energy and Generic FSK Demo Application

5.23.1 Implementation

The Hybrid Bluetooth LE-GFSK application demonstrates Generic FSK transmission/reception and Bluetooth advertising/scanning/multiple connections coexistence.

The Bluetooth part of this demo implements a modified version of the Wireless UART demo application.

The GenFSK part can receive/transmit data in the idle periods of the Bluetooth protocol. A predefined GFSK data packet is sent on the default channel (gGenFskDefaultChannel_c) at an interval (gGenFskApp_TxInterval_c). If at that time, the radio is in use by the Bluetooth protocol, the transmission will be postponed until the idle signal is received from the MWS coexistence module.

When in scanning mode, all received GenFSK packets will be displayed on the console along with all received Bluetooth LE events/data, preceded by a string which informs the protocol on which it was received: "BLE:" / "GFSK:"

A device can start Bluetooth advertising, scanning in parallel with GenFSK reception and transmissions. All these operations will not overlap.

Also, multiple Bluetooth connections are supported in both roles (Central and Peripheral) along with all the above.

Table 21. Application files

File name	Description
app_prelude.h	Files common to both GenFSK and Bluetooth application
main.c	

Table continues on the next page...

Table 21. Application files (continued)

File name	Description
app_config.c gatt_db.h gatt_uuid128.h wireless_uart.c wireless_uart.h	Bluetooth application files
genfsk_adv.c genfsk_adv.h	GenericFSK application files

5.23.1.1 How it works

When a switch is pressed for the first time, the specific protocol application starts. The first protocol to start has complete access to the radio (XCVR).

When the other switch is pressed, the second protocol stack tries to start by acquiring access to the XCVR. If the first protocol is idle, access will be granted. Else it will be informed when the XCVR is idle, and the acquire control.

Since the Bluetooth protocol has strict timings, the GenFSK should not acquire the XCVR for long periods. Instead it should check the inactivity duration of the Bluetooth stack using the *MWS_GetInactivityDuration()* API and release access to the XCVR before the next Bluetooth event.

Also, to maximize the GenFSK application activity, the MWS idle signal should be monitored. The demo application is doing this by registering its own callback into the MWS module using: *MWS_GetRegisteredCallback()* API.

The GenFSK link layer also needs to be informed of the MWS events, so to achieve this, the application will first get the registered callback for the GenFSK protocol using *MWS_GetRegisteredCallback()* API, save this callback and call it in the registered application callback. Using this method, multiple layers can chain callback to monitor MWS events.

By monitoring the MWS idle signal, the GenFSK application can start the RX operation asap. Also, to give the control to the Bluetooth stack in time, the GenFSK application starts a timer with an expire time less than the inactivity duration of Bluetooth to release access to the XCVR. Upon release, the Bluetooth stack will receive an MWS idle signal, and the handler will configure the XCVR for Bluetooth mode.

The GenFSK TX is done periodically, using a timer. If when the timer expires, the Bluetooth stack has access to the XCVR, or there is not enough idle time to perform the GenFSK TX, then it will be postponed until the next idle signal is received.

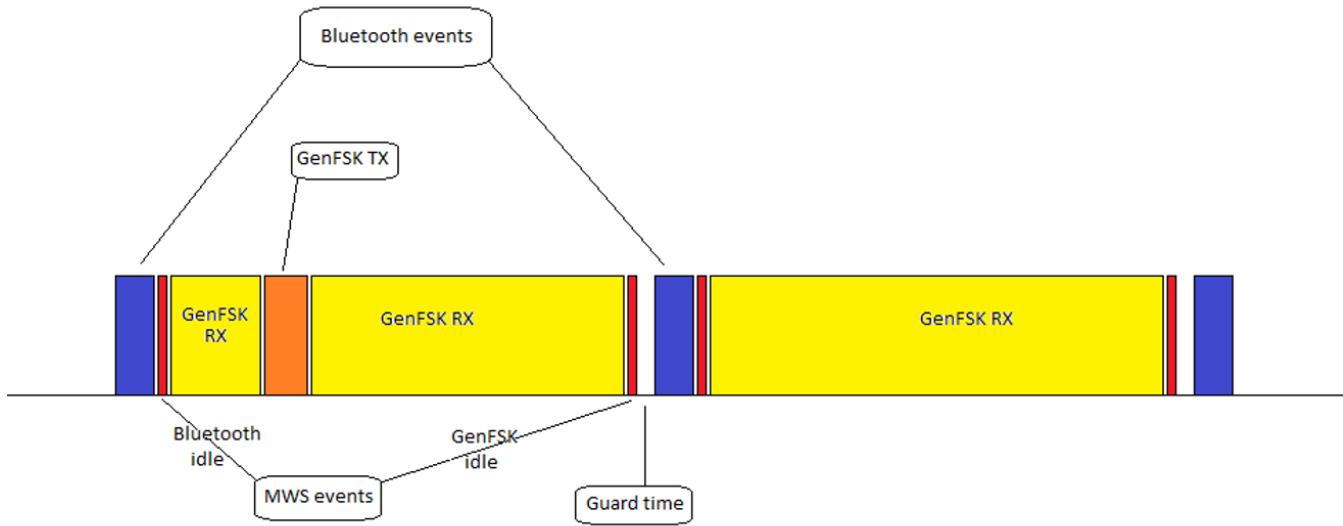


Figure 47. Working of GenFSK

5.23.2 Supported platforms

The Hybrid (Dual-Mode) Bluetooth Low Energy and Generic FSK Advertising application is supported by the following platforms:

- FRDM-KW36

5.23.3 User interface

By default, after power up, the application is in idle mode: all LEDs are flashing. To control the application, the on-board switches are used:

- BLESW – Short press this button to start the Bluetooth advertising.
- BLESW – Long press this button to start the Bluetooth scanning.
- GFSKSW – Short press this button to start the Generic FSK transmission.
- GFSKSW – Long press this button to start the Generic FSK reception.
- CONNLED – If only this LED is flashing, the application is in advertising/scanning mode (Bluetooth LE). When the LED turns solid a Bluetooth connection has been established.

Also, a serial console application can be used to track the messages displayed, and the received Bluetooth LE/GFSK packets.

Table 22. Hardware references

Platform	BLESW	GFSKSW	CONNLED
FRDM-KW36	SW2	SW3	LED3

5.23.4 Customization

The steps below will help changing the default settings of this demo.

For Bluetooth LE, the default advertising config (gAppAdvParams), and data (gAppAdvertisingData) are found in the app_config.c file. Also, the scanning parameters (gScanParams) can be found in this file. The default scan interval is 100ms with a scan window of 50ms.

NOTE

The GFSK protocol is active during the inactive periods of the Bluetooth LE protocol. Configuring a large scan window in comparison to the scan interval will not leave enough room for the GFSK protocol to work.

For GFSK, the following defines (self-explanatory) are used by the application, and can be found in the “ble_genfsk_advertising.h” file:

- gGenFSK_AdvAddress_c
- gGenFskDefaultSyncAddress_c
- gGenFskDefaultTxPowerLevel_c
- gGenFskDefaultChannel_c
- gGenFskApp_TxInterval_c

The “gGENFSK_MwsControl_c” define controls where the coexistence management should be done:

Value	Description
gGENFSK_NoMwsControl_c	No protocol coexistence management
gGENFSK_LLMwsControl_c	The GenFSK link layer manage the coexistence with Bluetooth protocol. In this case, the GenFSK will release control to the XCVR for Bluetooth after every sequence (TX/RX)
gGENFSK_AppMwsControl_c	The Application controls when the GenFSK releases the access to the XCVR. The GenFSK link layer still need to perform the XCVR configuration when the idle signal is received from the Bluetooth stack.

The payload to be transmitted over GFSK is represented by the “message” array, used by the “GfskApp_Tx()” function.

Other GFSK settings can also be changed, but require a more advanced knowledge of the system:

- pktConfig – configures the preamble size, length field config, synch address size
- crcConfig – enable/disable the data CRC, and the polynomial used
- whitenConfig – enable/disable data whitening, polynomial used, start/end markers
- radioConfig – change data rate and modulation

5.24 ANCS Client

This section describes the implemented profiles, services, user interactions, and testing methods for the Bluetooth LE OTAP application.

5.24.1 Implemented profile and services

The ANCS Client application implements an ANCS Client for the custom ANCS Service available on iOS mobile devices.

Check the documentation available on the iOS website for details about the ANCS service, its characteristics and supported features.

The demo application acts as a GAP Peripheral which advertises a service solicitation for the custom ANCS Service. It also acts as a GATT Client once connected to a device offering the ANCS Service. The application offers some services as GATT Server.

Once connected to a mobile device offering the ANCS Service, the application displays information about ANCS Notifications received from that device. The notifications are received via ATT Notifications for which the ANCS Client must register on the peer

ANCS Server. The application also retrieves and displays additional information about the received ANCS Notifications. This is achieved by writing commands to specified characteristics on the ANCS Server and receiving responses via ATT Notifications from other characteristics. All information is displayed to the user using a shell available over a serial communications interface.

Accessing the ANCS Service requires Bluetooth LE security to be enabled.

5.24.2 Supported platforms

The ANCS Client application is supported on the following platforms:

- FRDM-KW36

5.24.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When the ANCS Server (Gap Central) connects to the ANCS Client (GAP Peripheral), CONNLED turns solid. To disconnect, hold the ADVSW for 2-3 seconds. The ANCS Client then re-enters the advertising state.

For displaying operating information and ANCS Notifications, the demo application uses a shell exposed via a serial communication interface.

See details below for hardware references.

Table 23. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW36	SW2	LED3

5.24.4 Usage

The ANCS Client demo application is designed to work with a peer mobile device which exposes the ANCS service. Also, a serial terminal application is required for displaying ANCS Notifications information.

- Open a serial terminal application on the PC and connect it to the serial port corresponding to the board on which the ANCS Client runs. See the details in Section 5.1.3, "User Interface". A start screen is displayed immediately after the board is reset. All LEDs should be flashing.

```

#####
#####        #####
#####        #####  #####
#####        # ## #####
#####        ###### ###### #####
#####        # ## #####
#####        #####  #####
#####        # ## #####
#####        ###### ###### #####
#####        # ## #####
#####        #####  #####
#####        # ## #####
#####        ###### ###### #####
#####        # ## #####
#####        #####  #####
#####        # ## #####
#####        ###### ###### #####
#####        # ## #####
#####        #####  #####
#####        # ## #####
SHELL build: Mar  9 2018
Copyright (c) 2016 NXP Semiconductors
BLE ANCS Client>
Press ADVSW to start advertising to find a device with the ANCS Service!
Advertising...

```

- Press the ADVSW to start advertising. This instruction is also displayed in the serial terminal as shown in the screenshot above.
- The peer device starts scanning for Bluetooth LE devices and connect to the ANCS Client device which is advertising.
- Once connected to a peer the application, it looks for the ANCS Service and its characteristics. If they are found, the ANCS Client tries to register for receiving notifications.
- If any security related ATT errors are encountered than the application automatically performs Pairing and Bonding and retries the failed ATT operations. Depending on the negotiated Pairing Method, user interaction may be needed to complete the Pairing. Follow the on-screen instructions provided by both the ANCS Client and the mobile device. If a passkey is to be generated by the ANCS Client then the default 999999 passkey is used.

```
Pairing was successfull!  Pairing completed successfully

Writing ANCS Notification Source CCCD...  Enabling ANCS Notifications

ANCS Notification Source CCCD written successfully.  Success!

Writing ANCS Data Source CCCD...

ANCS Data Source CCCD written successfully.  Success!
```

- After bidirectional communication is established via GATT the ANCS Client will start displaying ANCS Notifications information as shown below.

BLE ANCS Client>			
Notif_UID Flags Category		Application	3 existing notifications, 1 new notification for which the application name is not available yet
0x00000000 S_E_N Social	Hangouts		
0x00000001 S__N Social	Hangouts		
0x00000002 S__N Social	Hangouts		
0x00000003 ___N Email			
BLE ANCS Client>			
Notif_UID Flags Category		Application	
0x00000000 S_E_N Social	Hangouts		The application name for the new notification has been obtained from the ANCS Server
0x00000001 S__N Social	Hangouts		
0x00000002 S__N Social	Hangouts		
0x00000003 ___N Email	Mail		
BLE ANCS Client>			
Notif_UID Flags Category		Application	One notification was deleted by the ANCS Server and it has notified the ANCS Client to delete it too.
0x00000000 S_E_N Social	Hangouts		
0x00000001 S__N Social	Hangouts		
0x00000002 S__N Social	Hangouts		
BLE ANCS Client>			
Notif_UID Flags Category		Application	A second notification is deleted by the ANCS Server.
0x00000001 S__N Social	Hangouts		
0x00000002 S__N Social	Hangouts		
BLE ANCS Client>			
Notif_UID Flags Category		Application	A third notification is deleted by the ANCS Server.
0x00000002 S__N Social	Hangouts		
BLE ANCS Client>			
Notif_UID Flags Category		Application	The last notification is deleted by the ANCS Server.
BLE ANCS Client>			
Notif_UID Flags Category		Application	1 new notification is received from the ANCS Server for which the application name is not available yet.
0x00000004 ___N Social			
BLE ANCS Client>			
Notif_UID Flags Category		Application	The application name for the last notification is retrieved from the ANCS Server.
0x00000004 ___N Social	Hangouts		
BLE ANCS Client>[]			

5.25 Bluetooth LE FSCI Black Box

This section describes the functionality, user interactions, and testing methods for the Bluetooth LE FSCI Black Box demo application.

5.25.1 Description

The Bluetooth LE FSCI Black Box demo application gives access to the Bluetooth LE Host Stack via a serial interface using the FSCI protocol. See the *FSCI (Framework Serial Communication Interface) manual* for the format of the FSCI commands and a full list of supported commands.

The demo can be used with the Test Tool for Connectivity Products. Command Console application can be downloaded from the NXP website or with a custom application which supports the FSCI protocol and commands.

5.25.2 Supported platforms

The Bluetooth LE FSCI Black Box application is supported on the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080XCDK
- FRDM-KW36

5.25.3 Usage with Test Tool for Connectivity Products

The Bluetooth LE FSCI Black Box demo application is designed to be used via serial interface. This can be done using the TEST Tool for Connectivity Products – Command Console application as described below.

1. Download the demo application onto a supported board
2. Connect the board to a USB port of the PC. The UASB COM port drivers must be installed properly and a COM port corresponding to the board should be available.
3. Open the Test Tool application and connect to the serial port corresponding to the board on which the Bluetooth LE FSCI Black Box application runs. The serial communication parameters are: baud rate 115200, 8N1

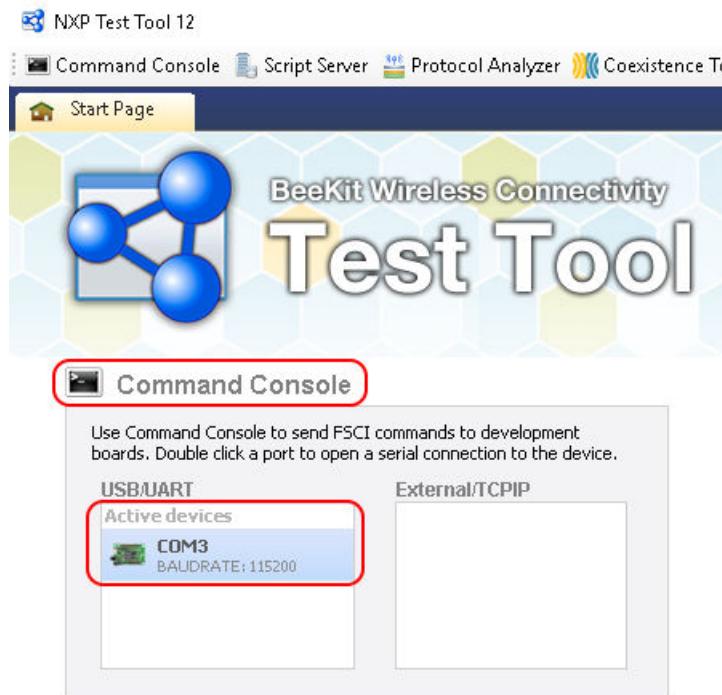


Figure 48. Test tool command console serial port selection

4. Select the appropriate Test Tool XML file from the drop-down list for the release being used and send some commands to the application.

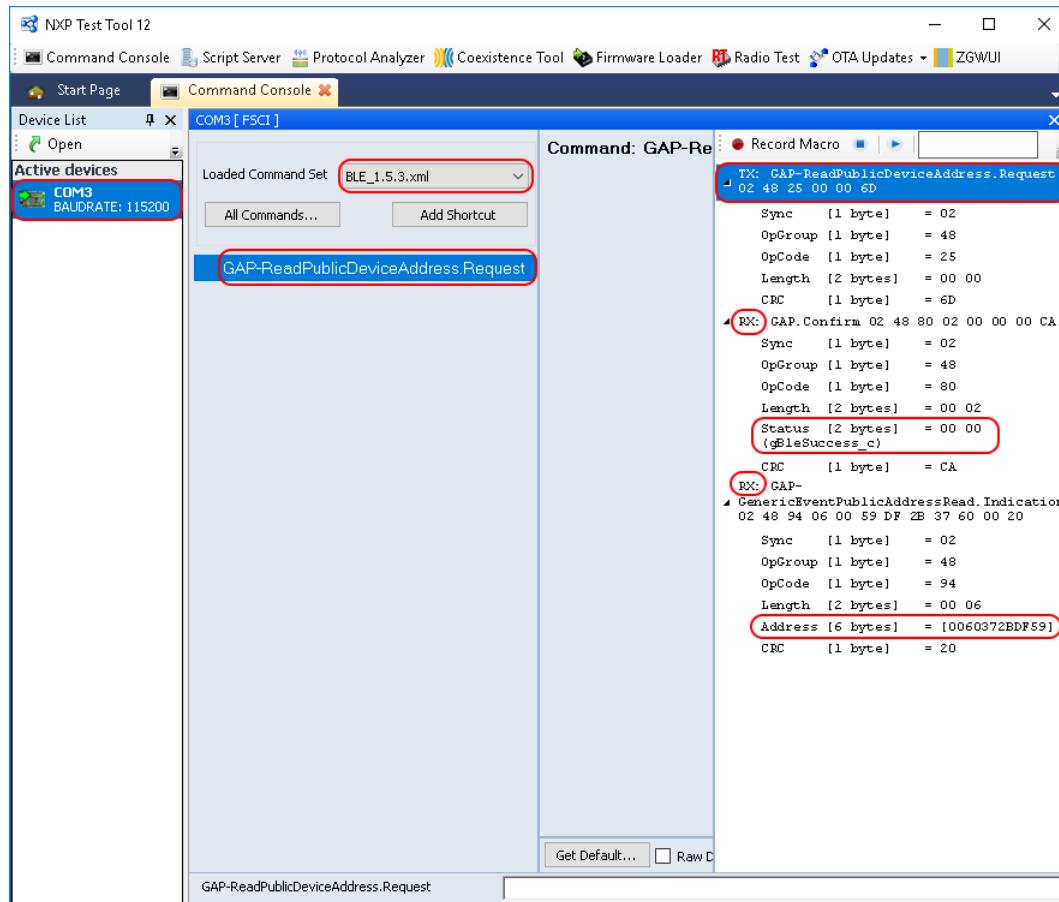


Figure 49. FSCI black box command example

5.26 HCI Black Box

This section describes the functionality, user interactions, and testing methods for the Bluetooth LE HCI Black Box demo application.

5.26.1 Description

The Bluetooth LE HCI Black Box demo application gives access to the Bluetooth LE Controller via a serial interface using the HCI protocol over serial interface. See the Bluetooth Specification for the format of HCI commands and events over serial interface and the full list of supported commands and events.

The demo can be used with the Test Tool for Connectivity Products. Command Console application can be downloaded from the NXP website or with a custom application which supports the HCI protocol and commands and events over serial interface.

Note that the HCI protocol encapsulation is dependent on the type of interface it is being used on. See the Bluetooth Specification for the HCI message format on each type of supported interface.

For instructions using the Bluetooth LE HCI Black Box with a serial terminal application or the *hcitool* in Linux, check this [article](#)

5.26.2 Supported platforms

The HCI Black Box application is supported on the following platforms:

- FRDM-KW41Z
- USB-KW41Z

- QN9080XCDK
- FRDM-KW36

5.26.3 Usage with Test Tool for Connectivity Products

The Bluetooth LE HCI Black Box demo application is designed to be used via serial interface. This can be achieved using the TEST Tool for Connectivity Products – Command Console application as described below.

1. Download the demo application to a supported board
2. Connect the board to an USB port of the PC. The UASB COM port drivers must be installed properly and a COM port corresponding to the board should be available.
3. Open the Test Tool application and connect to the serial port corresponding to the board on which the Bluetooth LE HCI Black Box application runs. The serial communication parameters are: baud rate 115200, 8N1

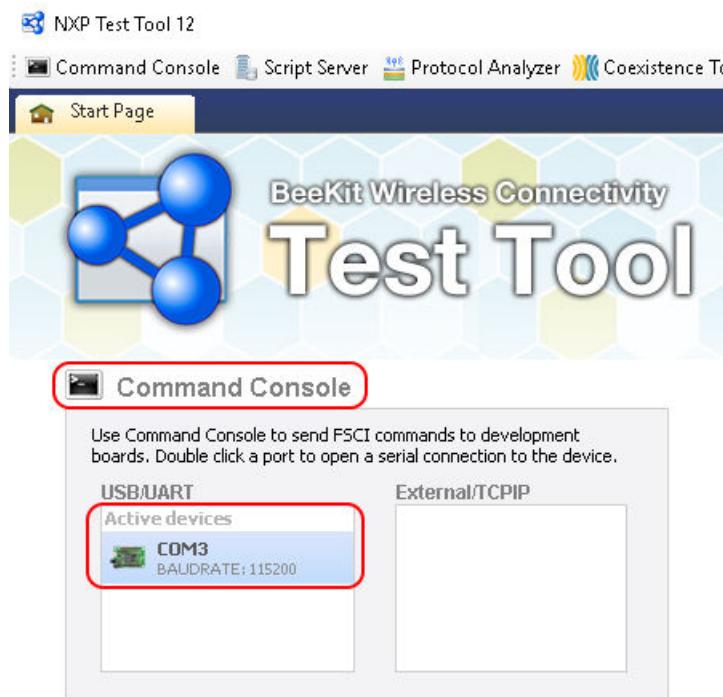


Figure 50. Test tool command console serial port selection

4. Select the appropriate Test Tool HCI XML file from the drop-down list for the release you are using and send some commands to the application.

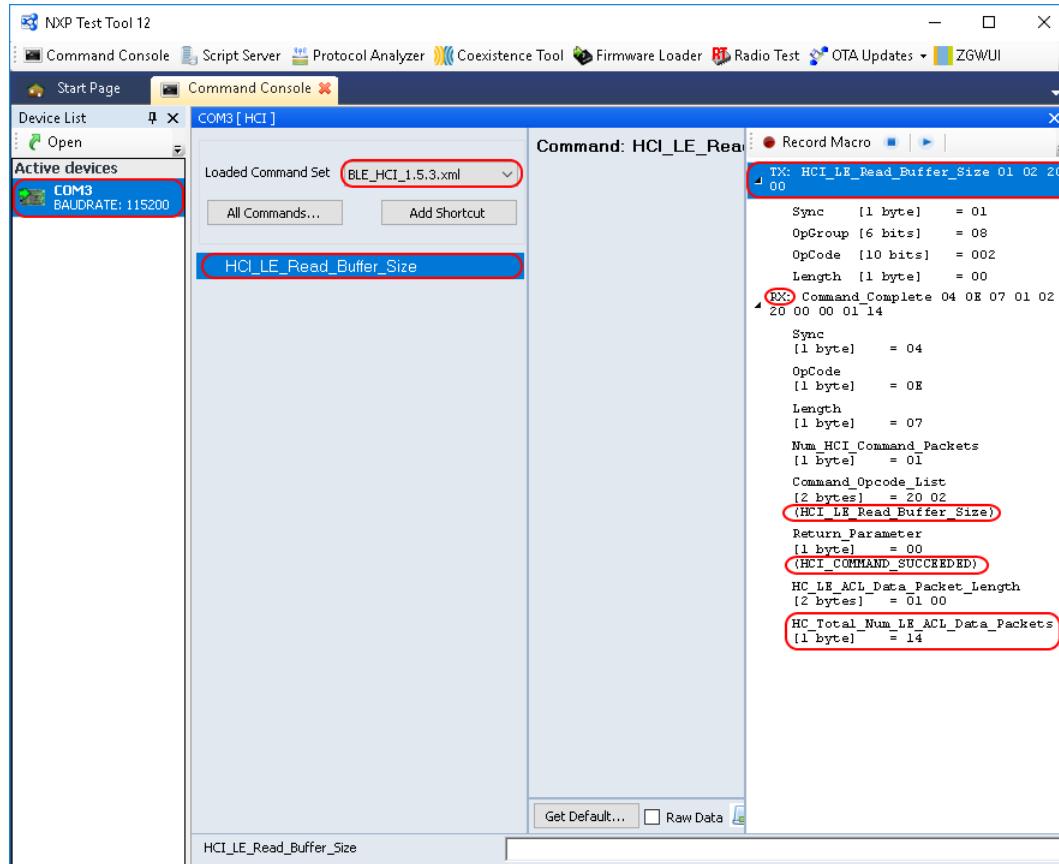


Figure 51. HCI black box command example

5.26.4 Direct Test Mode

HCI Black Box application can be used to test radio functionality at physical layer through Direct Test Mode (DTM) described in Bluetooth Specification Version 5.0, Vol 6, Part F. The testing done so can cover physical layer characteristics such as:

- Transmission power and receiver sensitivity
- Frequency offset and drift
- Modulation characteristics
- Packet error rate
- Intermodulation performance

DTM supports two interfaces for communication:

- Over HCI (enabled by default in HCI Black Box)
- Over 2-Wire UART interface

To use DTM over 2-Wire UART, it must be enabled setting gEnableDTM_d on TRUE and connecting to the proper pins on the board. The default baud rate speed is set to 115200 but it can be changed by configuring gDefaultDTMBaudrate(For 2-Wire UART) or gHcitInterfaceSpeed_d(For HCI); For DTM pin connection, refer to Pinout chapter in Reference Manual.

5.27 Pulse Oximeter Sensor

This section describes the implemented profiles and services, user interactions, and testing methods for the Pulse Oximeter Sensor application.

5.27.1 Implemented profile and services

The Pulse Oximeter Sensor application implements a GATT server and the following profiles and services.

- Pulse Oximeter Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When a peer device connects and configures notifications or indications, the sensor starts sending blood oxygen saturation measurements at regular intervals.

5.27.2 Supported platforms

The Pulse Oximeter Sensor application is supported on the following platforms:

- FRDM-KW41Z
- USB-KW41Z
- QN9080XCDK
- FRDM-KW36

5.27.3 User interface

After flashing the board, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. When a central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the ADVSW button for 2-3 seconds. The node then re-enters GAP Discoverable Mode.

The location and navigation measurement values are generated randomly on the device.

See details below for hardware references.

Table 24. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW41Z	SW4	LED3
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.27.4 Usage

The application can be tested against the Profile Tuning Suite (PTS) black-box testing tool from the Bluetooth SIG.

5.28 Location and Navigation Server

This section describes the implemented profiles and services, user interactions, and testing methods for the Location and Navigation Server application.

5.28.1 Implemented profile and services

The Location and Navigation Server application implements a GATT server and the following profiles and services.

- Location and Navigation Service v1.0
- Battery Service v1.0

- Device Information Service v1.1

The application behaves as a GAP peripheral node. It enters GAP General Discoverable Mode and waits for a GAP central node to connect. When a peer device connects and configures notifications or indications, the server starts sending location and navigation measurements at regular intervals.

5.28.2 Supported platforms

The Location and Navigation Server application is supported on the following platforms:

- FRDM-KW36

5.28.3 User interface

After flashing the board with the server application, the sensor is in idle mode (all LEDs flashing). To start advertising, press the ADVSW button. When in GAP Discoverable Mode, CONNLED is flashing. After flashing the board with the client application, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When scanning, CONNLED is flashing. When the client and server are connected, CONNLED turns solid on both. To disconnect the server, hold the ADVSW button for 2-3 seconds. The node then re-enters GAP discoverable Mode.

Table 25. Hardware references

Platform	ADVSW	CONNLED
FRDM-KW36	SW2	LED3

5.28.4 Usage

The two applications are tested together.

- Open a serial terminal application on the PC and connect it to the serial port corresponding to the board on which the Client runs.
- Press ADVSW on the Server.
- Press SCANSW on the Client.
- Observe the notifications arriving periodically on the Client.

```

Scanning...
Found device:
NXP_LNS
00:60:37:46:DC:CA
Connected!

Received Report:
=====
UTC Time: 6537216

Received Report:
=====
Instantaneous Speed: 17
Total Distance: 436207617
Location: 537250074, 2584109489
Elevation: 1403

Received Report:
=====
UTC Time: 6542368

```

Figure 52. Notification arriving periodically

5.29 Location and Navigation Client

This section describes the implemented profiles, services, user interactions, and testing methods for the Location and Navigation Client application.

5.29.1 Implemented profile and services

The Location and Navigation Client application implements a GATT client for the following profiles and services.

- Location and Navigation Service v1.0
- Battery Service v1.0
- Device Information Service v1.1

The application behaves as a GAP central node. It enters the GAP Limited Discovery procedure and searches for a Location and Navigation server to connect. After connecting with the peripheral, it configures notifications and monitors the data received through notifications.

5.29.2 Supported platforms

The Location and Navigation Server application is supported on the following platforms:

- QN9080XCDK
- FRDM-KW36

5.29.3 User interface

After flashing the board, the device is in idle mode (all LEDs flashing). To start scanning, press the SCANSW button. When in GAP Limited Discovery Procedure, CONNLED is flashing. When a central node connects to the peripheral, CONNLED turns solid. To disconnect the node, hold the SCANSW button for 2-3 seconds. The node then re-enters GAP Limited Discovery Procedure.

See details below for hardware references.

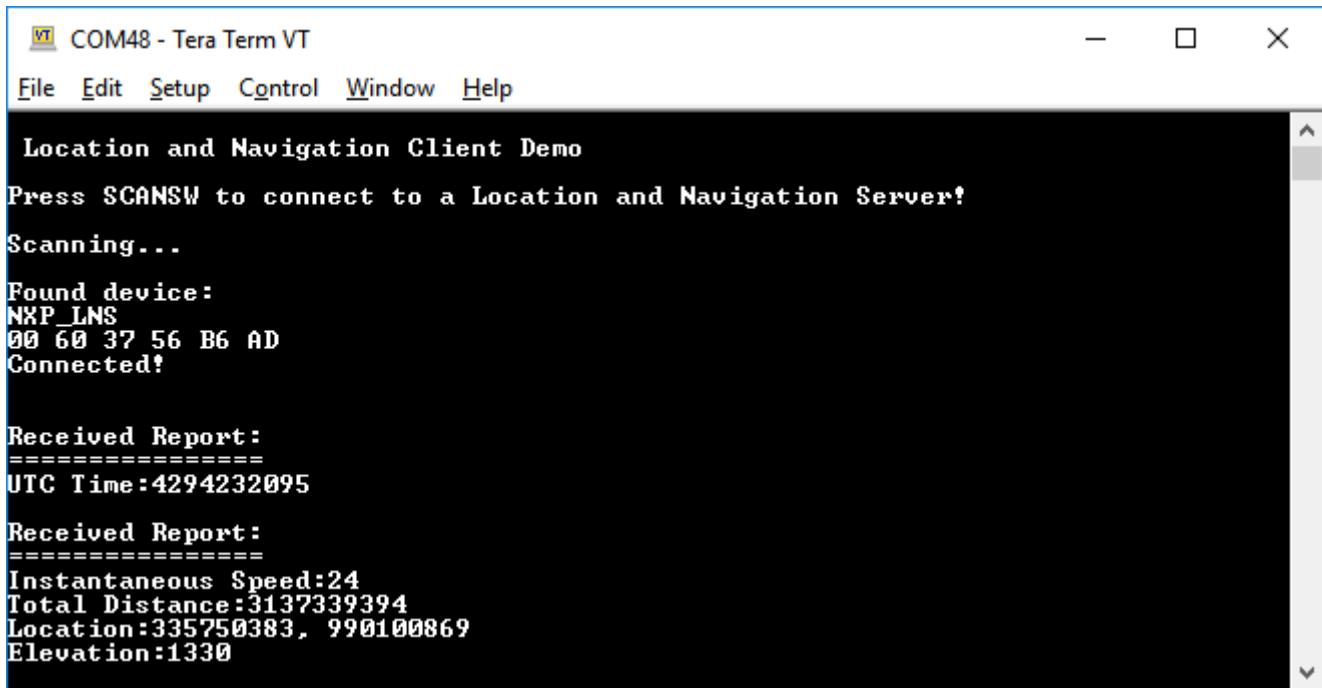
Table 26. Hardware references

Platform	SCANSW	CONNLED
QN9080CDK	BUTTON1	D5-RED
FRDM-KW36	SW2	LED3

5.29.4 Usage

The setup requires two supported platforms, one for the location and navigation server and other for the location and navigation client.

- Open a serial port terminal and connect it to the temperature collector board, in the same manner as described in 5.1.3.
- To start scanning for a server, press the SCANSW button.
- Once connected to a server, the client will enable the location and speed characteristic notifications.
- Monitor the received reports on the client's console.



```
Location and Navigation Client Demo
Press SCANSW to connect to a Location and Navigation Server!
Scanning...
Found device:
NXP_LNS
00 60 37 56 B6 AD
Connected!

Received Report:
=====
UTC Time:4294232095

Received Report:
=====
Instantaneous Speed:24
Total Distance:3137339394
Location:335750383, 990100869
Elevation:1330
```

Figure 53. Location and Navigation Client Demo

Chapter 6

Revision History

This table summarizes revisions to this document.

Table 27. Revision history

Revision number	Date	Substantive changes
0	06/2015	Initial release
1	10/2015	Added new applications
2	04/2016	Added Bluetooth LE Shell App Added KW41Z UI section Updated IPSP section Added interaction with Kinetis Bluetooth LE Toolbox Application Changed OTAP demo application: removed instructions for use with the OTAP Python script for PC, added instructions for use with the Test Tool for Connectivity products Bluetooth LE OTAP tool, and added instructions for use with the Kinetis Bluetooth LE Toolbox mobile application
3	07/2016	Added Bluetooth LE Relay Proxy application
4	09/2016	Updated for KW41Z
5	06/2017	Updated for QN9080CDK
6	10/2017	Updated for KW36
7	12/2017	Updated for QN9080x

Table continues on the next page...

Table 27. Revision history (continued)

Revision number	Date	Substantive changes
8	03/2018	<ul style="list-style-type: none">• Added the KW36 platform to the supported platforms lists and the hardware references tables.• Added clarifications regarding LED behaviour on demo applications which use the low power feature.• Small corrections to multiple demo applications sections.• Added sections in demo applications Section 5.23, “ Hybrid (Dual-Mode) Bluetooth Low Energy and Generic FSK Advertising Demo Application ”, Section 5.24, “ ANCS Client ”, Section 5.25, “ Bluetooth LE FSCI Black Box ”, Section 5.26, “ HCI Black Box ”, Section 5.27, “ Pulse Oximeter Sensor ”, Section 5.28, “ Location and Navigation Server ”.
9	06/2018	Updated for KW35
10	12/2018	Added Section 5.29 , “ Location and Navigation Client ” and updated BLE to Bluetooth LE
11	06/2019	Updated for KW35
12	07/2019	Updated for K32W and QN90xx
13	10/2019	Updated for QN908x
14	11/2019	Updated for KW35 Maintenance Release 3

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Date of release: 12 November 2019

Document identifier: BLEDAUG

