Getting started with the STM32Cube function pack for STM32WB with Bluetooth® Low Energy connectivity and environmental, motion and Time-of-Flight sensors

Introduction

The FP-SNS-MOTENVWB1 function pack for STM32Cube lets you connect your IoT node to a smartphone via Bluetooth® Low Energy (BLE) and use a suitable Android or iOS application such as the STBLESensor app to view real-time motion, environmental (temperature, pressure and relative humidity), and Time-of-Flight sensor data.

The package also enables advanced functions such as the sensor data fusion, accelerometer-based real-time activity recognition, carry position, gesture recognition, pedometer, motion intensity, compass, and object distance.

Together with the suggested combination of STM32WB and other ST devices, it can be used to develop specific wearable and environmental applications, or smart things applications in general.

The software runs on the STM32WB microcontroller and includes all the necessary drivers to recognize the devices on the STM32WB55 Nucleo development board (P-NUCLEO-WB55 or NUCLEO-WB55RG), X-NUCLEO-IKS01A3 (or X-NUCLEO-IKS4A1), and X-NUCLEO-53L3A2 (optional) expansion board.

The software is available also on GitHub, where the users can signal bugs and propose new ideas through [Issues] and [Pull Requests] tabs.

Related links

Visit the STM32Cube ecosystem web page on www.st.com for further information

1 FP-SNS-MOTENVWB1 software expansion for STM32Cube

1.1 Overview

FP-SNS-MOTENVWB1 key features are:

- Complete firmware to develop an IoT node with Bluetooth® Low Energy connectivity, environmental, motion, and Time-of-Flight sensors
- Middleware libraries for sensor data fusion, accelerometer-based real-time activity recognition, carry position, gesture recognition, motion intensity recognition, and pedometer
- Compatible with STM32CubeMX, it can be downloaded from and installed directly into STM32CubeMX
- Compatible with STBLESensor applications for Android/iOS to perform sensor data reading, motion algorithm feature demo, and firmware update (FOTA)
- Sample implementation available for the X-NUCLEO-IKS01A3 (or X-NUCLEO-IKS4A1) and X-NUCLEO-53L3A2 (optional) connected to a P-NUCLEO-WB55 or NUCLEO-WB55RG
- Easy portability across different MCU families, thanks to STM32Cube

This software creates the following Bluetooth® Low Energy services:

1. The first service exposes all the hardware features with the following characteristics:
   - temperature
   - pressure
   - humidity
   - 3D gyroscope, 3D magnetometer, 3D accelerometer
   - object distance
2. The second service exposes the software characteristics:
   - quaternions generated by the MotionFX library in short precision
   - magnetic North direction (e-Compass)
   - recognized activity using the MotionAR algorithm
   - recognized carry position using the MotionCP algorithm
   - recognized gesture using the MotionGR algorithm
   - number of steps and frequency using the MotionPM algorithm
   - recognized motion intensity using the MotionID
3. The third service exposes the console service with:
   - stdin/stdout for bidirectional communication between client and server
   - stderr for a mono-directional channel from the P-NUCLEO-WB55 to an Android/iOS device
4. The last service is for transmitting/resetting the calibration status and enabling the following expansion hardware features for the STM32 Nucleo boards for theLSM6DS0 on the X-NUCLEO-IKS01A3 expansion board and for LSM6DSV16X on an X-NUCLEO-IKS4A1 expansion board:
   - pedometer
   - free fall detection
   - single tap detection
   - double tap detection
   - wakeup detection
   - tilt detection
   - 3D orientation
   - multievent detection (3D orientation, pedometer, single tap, double tap, free fall and tilt detection)

This software gathers:

- the temperature, humidity, pressure, and motion sensor drivers for the STTS22H, SHT40AD1B, LPS22DF, LIS2DUXS12, LIS2MDL and LSM6DSV16X devices available on the X-NUCLEO-IKS4A1 expansion board
- the temperature, humidity, pressure, and motion sensor drivers for the HTS221, LPS22HH, LSM6DS0 , LIS2DW12, and LIS2MDL devices available on the X-NUCLEO-IKS01A3 expansion board
- object distances for the VL53L3CX device available on the X-NUCLEO-53L3A2 expansion board when is mounted on the P-NUCLEO-WB55 (or NUCLEO-WB55RG).

This package is compatible with the STBLESensor and STBLESensClassic Android/iOS (ver. 4.20.0 or later) application available at the respective Play/iTunes stores, which can be used for displaying information sent via the Bluetooth low energy protocol.

1.2 Architecture

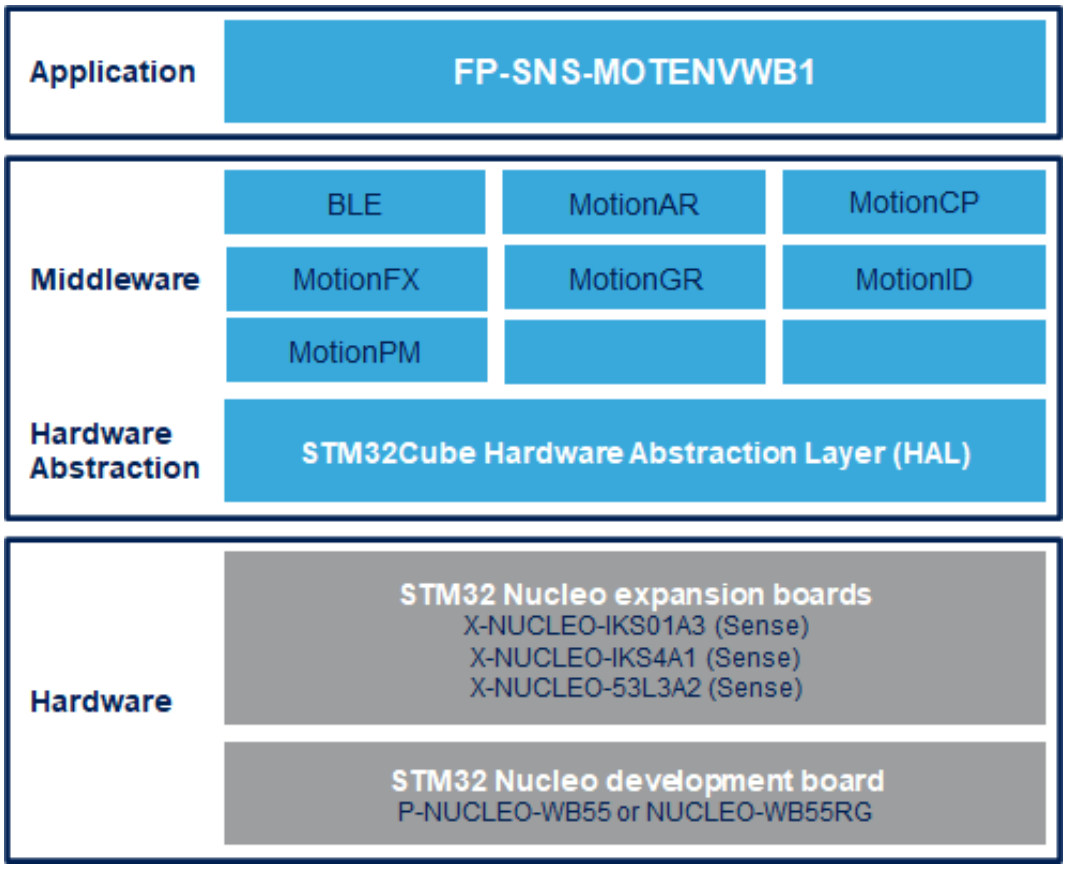
The software is based on the STM32CubeHAL, the hardware abstraction layer for the STM32 microcontroller. The package extends STM32Cube by providing a Board Support Package (BSP) for the sensor expansion board and middleware components for communication with other Bluetooth low energy devices and for sensor data fusion.

The implementation makes use of low power consumption strategies suitable for this field of application, compliant with the Bluetooth specifications core 5.0.

The software layers used by the application software to access and use the expansion boards are:

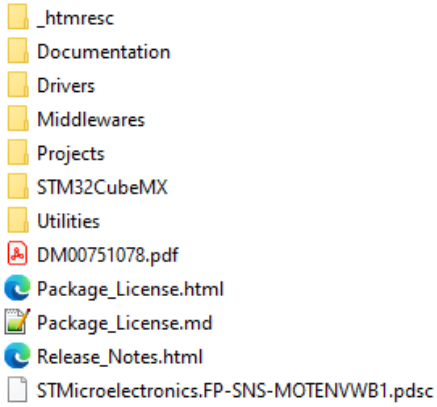
- the **STM32Cube HAL layer**, which provides a simple, generic, multi-instance set of application programming interfaces (APIs) to interact with the upper application, library and stack layers. It has generic and extension APIs and is directly built around a generic architecture and allows successive layers like the middleware layer to implement functions without requiring specific hardware configurations for a given microcontroller unit (MCU). This structure improves library code reusability and guarantees an easy portability on other devices.
- the **board support package** (BSP) layer supports all the peripherals on the STM32 Nucleo except the MCU. This limited set of APIs provides a programming interface for certain board-specific peripherals like the LED, the user button, etc. This interface also helps in identifying the specific board version.
- the **middleware** provides advanced motion libraries. The motion libraries include MotionAR (activity recognition library), MotionCP (carrying position library), MotionEC (eCompass library), MotionFX (sensor fusion library), MotionGR (gesture recognition library), MotionID (intensity detection library), MotionPM (pedometer).

Figure 1. FP-SNS-MOTENVWB1 software architecture



1.3 Folder structure

Figure 2. **FP-SNS-MOTENVWB1 package folder structure**



The following folders are included in the software package:

- **Documentation**: contains a compiled HTML file generated from the source code which details the software components and APIs.
- **Drivers**: contains the HAL drivers and the board-specific drivers for each supported board or hardware platform, including the on-board components and the CMSIS vendor-independent hardware abstraction layer for ARM Cortex-M processor series.
- **Middlewares**: contains libraries and protocols for STM32 WPAN Bluetooth® Low Energy, MotionFX (iNEMOEngine PRO) sensor fusion library, MotionAR activity recognition library, MotionCP carry position recognition library, MotionGR gesture recognition library, MotionPM real-time pedometer library, MotionID motion intensity recognition library.
- **Projects**: contains a sample application used to transmit the output of the sensor data and of the MotionFX sensor fusion and e-Compass, MotionAR activity-recognition, MotionID motion intensity-recognition, MotionCP carry position, MotionGR gesture recognition and MotionPM pedometer libraries. Data are transmitted using the Bluetooth low energy protocol provided for the P-NUCLEO-WB55 (or NUCLEO-WB55RG) platform. Projects are configured for the IAR Embedded Workbench for ARM, RealView Microcontroller Development Kit (MDK-ARM) and System Workbench for STM32 development environments.

1.4 APIs

Detailed technical information with full user API function and parameter description are in a compiled HTML file in the “Documentation” folder.

1.5 Sample application description

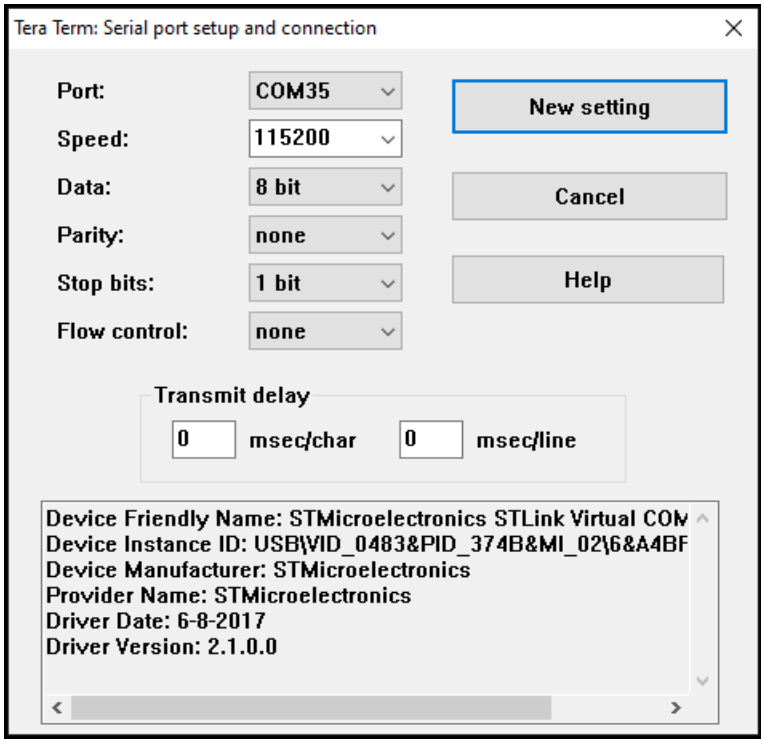
A sample application is provided in the Projects folder for the X-NUCLEO-IKS01A3 (or X-NUCLEO-IKS4A1) and the X-NUCLEO-53L3A2 (optional) with the P-NUCLEO-WB55 (or NUCLEO-WB55RG).

Ready-to-build projects are available for multiple IDEs.

Ready-to-build projects are available for multiple IDEs.

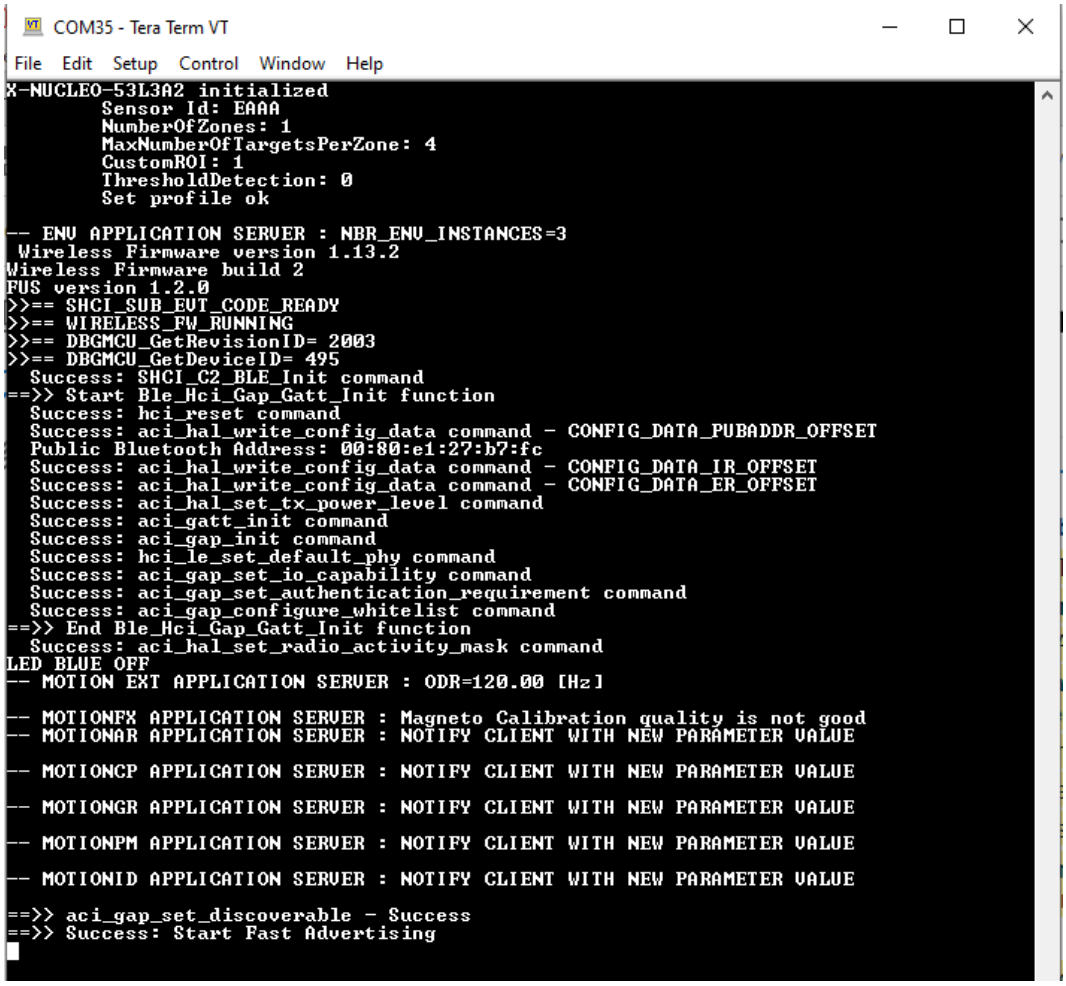
You can set up a terminal window for the appropriate UART communication port (use the baud, data, parity and stop settings below) to control the initialization phase.

Figure 3. Terminal settings



When you first press the reset button on the P-NUCLEO-WB55 board, you can see the initialization phase using serial line monitor (e.g. Teta Term):

Figure 4. **Tera Term**



The MotionAR library can recognize the following activities:

- stationary
- walking
- fast walking
- jogging
- biking
- driving

The MotionCP library recognizes and provides real-time information about the way the user is carrying the board, which equates to the phone carry position:

- on desk
- in hand
- near head
- shirt pocket
- trouser pocket
- arm swing

The MotionGR library can recognize gestures like:

- pick up
- glance
- wake up in hand

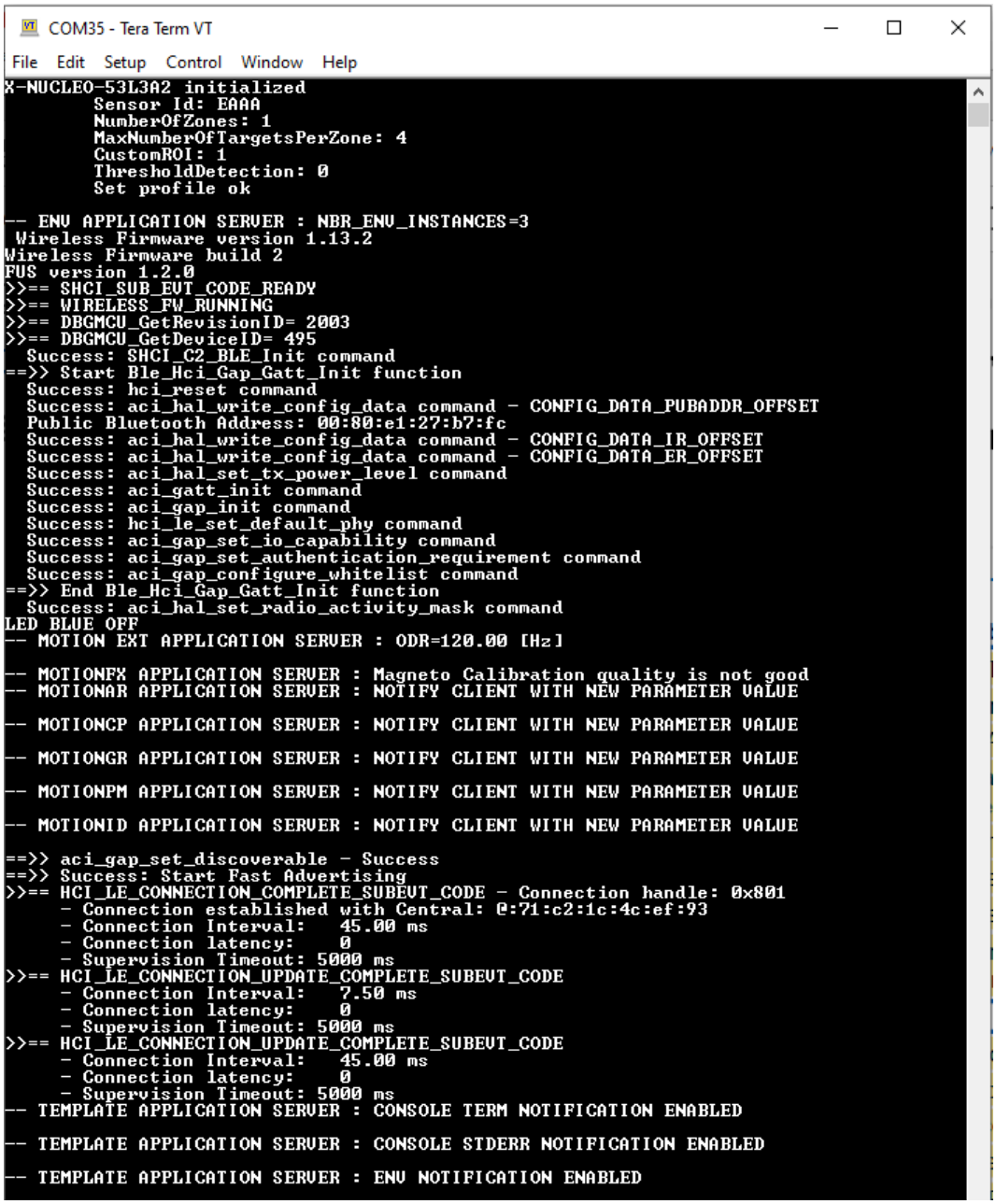
The MotionPM library counts the number of steps and computes their frequency.

The MotionID library can recognize the following activities:

- on desk
- bed, couch
- light movement
- biking
- typing/writing
- slow walking
- walking
- fast walking
- jogging
- fast jogging
- sprinting

When an Android/iOS device is connected to the P-NUCLEO-WB55 board (or NUCLEO-WB55RG), you can control data transmitted via the board.

Figure 5. **Tera Term VT**



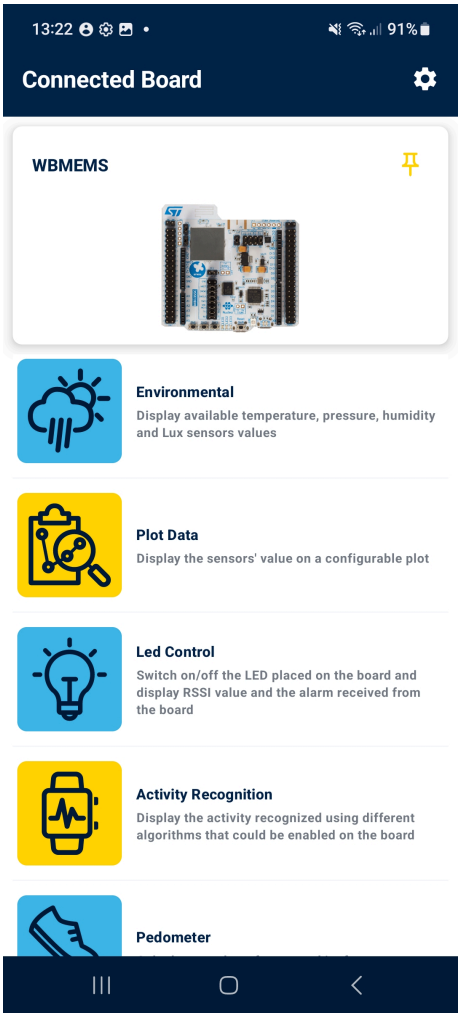
1.6 Android and iOS STBLESensor client application

The FP-SNS-MOTENVWB1 software for STM32Cube is compatible with the STBLESensor Android/iOS applications (ver. 4.20.0 or later) available at the respective stores.

In this example, we use the Android version.

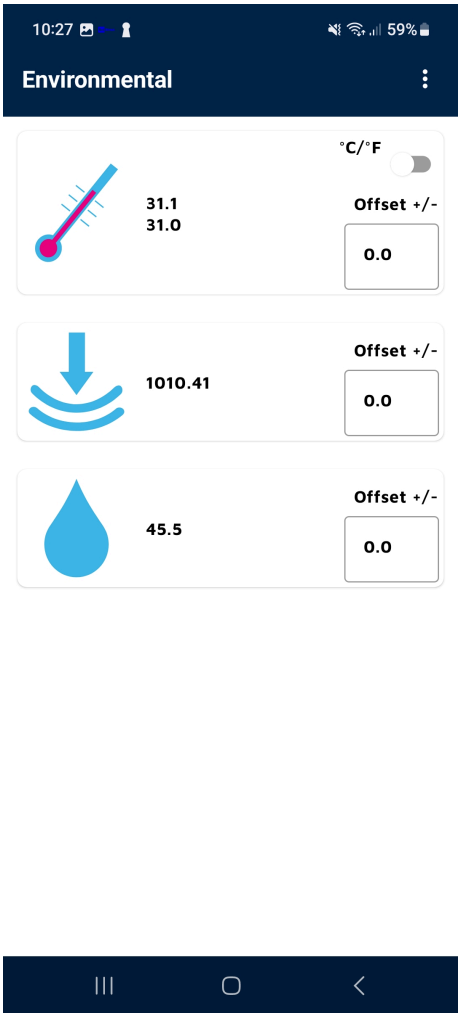
Following connection, STBLESensor starts with the main page shown below.

Figure 6. **STBLESensor (Android version) main page following BLE connection**



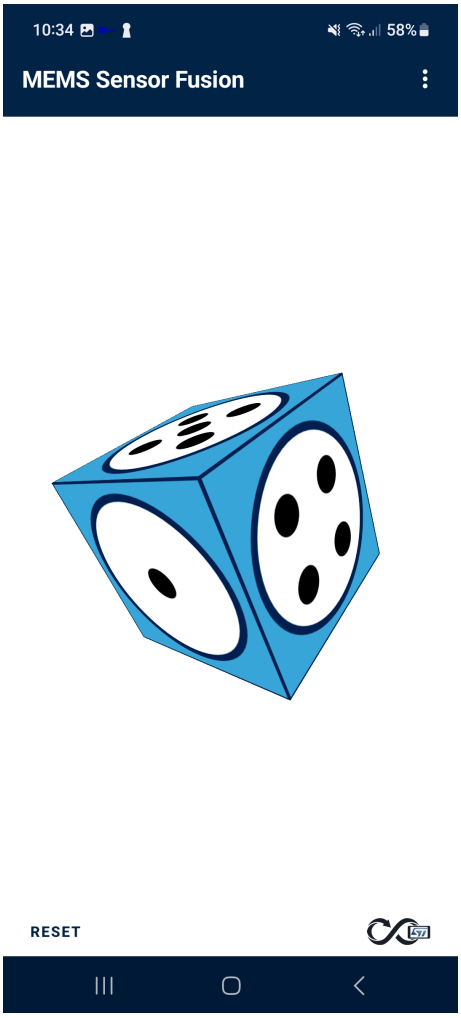
The following page shows the values of temperature, pressure and humidity:

Figure 7. **STBLESensor (Android version) environmental page**



The following page shows a cube that rotates with board movement.

Figure 8. **STBLESensor (Android version) MotionFX sensor fusion page**



On this page, there are two buttons along the bottom:

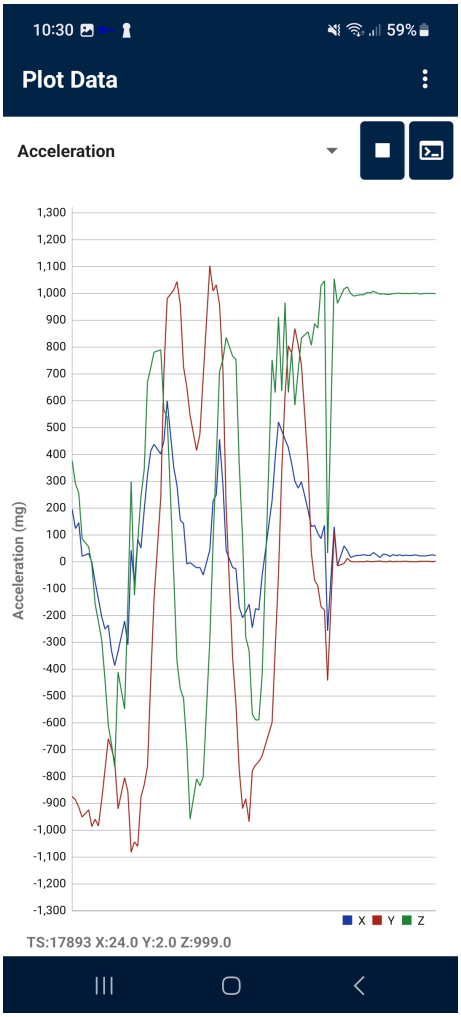
- the left is for resetting the cube position.
- the right shows the calibration status of the MotionFX library (black for not calibrated, green for calibrated). Clicking it forces a magneto calibration.

When either button is pressed, the application pops up a window describing how to position the board for correct cube rotation and how to move the board to facilitate calibration (see figure below).

Figure 9. **STBLESensor (Android version) popup windows**

With the Plot Data page, you can plot any value from the sensor expansion boards.

Figure 10. **STBLESensor (Android version) accelerometer plot**



There is another page where you can choose which accelerometer hardware feature to enable (one at the time). The orientation hardware feature is the default setting.

Figure 11. **STBLESensor (Android version) orientation feature**

From the **Accelerometer Events** menu, a single harware feature can be selected:

Figure 12. **STBLESensor (Android version) hardware feature menu**

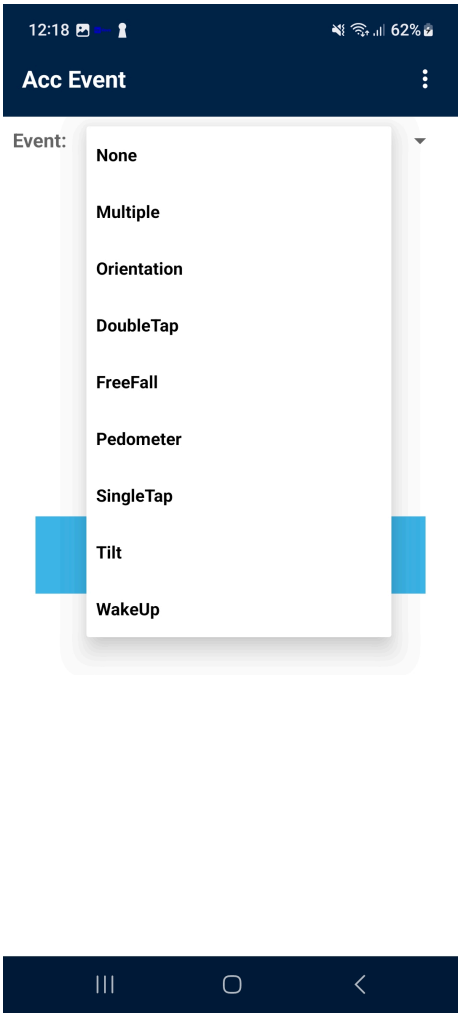
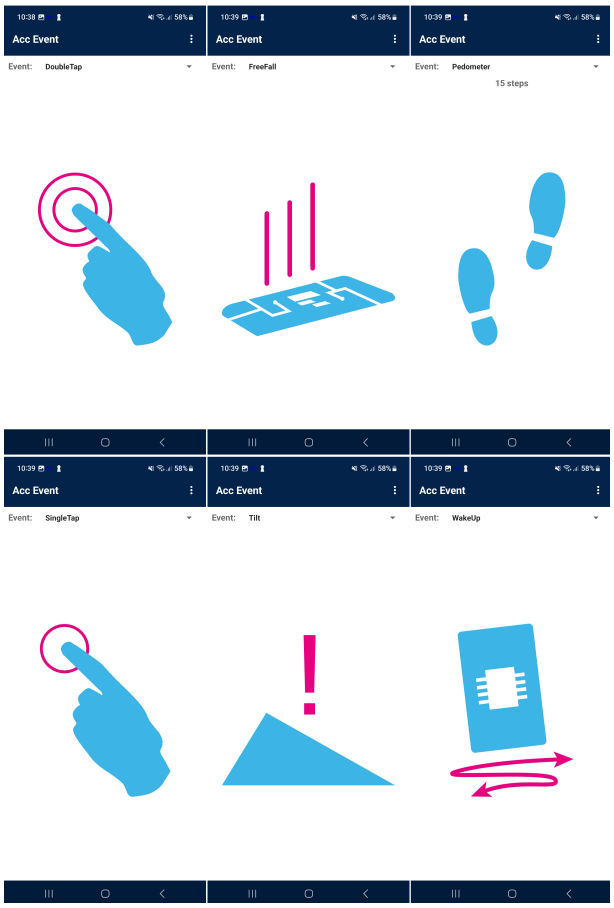
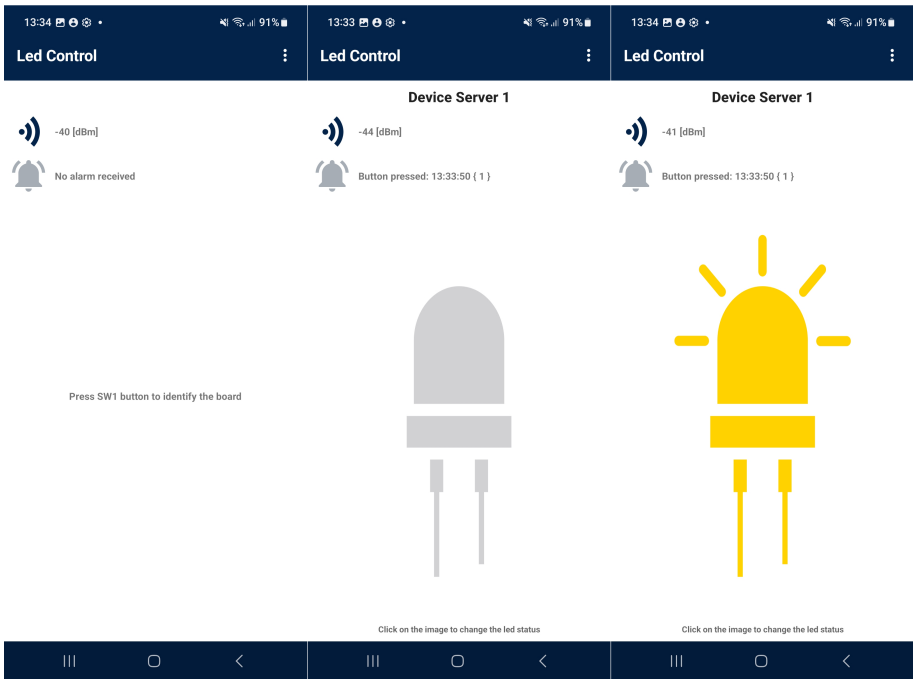


Figure 13. STBLESensor (Android version) hardware feature examples: double tap, free fall, pedometer, single tap, tilt, wake up



The following page shows the LED on/off control.

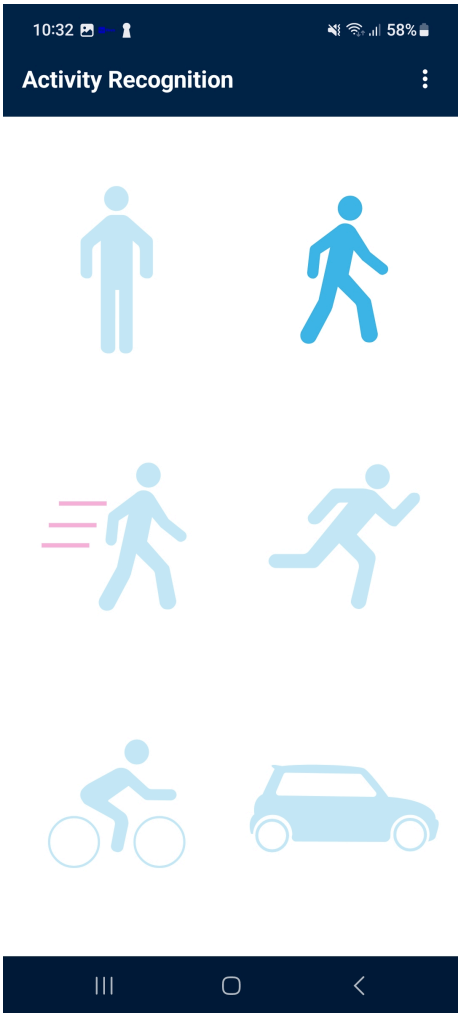
Figure 14. STBLESensor (Android version) board LED control



For the MotionAR algorithm, the page shown below is available, signaling one of the following recognized activities:

- Stationary
- Walking
- Fast walking
- Jogging
- Biking
- Driving

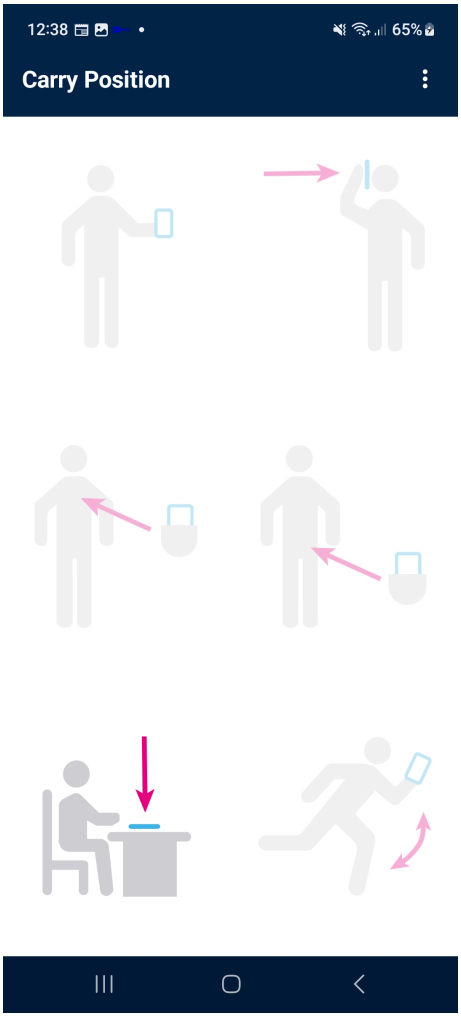
Figure 15. STBLESensor (Android version) MotionAR activity recognition page



For the MotionCP algorithm, the page shown below is available, with information about how the user is carrying the board, which equates to phone carry positions:

- on desk
- in hand
- near head
- shirt pocket
- trousers pocket
- arm swing

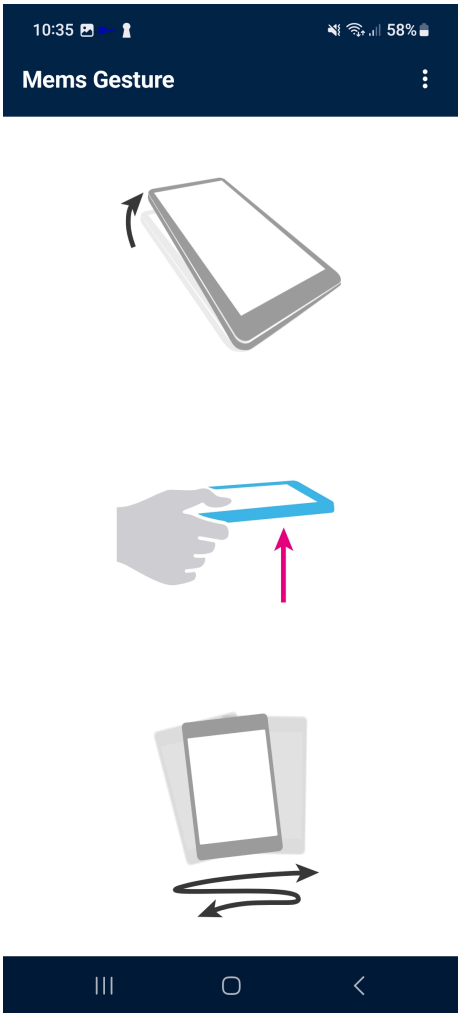
Figure 16. **STBLESensor (Android version) MotionCP carry position recognition page**



For the MotionGR algorithm, the page shown below is available with gesture recognition information like:

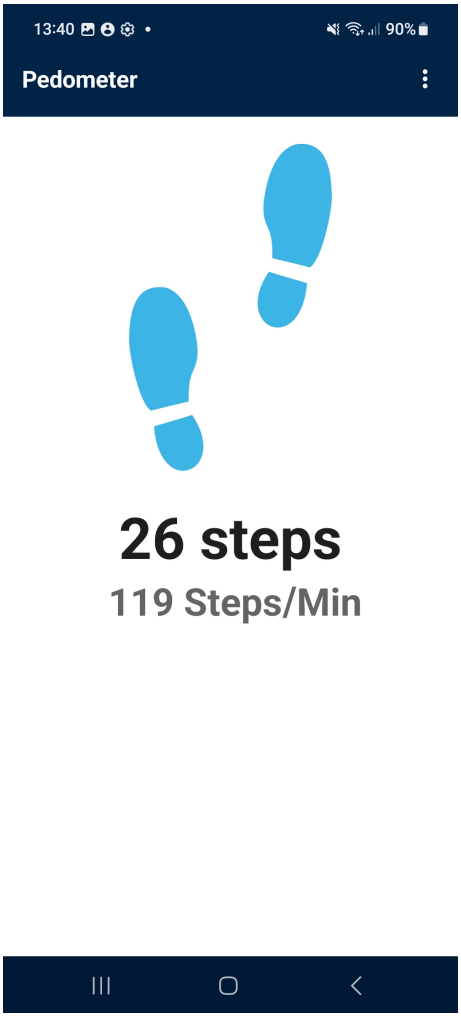
- pick up
- glance
- wake up in hand

Figure 17. **STBLESensor (Android version) MotionGR gesture recognition page**



For the MotionPM algorithm, the page shown below is available with pedometer information:

Figure 18. **STBLESensor (Android version) MotionPM pedometer page**



For the MotionID algorithm, the page shown below is available:

Figure 19. **STBLESensor (Android version) Motion Intensity page**

For the MotionFX algorithm, the following page shows a e-compass that rotates with board movement.

Figure 20. **STBLESensor (Android version) e-compass page**

On this page and on the bottom, the right button shows the calibration status of the MotionFX library (black for not calibrated, green for calibrated). Clicking it forces a magneto calibration.

If the X-NUCLEO-53L3A2 expansion board is plugged, ToF Objects Detection shows the distances of the detected objects (up to four objects) or the person presence.

Figure 21. **STBLESensor (Android version) ToF object distance page**

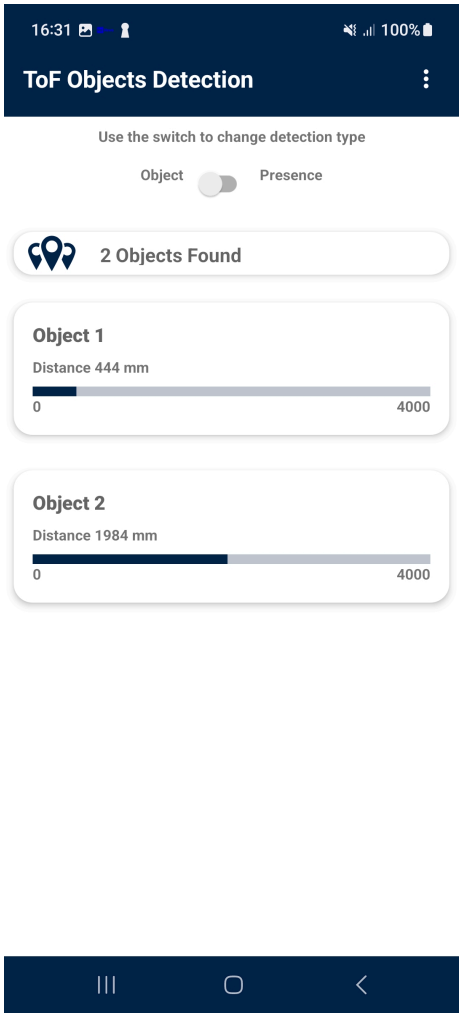
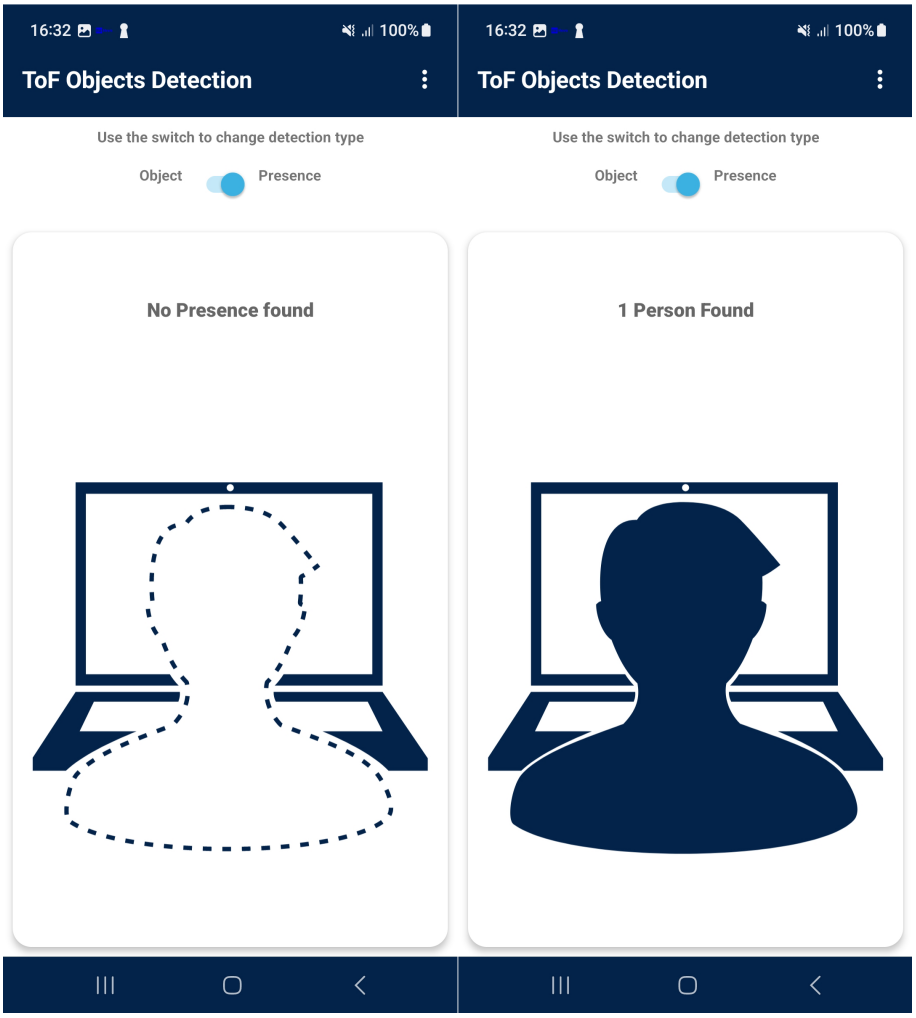


Figure 22. **STBLESensor (Android version) ToF human presence page**



The presence is identified inside a fixed range distance that can be modified by the following defines in STM32_WPAN\App\ToF_server_app.c:

- `#define PRESENCE_MIN_DISTANCE_RANGE 300`
- `#define PRESENCE_MAX_DISTANCE_RANGE 800`

1.7 FOTA support

To make the OTA work, use ST32CubeProgrammer and follow the procedure below.

Step 1. Erase full Flash memory.

Step 2. Flash BLE_Ota_reference.hex (from the MOTENV1_OTA/Binary directory) at 0x08000000.

Step 3. Flash MOTENV1_OTA.bin (from the MOTENV1_OTA/Binary directory) at 0x08007000.

Related links

For further details on FOTA, see AN5247 "Over-the-air application and wireless firmware update for STM32WB Series microcontrollers"

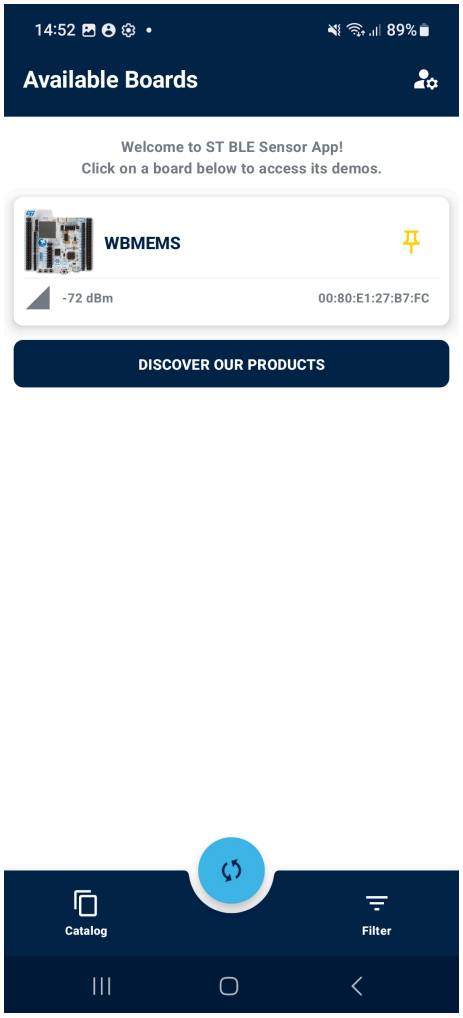
1.7.1 User application update for Android

To update the user application using an Android mobile phone, follow the steps below.

Step 1. Copy the new user application to your phone.

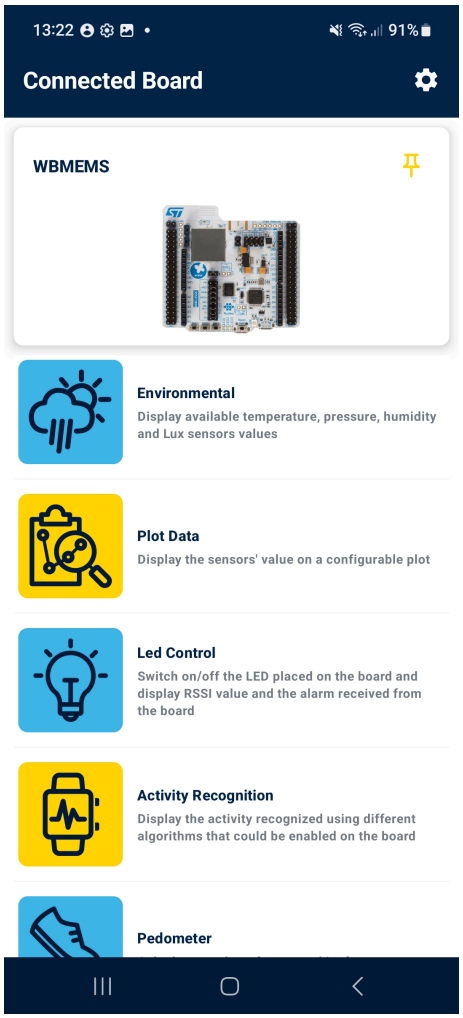
Step 2. Open STBLESensor mobile app.

Figure 23. STBLESensor app - home page



Step 3. Search for and connect to the “WBMEMS” device.

Figure 24. Searching for and connecting to the WBMEMS device



Step 4. Tap the option button (top right) to open the option window, scroll the menu option, and select "Firmware Update".

Figure 25. Menu window

Step 5.

Step 5a. Select the board type and after Application Coprocessor reboot.

Step 5b. Select the binary file for OTA from your mobile phone folders.

Step 5c. Start OTA with the "UPGRADE" button.

Figure 26. STBLESensor reboot

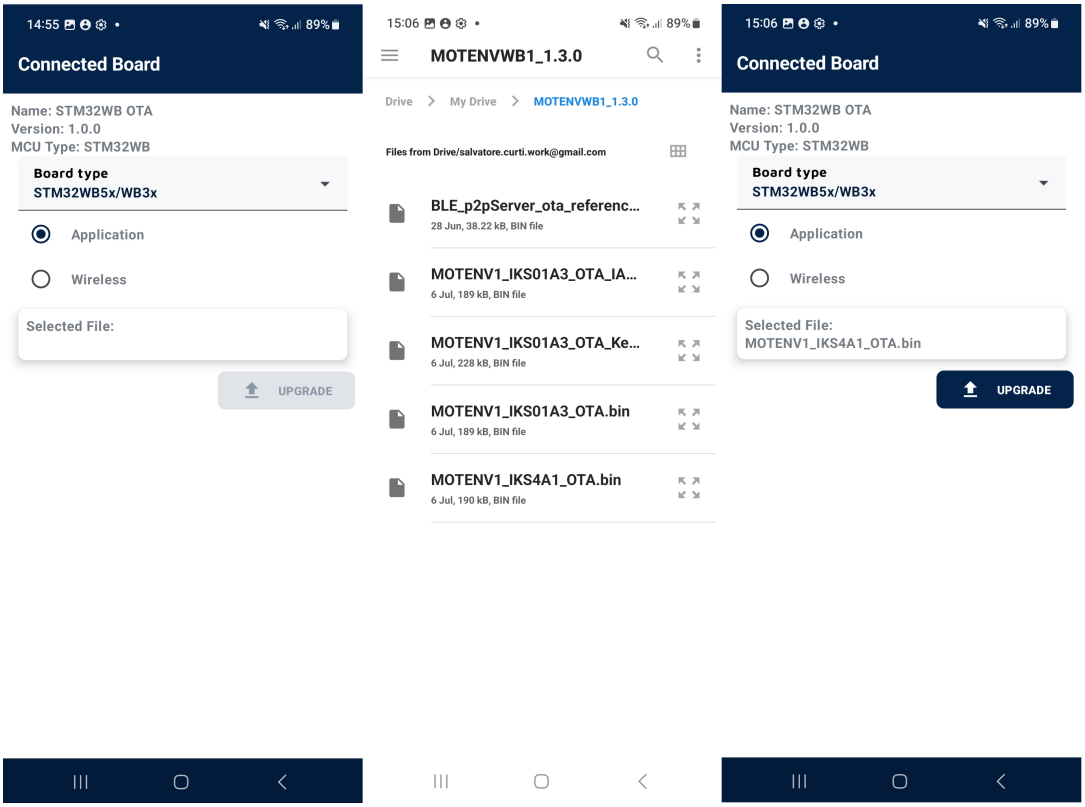
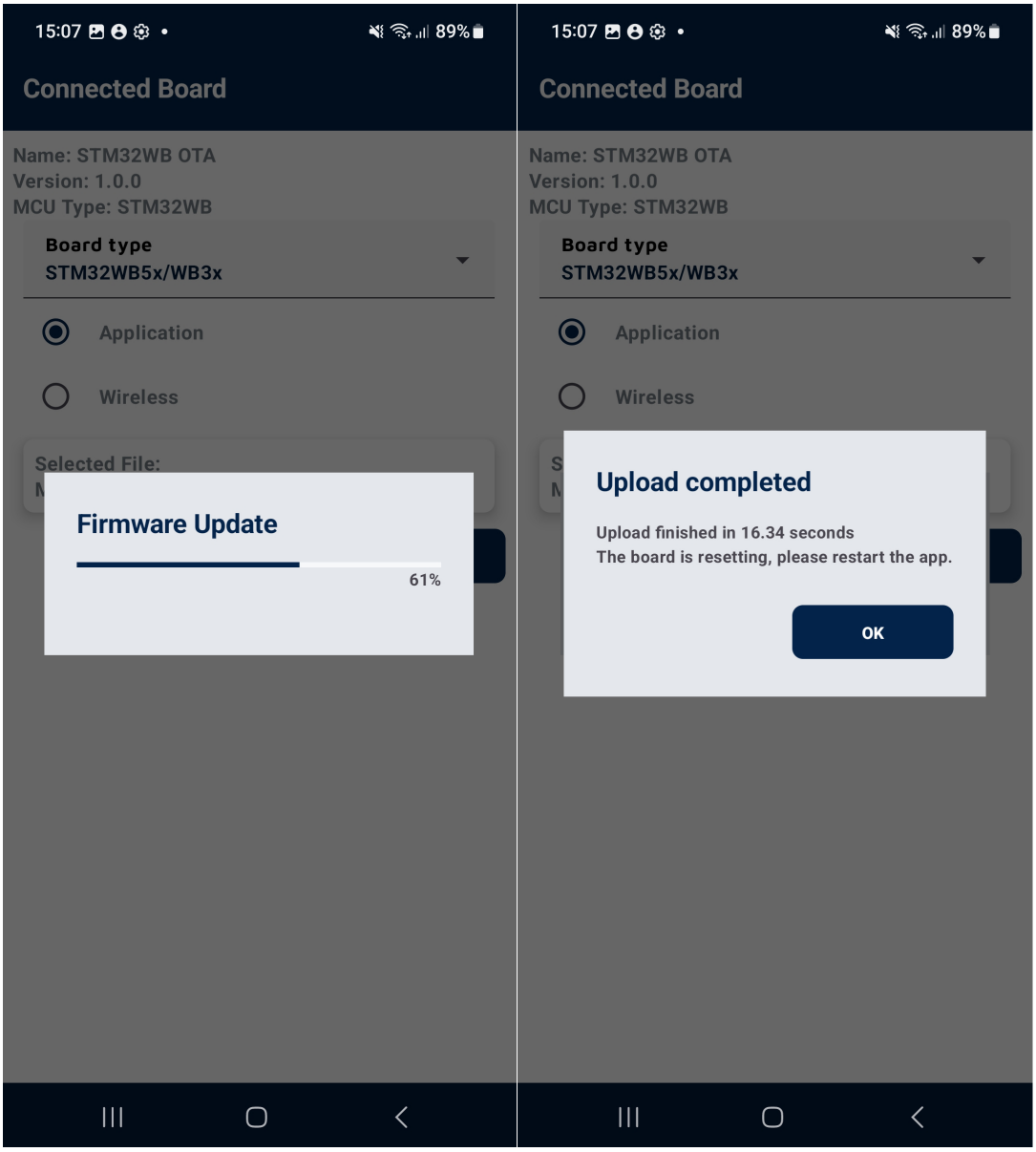


Figure 27. **STBLESensor - upgrading the firmware**



2 System setup guide

2.1 Hardware description

2.1.1 STM32WB series

Based on an Arm® Cortex®-M4 core running at 64 MHz (application processor) and an Arm® Cortex®-M0+ core at 32 MHz (network processor), STM32WB55 microcontrollers support Bluetooth™ 5 and IEEE 802.15.4 wireless standards.

Thanks to these two totally independent cores, this innovative architecture is optimized for real-time execution (radio related software processing) as well as flexible resource use and power management for a lower BOM cost and a better user experience.

Developed with the same technology as our ultra-low-power STM32L4 microcontrollers, the STM32WB series provides the same digital and analog peripherals suitable for applications requiring extended battery life and complex functionalities.

2.1.2 P-NUCLEO-WB55

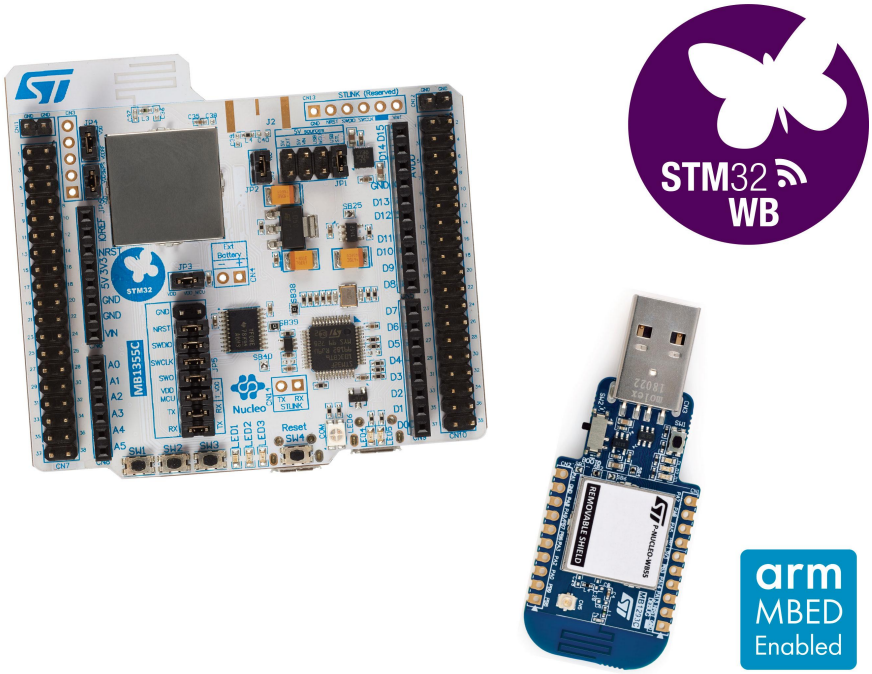
The P-NUCLEO-WB55 pack is a multi-protocol wireless and ultra-low-power device embedding a powerful and ultra-low-power radio compliant with the Bluetooth® Low Energy (BLE) SIG specification v5.0 and with IEEE 802.15.4-2011.

The pack consists of a Nucleo-68 development board and a USB dongle.

It features:

- STM32WB microcontroller in a VFQFPN68 package
- 2.4 GHz RF transceiver supporting Bluetooth® specification v5.0 and IEEE 802.15.4-2011 PHY and MAC
- Dedicated Arm® 32-bit Cortex® M0+ CPU for real-time Radio layer
- Three user LEDs
- Three user buttons and one reset button
- Board connector: USB user with Micro-B
- Arduino™ Uno V3 connector
- ST morpho connectors
- Integrated PCB antenna or footprint for SMA connector
- Flexible power-supply options: ST-LINK USB VBUS or external sources
- On-board socket for CR2032 battery
- On-board ST-LINK/V2-1 debugger/programmer with USB re- enumeration capability: mass storage, virtual COM port and debug port
- Comprehensive free software libraries and examples available with the STM32Cube package
- Support of a wide choice of Integrated Development Environments (IDEs), including IAR™, Keil®, GCC-based IDEs, Arm® Mbed™

Figure 28. **P-NUCLEO-WB55 development pack**



2.1.3 NUCLEO-WB55RG

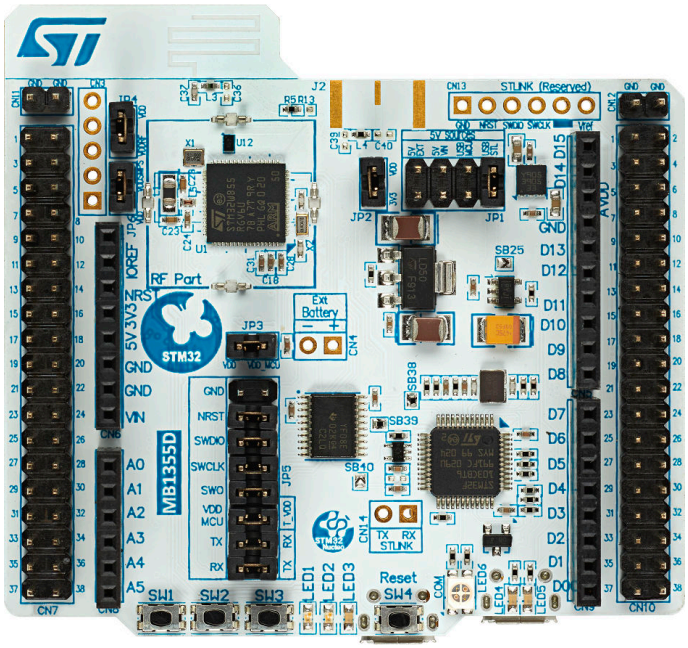
The NUCLEO-WB55RG and NUCLEO-WB15CC STM32WB Nucleo-64 boards are Bluetooth® Low Energy (BLE) wireless and ultra-low-power devices embedding a powerful and ultra-low-power radio compliant with the Bluetooth® Low Energy (BLE) SIG specification v5.2. NUCLEO-WB55RG also offers a radio compliant with IEEE 802.15.4-2011 standard and allows the simple and quick evaluation of STM32WB55xx and STM32WB35xx devices. The ARDUINO® Uno V3 connectivity support and the ST morpho headers provide an easy means of expanding the functionality of the STM32WB Nucleo open development platform with a wide choice of specialized shields.

It features:

- Common features:
  - STM32WB55RG (1-Mbyte Flash memory, 256-Kbyte SRAM, in VFQFPN68 package) or STM32WB15CC (320-Kbyte Flash memory, 48-Kbyte SRAM, in VFQFPN48 package) ultra-low-power wireless microcontroller featuring:
    - Dual-core 32-bit (Arm® Cortex®-M4 and dedicated M0+ CPU for real\u0002time radio layer)
    - 2.4 GHz RF transceiver supporting Bluetooth® specification v5.2
  - Three user LEDs
  - One reset and three user push-buttons
  - Board connectors:
    - ARDUINO® Uno V3 expansion connector
    - ST morpho extension pin headers for full access to all STM32WB I/Os
  - Integrated PCB antenna and SMA connector footprint
  - Flexible power-supply options: ST-LINK, USB VBUS, or external sources
  - On-board footprint to mount a CR2032 battery socket
  - On-board ST-LINK/V2-1 debugger/programmer with USB re-enumeration capability: mass storage, Virtual COM port, and debug port
  - Comprehensive free software libraries and examples available with the STM32CubeWB MCU Package
  - Support of a wide choice of Integrated Development Environments (IDEs) including IAR Embedded Workbench®, MDK-ARM, STM32CubeIDE, and Mbed Studio

- Board-specific features (STM32WB55RG only)
  - USB user with Micro-B connector
  - 2.4 GHz RF transceiver supporting IEEE 802.15.4-2011 PHY and MAC with Zigbee®, Thread®, and proprietary protocols

Figure 29. NUCLEO-WB55RG development pack



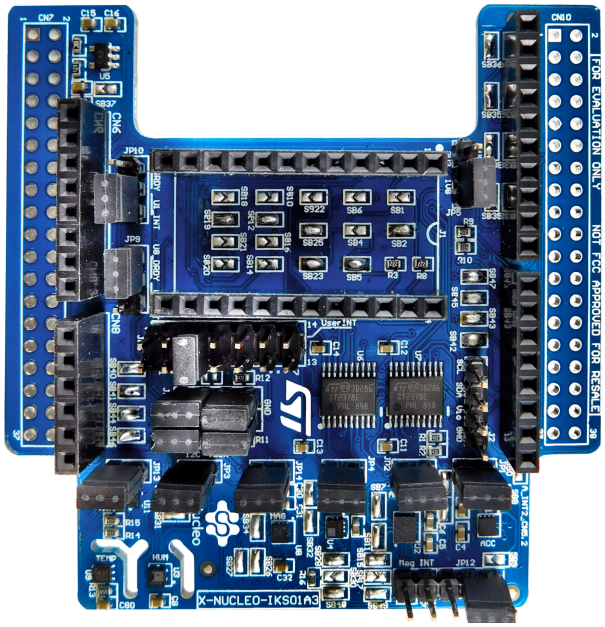
2.1.4 X-NUCLEO-IKS01A3 expansion board

The X-NUCLEO-IKS01A3 is a motion MEMS and environmental sensor evaluation board system.

It is compatible with the Arduino UNO R3 connector layout and features the LSM6DSO 3-axis accelerometer + 3-axis gyroscope, the LIS2MDL 3-axis magnetometer, the LIS2DW12 3-axis accelerometer, the HTS221 humidity and temperature sensor, the LPS22HH pressure sensor, and the STTS751 temperature sensor.

The X-NUCLEO-IKS01A3 interfaces with the STM32 microcontroller via the I²C pin, and it is possible to change the default I²C port.

Figure 30. **X-NUCLEO-IKS01A3 MEMS and environmental sensor expansion board**



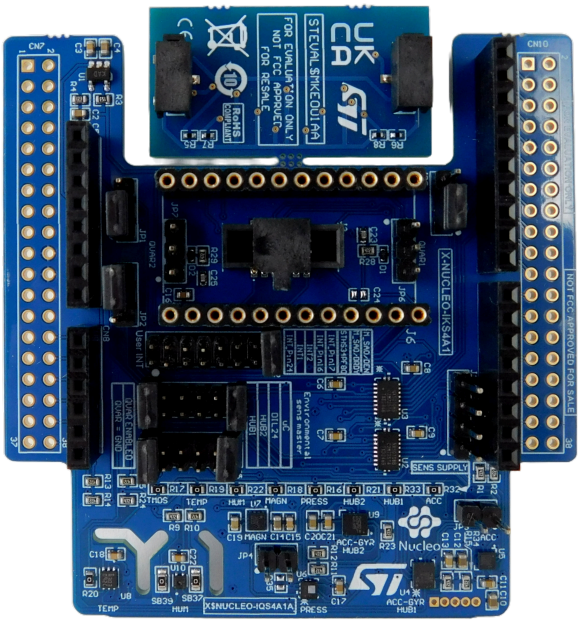
2.1.5 X-NUCLEO-IKS4A1 expansion board

The X-NUCLEO-IKS4A1 is a motion MEMS and environmental sensor expansion board for STM32 Nucleo.

It is compatible with the Arduino UNO R3 connector layout, and is designed around the LSM6DSV16X 3-axis digital accelerometer and a 3-axis digital gyroscope, the LIS2MDL ultra-low-power and high-performance 3-axis digital magnetic sensor, the STTS22H temperature sensor, SHT40AD1B humidity, LPS22DF pressure sensor.

The X-NUCLEO-IKS4A1 interfaces with the STM32 microcontroller via the I²C pin, and it is possible to change the default I²C port.

Figure 31. **X-NUCLEO-IKS4A1 expansion board**



2.1.6 X-NUCLEO-53L3A2 expansion board

The X-NUCLEO-53L3A2 is an expansion board for the NUCLEO-F401RE development board.

It provides a complete evaluation kit allowing anyone to learn, evaluate, and develop their applications using the VL53L3CX ranging sensor with multitarget detection.

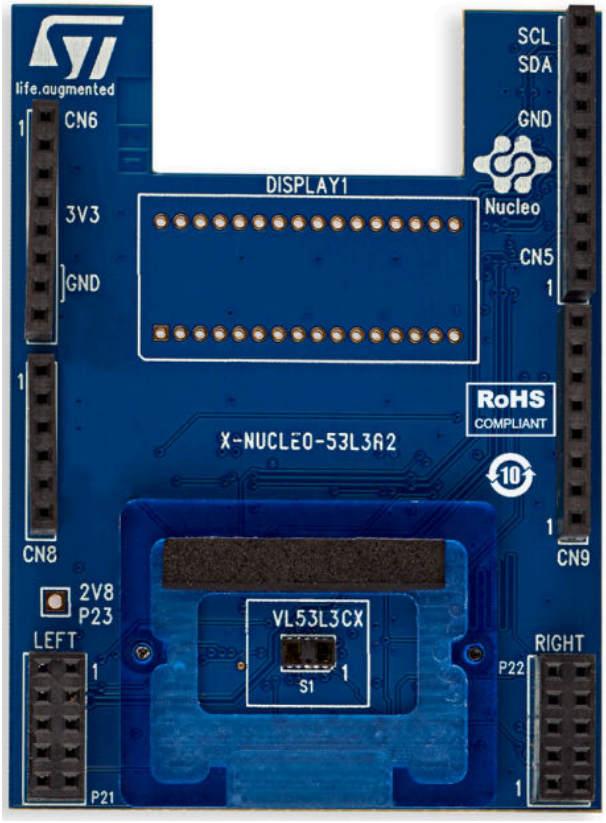
The X-NUCLEO-53L3A2 expansion board is delivered with a cover glass holder in which three different spacers of 0.25, 0.5, and 1 mm height can be fitted below the cover glass to simulate various air gaps.

Two VL53L3CX breakout boards can be connected using two 10-pin connectors.

The X-NUCLEO-53L3A2 expansion board is compatible with the STM32 Nucleo board family and with the Arduino UNO R3 connector layout.

Several ST expansion boards can be superposed through the Arduino connectors, which allow, for example, the development of VL53L3CX applications with Bluetooth® Low Energy or Wi-Fi interfaces.

Figure 32. X-NUCLEO-53L3A2 expansion board



2.2 Hardware setup

The following hardware components are needed:

1. One P-NUCLEO-WB55 development board
2. One sensor expansion board (order code: X-NUCLEO-IKS01A3 or X-NUCLEO-IKS4A1)
3. Optional - one VL53L3CX ToF ranging sensor expansion board (order code: X-NUCLEO-53L3A2)
4. One USB type A to Mini USB Type B cable to connect the P-NUCLEO-WB55 board to the PC

2.3 Software setup

The following software components are required for the setup of a suitable development environment to create applications for the P-NUCLEO-WB55 (or NUCLEO-WB55RG) board with the X-NUCLEO-IKS01A3 (or X-NUCLEO-IKS4A1) sensor expansion board and the X-NUCLEO-53L3A2 ToF ranging sensor expansion board:

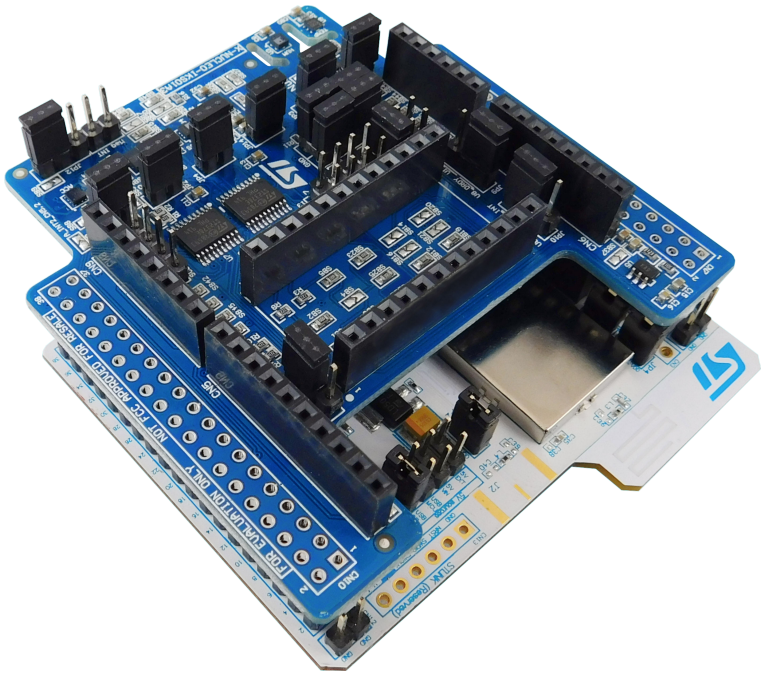
- FP-SNS-MOTENWB1: an STM32Cube function pack for Bluetooth low energy connection and sensors. The firmware and related documentation are available on www.st.com.
- Development tool-chain and Compiler. The STM32Cube expansion software supports the three following environments to select from:
  - IAR Embedded Workbench for ARM® (EWARM) toolchain + ST-LINK
  - RealView Microcontroller Development Kit (MDK-ARM) toolchain + ST-LINK
  - STM32CubeIDE + ST-LINK

2.4 System setup

The P-NUCLEO-WB55 board integrates the ST-LINK/V2-1 debugger/programmer. The developer can download the relevant version of the ST-LINK/V2-1 USB driver by searching STSW-LINK008 or STSW-LINK009 on www.st.com (depending on your Windows version).

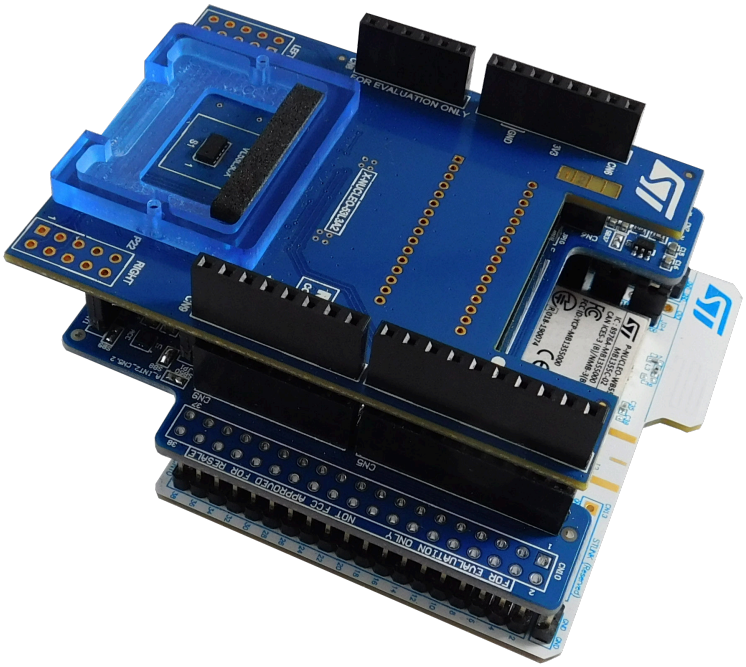
The X-NUCLEO-IKS01A3 (or X-NUCLEO-IKS4A1) sensor board is easily connected to the P-NUCLEO-WB55 through the Arduino UNO R3 extension connector, as shown below.

Figure 33. P-NUCLEO-WB55 plus X-NUCLEO-IKS01A3



The X-NUCLEO-53L3A2 ToF ranging sensor expansion board is easily connected to the X-NUCLEO-IKS01A3 sensor expansion board through the Arduino UNO R3 extension connector, as shown below.

Figure 34. **P-NUCLEO-WB55 plus X-NUCLEO-IKS01A3 and X-NUCLEO-53L3A2**



Revision history

Table 1. **Document revision history**

Date	Version	Changes
09-Jul-2019	1	Initial release.
20-Oct-2021	2	Updated Section 1.1 Overview. Added Section 1.7 FOTA support, Section 1.7.1 User application update for iOS and Section 1.7.2 User application update for Android.
02-Sep-2022	3	Updated introduction, Section 1.1 Overview, Section 1.2 Architecture, Section 1.3 Folder structure, Section 1.5 Sample application description, Section 1.6 Android and iOS STBLESensor client application, Section 1.7 FOTA support, Section 1.7.1 User application update for Android, Section 2.2 Hardware setup, Section 2.3 Software setup, and Section 2.4 System setup. Added Section 2.1.6 X-NUCLEO-53L3A2 expansion board.
27-Sep-2023	4	Updated Section Introduction, Section 1.1 Overview, Section 1.2 Architecture, Figure 2. FP-SNS-MOTENVWB1 package folder structure, Section 1.5 Sample application description, Section 1.6 Android and iOS STBLESensor client application and Section 1.7 FOTA support. Removed section 1.7.1 User application update for iOS. Updatd Section 1.7.1 User application update for Android. Added Section 2.1.5 X-NUCLEO-IKS4A1 expansion board and Section 2.1.3 NUCLEO-WB55RG.

Contents

List of figures