Simplify the Integration of Sensors and Bluetooth Low Energy (BLE) Connectivity using the BlueNRG-Tile Eval Kit

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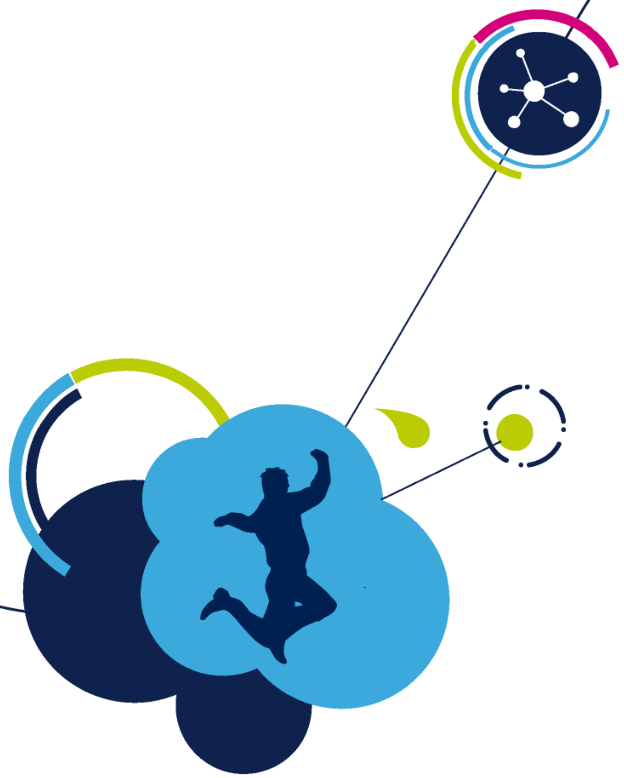
Technology Tour 2019
Dallas-Richardson, TX | March 7



Training Material Check / Installation Help

BlueNRG-Tile Hands-on - LABs Preparation

Please return it at the end of the workshop

ON YOUR LAPTOP

- **USB Flash drive** with relevant material for the hands-on
- Unzip the content to **C:**
    - **Mandatory: installation folder shall be *C:\BlueNRG_Tile_HandsOn***

ON YOUR PHONE

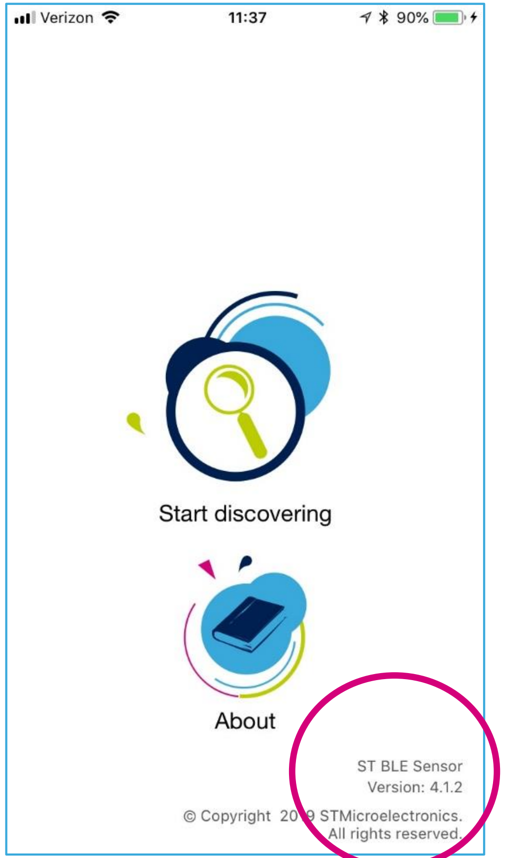
- Install "**ST BLE Sensor**" **app** on your smartphone

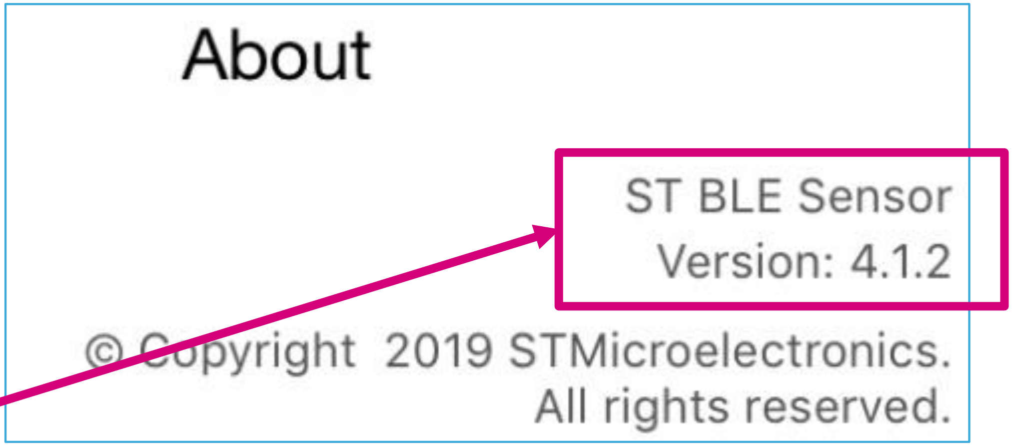
Download on the App Store

GET IT ON Google Play

If you have already the ST BLE Sensor app installed…

- You need to upgrade the “ST BLE Sensor” app to the **version 4.1.2**





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Agenda

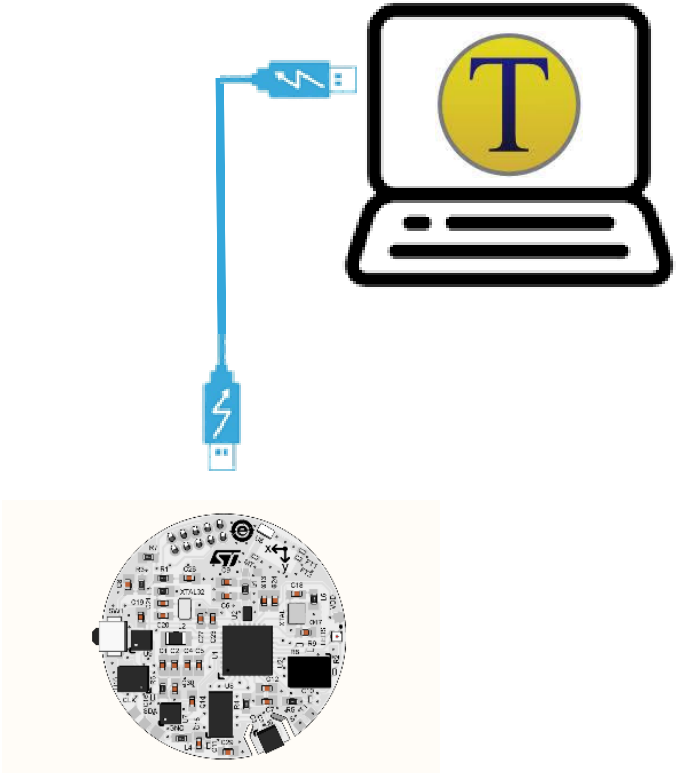
BlueNRG-Tile
(STEVAL-BCN002V1)

- Training Material Check/Installation Help
- ARM® Keil MDK Installation
- Introduction to Bluetooth® Low Energy
- BlueNRG-Tile Development Kit
- ARM® Keil MDK License Installation
- Lab 1: Getting Started with BlueNRG-Tile “Hello World”
- Lab 2: Connecting to the ST BlueMS app
- Lab 3: LED characteristic
- Lab 4: Accelerometer embedded events detection
- Lab 5: 9-axis Acc+Gyro+Mag Sensor Data Fusion
- Lab 6: Cloud data logging on IBM Watson
- Lab 7: Bonus – Voice over BLE

Today’s workout!

LAB1

- Connect BlueNRG-Tile (STEVAL-BCN002V1) to PC using USB
- Run TeraTerm virtual serial terminal



LAB2

Start a BLE Connection

- Run ST BlueMS and discover ***YOUR*** BlueNRG-Tile
- Connect your phone to the BlueNRG-Tile
- Sensor data on the BlueMS client

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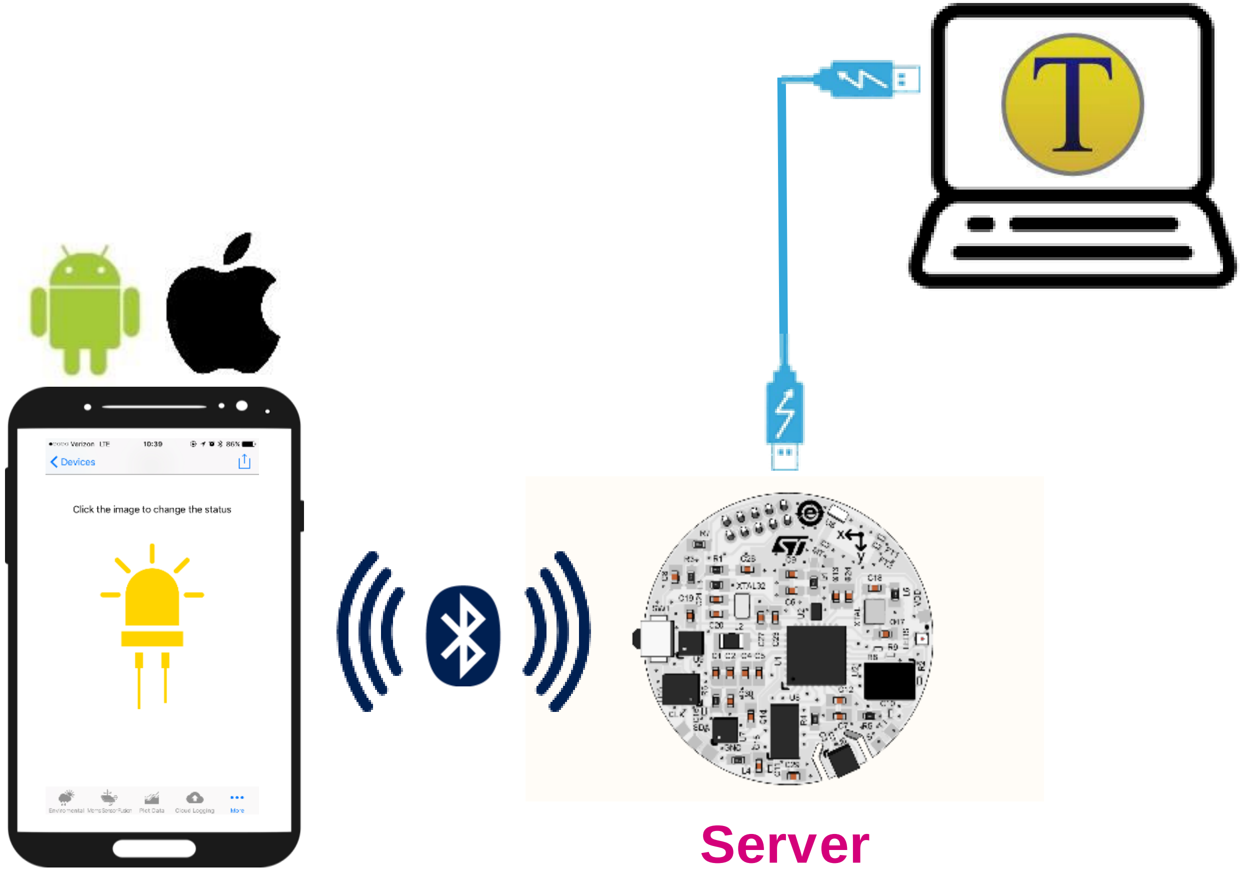
Today's workout!

LAB3

Add LED characteristic and remotely toggle the LED



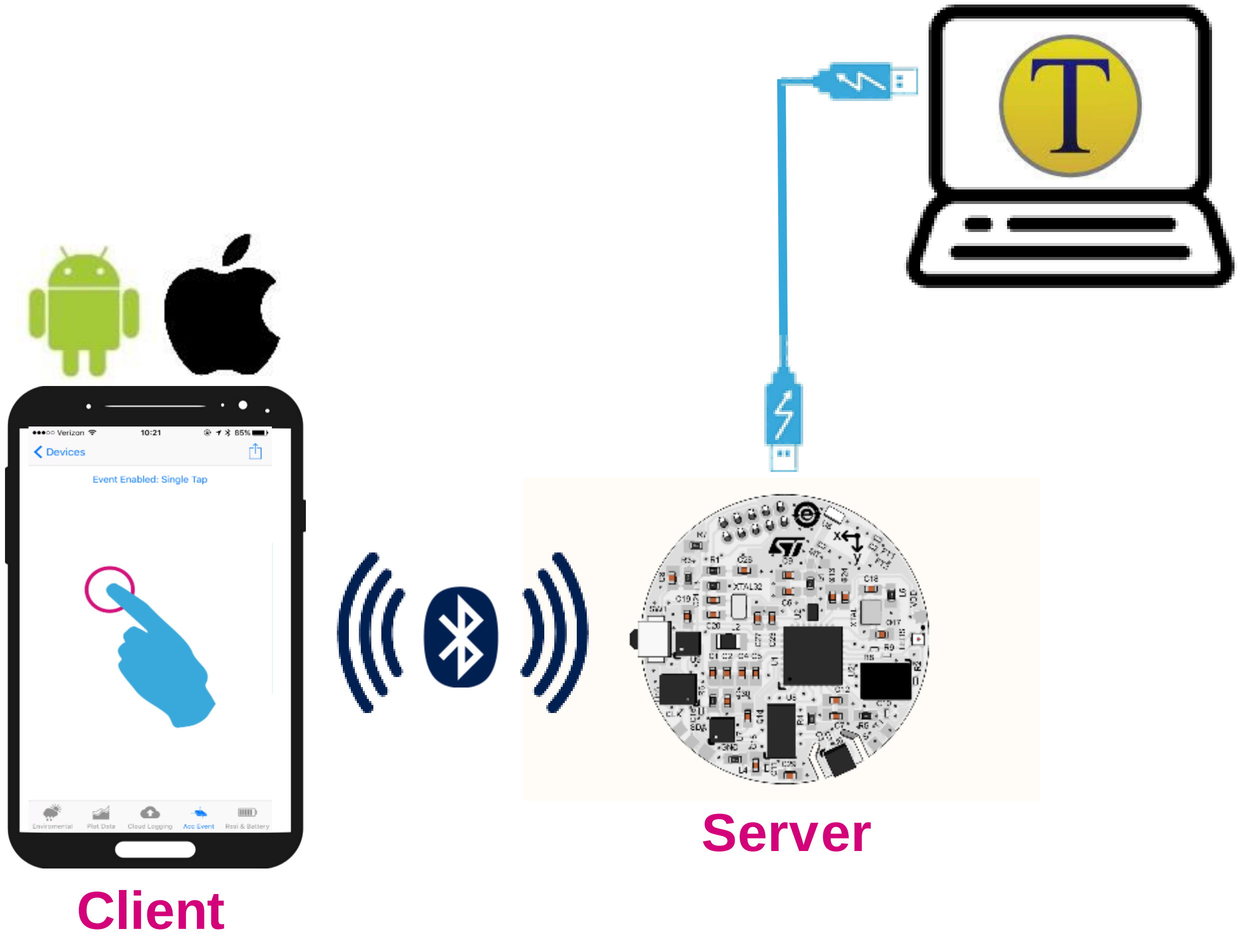
Server

Client

Today’s workout!

LAB4

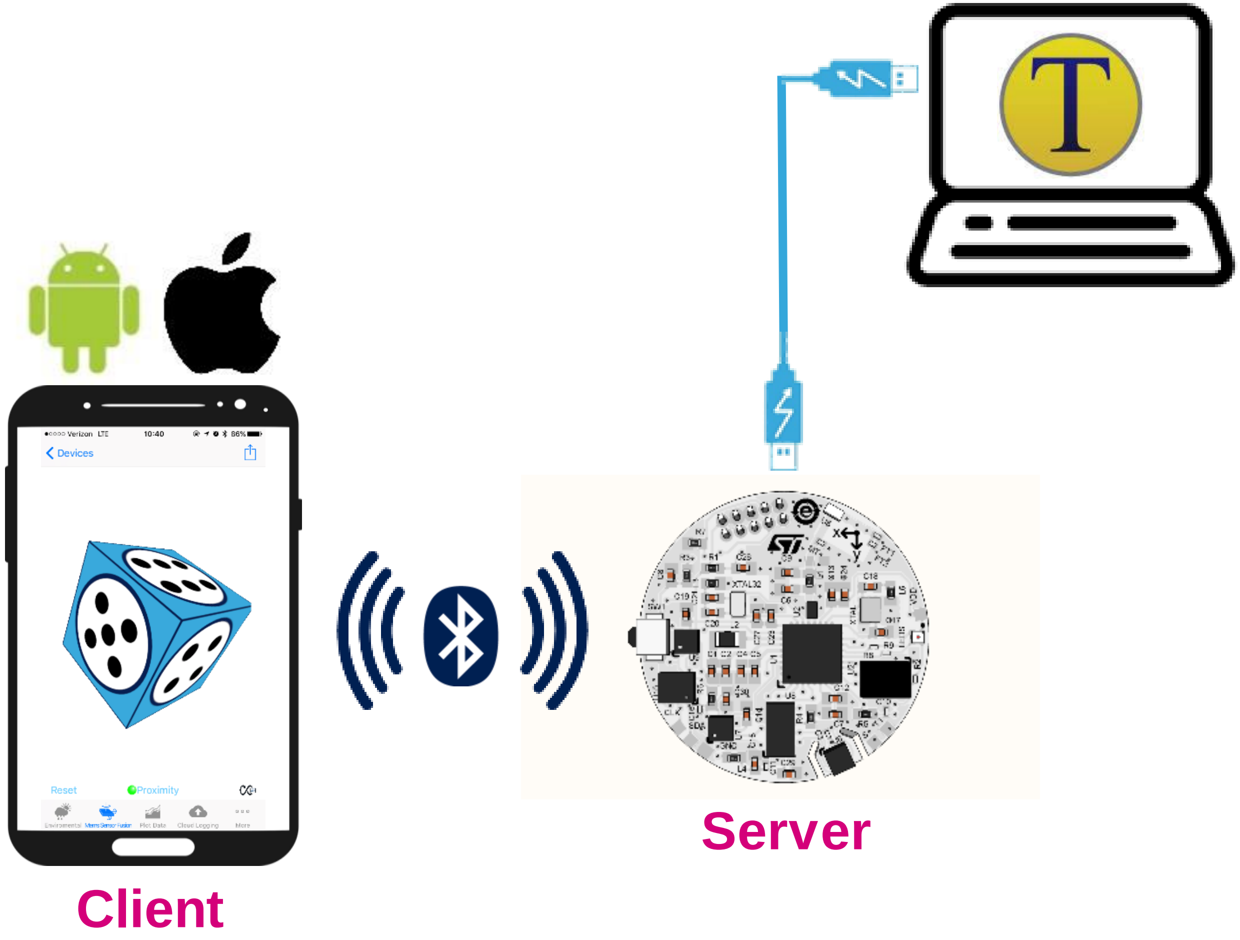
Add Accelerometer embedded events detection feature



Today’s workout!

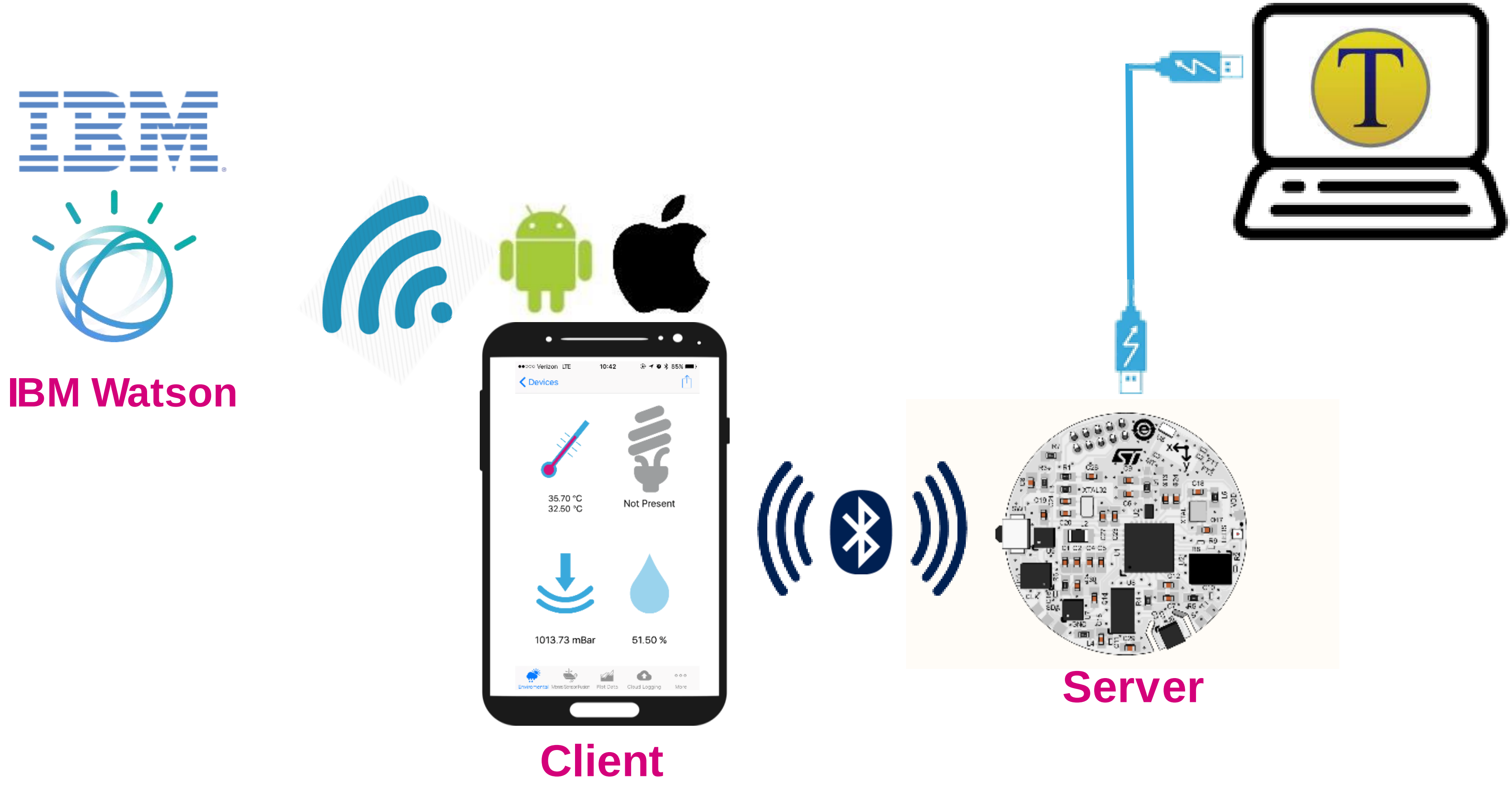
LAB5

Add 9-axis Sensor Data Fusion feature



LAB6

Enable Cloud sensor logging on IBM Watson



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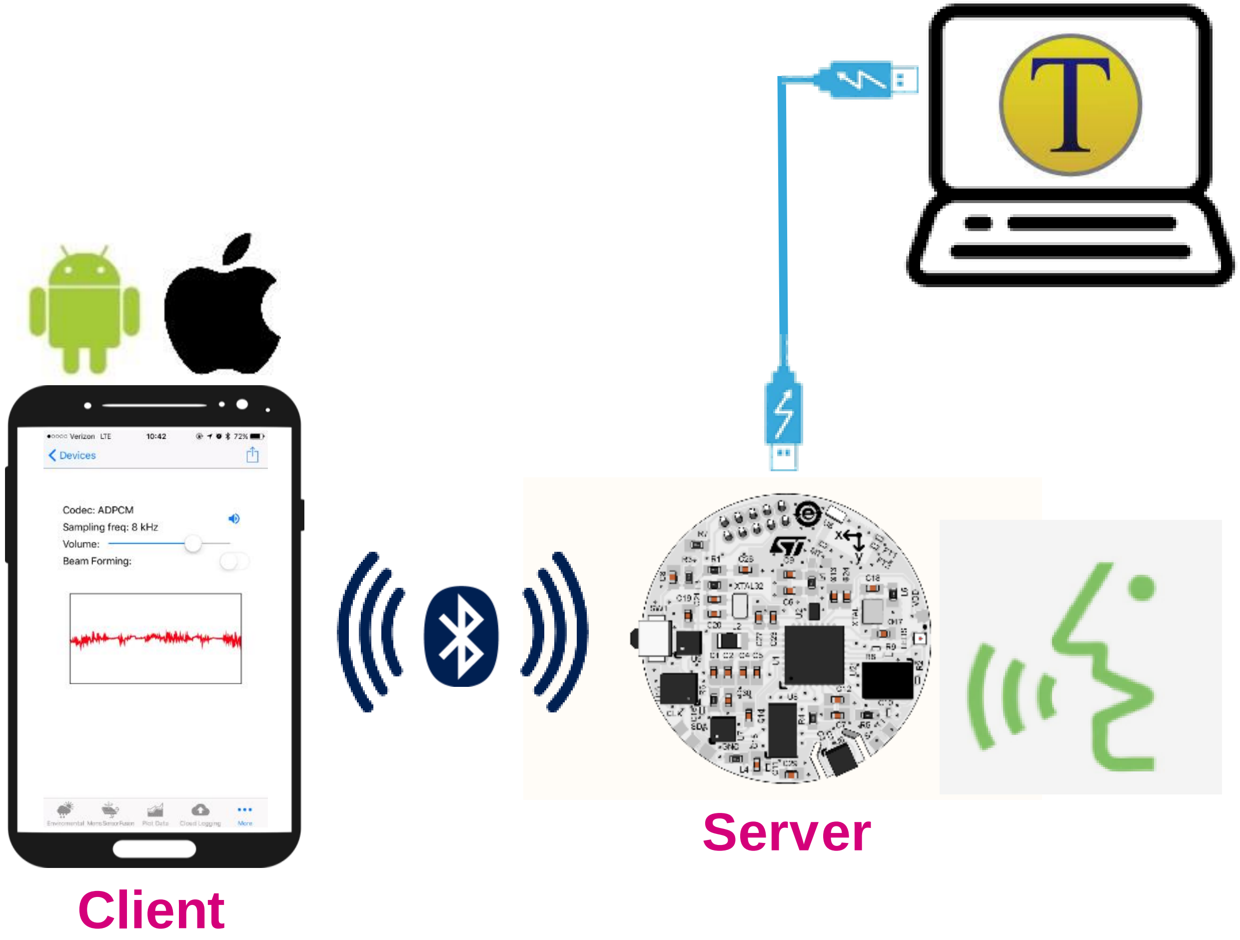
LAB7

Bonus lab: add Voice over BLE feature



it’s a class: remember that…

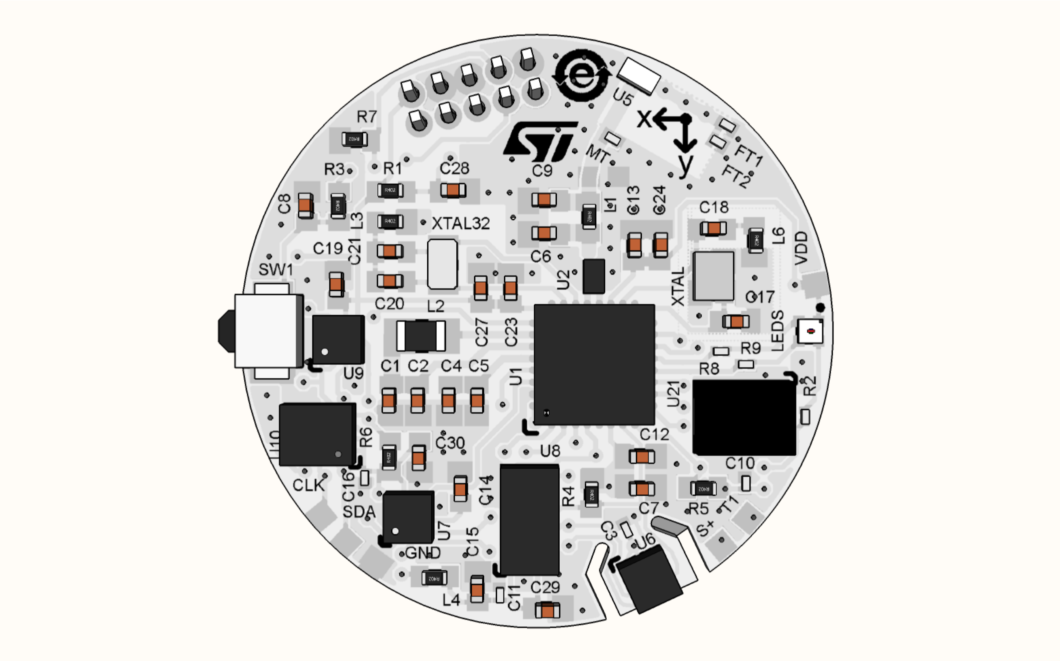
- **OUR GOAL** is for **ALL OF YOU to successfully** complete all the Labs.

- Each lab has step-by-step procedure. We need to go through each step!

- It’s not a race. If you’re ahead, please help your neighbor… ☺

And there is a prize…

At the end of the workshop each of you will receive a **free BlueNRG-Tile eval kit (STEVAL-BCN002V1)**



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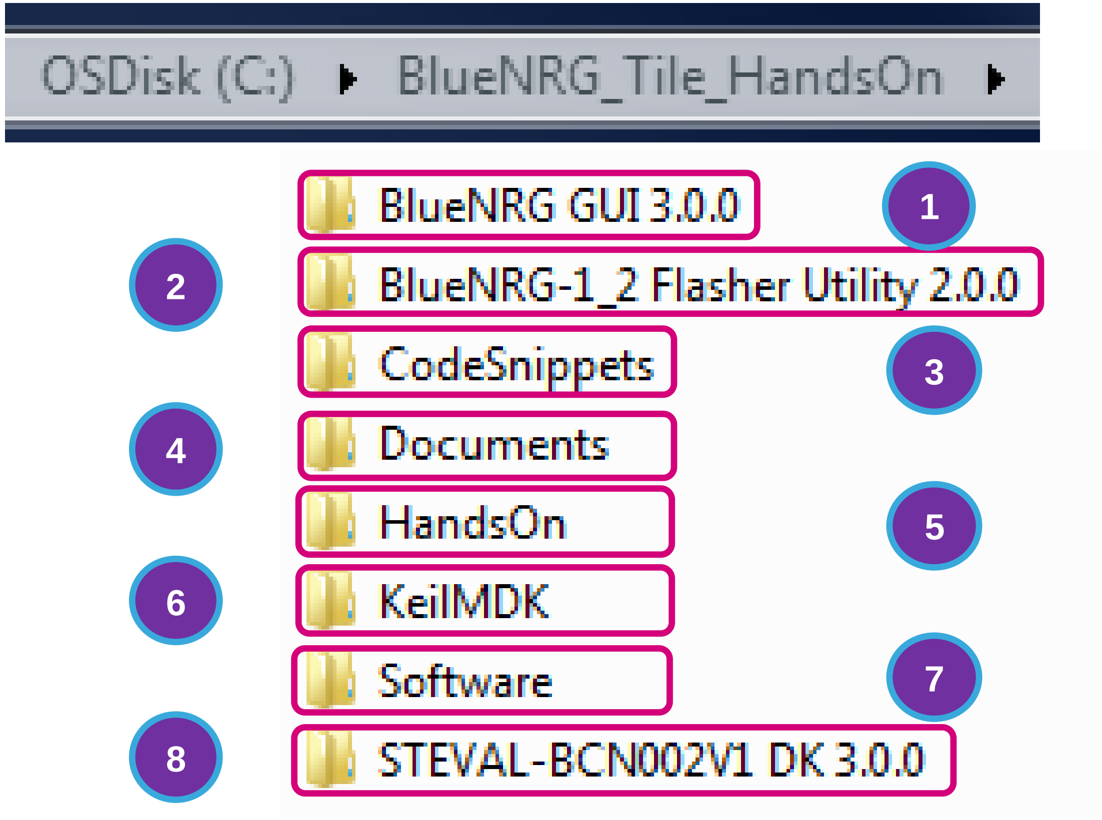
Hands On Directory Content



1. BlueNRG Graphical User Interface
2. UART Flasher
3. Code Snippets
4. Documents
5. Hands on Labs
6. Keil MDK
7. Software
8. BlueNRG-Tile DK V 3.0.0

Open “**BlueNRG_Tile_HandsOn.pdf**” presentation

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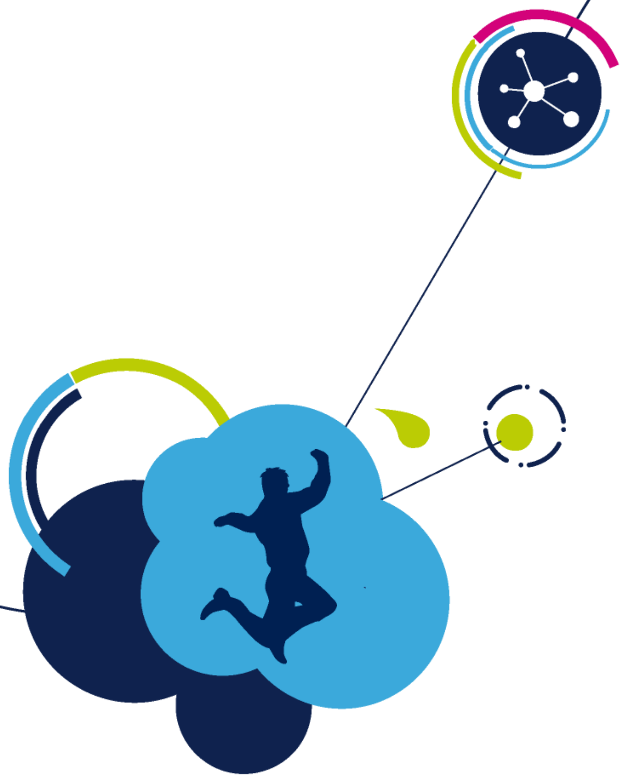


ARM Keil MDK Installation

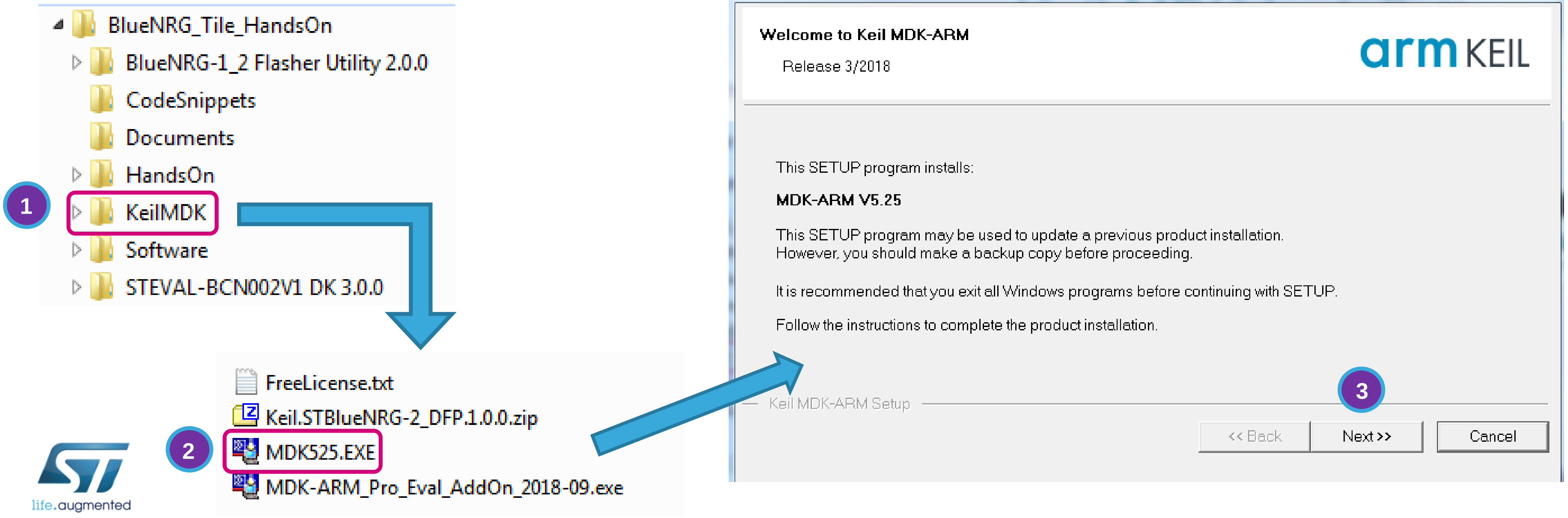
What is Arm Keil MDK?

- **MDK**: **M**icrocontroller **D**evelopment **K**it
  - Complete software development environment from Arm for a wide range of Arm Cortex-M based microcontroller devices.
  - MDK includes the µVision IDE, debugger, and Arm C/C++ compiler

- A **FREE** license is available for ST BlueNRG-2 device

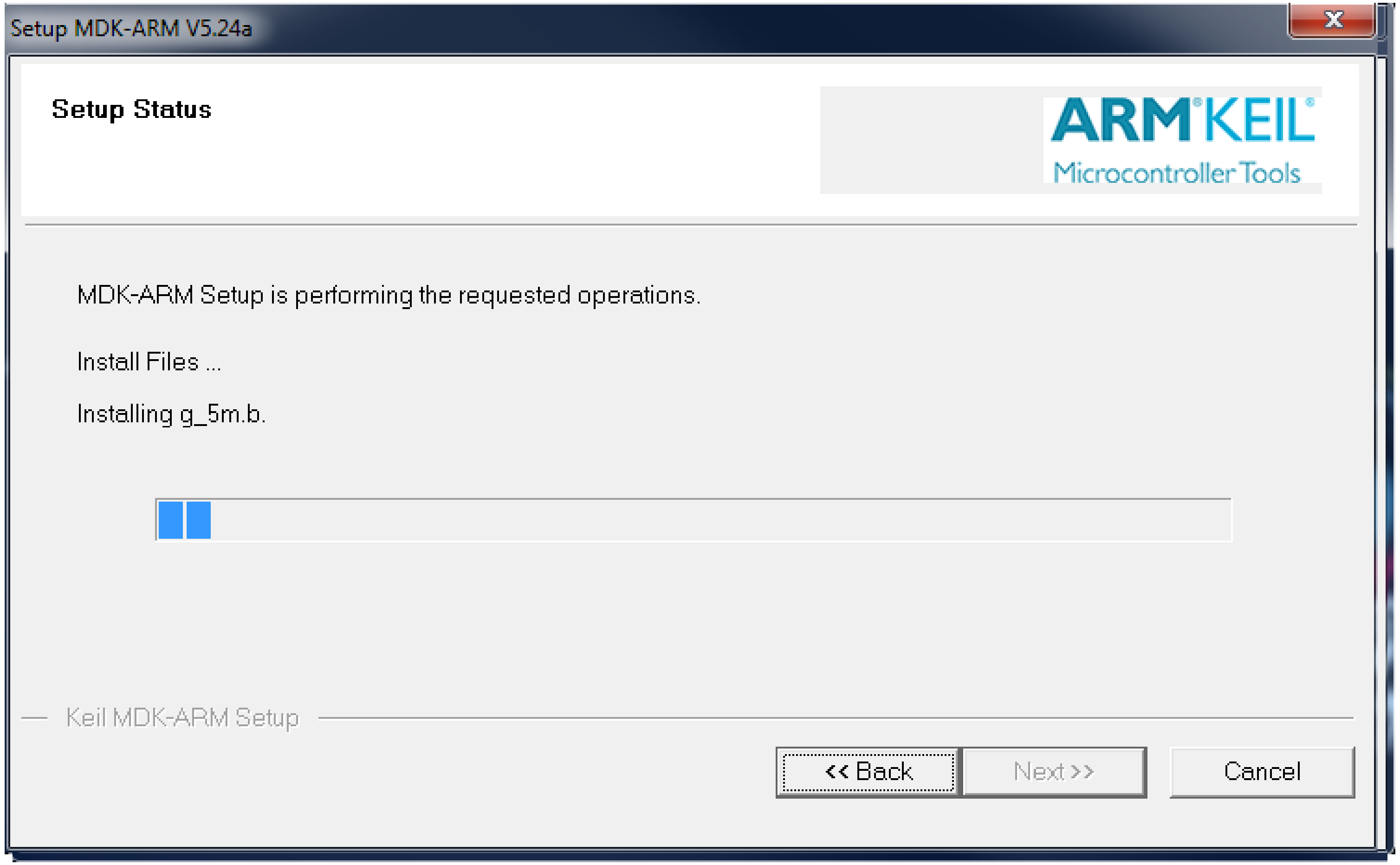
Keil MDK Installation 1/6

1. Go to the folder **C:\BlueNRG_Tile_HandsOn\KeilMDK**
2. Double click on **MDK525.EXE**
3. Click on Next in the Setup window



Keil MDK Installation 2/6

1. Click on **Agree** and then **Next**
2. Click on **Next**
3. Fill in your info and click on **Next**



Installation starts.

TO BE CONTINUED IN A FEW MINUTES…

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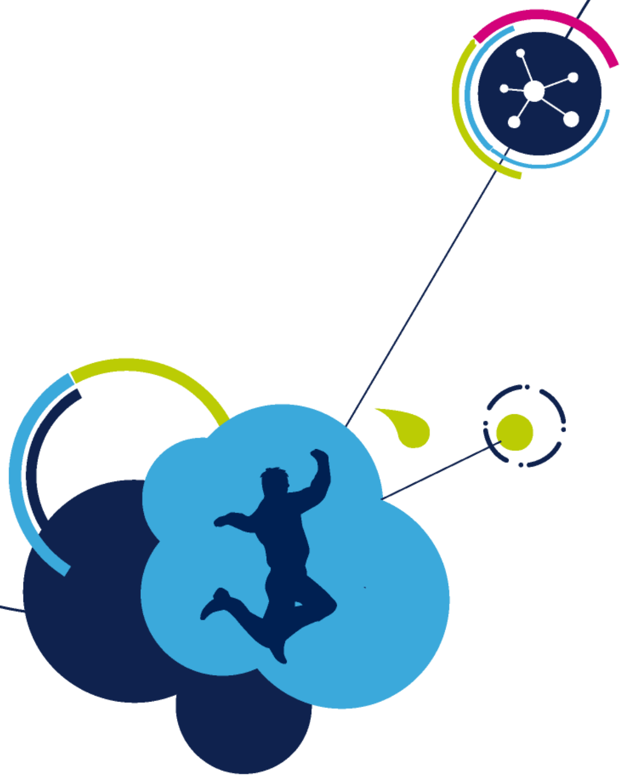

Introduction to Bluetooth Low Energy

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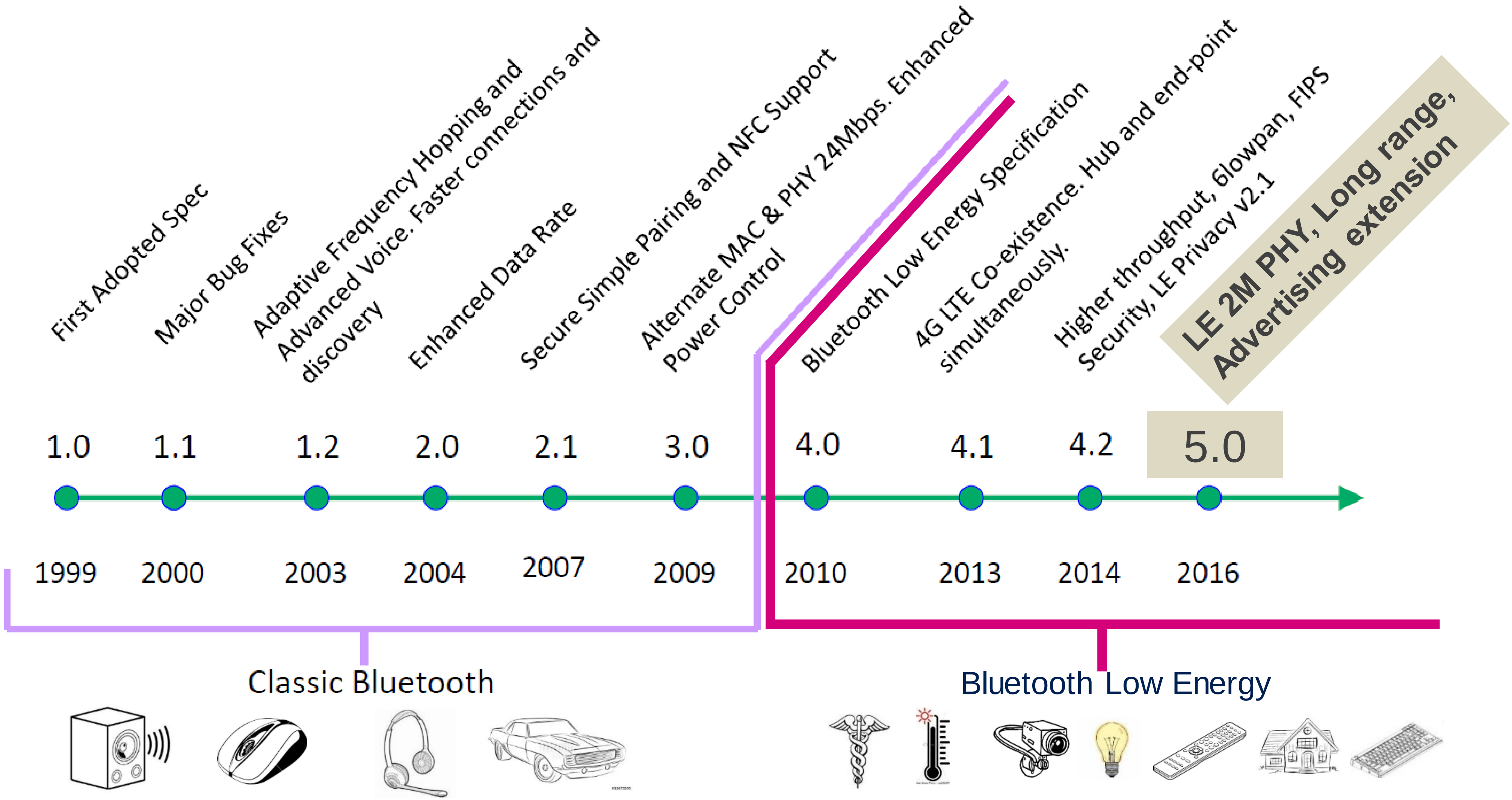
Bluetooth® Evolution



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Bluetooth low energy (LE): Designed for Success

- Lower power than Bluetooth “Classic” (or Bluetooth 3.0)
    - Lower duty cycle
    - Faster connection
    - Lower peak power (relaxed RF parameters)
- Compatible with all major platforms (iOS, Android, Windows, Linux)
- Multiple network topologies:
    - **Point to point**: single master connects to single slave (and each slave can connect to 2 master)
    - **Star**: Multiple slaves connected to a single master
    - **Mesh**: newly introduced (**please join our afternoon BLE Class for more details!**)
- State of the Art encryption, security including privacy/authentication

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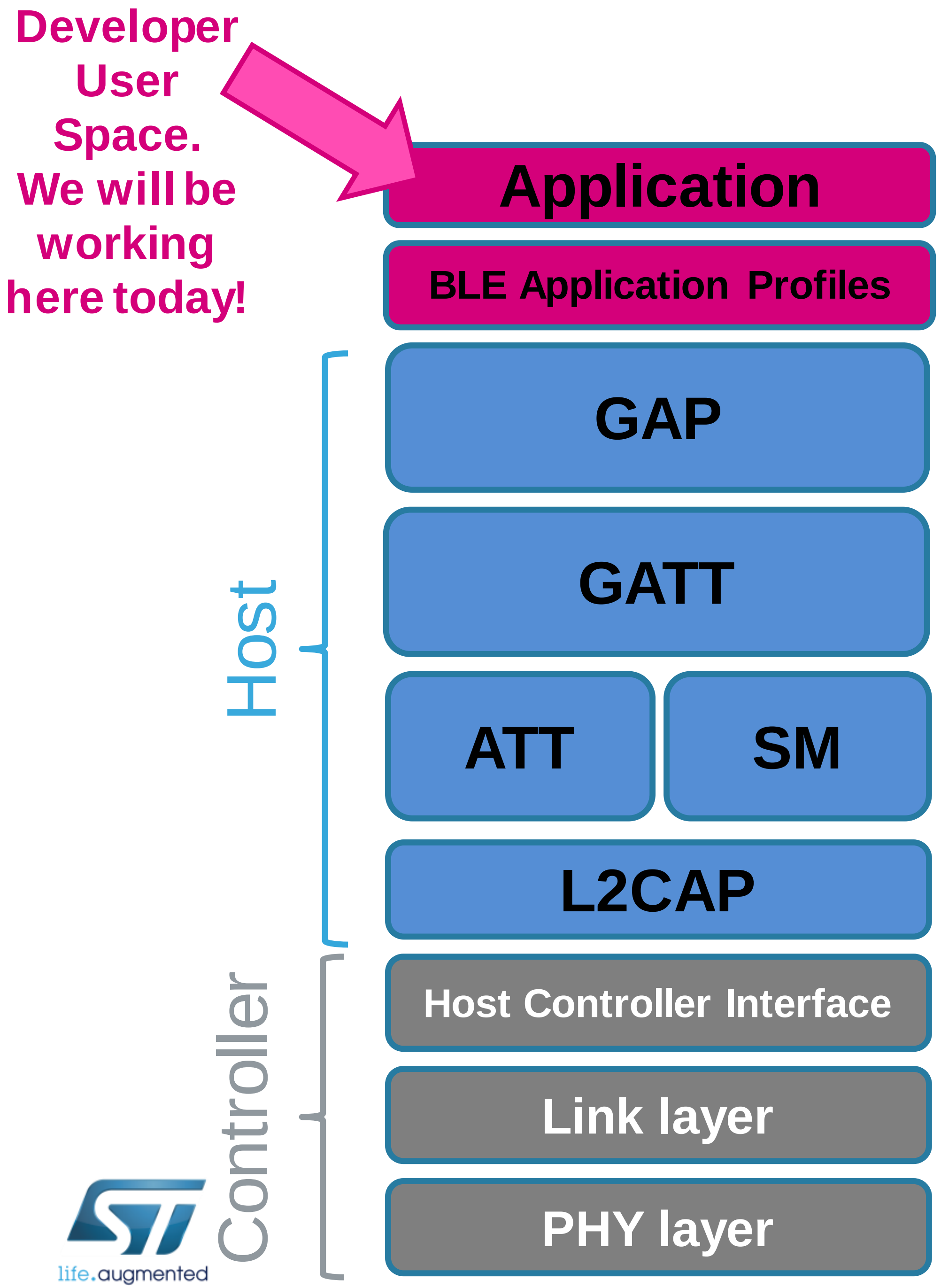
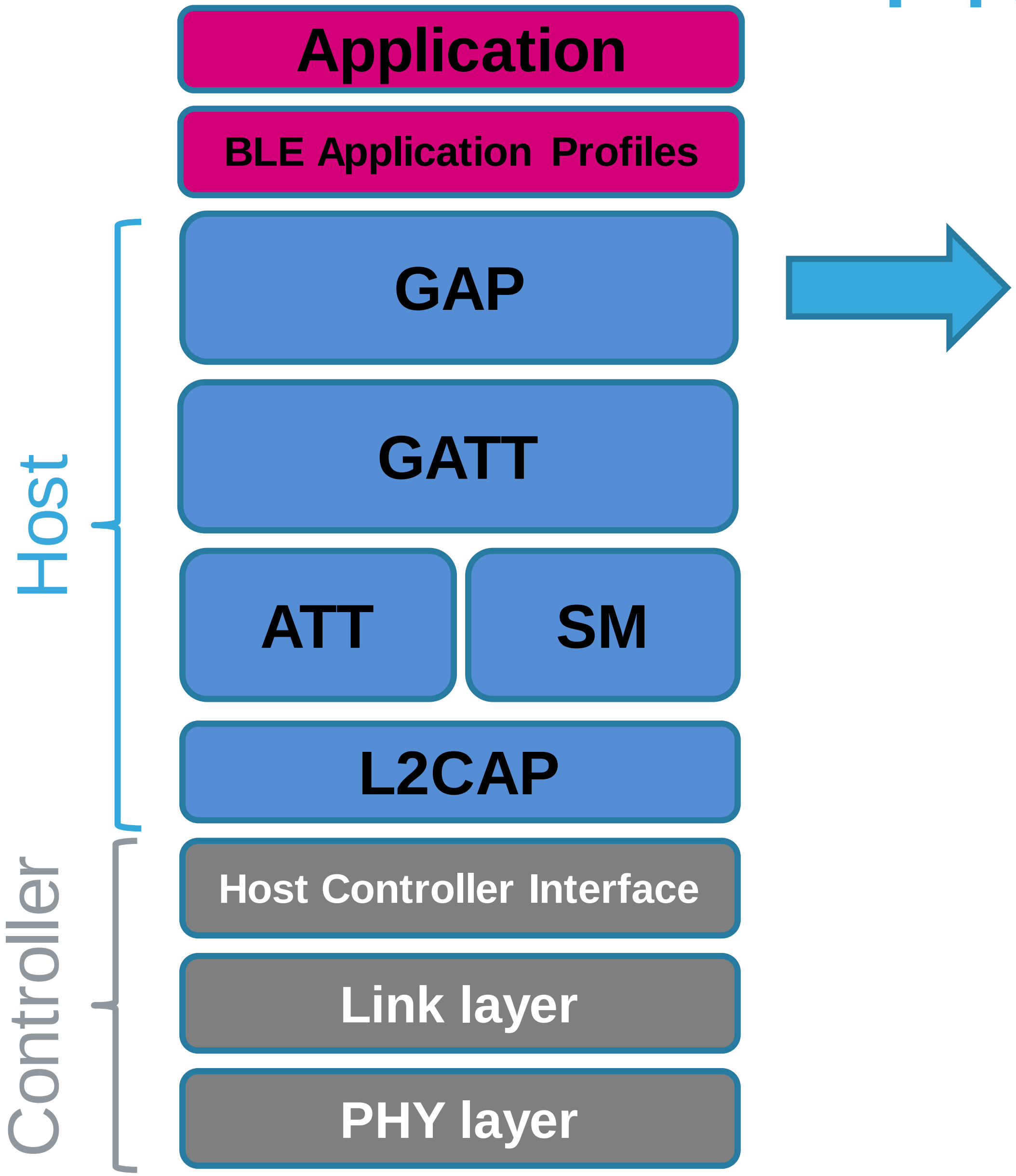
Protocol Stack



- **Generic Acces Profile**
  - How devices can discover and connect with one another
- **Generic Attribute Profile**
  - How services, characteristics can be discovered and then used
- **Attribute Protocol**
  - Protocol for discovering, reading, and writing attributes on a peer
- **Security Manager**
  - Handles the secure communication
- **L2CAP**
  - Protocol multiplexer. Segmentation and reassembly of packets

- **HCI**
  - Interface between Host and Controller
- **Link Layer**
  - Handles packets, channels, advertising, scanning & connections
- **Physical Layer**
  - Transmits/receives bits

Protocol Stack - GAP



- Who controls the radio network?
  - **GAP (Generic Access Profile)**
  - Defines 4 roles
    - Broadcaster
    - Observer
    - Peripheral
    - Central

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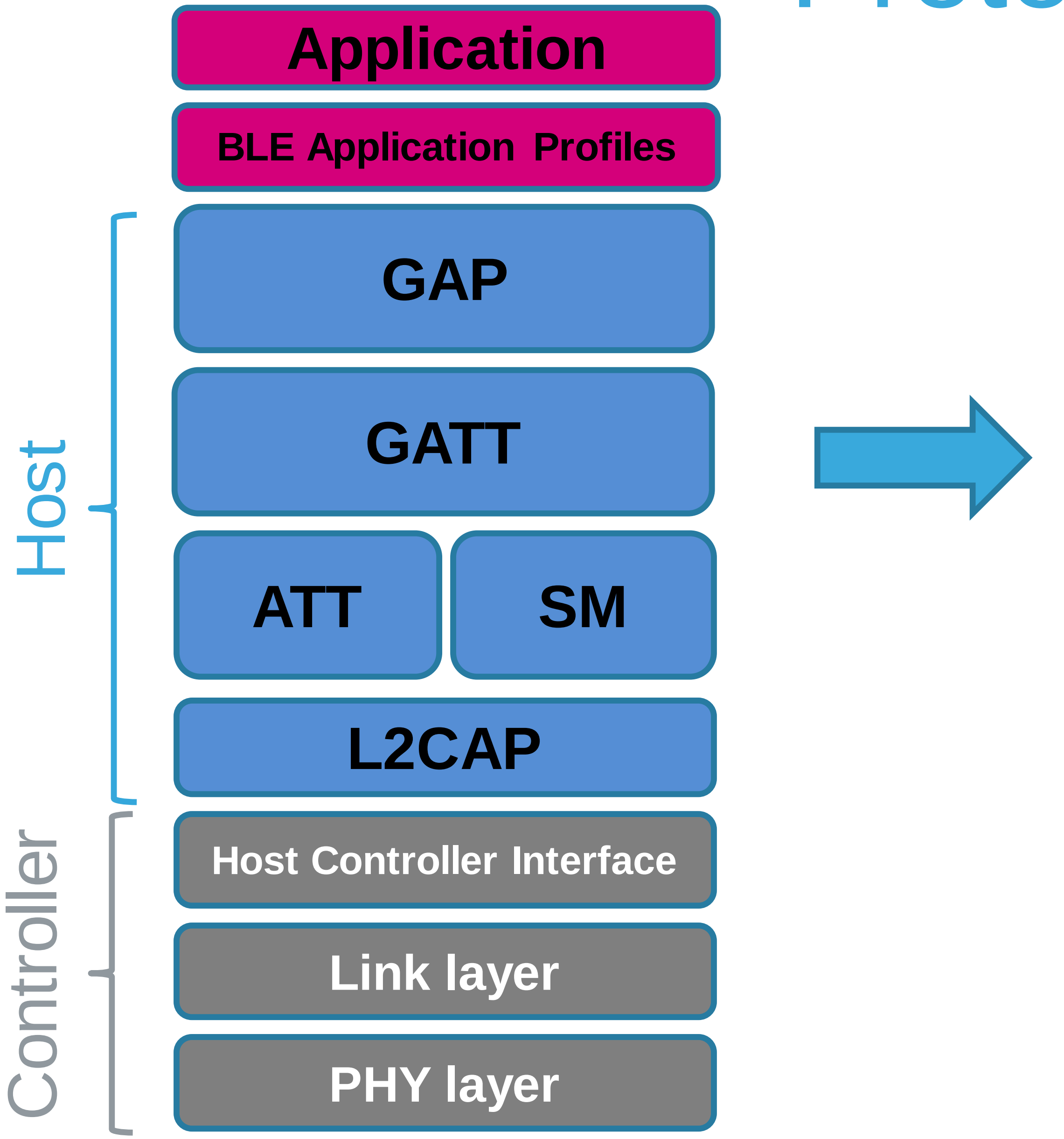
Protocol Stack - GATT



- Who controls the data flow?
  - **GATT (Generic Attribute Profile)**
  - Defines 2 roles
    - Client
    - Server

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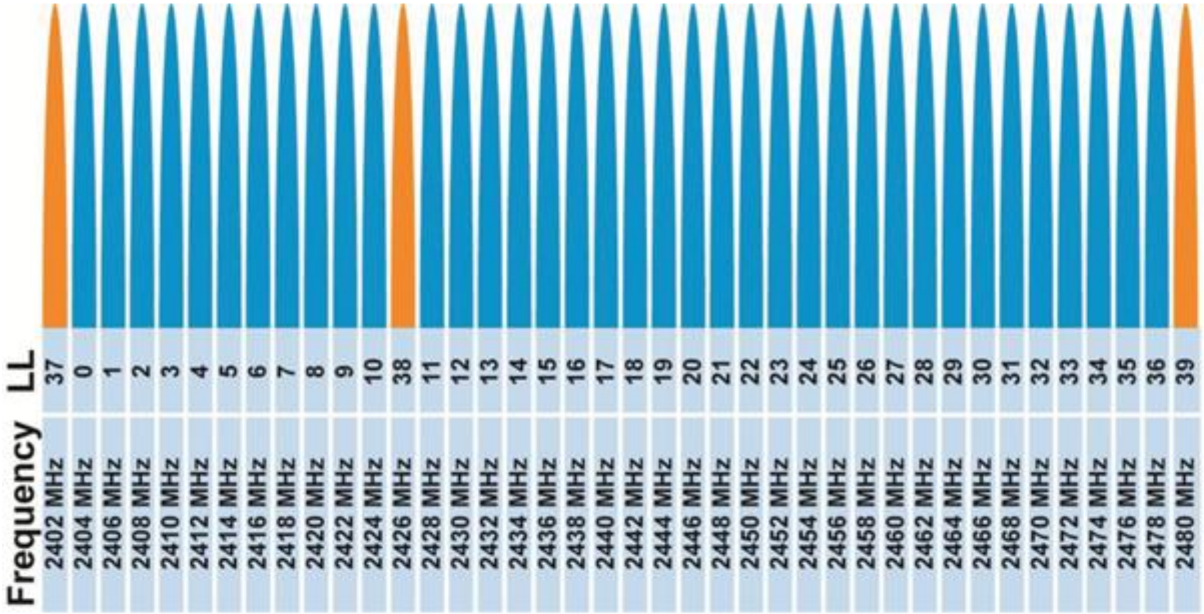
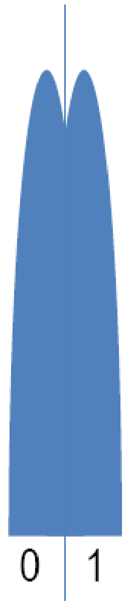
Protocol Stack: PHY

- 2.4 GHz ISM Band Transceiver

- 40 RF Channels, 2 MHz channel Spacing. Two types of channels:
  - **Advertising** channels (3 - orange) for Advertising Channel Packets. Used for Discoverability and for Broadcasting/Observing
  - **Data** Channels (37 - blue) for Data channel Packets. Used to send application data in Connection

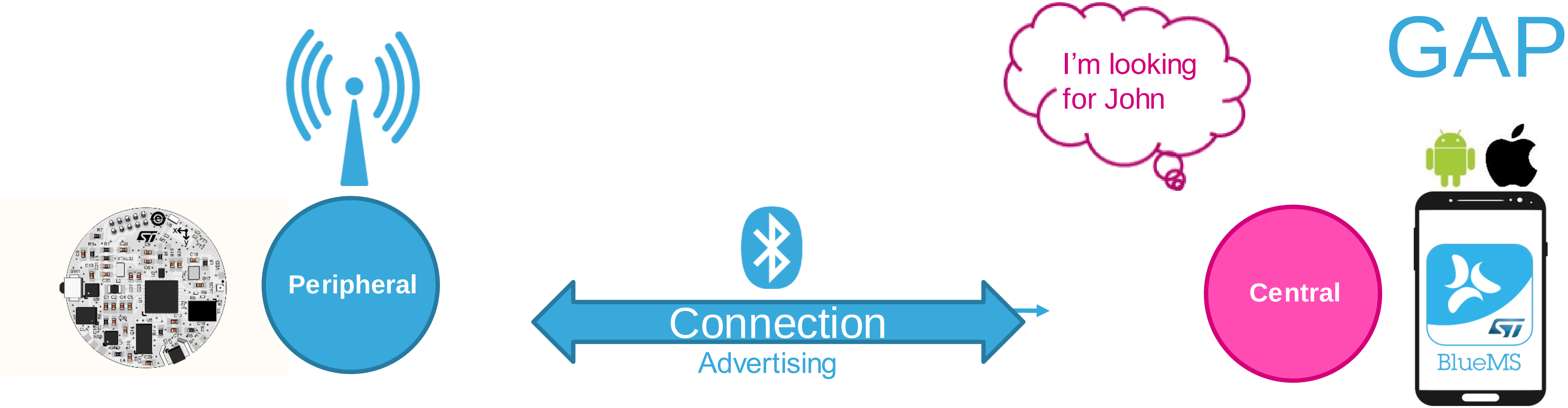


Source : Bluetooth® SIG



- GFSK Modulation
  - BT = 0.5
  - Modulation Index = 0.5
  - “pulse shaping” Gaussian filter smoothes transitions from zero to one reduces spectral width

GAP



Peripheral is in Advertising mode.
Sends Advertising packets.

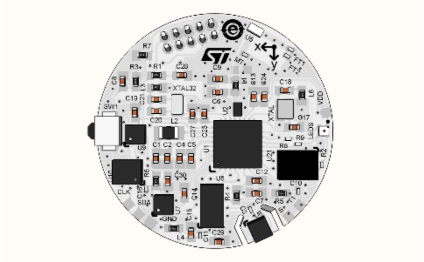
Central is Scanning.
Look for known peripherals by *listening* to advertising packets.

My name is John
My capabilities are X, Y, Z, etc…

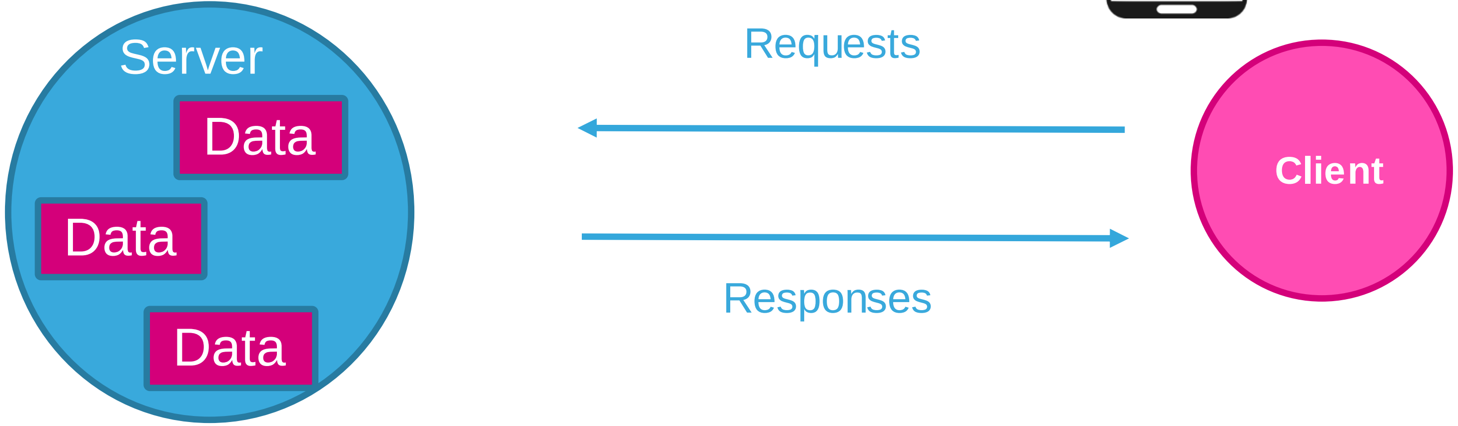
Advertising packets consists of multiple information units known as **AD types**.
E.g.: Local Name, TX Out Power, Manufacturer Specific info, etc…

As the John peripheral is found, it initiates a BLE connection.

GATT



Contains all attributes.
Receives requests, executes, responds.
Can indicate value



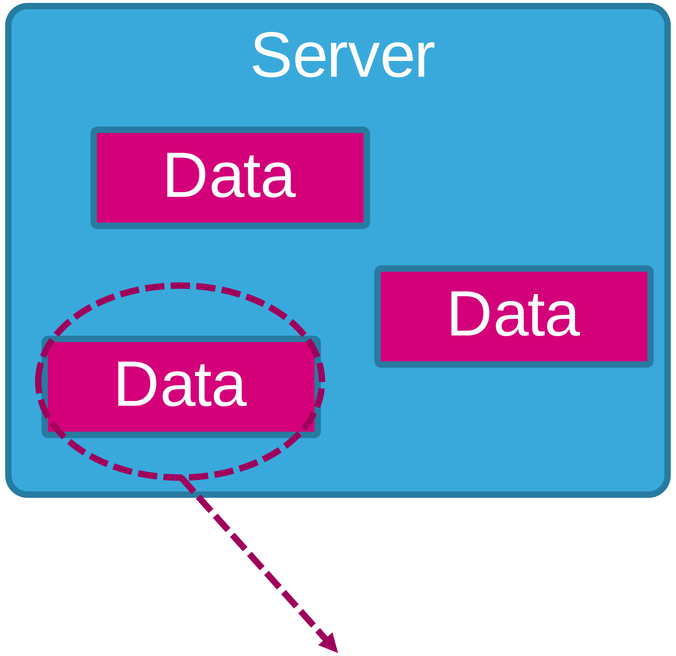
Talks with server.
Sends requests, wait for response.
Can confirm indications

Protocol PDU Type	Sent by	Description
Request	Client	Client requests something from server (it always causes a response)
Response	Server	Server sends response to a request from a client
Command	Client	Client commands something to server (no response)
Notification	Server	Server notifies client of new value (no confirmation)
Indication	Server	Server indicates to client new value (it always causes a confirmation)
Confirmation	Client	Confirmation to an indication

Attributes

- Data are organized and exposed using attributes

- Each attribute has:
  - A value (0 to 512 octets)
  - An handle: it identifies the attribute on the server
  - A type (defined by Universal Unique ID - UUID): what the value means
    - 16-bit UUID: pre-defined by Bluetooth SIG
    - 128-bit UUID: Vendor Specific identifiers



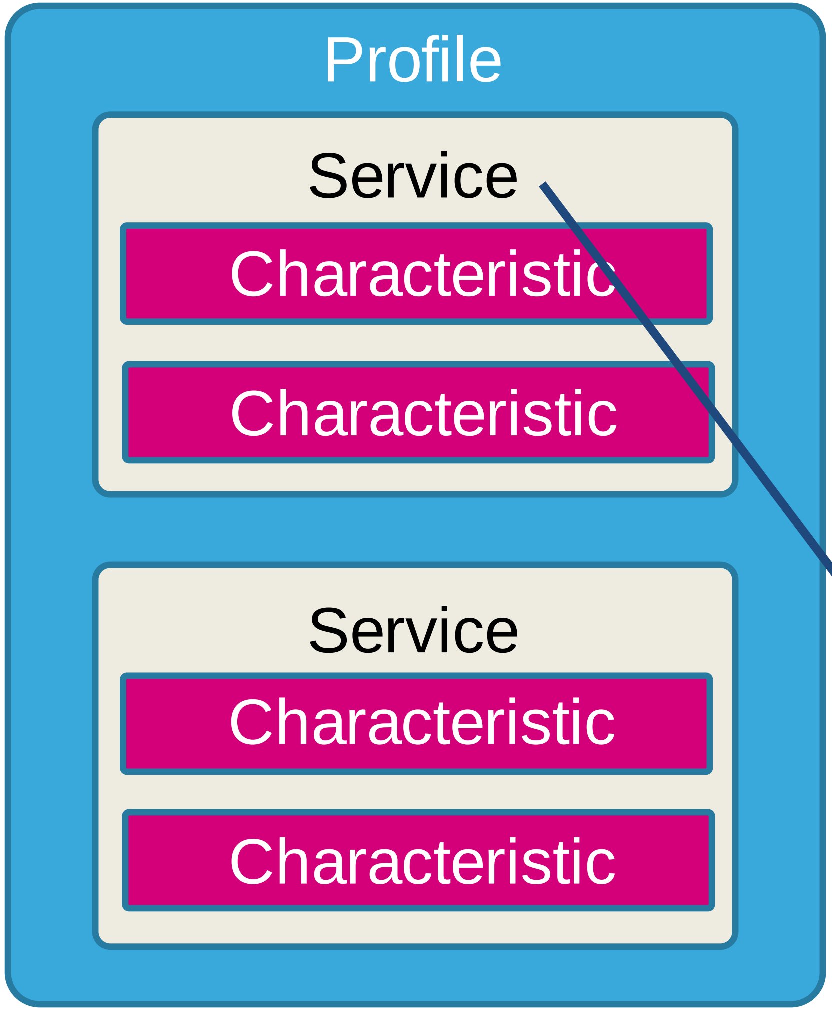
Each Data element in the Server is called Attribute

- Example

Handle	Type	Value
0x0009	«Device Name»	"Temperature Sensor"
0x0022	«Battery State»	0x04
0x0098	«Temperature»	0x0802

Source : Bluetooth® SIG

GATT Profile



- Attributes are organized in Services and Characteristics
- A GATT Profile defines how attributes are organized and how the application can access to them.

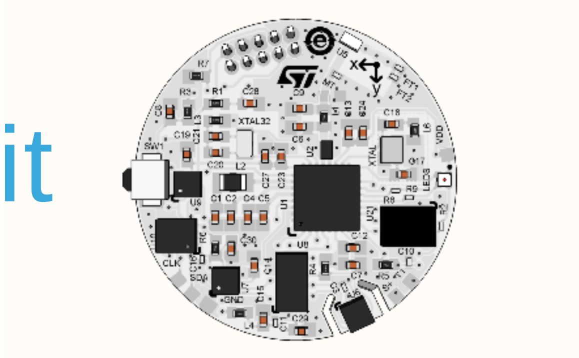
a typical example:

1 service: "ARG" *(Angular Rate and Gravity)*

2 characteristics: "Gyro", "Acc"

Values: [0,-1,+2], [-10,+15,+950]

BlueNRG-Tile Development Kit



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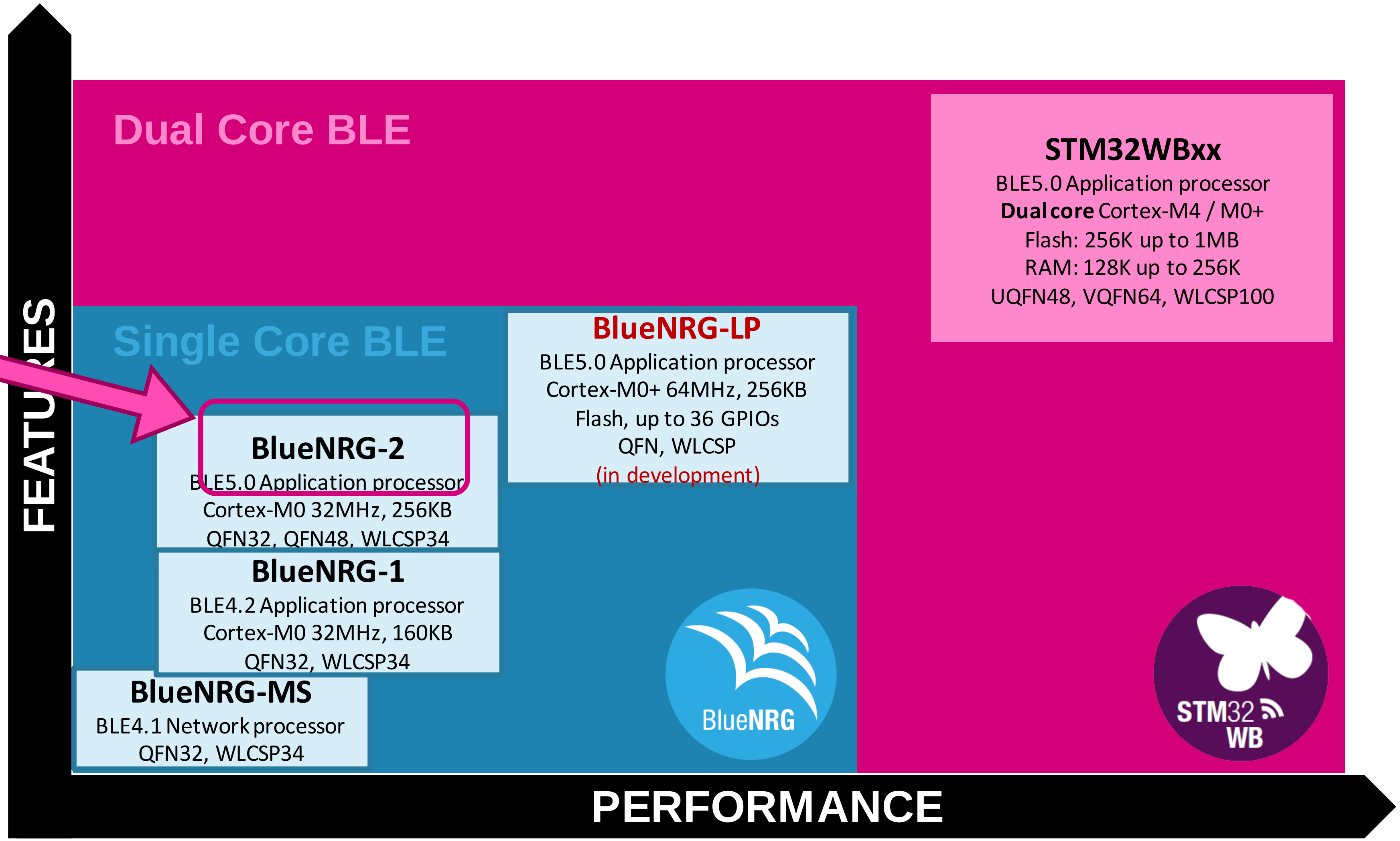
ST BLE Roadmap

TODAY'S Hands on



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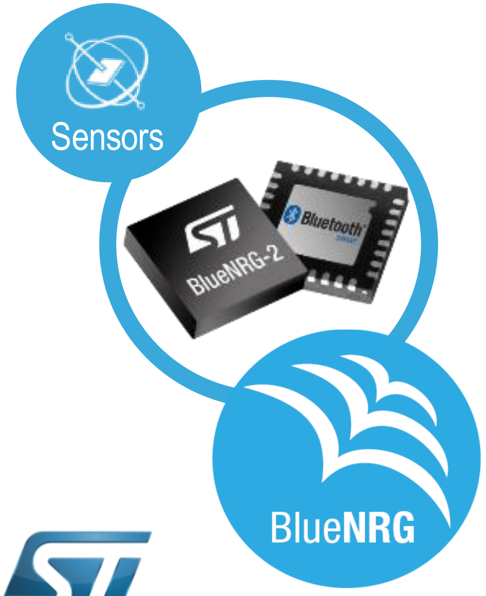
BlueNRG-2 SoC at a glance

The lowest power consumption	Processing power on demand	Flexible memory architecture	Optimized BLE Radio stack	Maximum security
>3 years lifetime on CR2032(*) 59 µA/MHz 0.9 µA sleep	Low-power architecture, Cortex-M0 @ 32 MHz	256 KB eFLASH 24 KB ULL SRAM (with full SRAM data retention)	70 kB FLASH 8 kB RAM 0.9uA with full RAM retention	ECC-256 AES-128 Factory UID Secure KEY



Seamless connection with SENSORS

Robust and Reliable BLE Link

Small form factor

Bluetooth 5.0 certified

Privacy 1.2 and secure connection 4.2

Faster and more reliable data transfer

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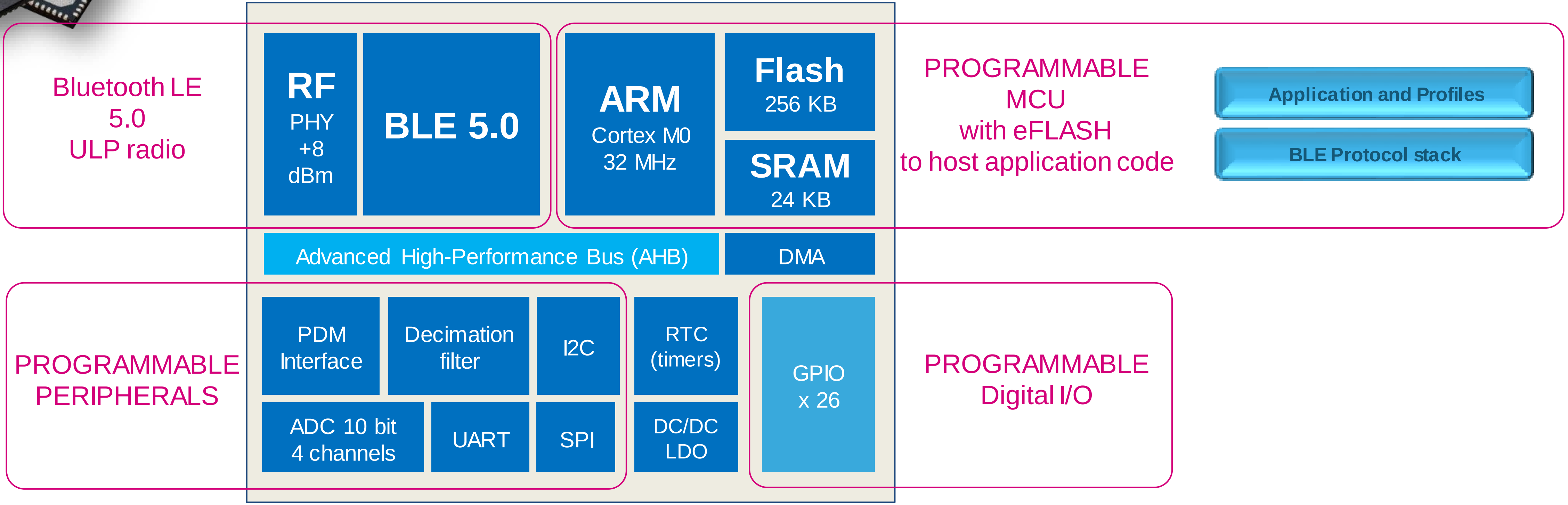
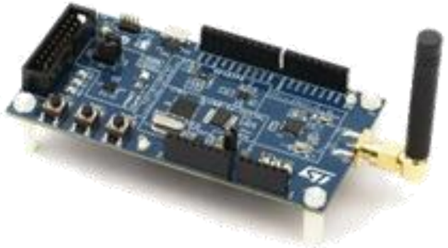
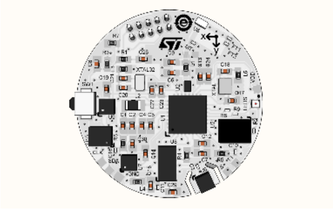
(*) Based on the average current consumption in connection mode (7.059 µA, connection interval 1000 ms)

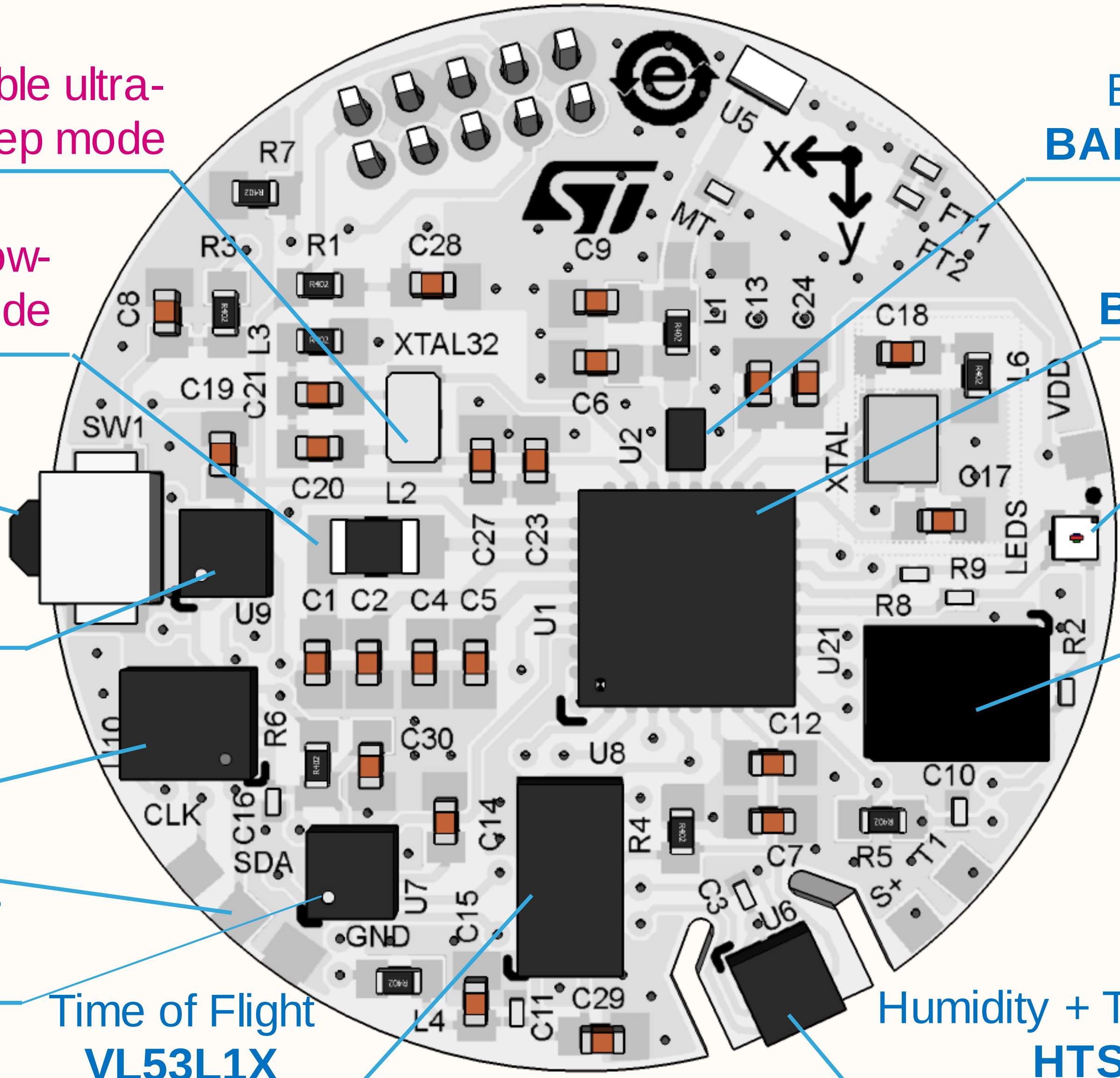
Bluetooth LE programmable processor







STEVAL-BCN002V1



32KHz XTAL to enable ultra-low-power BLE sleep mode

L2 bead to enable low-power BLE active mode

Wake-up button

Pressure Sensor
LPS22HH

Accelerometer + Gyro
LSM6DSO

I2C for expansion

Magnetometer
LIS2MDL

Time of Flight
VL53L1X

Balun
BALF-NRG

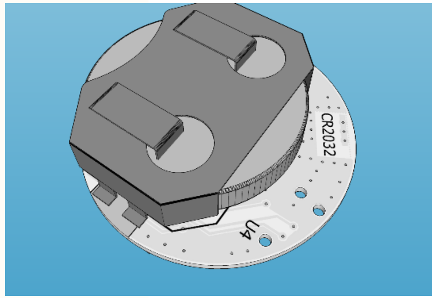
BLE SoC
BlueNRG-232

RGB LED

Microphone
MP34DT05-A

Humidity + Temperature
HTS221

Bottom view



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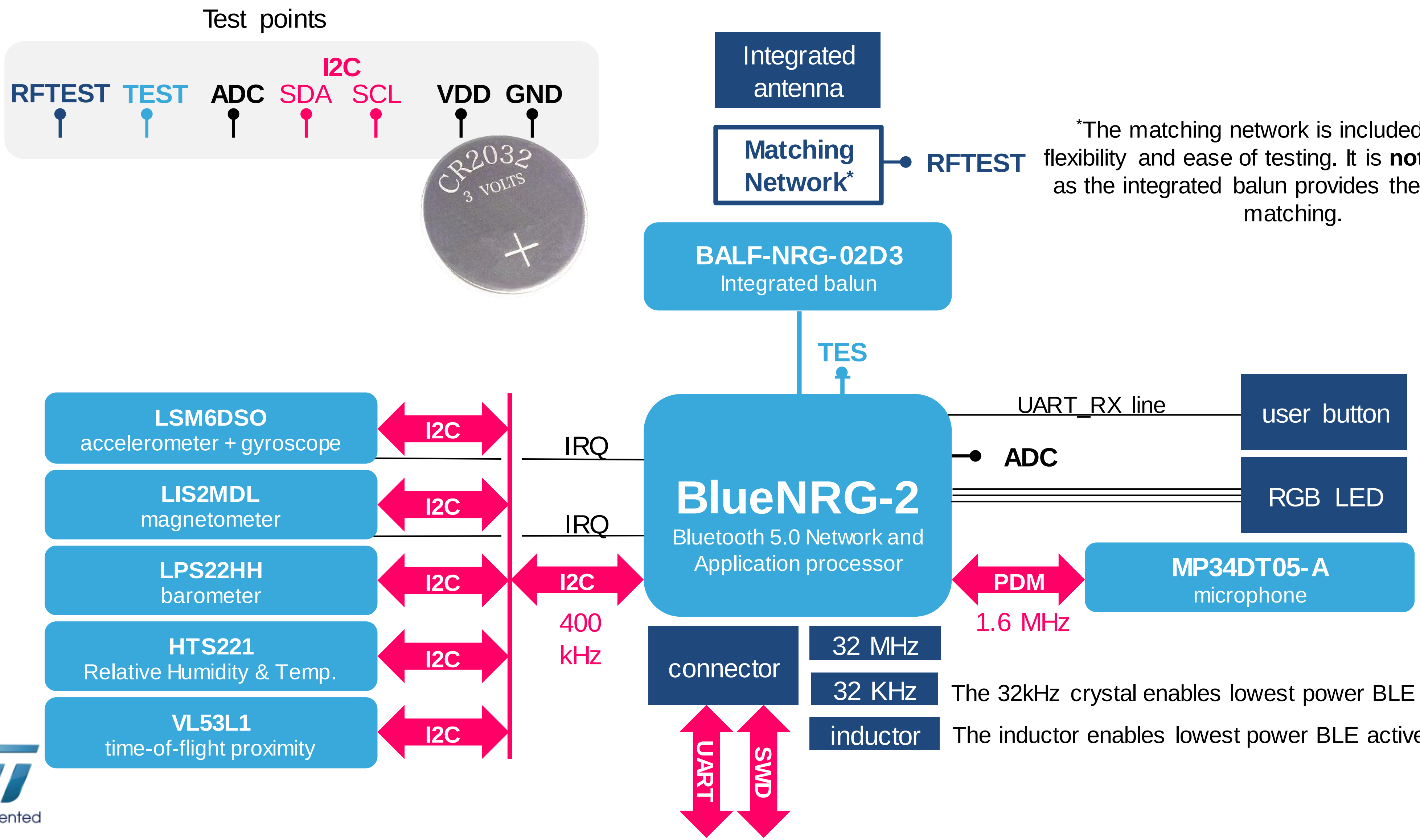
STEVAL-BCN002V1 Block Diagram



*The matching network is included only for flexibility and ease of testing. It is **not populated** as the integrated balun provides the necessary matching.

The 32kHz crystal enables lowest power BLE sleep mode.

The inductor enables lowest power BLE active mode.

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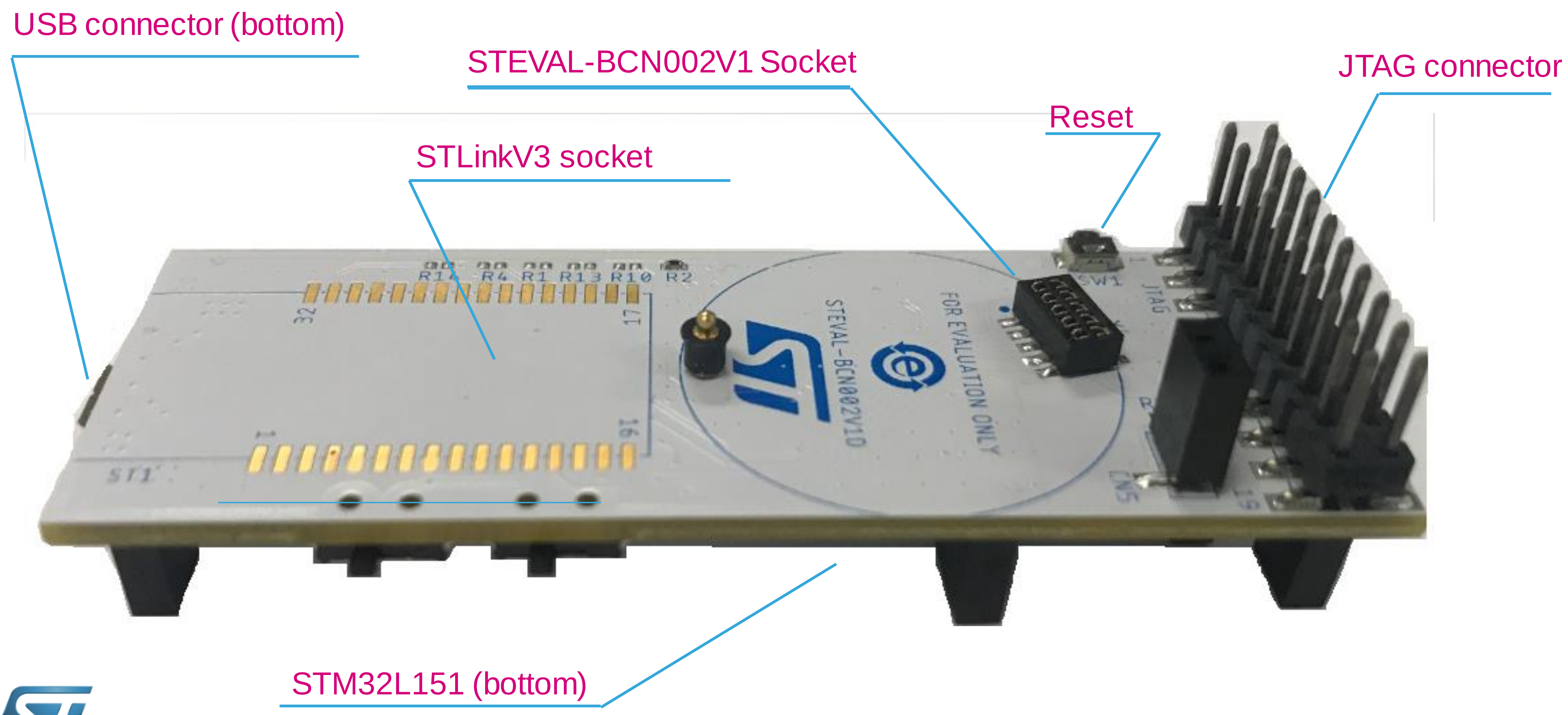
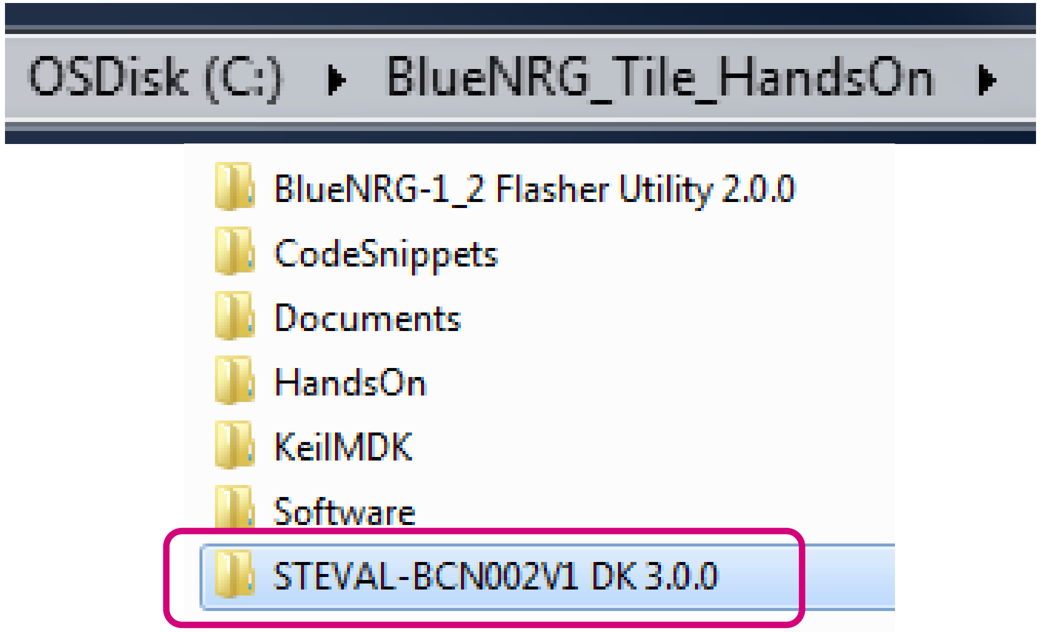
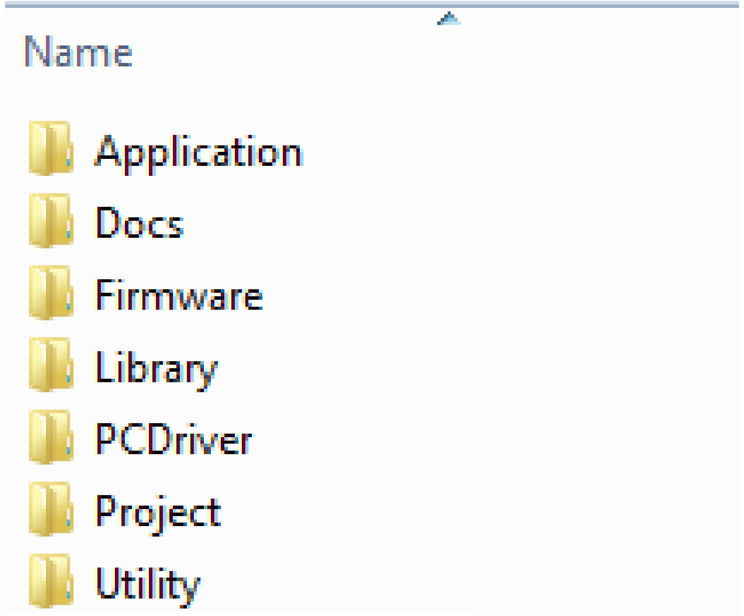
STEVAL-BCN002V1D



BlueNRG-Tile DK

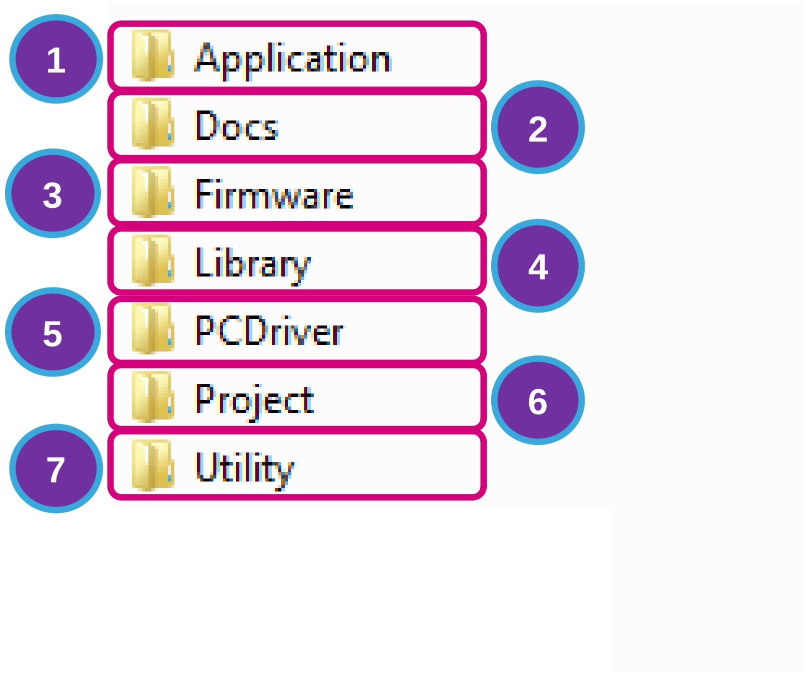
- Open the **BlueNRG_Tile_HandsOn** folder in C:\





- Open the **STEVAL-BCN002V1 DK 3.0.0** folder

BlueNRG-Tile DK overview



1. PC Applications
2. Documentation
3. Pre-build FW images
4. Low level drivers and BLE stack library
5. Virtual COM port drivers
6. Reference examples in source code
7. Utility section

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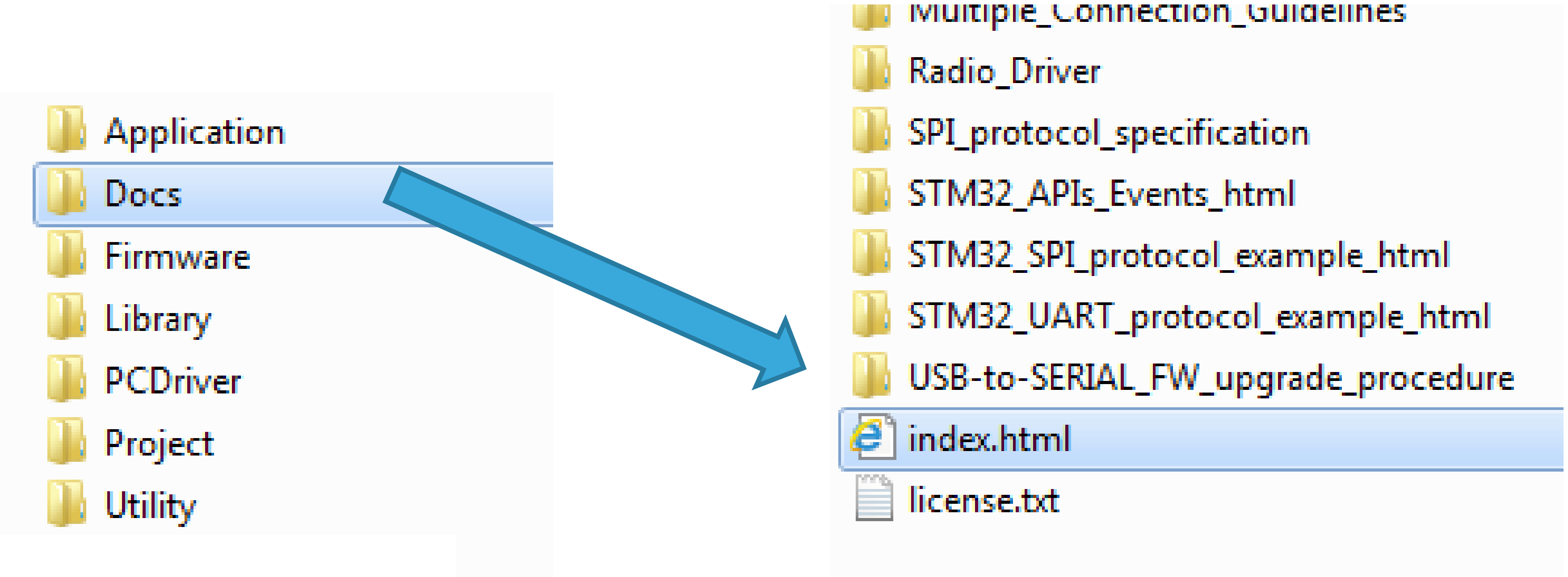
Documents

- Open the **Docs** folder from the **STEVAL-BCN002V1 DK 3.0.0** folder



- Double click on **index.html**

- Device Datasheet
- BLE stack documentation
  - Release notes
  - APIs and events
  - Programming manual
- Device (and kits) documentation
  - PCB design guidelines
  - Bring up guide
  - Getting started

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http://www.st.com/bluetile

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≡ Menu

Search

Home › Evaluation Tools › Solution Evaluation Tools › Sensor Solution Eval Boards › **STEVAL-BCN002V1B**

STEVAL-BCN002V1B

BlueNRG-Tile - Bluetooth LE enabled sensor node development kit

Download Databrief

QUICK VIEW	RESOURCES	SAMPLE & BUY	QUALITY & RELIABILITY

The STEVAL-BCN002V1B Bluetooth LE enabled sensor node development kit features the STEVAL-BCN002V1 multi-sensor board based on BlueNRG-2 SoC Bluetooth Low Energy application processor. This sensor board has accelerometer, gyroscope, magnetometer, pressure, humidity, Time-of-Flight and microphone sensors, and is powered by a common CR2032 coin battery.

The sensor board communicates with a Bluetooth LE enabled smartphone running the ST BlueMS APP, available on Google Play and iTunes stores.

The STEVAL-BCN002V1D adapter board is used to program and debug the sensor board. The adapter board is powered via USB.

Arm Keil MDK License Installation

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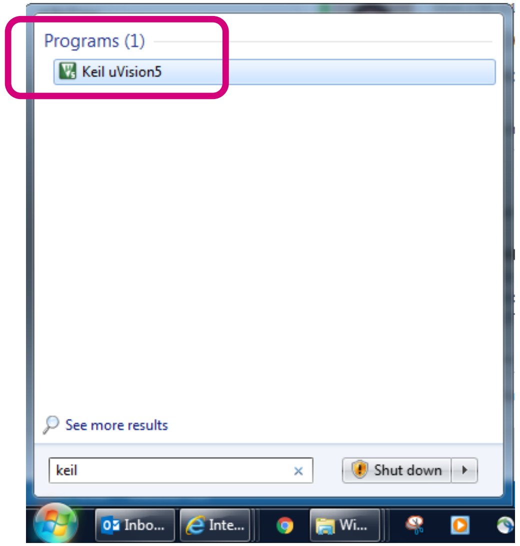
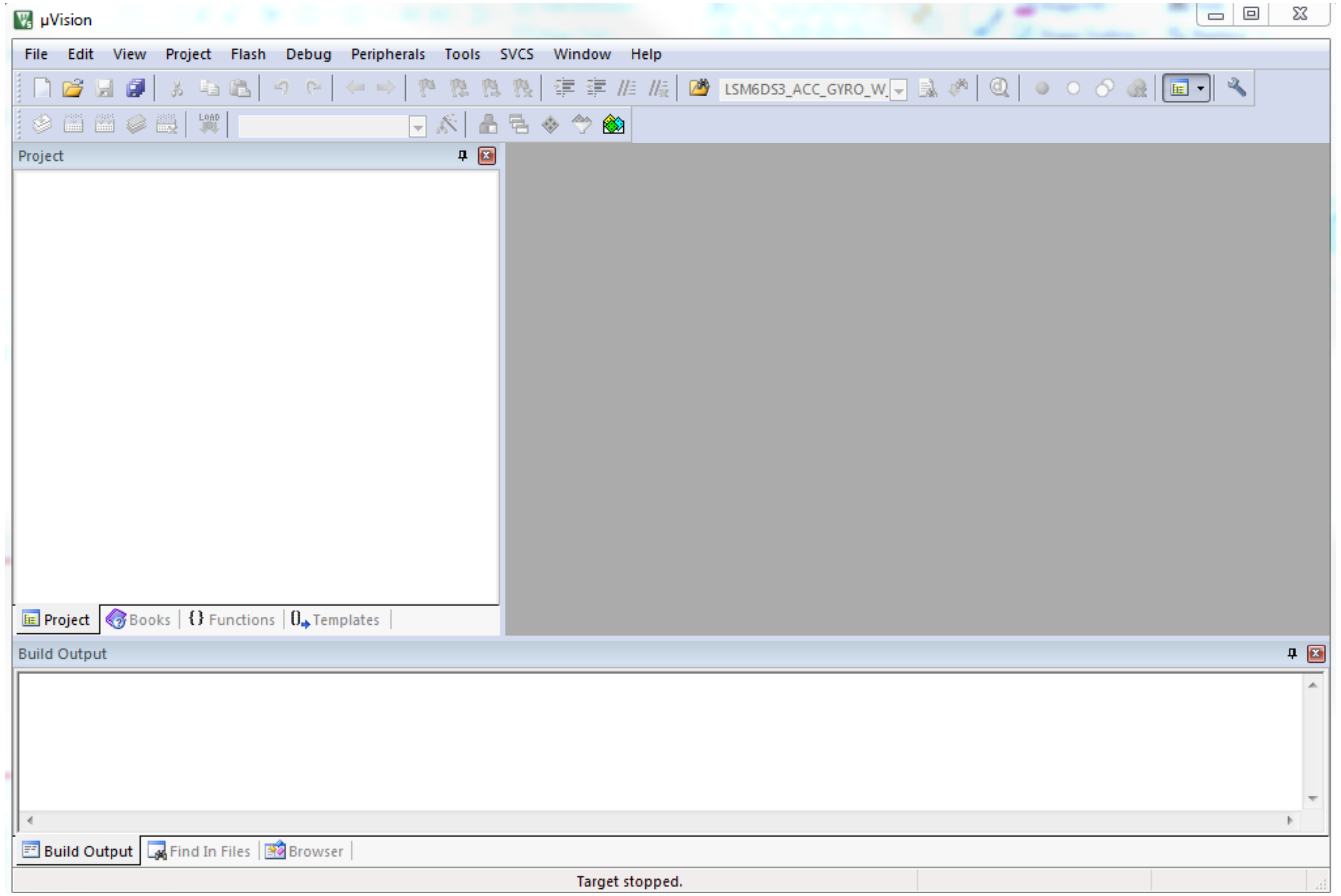
Check on successful tool installation

- **Open** Keil uVision5 IDE
- This is the main GUI





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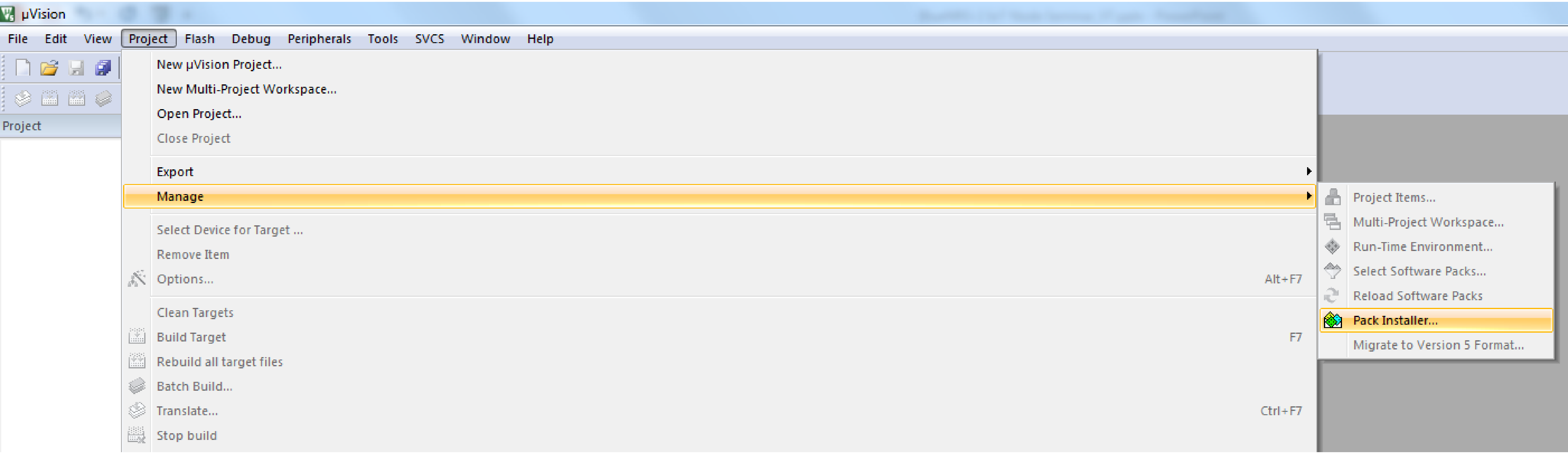
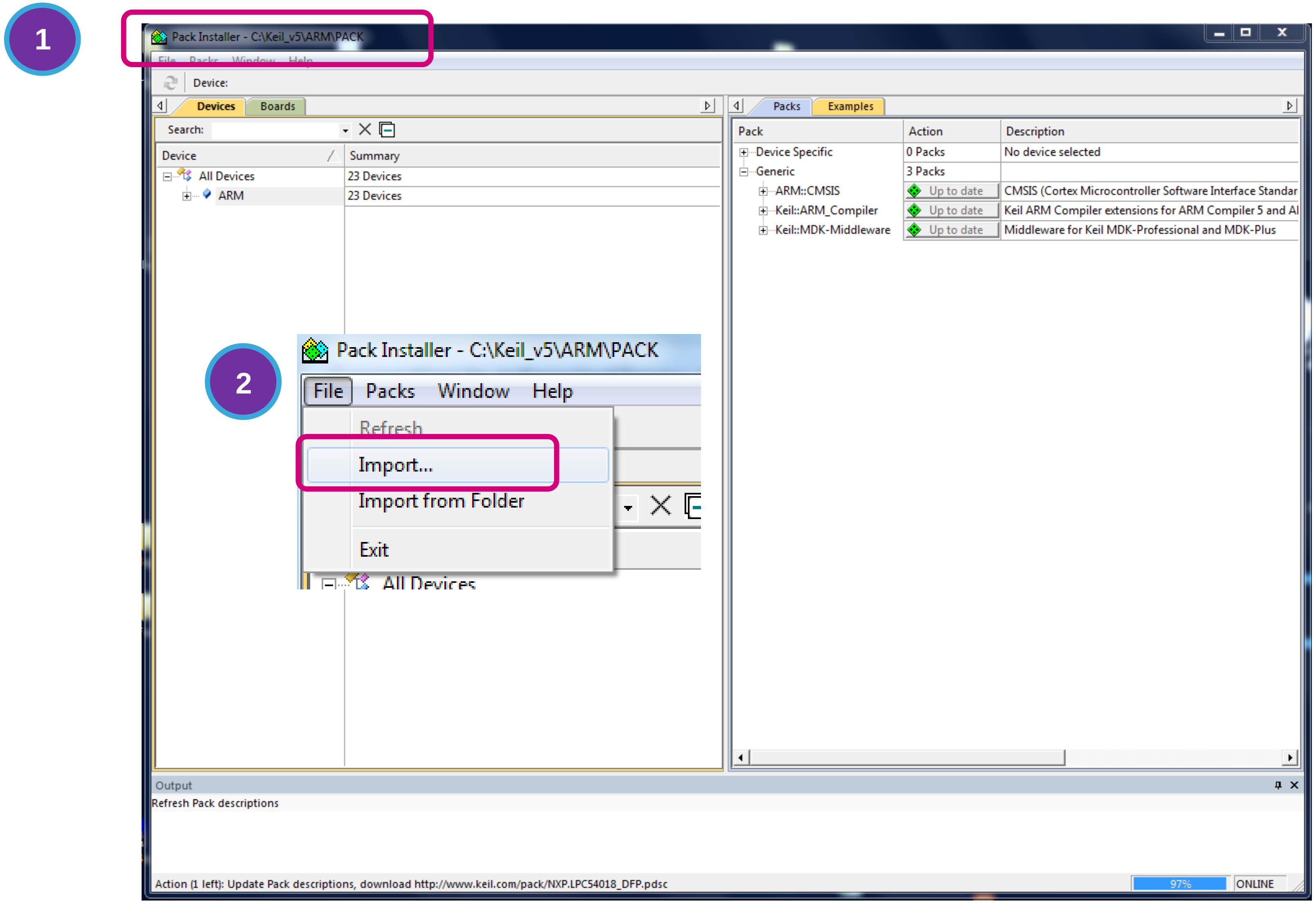
Keil MDK Installation 3/6

- Open the **Pack Installer**
  - Go to **Project->Manage->Pack Installer**



Keil MDK Installation 4/6

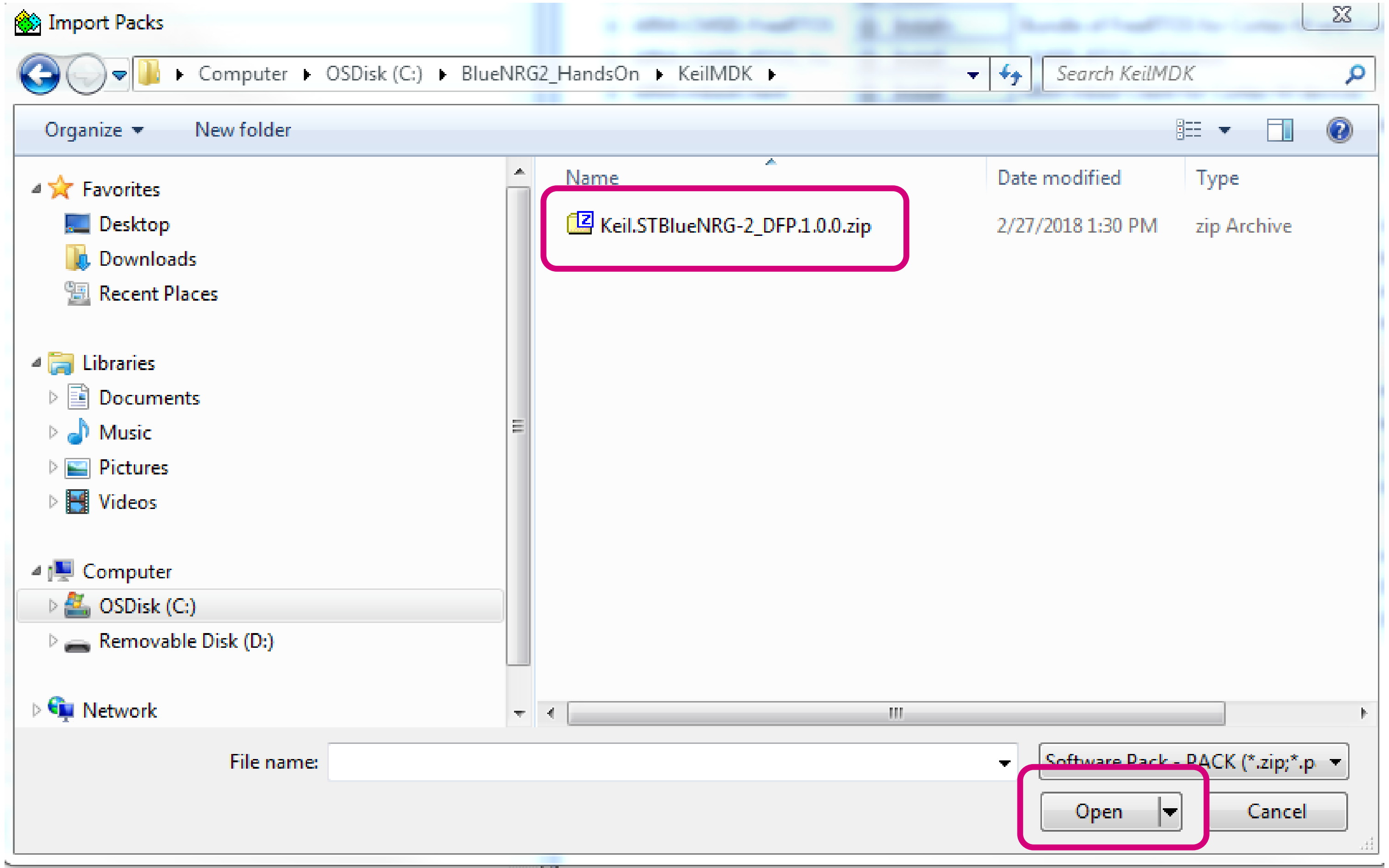
1. In the **Pack Installer**…
2. Go to **File->Import**.



Keil MDK Installation 5/6

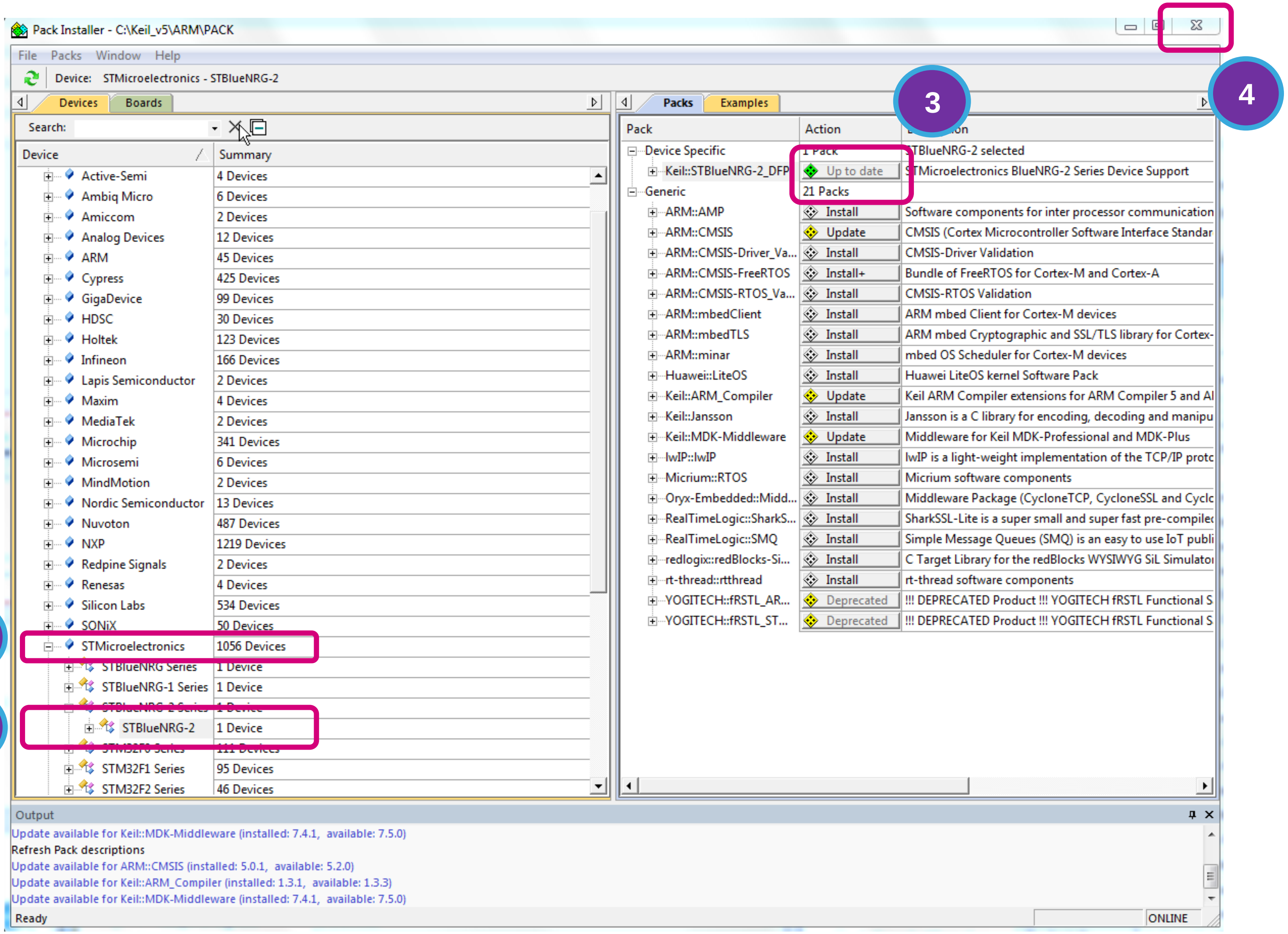
1. Select the .zip file “**Keil.STBlueNRG-2_DFP.1.0.0.zip**” from the folder “**C:\BlueNRG_Tile_HandsOn\KeilMDK**”

2. Click on **Open**.



Keil MDK Installation 6/6

1. Once the Device Support pack has been installed, select on the **Devices** list on the **left column** the vendor **STMicroelectronics**
2. Go to **STBlueNRG-2 Series** and select **STBlueNRG-2**
3. Now it will show in green "**Up to date**"
4. **Close** the Pack Installer



Arm Keil MDK License

- A **FREE** license is available for ST BlueNRG-2 device
  - This procedure requires on-line registration.
  - To avoid potential problems with the Wi-Fi network, we’re skipping it for this hands-on and we will install one temporary license (expiring end of the month)

- But, **AT THE END OF THE PRESENTATION** you can find the step-by-step procedure for installing the FREE and unlimited license!

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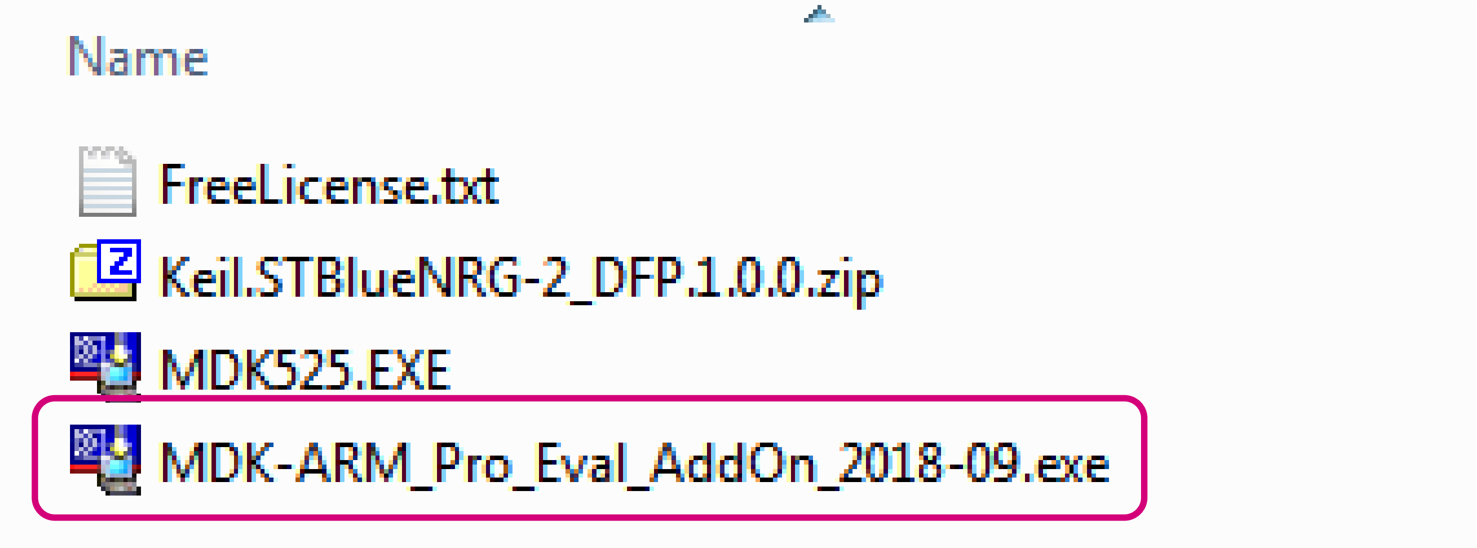
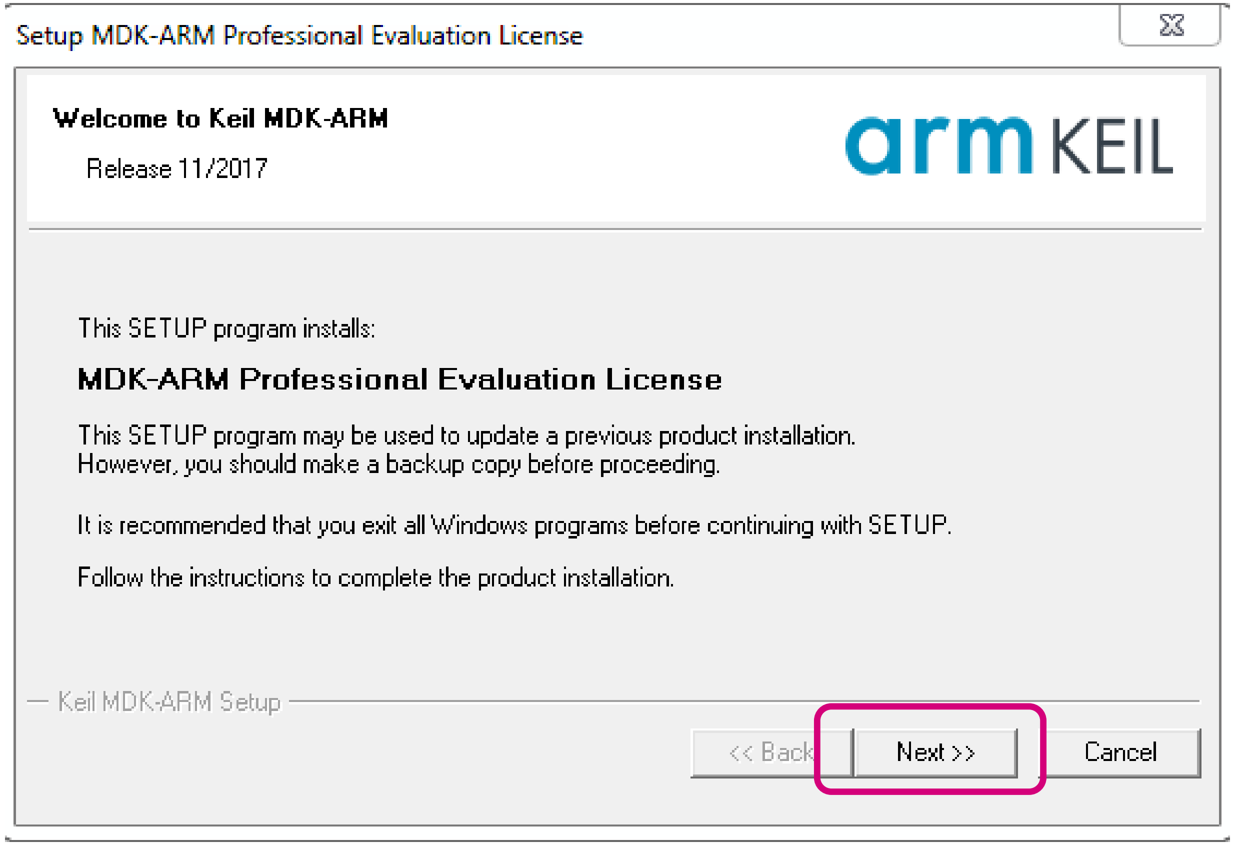
Arm Keil MDK License Installation 1/6

- Go to the folder “**C:\BlueNRG_Tile_HandsOn\KeilMDK**”
- Double click on the file **MDK-ARM_Pro_Eval_AddOn_2018-09.exe**



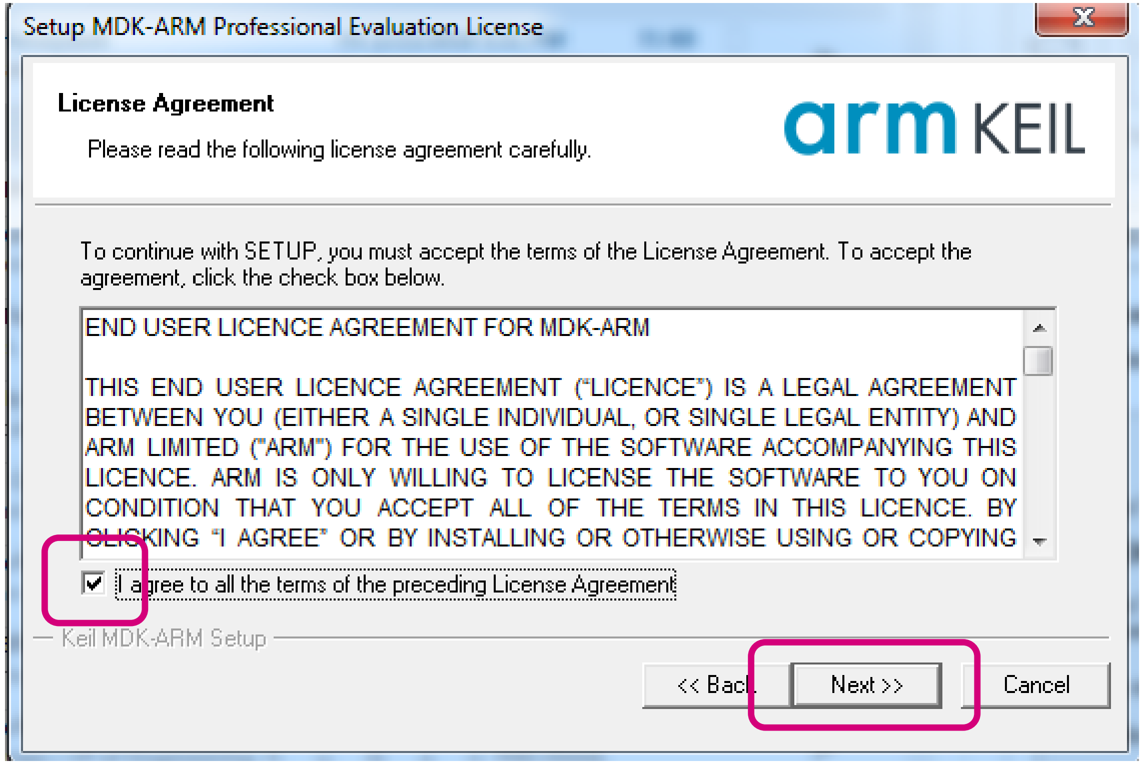
Arm Keil MDK License Installation 2/6

- This pop up window will appear
- Click on **Next**



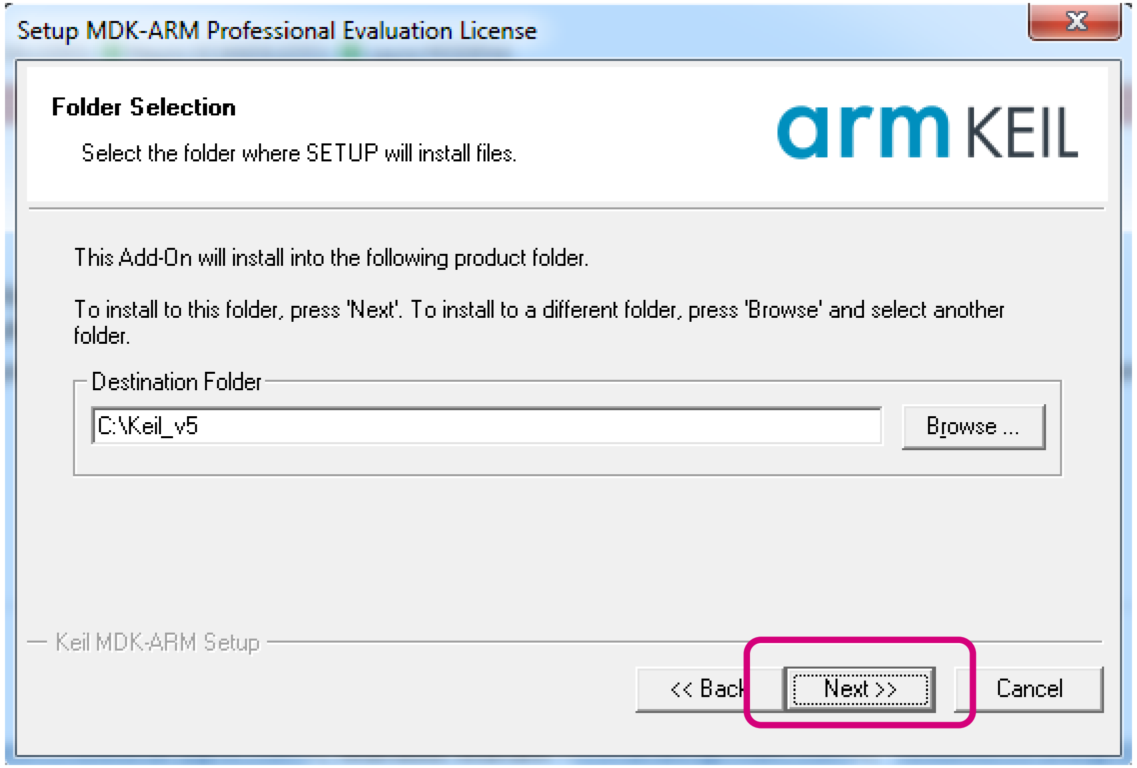
Arm Keil MDK License Installation 3/6

- Select on **Agree** License terms
- Click on **Next**



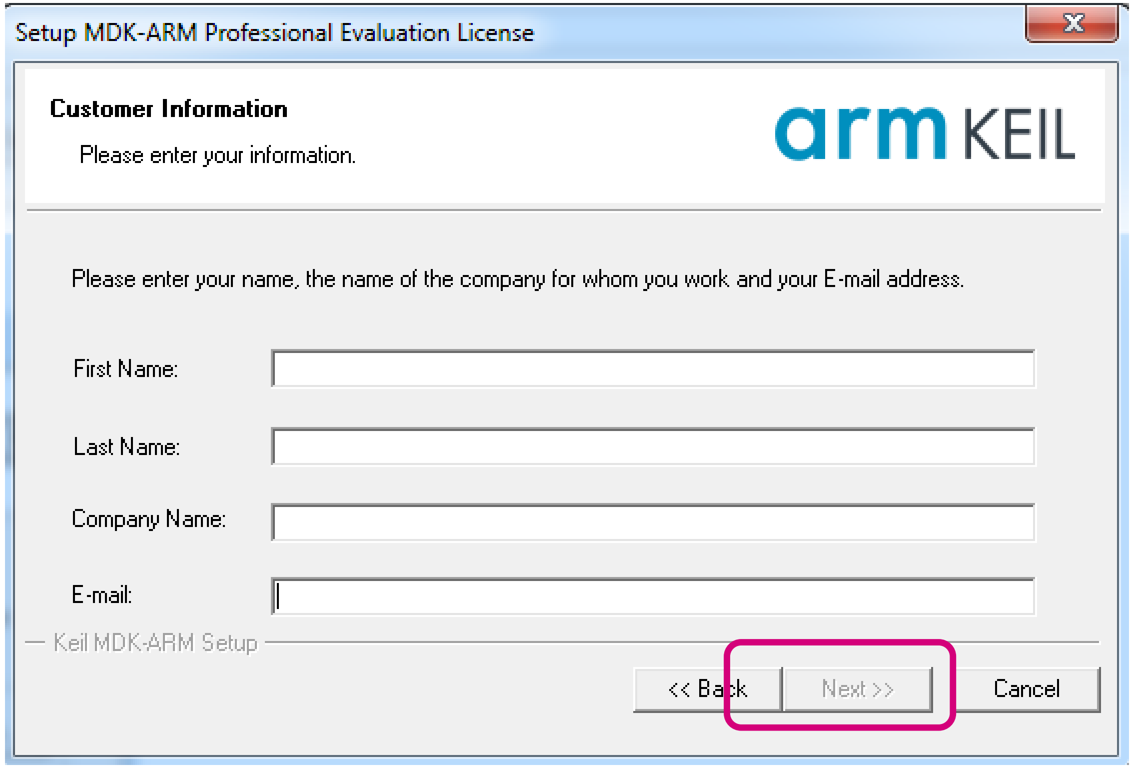
Arm Keil MDK License Installation 4/6

- Click on **Next**



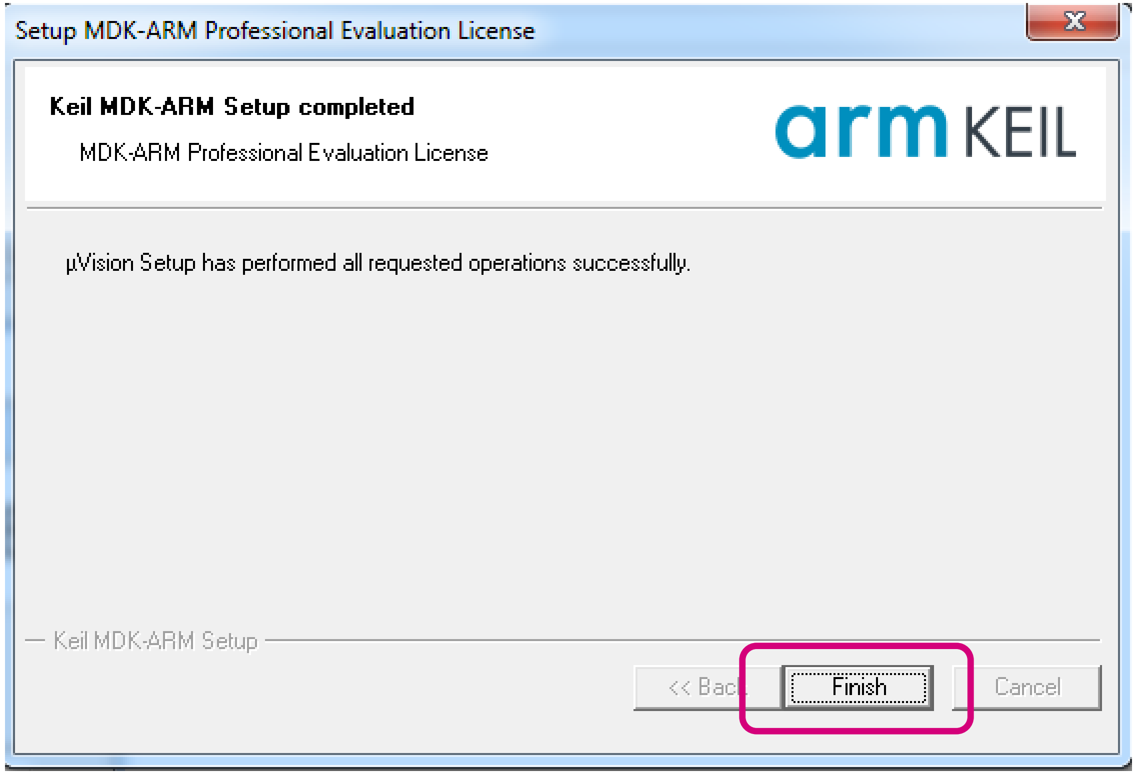
Arm Keil MDK License Installation 5/6

- Fill in your data and click on **Next**



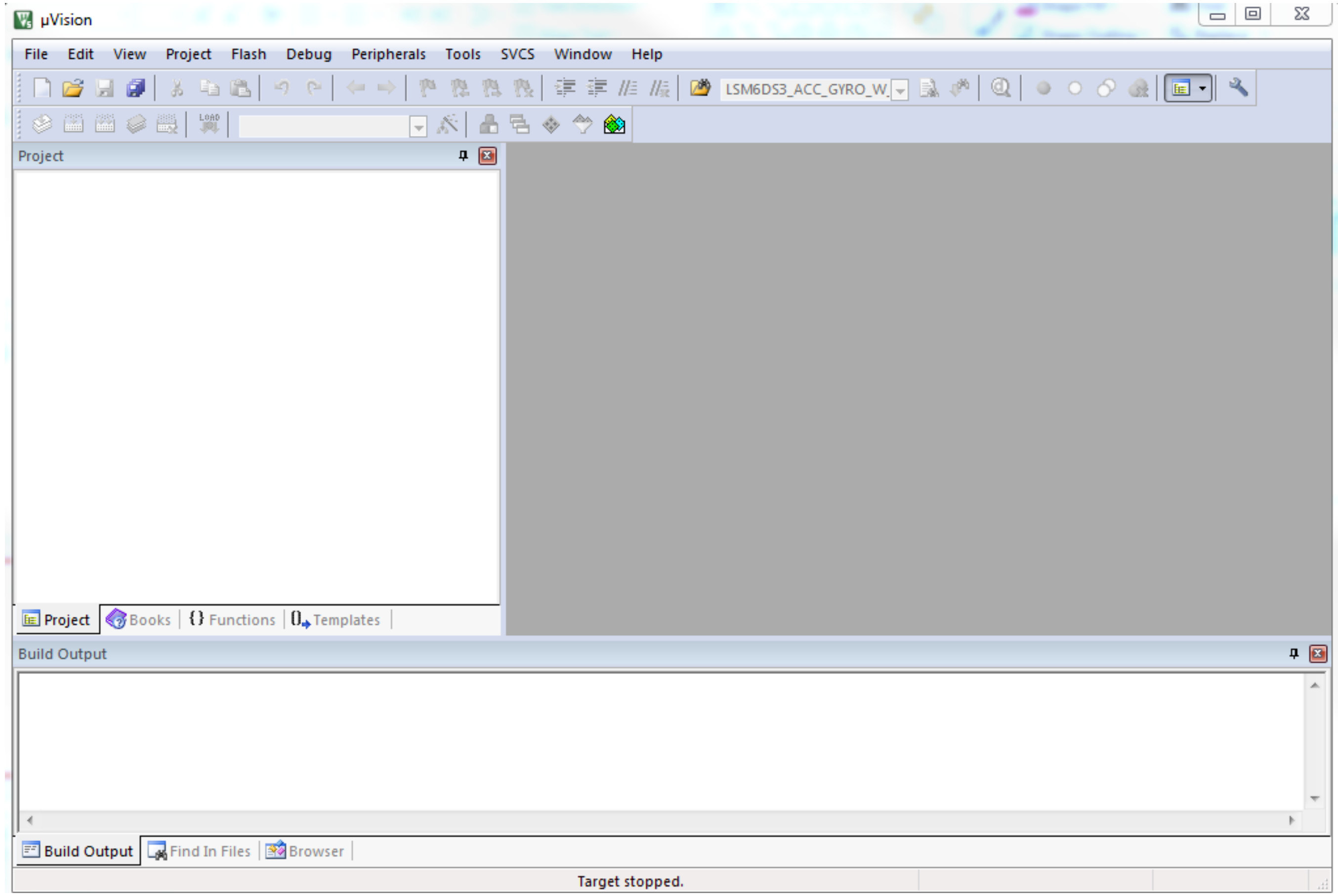
Arm Keil MDK License Installation 6/6

- Click on **Finish**



Arm Keil MDK License Installation – FINAL CHECK

- Go back to Keil uVision5 IDE



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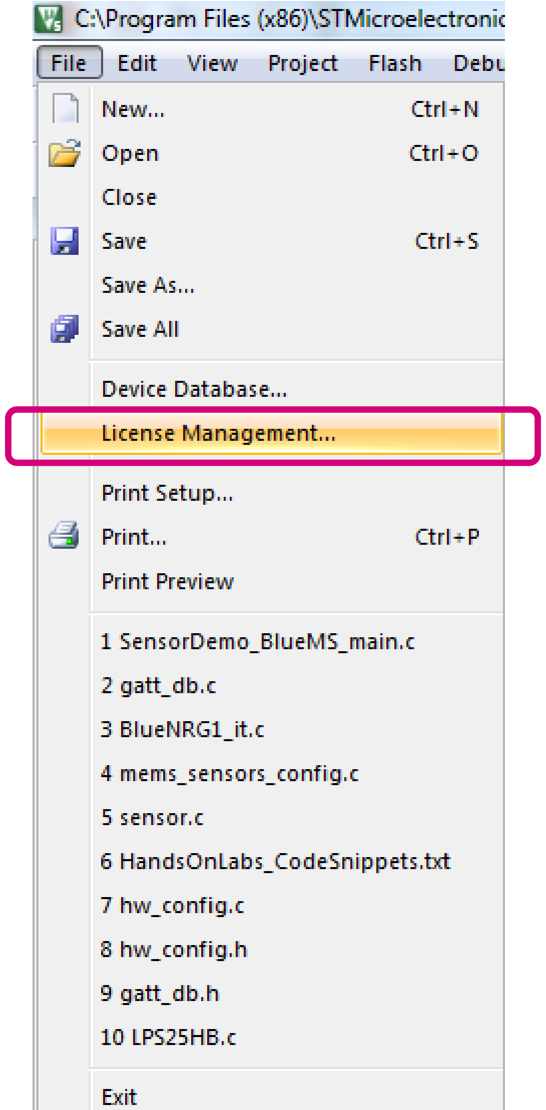
Arm Keil MDK License Installation – FINAL CHECK

- In Keil uVision tool open the dialog

File->License Management...



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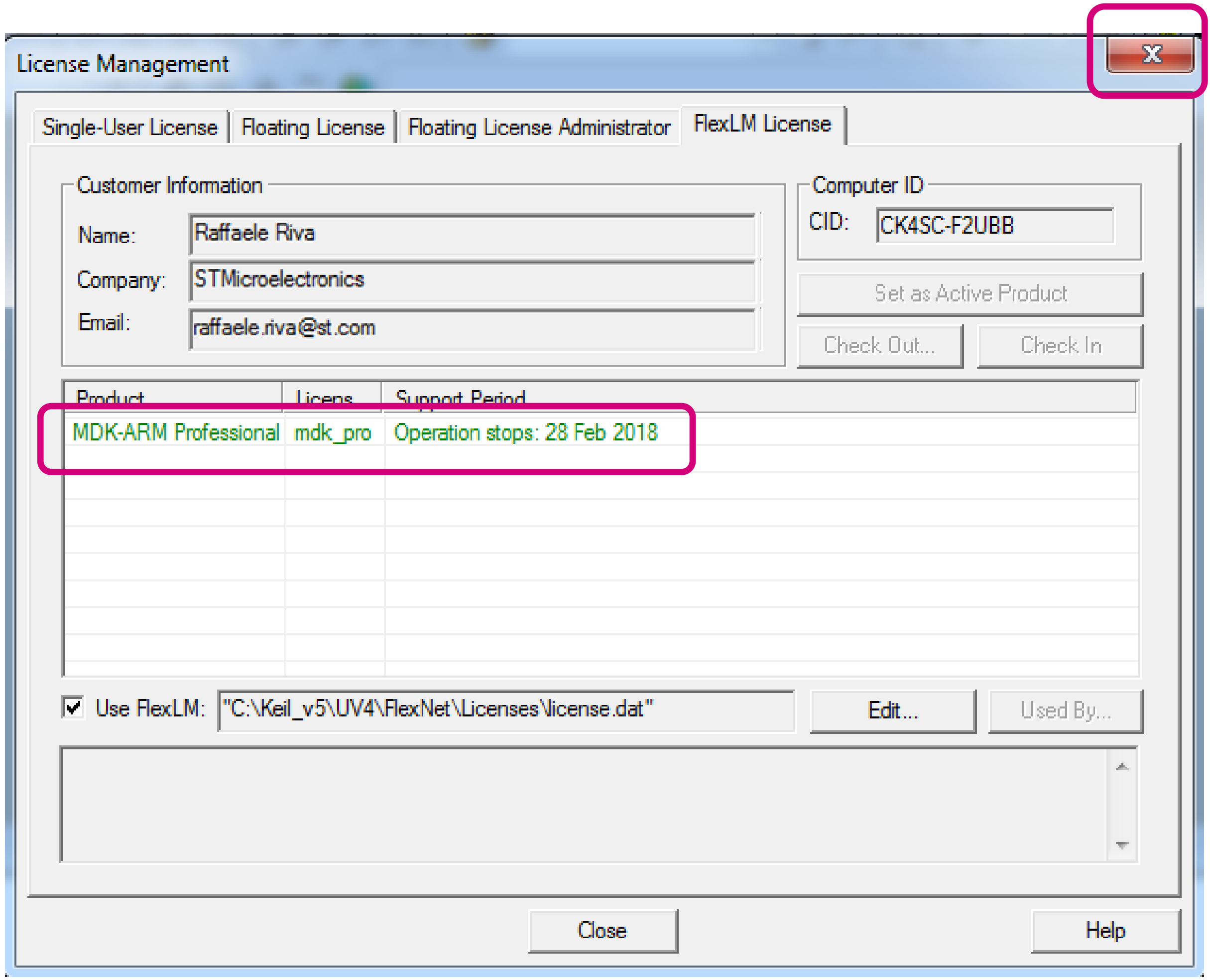
Arm Keil MDK License Installation – FINAL CHECK

- The product "**MDK-ARM Professional**" should appear
- Close the License Management popup window



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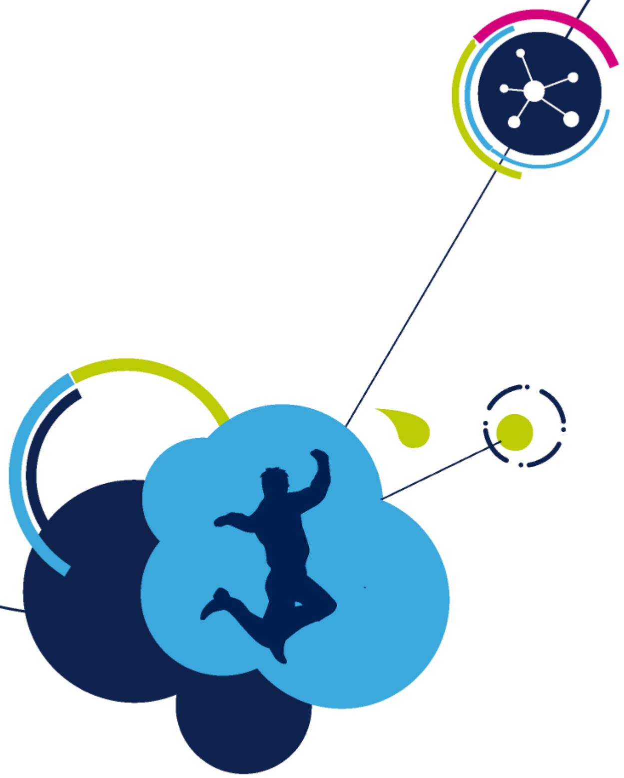

Hands on overview

Labs overview

- **Lab 1**: Getting started with STEVAL-BCN002V1 “Hello World” example
- **Lab 2**: Connecting to the ST BlueMS app
- **Lab 3**: LED characteristic
- **Lab 4**: Accelerometer embedded events detection
- **Lab 5**: 9-axis Acc+Gyro+Mag Sensor Data Fusion
- **Lab 6**: Cloud data logging on IBM Watson
- **Lab 7**: Bonus Lab – Voice over BLE

Lab 1

Getting Started with STEVAL-BCN002V1
“Hello World”

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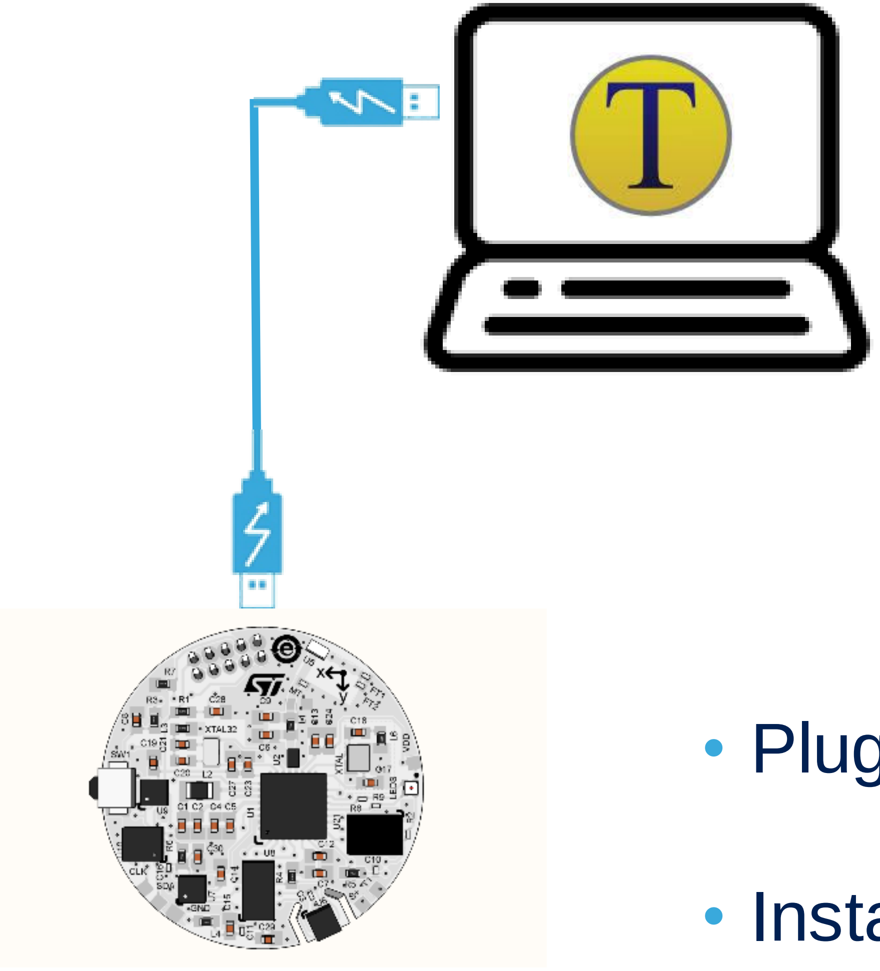
"Hello World"

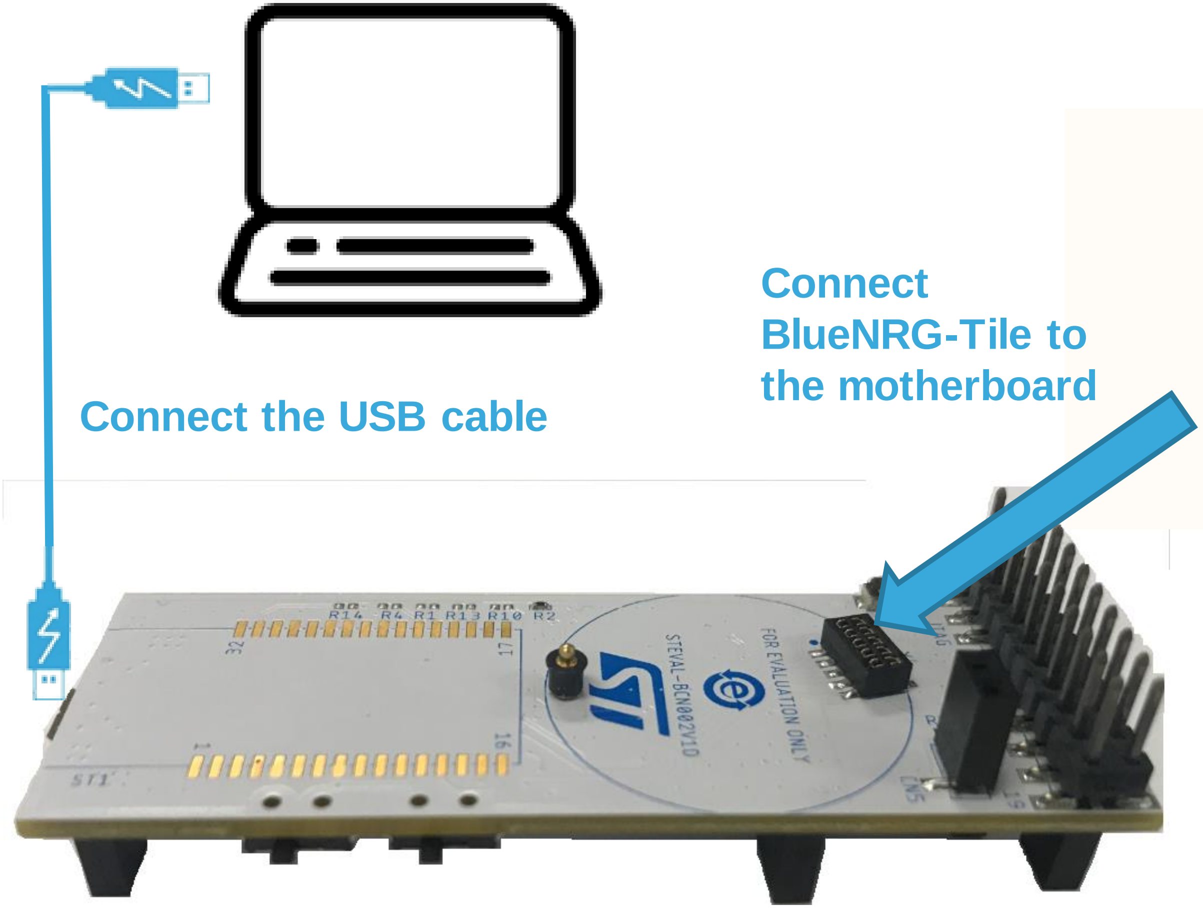


- Plug the BlueNRG-Tile to the PC using the USB cable
- Install and open **TeraTerm** and configure serial terminal

Code modifications

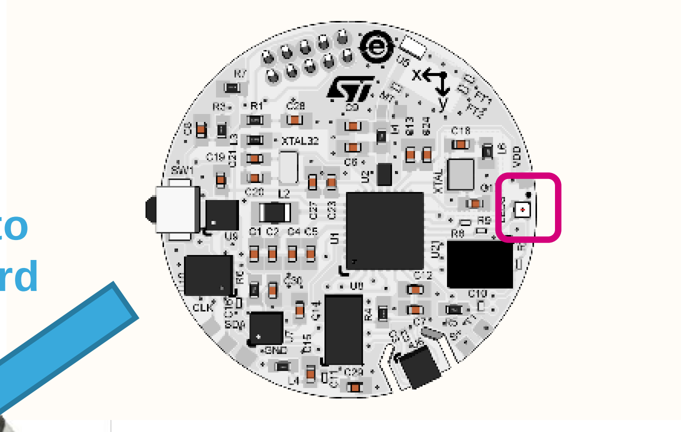
NO MODIFICATIONS NEEDED!

Connect your STEVAL-BCN002V1 to the PC using USB

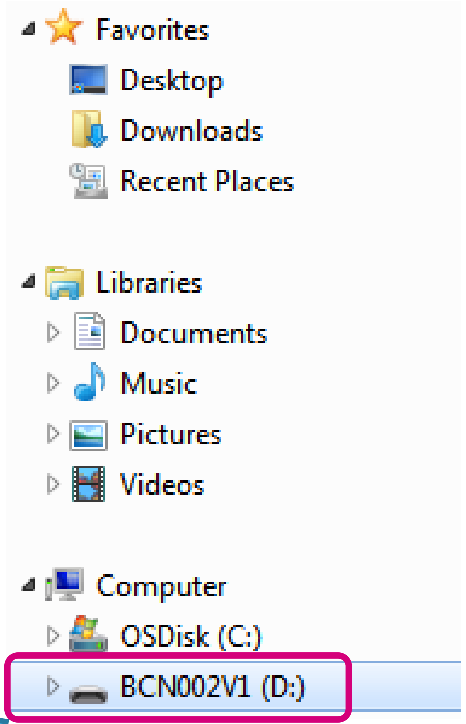


Connect the USB cable

Connect BlueNRG-Tile to the motherboard



BLUE LED ON

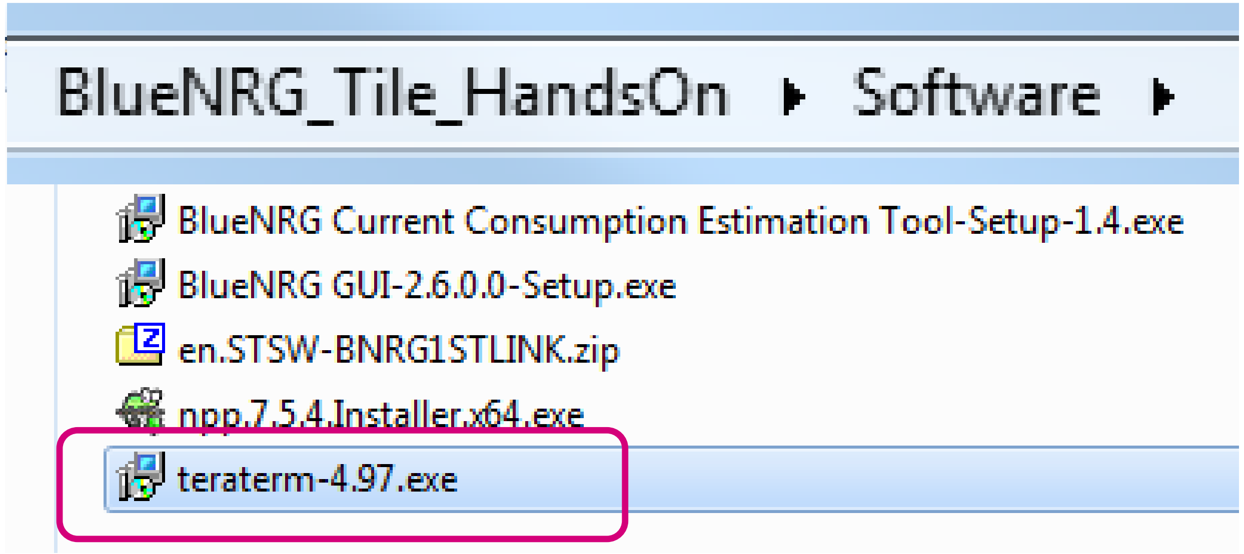


On the PC file system a BCN002V1 drive will appear

TeraTerm installation 1/10

1. Go to the folder **C:\BlueNRG_Tile_HandsOn\Software**

2. Double Click on **teraterm-4.97.exe**



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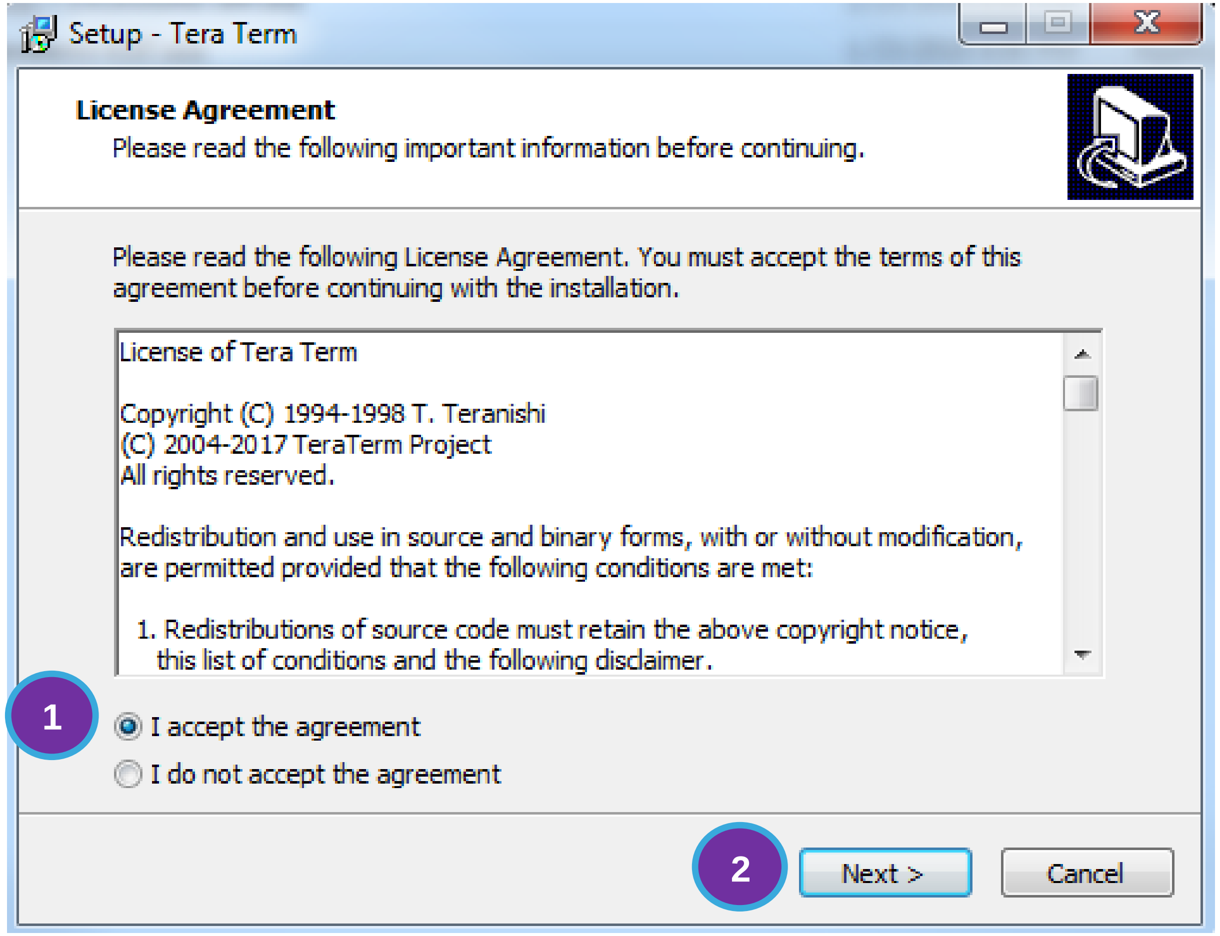
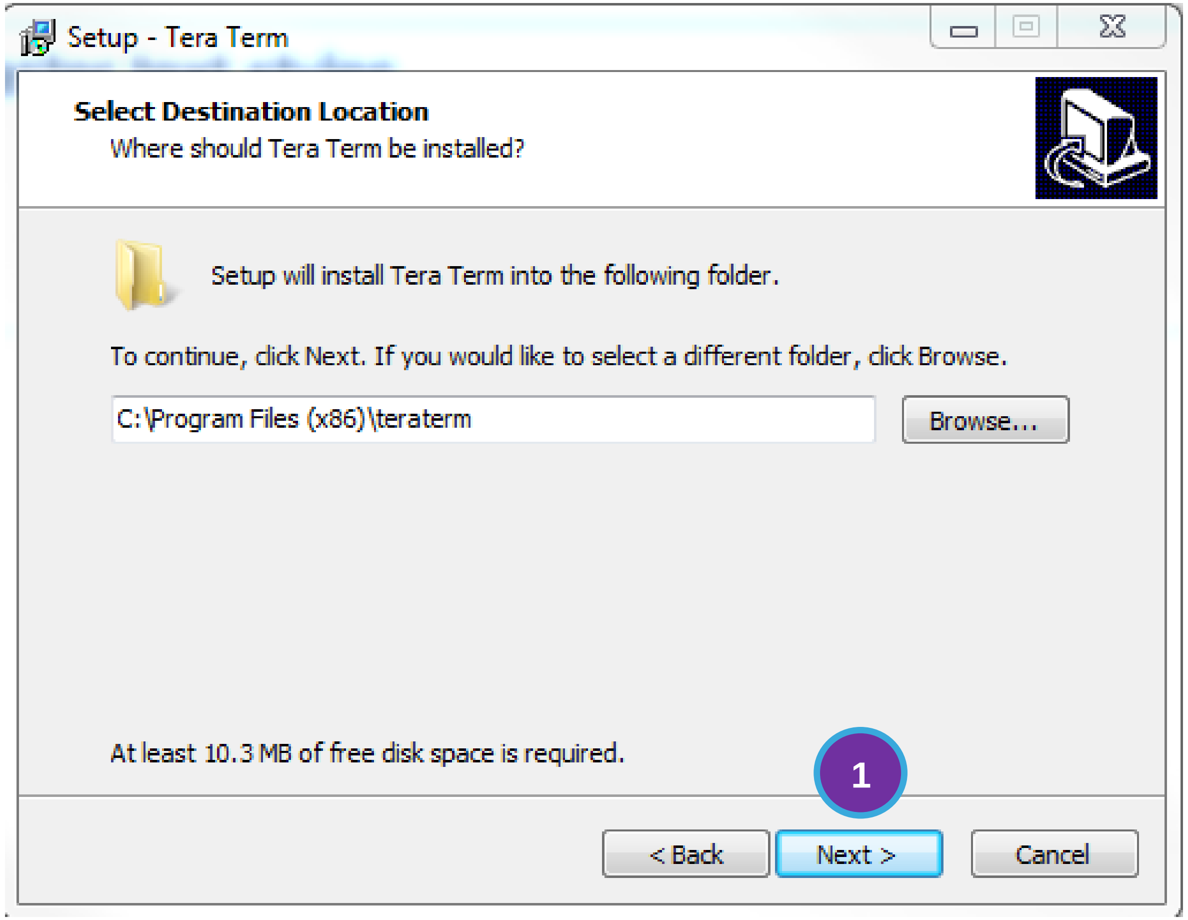
TeraTerm installation 2/10

1. Click on **Accept the agreement**
2. Click on **Next**



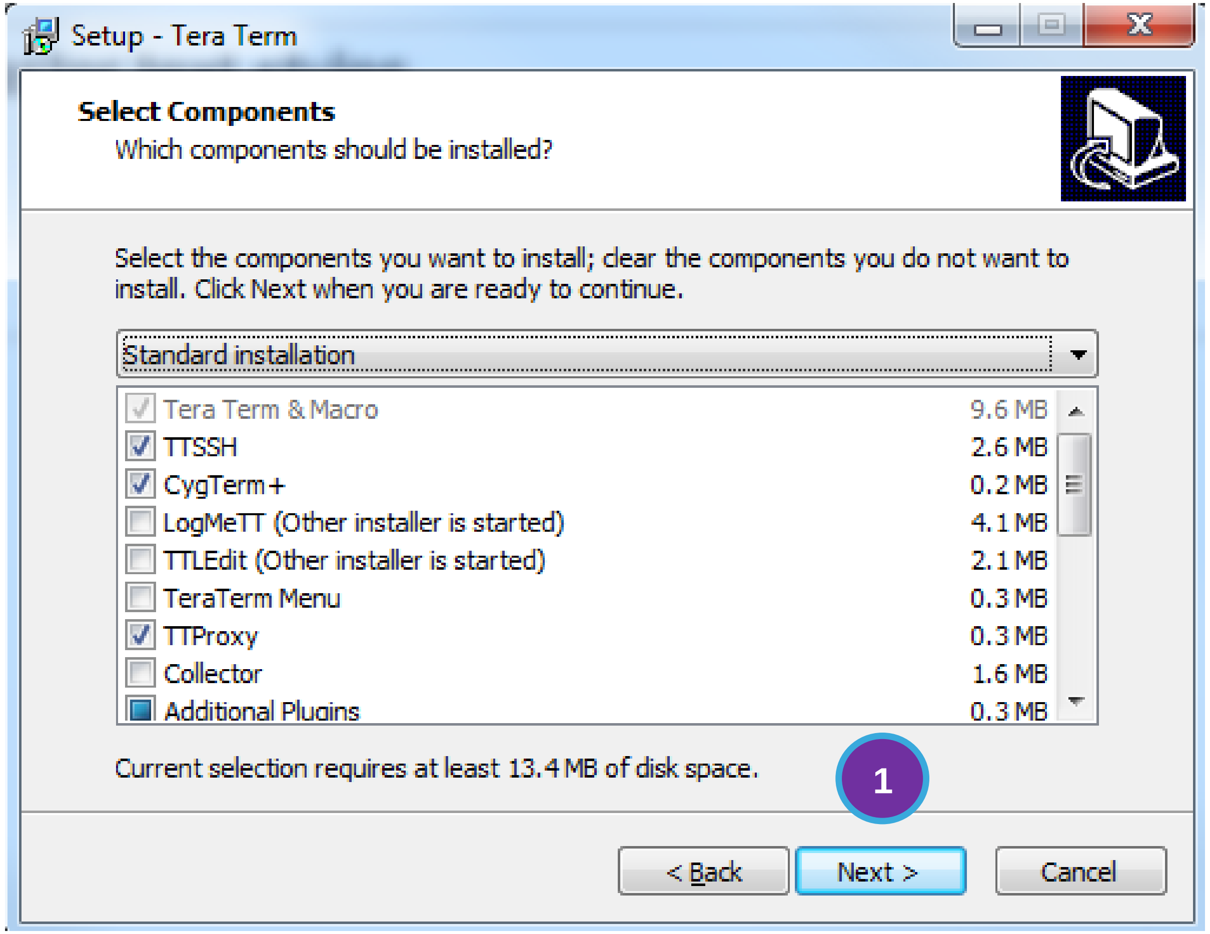
TeraTerm installation 3/10

1. Click on **Next**



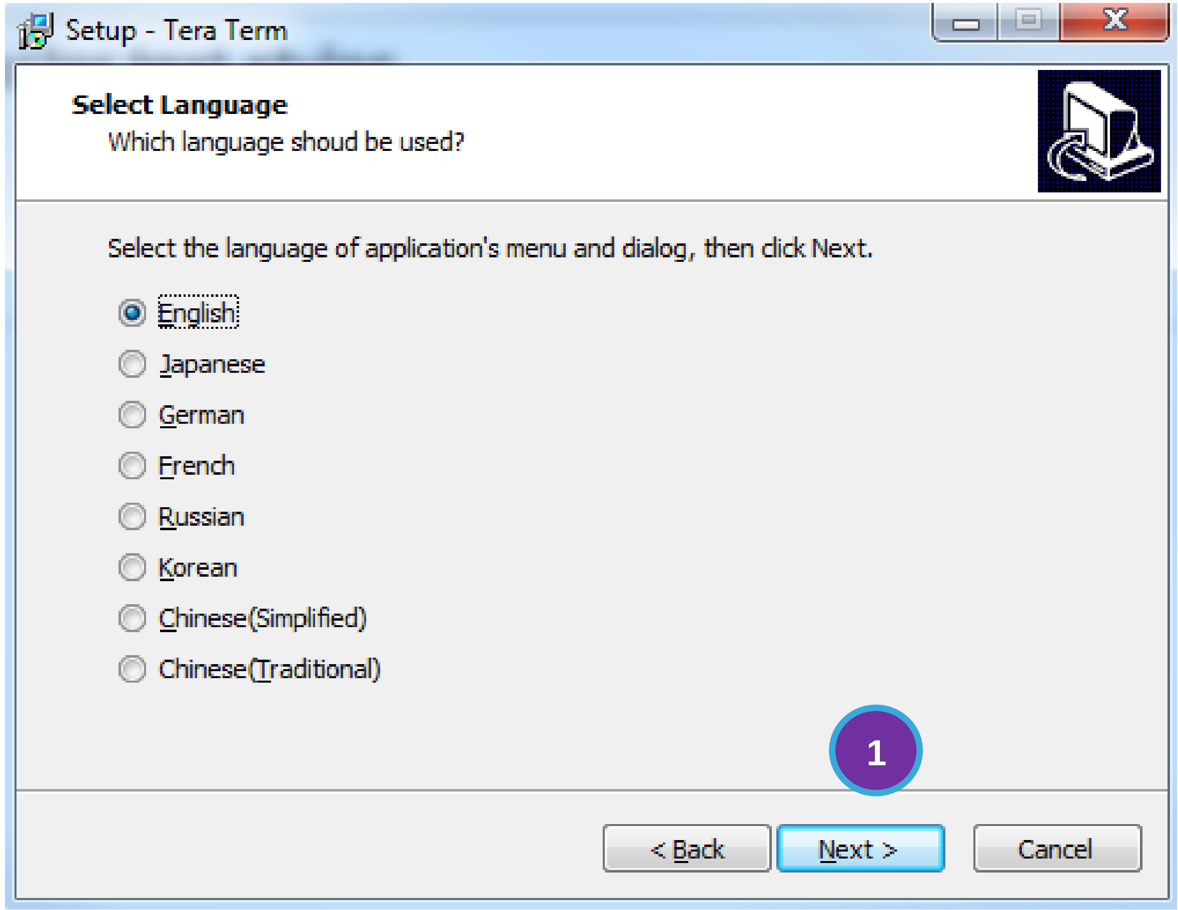
TeraTerm installation 4/10

1. Click on **Next**



TeraTerm installation 5/10

1. Click on **Next**



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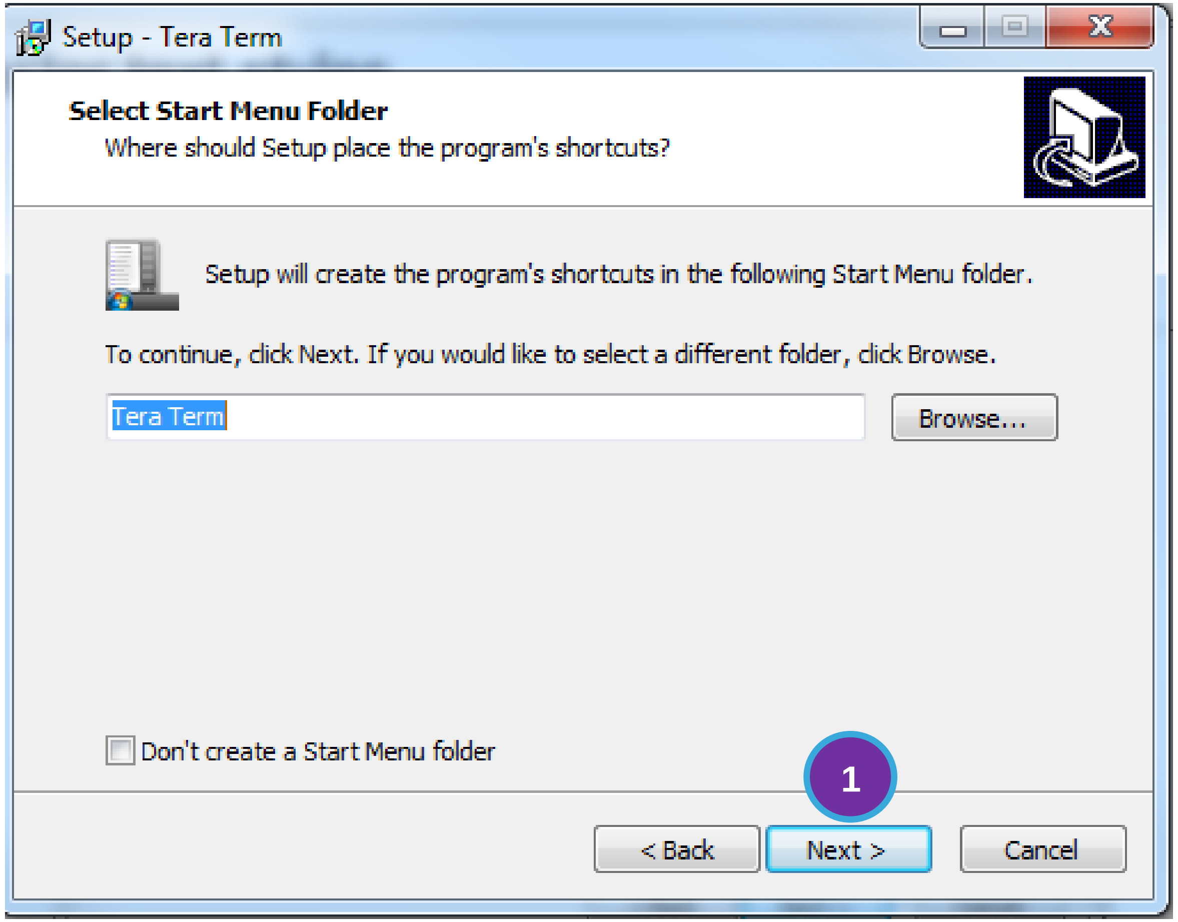
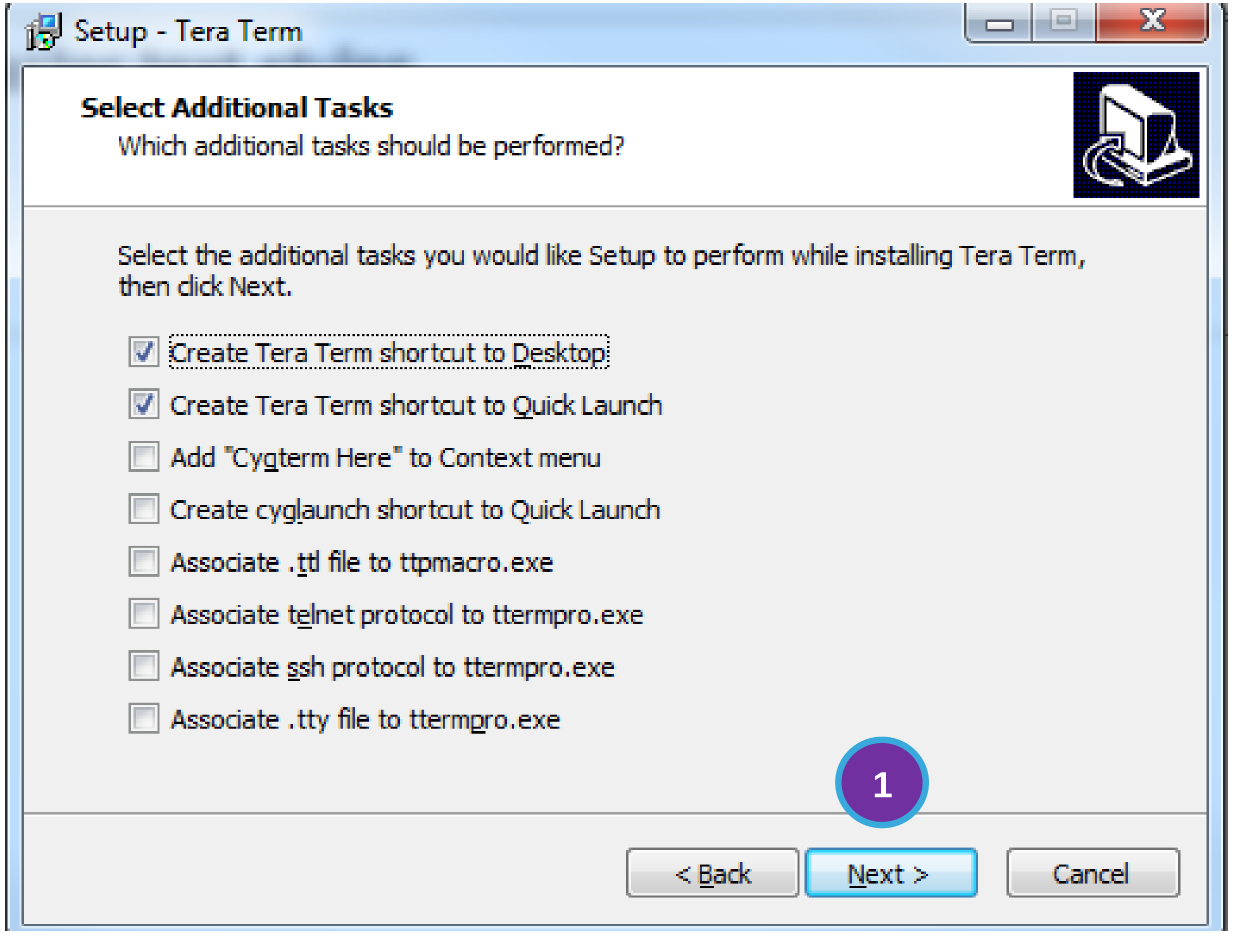
TeraTerm installation 6/10

1. Click on **Next**



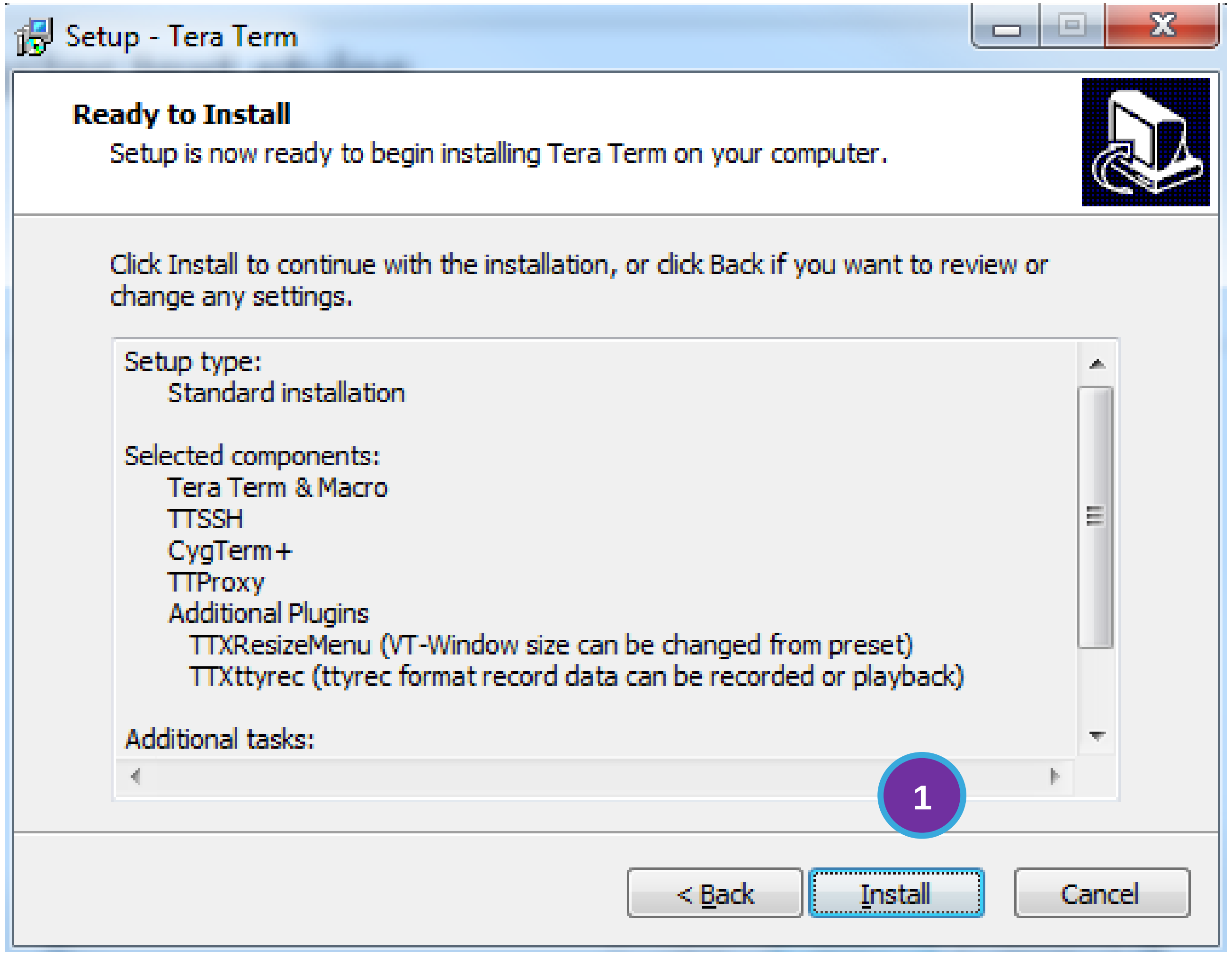
TeraTerm installation 7/10

1. Click on **Next**



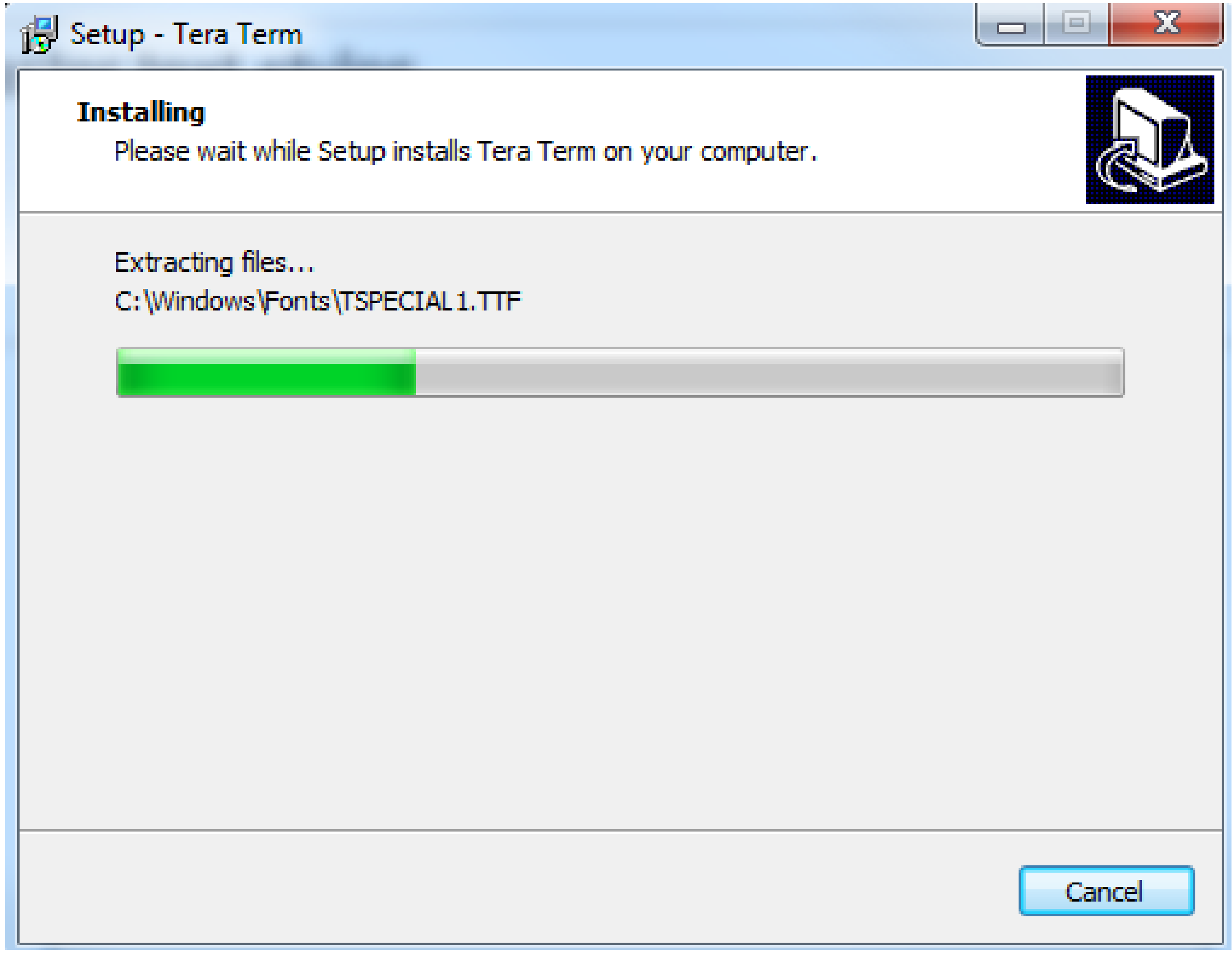
TeraTerm installation 8/10

1. Click on **Install**



TeraTerm installation 9/10

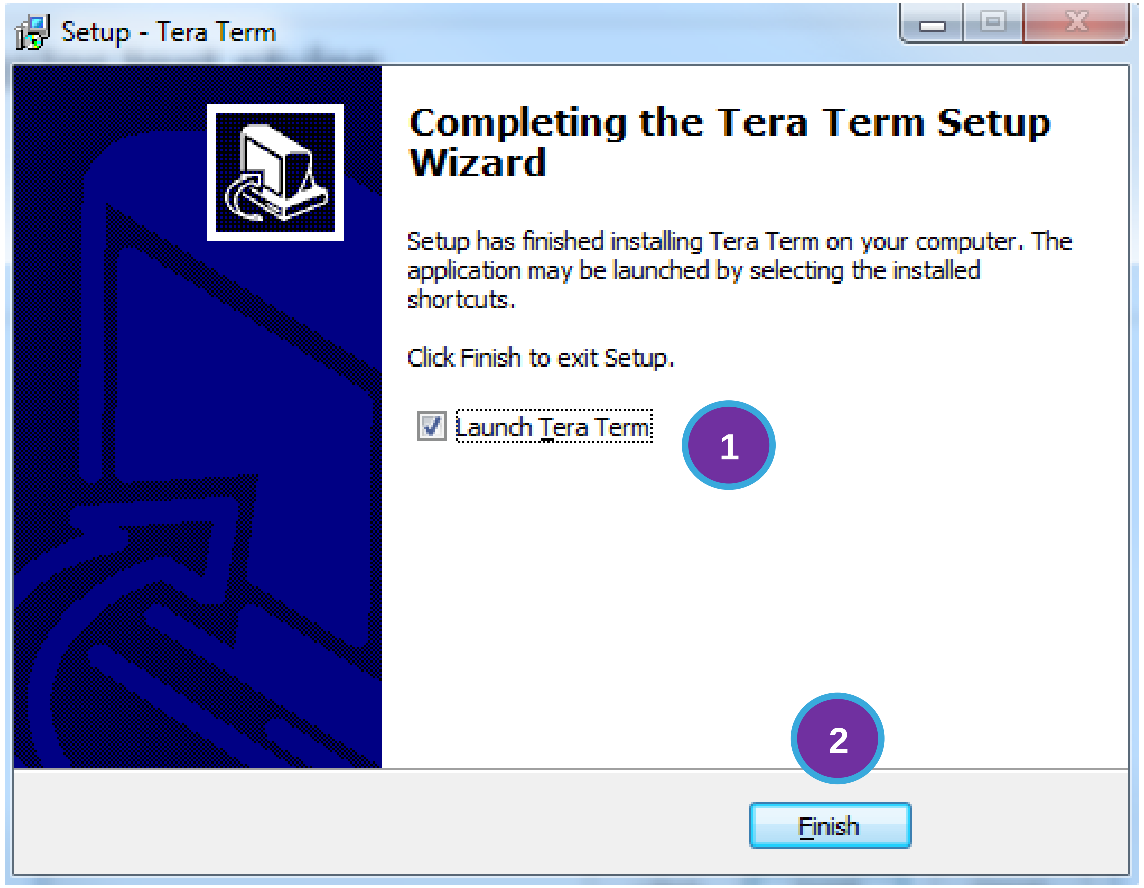
Installation starts...



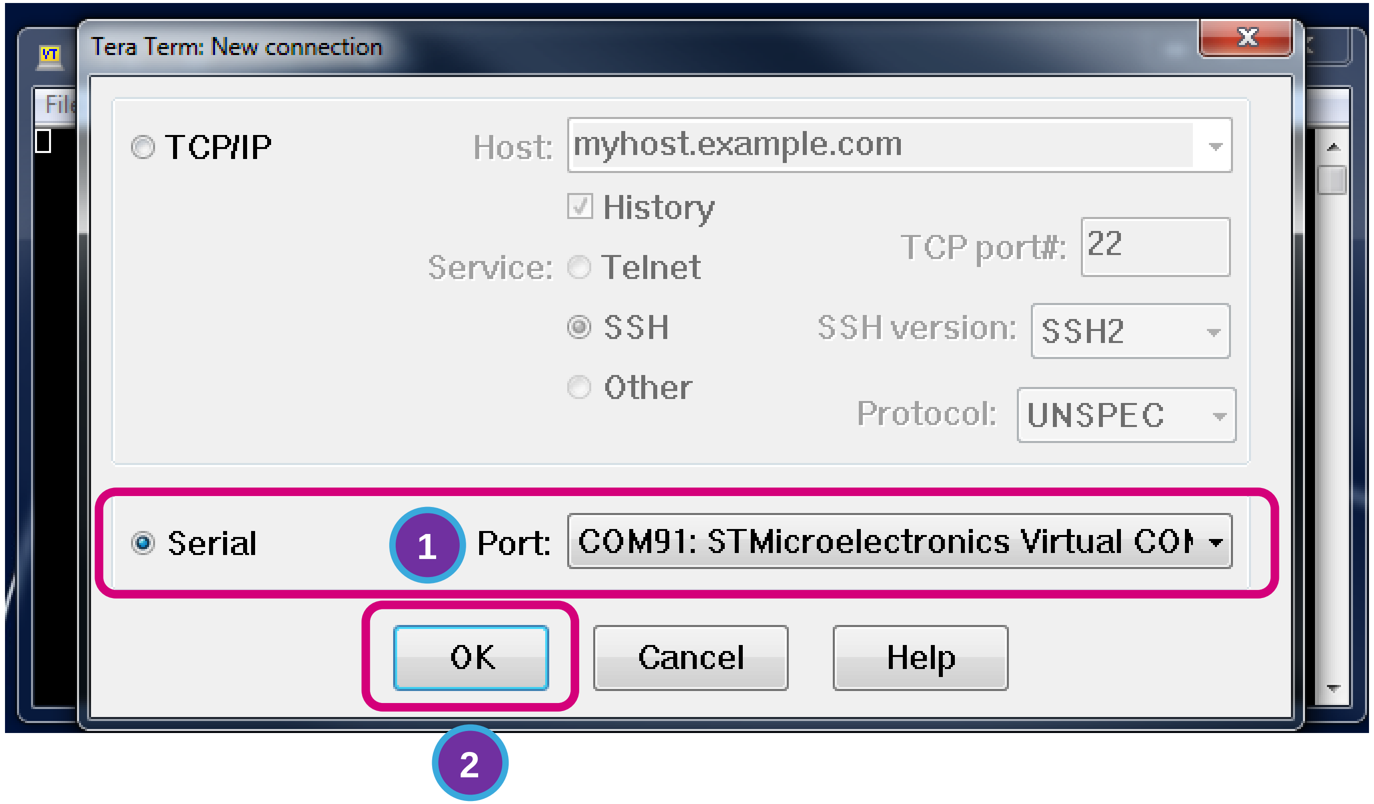
TeraTerm installation 10/10

1. Click on **Launch TeraTerm**

2. Click on **Finish**



Tera Term Configuration 1/5



NOTE: on **Win10 PC** the serial port is labeled only as **COM**

1. Select the **STMicroelectronics Virtual COM Port**
2. Click **OK**

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Virtual COM port driver

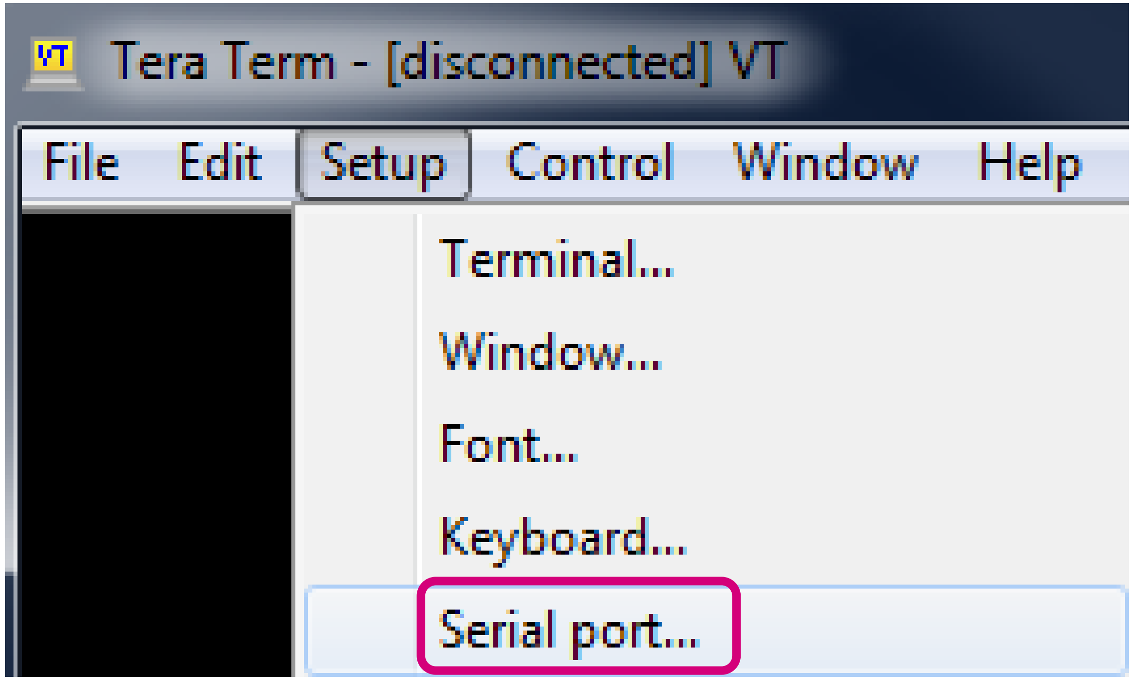
If you can NOT see a **STMicroelectronics Virtual COM Port** device, raise your hand.

Here the **instructions** for installing the Virtual COM port driver:

Win7 **Win10**

Tera Term Configuration 2/5

1. Click **Setup** -> **Serial port…**



Tera Term Configuration 3/5

1. Set the following:

    Baud rate : **115200**

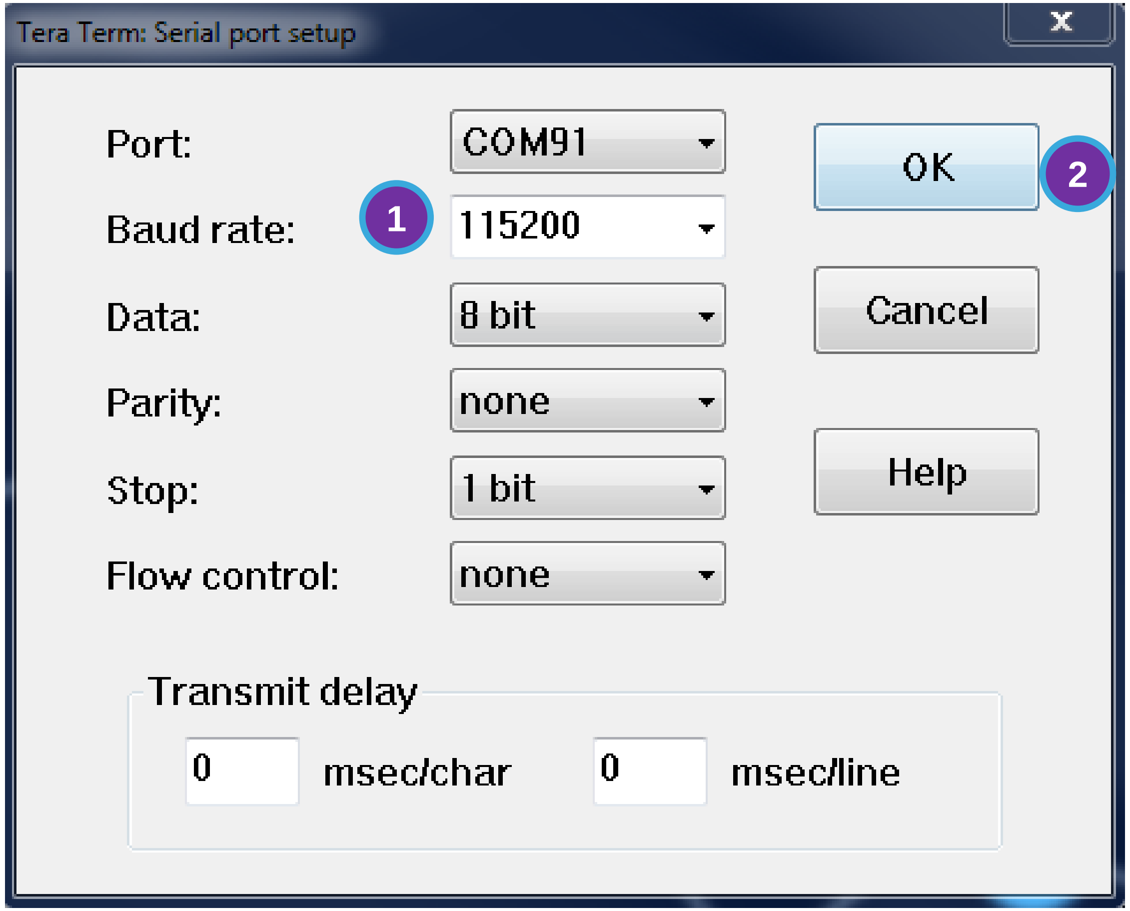
    Data : **8 bit**

    Parity : **none**

    Stop : **1 bit**

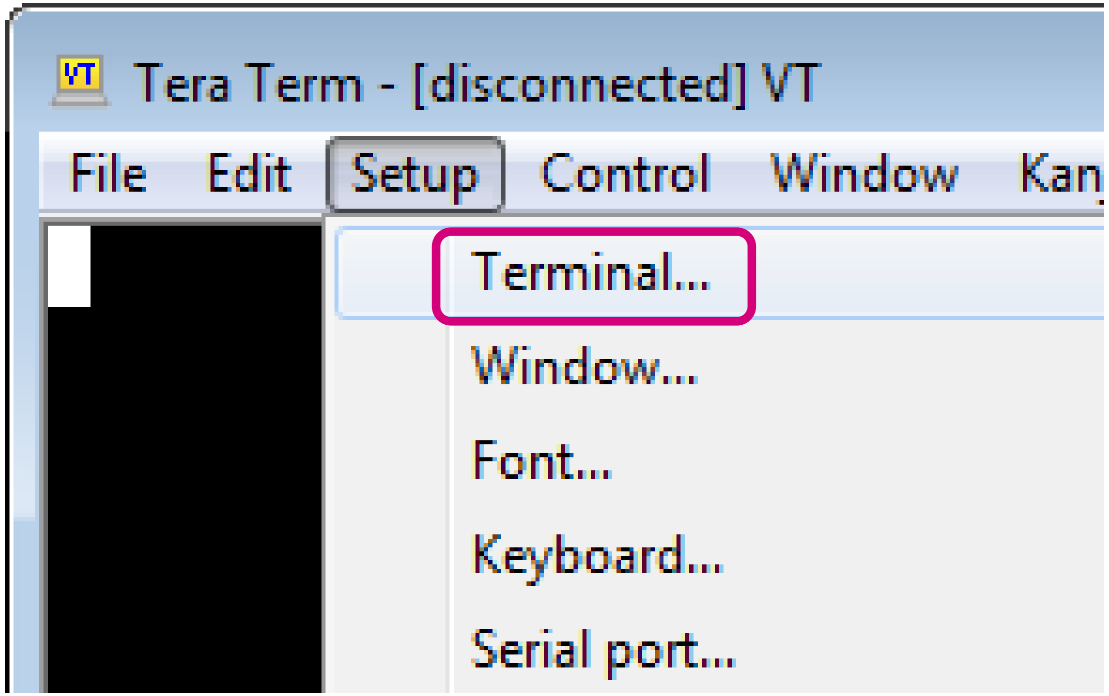
    Flow control : **none**

2. Click **OK**



Tera Term Configuration 4/5

1. Click **Setup** -> **Terminal…**



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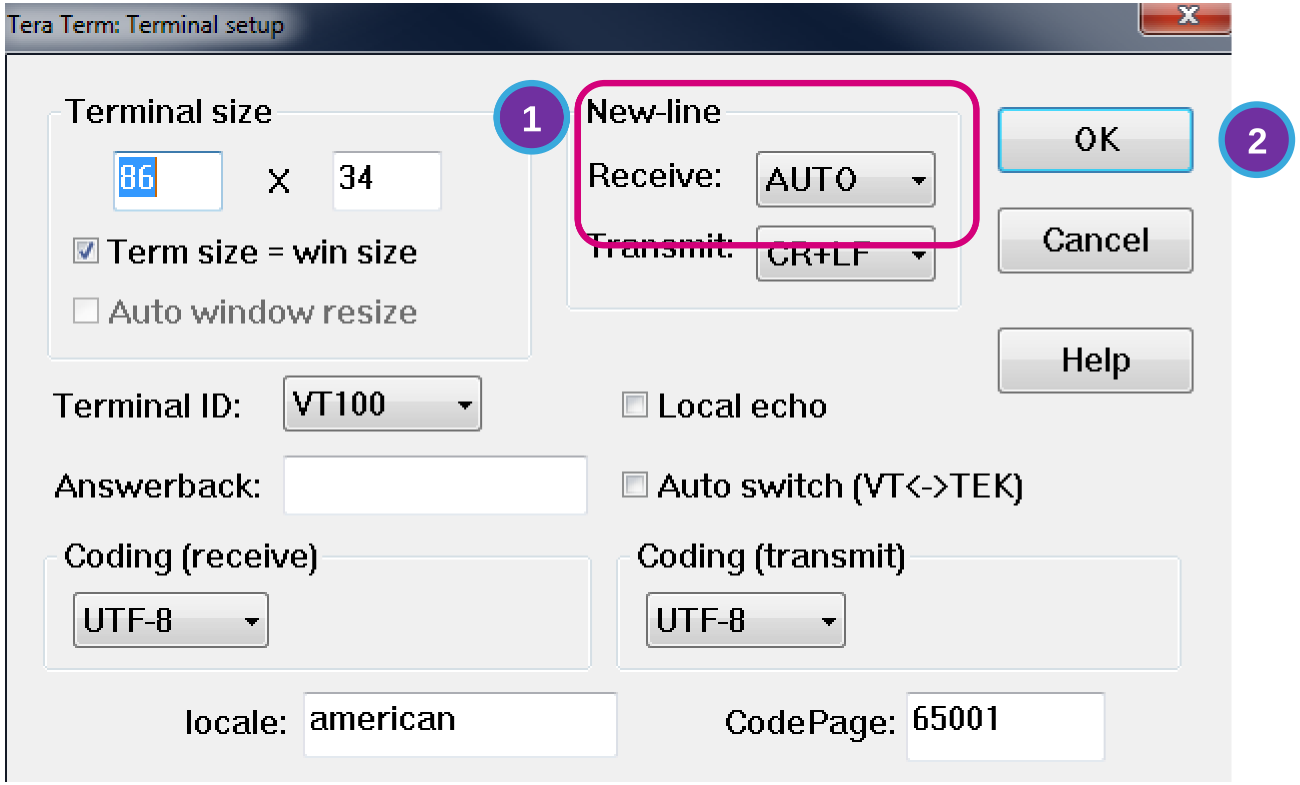
Tera Term Configuration 5/5

1. In the New-line set the following:

   New-Line Receive : **AUTO**

2. Click **OK**



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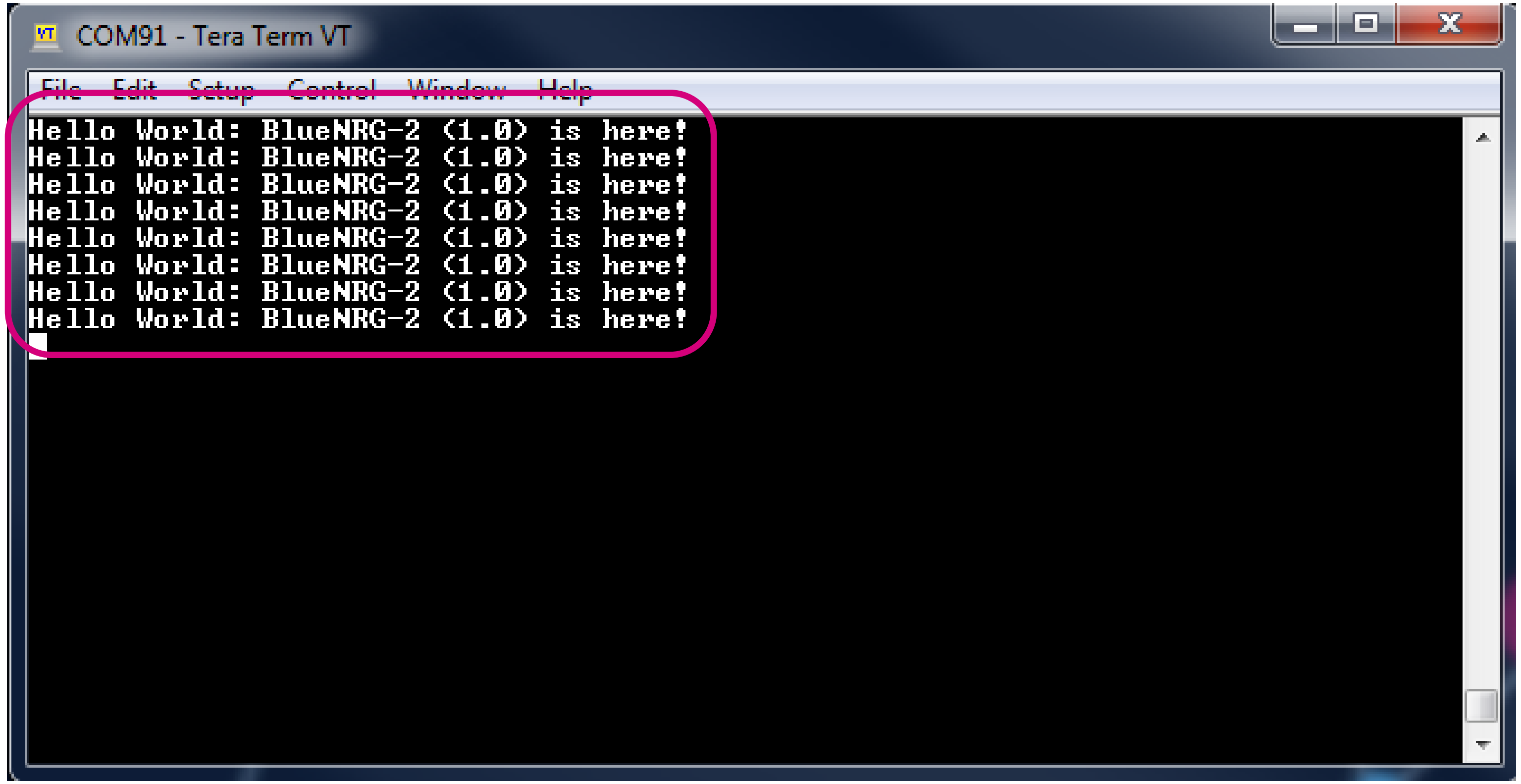
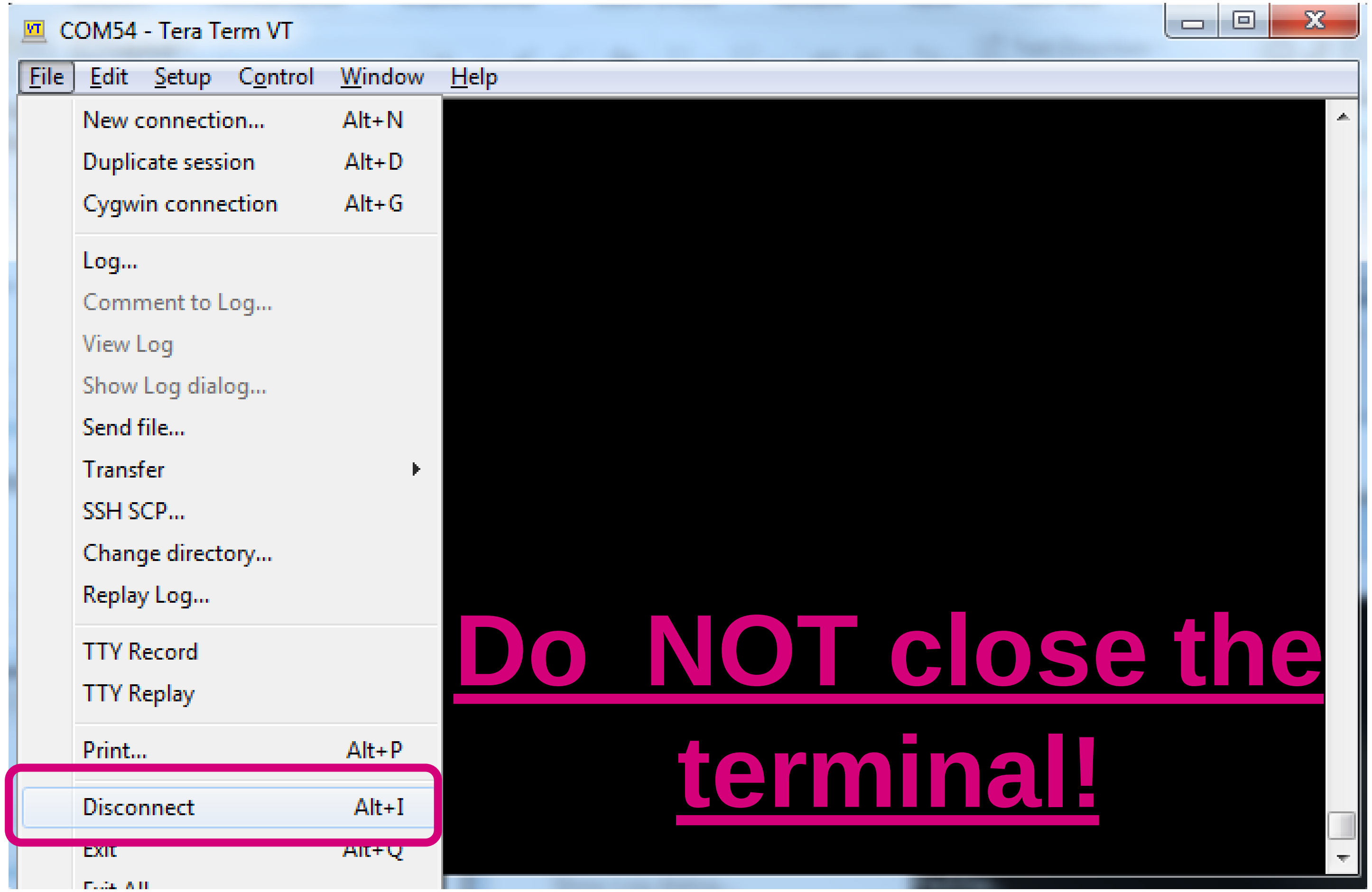
...done!

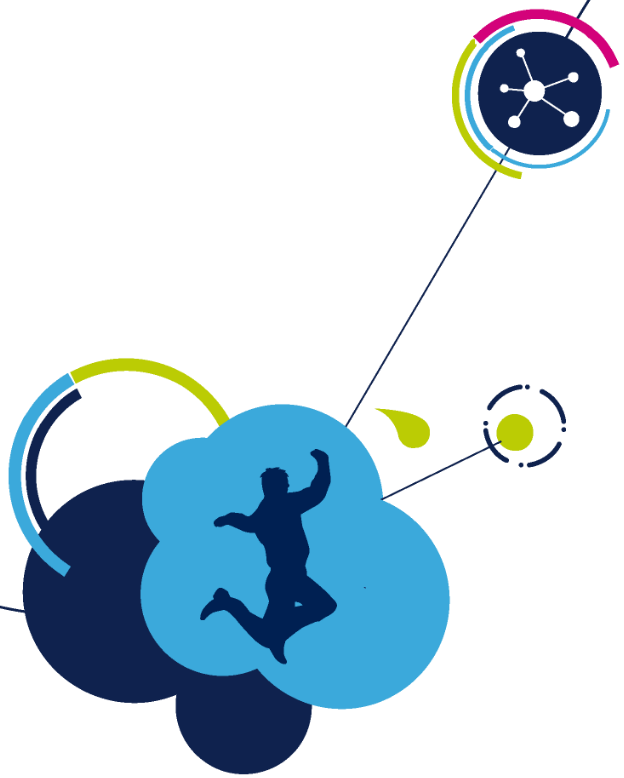


- If you see the string "**Hello World: BlueNRG-2 (1.0) is here!**" it means STEVAL is now properly configured.
- Note: (1.0) is the die major and cut number

Disconnect the serial terminal

1. Go back to TeraTerm and click on the **File->Disconnect**



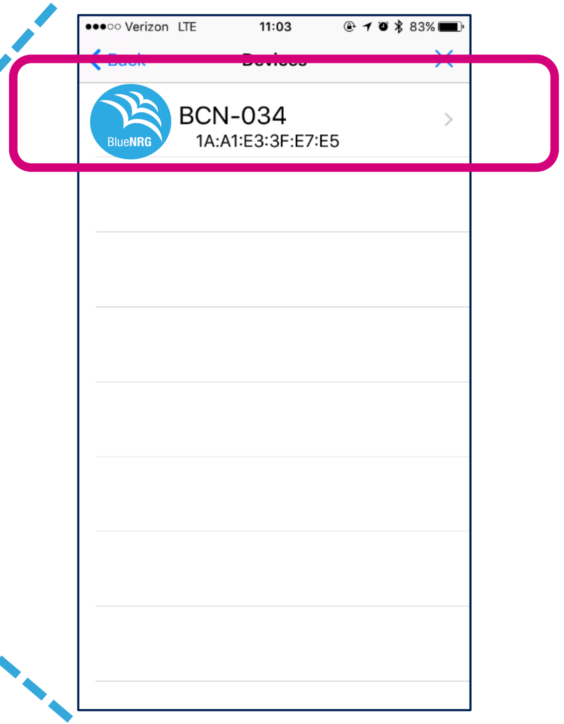


Lab 2

Connect to the ST BlueMS app

Customize *YOUR* STEVAL-BCN002V1

+ STEVAL-BCN002V1 DK
Sensor Demo ref FW



Client

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Code modifications

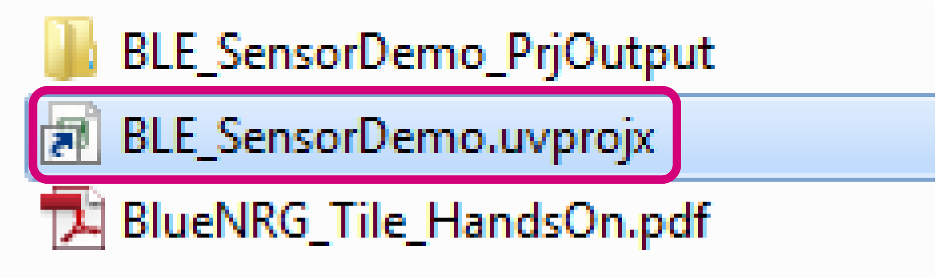
1. Modify local name in advertising packet

BLE_SensorDemo application

1. In Windows explorer browse to the path:

Go down till the root of installation folder and then in HandsOn folder

2. Double click on **BLE_SensorDemo.uvprojx**



Note: if the OS is not showing file extension, no worries. There is only one **BLE_SensorDemo** file

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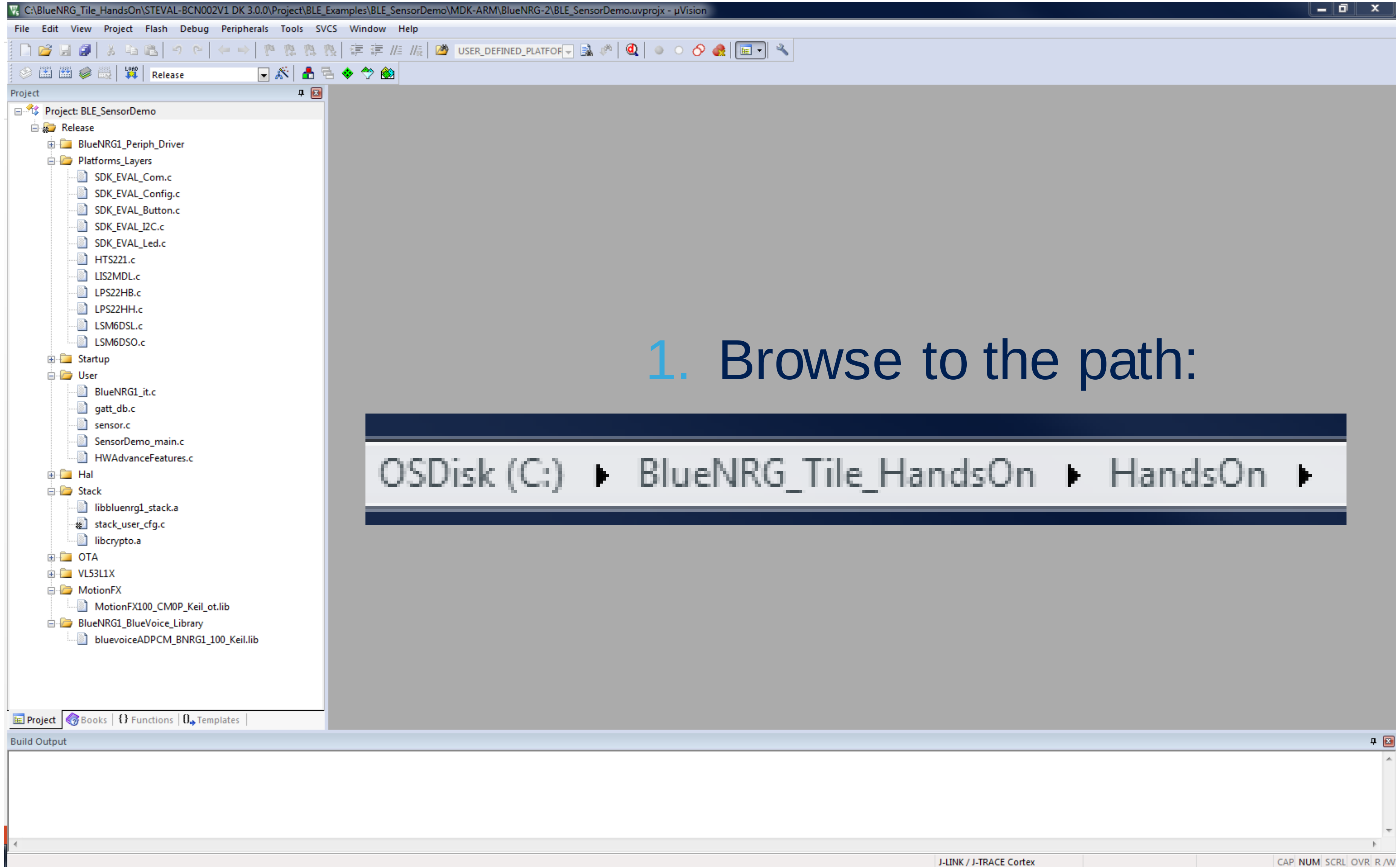
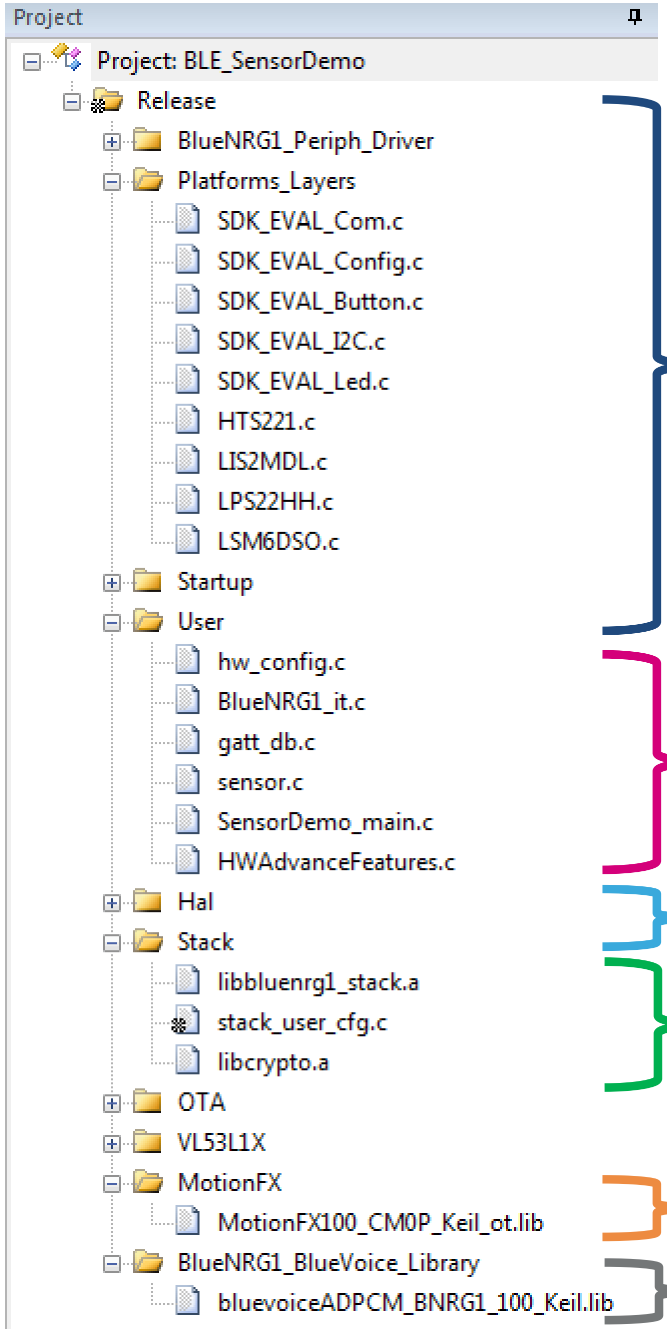
BLE_SensorDemo application



1. Browse to the path:

OSDisk (C:) ▸ BlueNRG_Tile_HandsOn ▸ HandsOn ▸

Application structure



HW peripherals drivers and platform layer files

Application source code
- **Main**
- **ATT DB**
- **Application**

Where we work today

Hardware Abstraction Layer and sleep management

BLE Stack library – provided in binary format

Sensor Data Fusion library

Voice over BLE library

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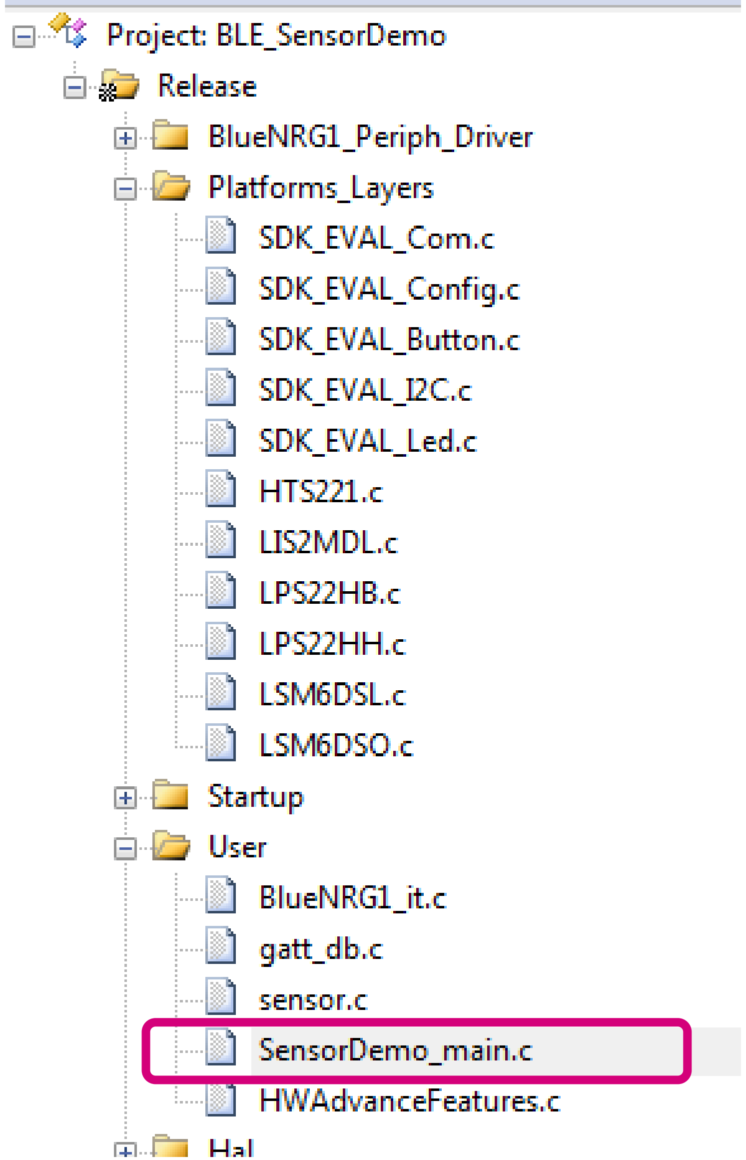
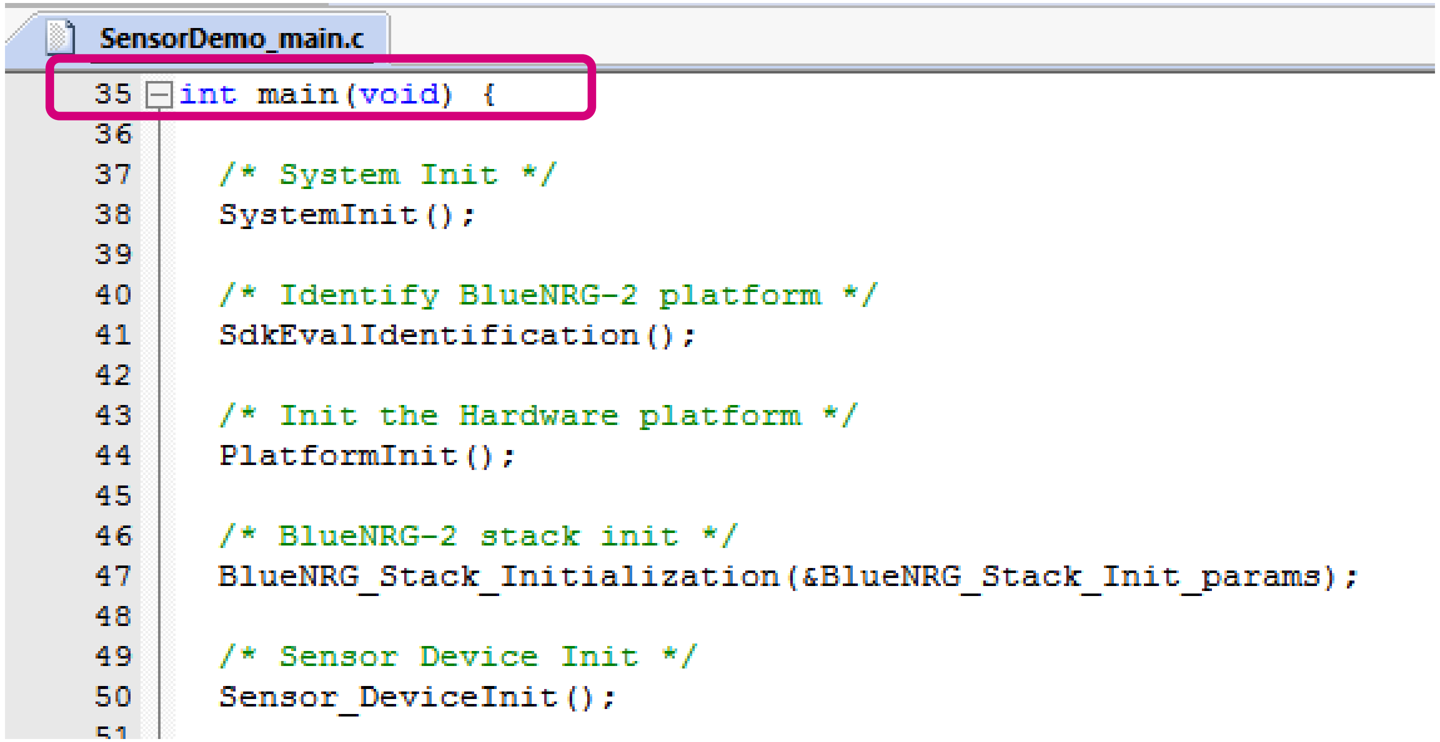
Open the BLE_SensorDemo main



1. Open the file **SensorDemo_main.c**
2. Scroll down to **line 35**

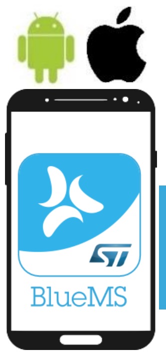


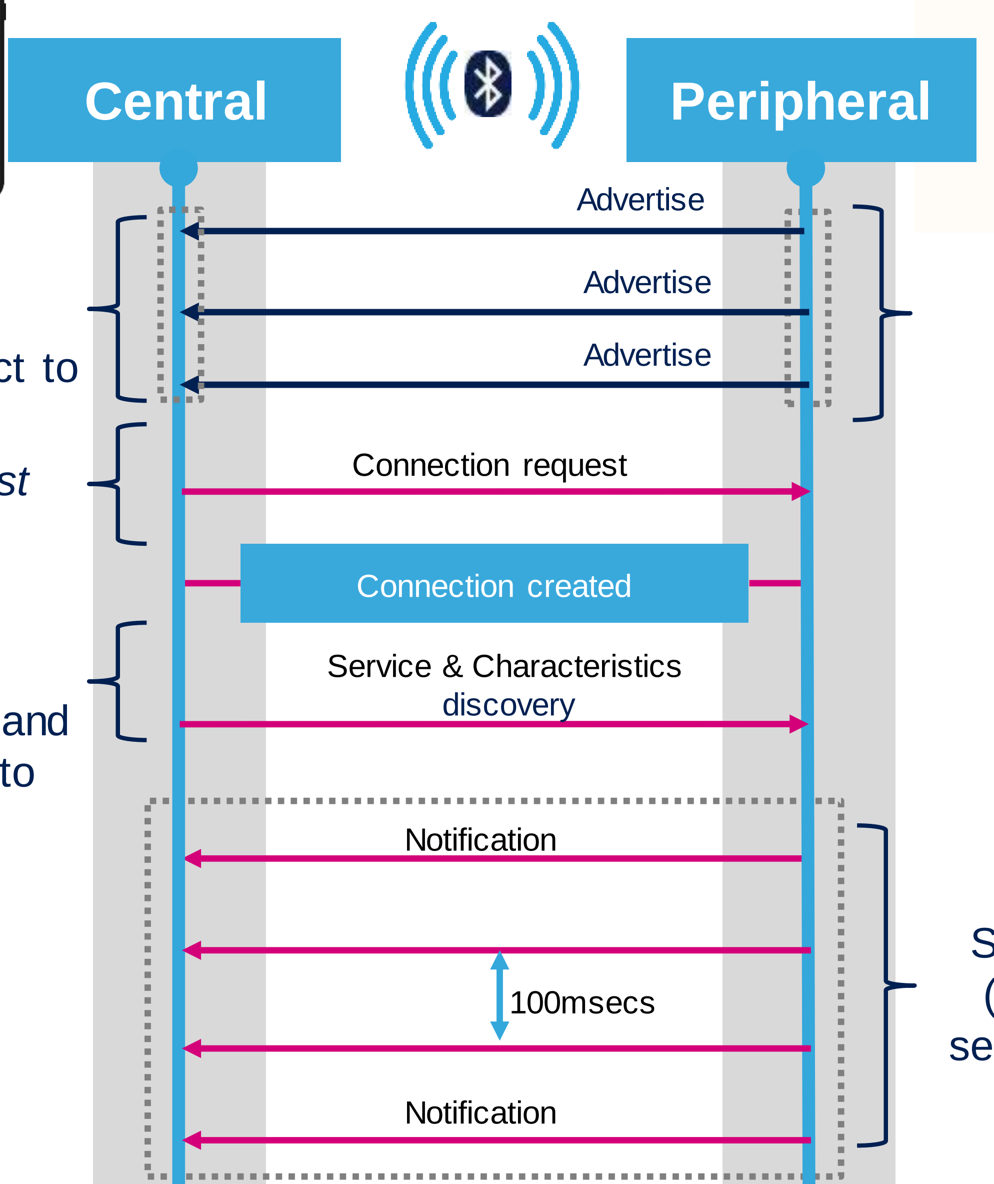
A look at the main application

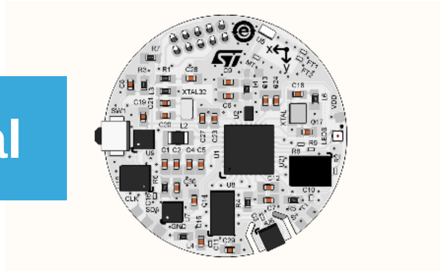
line 35

```
int main(void) {
  SystemInit();                  Remap vector table and configure all the interrupts priority
  SdkEvalIdentification();       Identifies STEVAL or custom PCB
  PlatformInit();                HW peripherals initialization
  BlueNRG_Stack_Initialization(&BlueNRG_Stack_Init_params);   BLE stack init
  Sensor_DeviceInit();           Sensors init
  Set_DeviceConnectable();       Set device in advertising
  while(1){                      Start of while loop
  BTLE_StackTick();              Advances the stack FSM
  User_AppTick();                Advances the application FSM. THIS IS DEVELOPERS USER SPACE!
  } // end while(1)
}
```

BLE flow







Step 1: *Advertising*
Slave is in Peripheral mode and sends ADV_IND PDU

Step 2: *Scan*
Master is in discovery mode looking for a ***specific*** slave to connect to

Step 3: *Connection request*

Step 4: *Services&Chars discovery*
Master (Client) starts the BLE Service and Characteristics discovery procedure to understand the Server ATT DB

Step 5: *Data flow*
Slave (Server) starts sending periodically (100 msecs) notifications packets about sensors values (acc&gyro and pressure) to the master.

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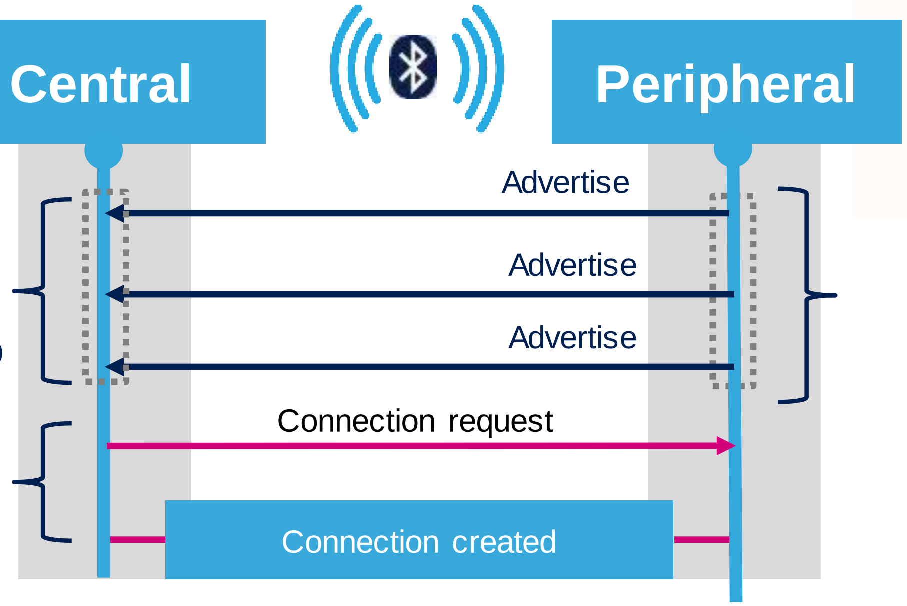
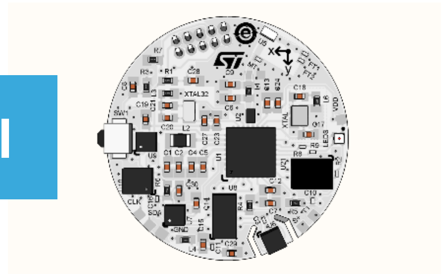
Advertising and scanning





Step 2: *Scan*
Master is in discovery mode looking for a ***specific*** slave to connect to

Step 1: *Advertising*
Slave is in Peripheral mode and sends ADV_IND PDU

Step 3: *Connection request*

Master:

needs an app for discovering the slave device in advertising

Off-the-shelf app: e.g.

LightBlue® Explorer

Custom app: e.g.

https://itunes.apple.com/us/app/lightblue-explorer/id557428110?mt=8

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Reminder: install ST BlueMS app

ON YOUR PHONE

- Look for "**ST BlueMS**" **app** on the App Store or Google Play

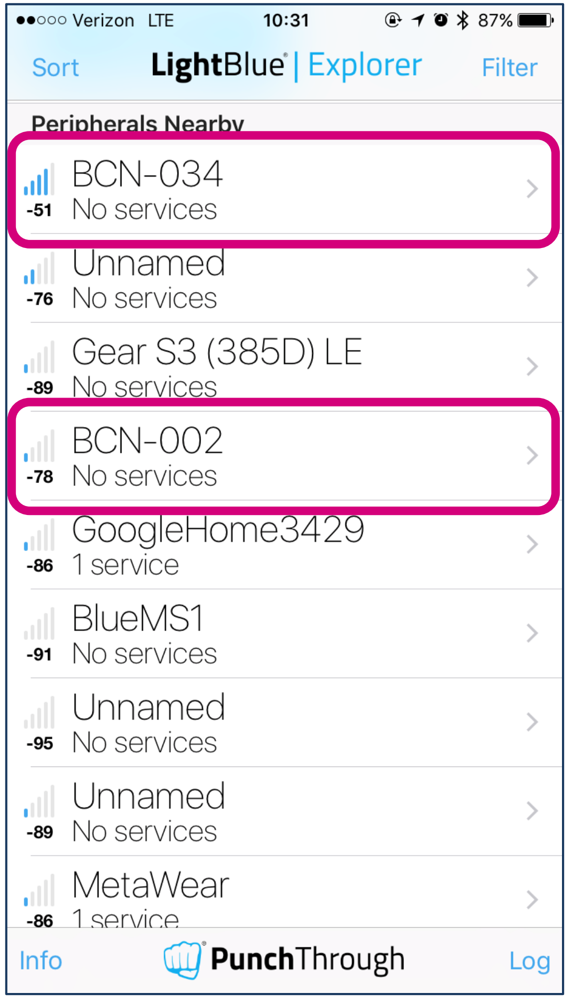
ST BlueMS
STMICROELECTRONICS INC

Download on the App Store

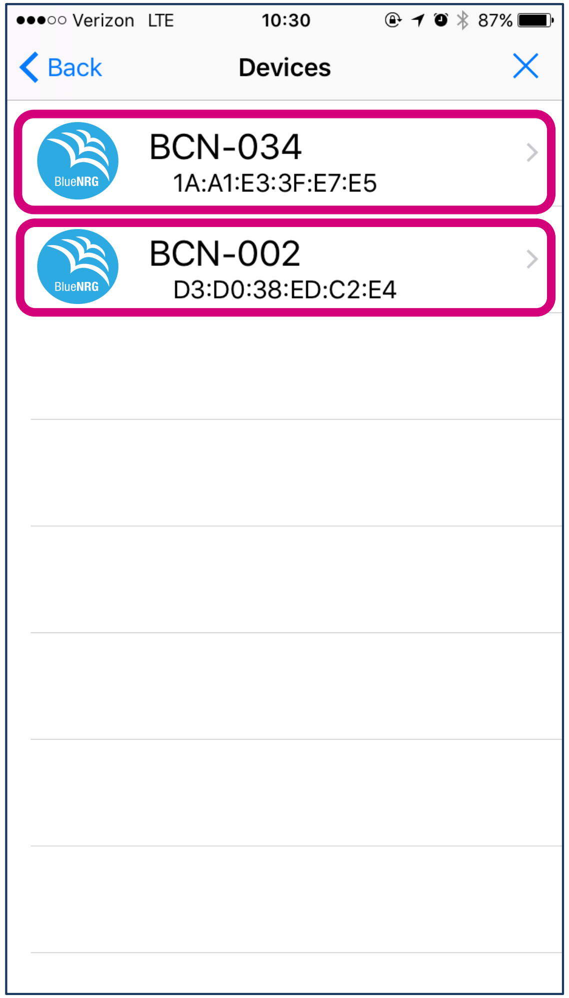
GET IT ON Google Play

Scan results

LighBlue scan results



BlueMS scan results



Why some devices are not present in the BlueMS app?

How devices will pop up in the BlueMS scan list?

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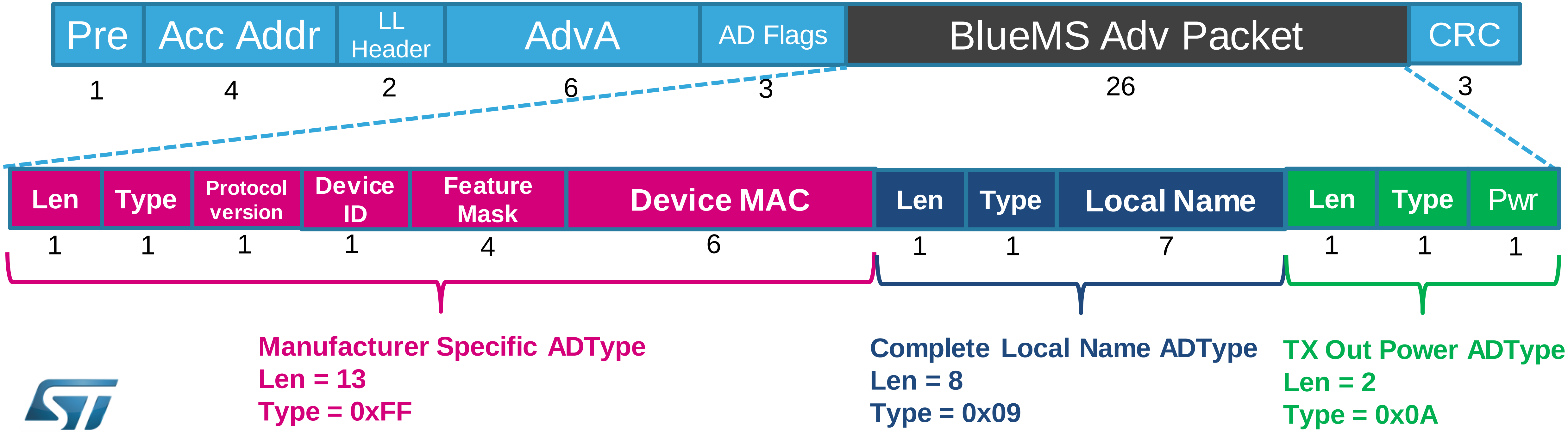
ST BlueMS Protocol

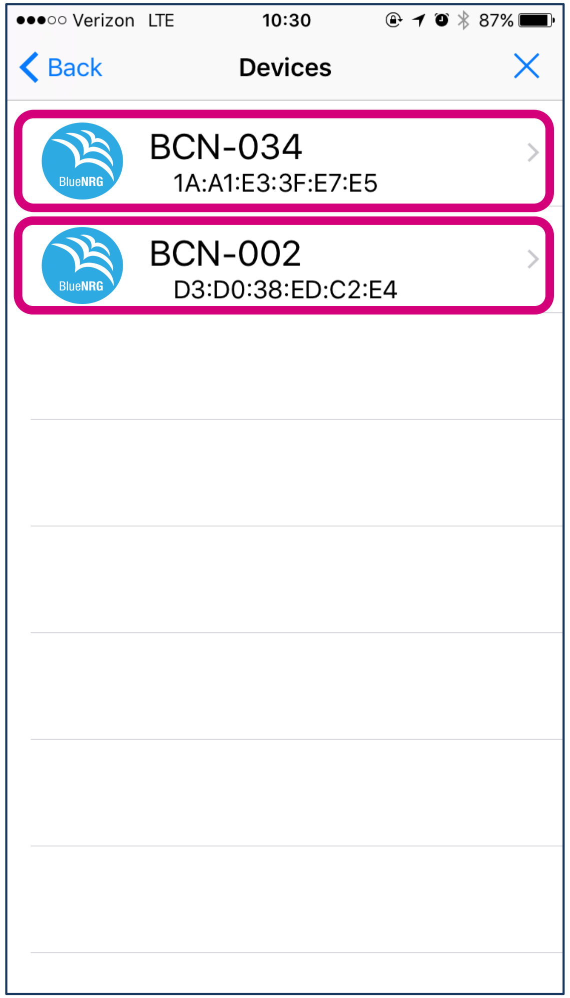
BlueMS

- In order to be connected to the ST BlueMS app, a BLE peripheral SHALL comply with a specific advertising packet format
- ST BlueMS protocol specifies a 26-byte packet format composed of Advertisment Types – ADTypes - compliant with BT SIG definitions



BlueMS Scan results

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name



Each node is recognized based on the Device ID (for STEVAL-BCN002V1 it is equal to 0x05)

Users can distinguish their node from the Local Name

BlueNRG

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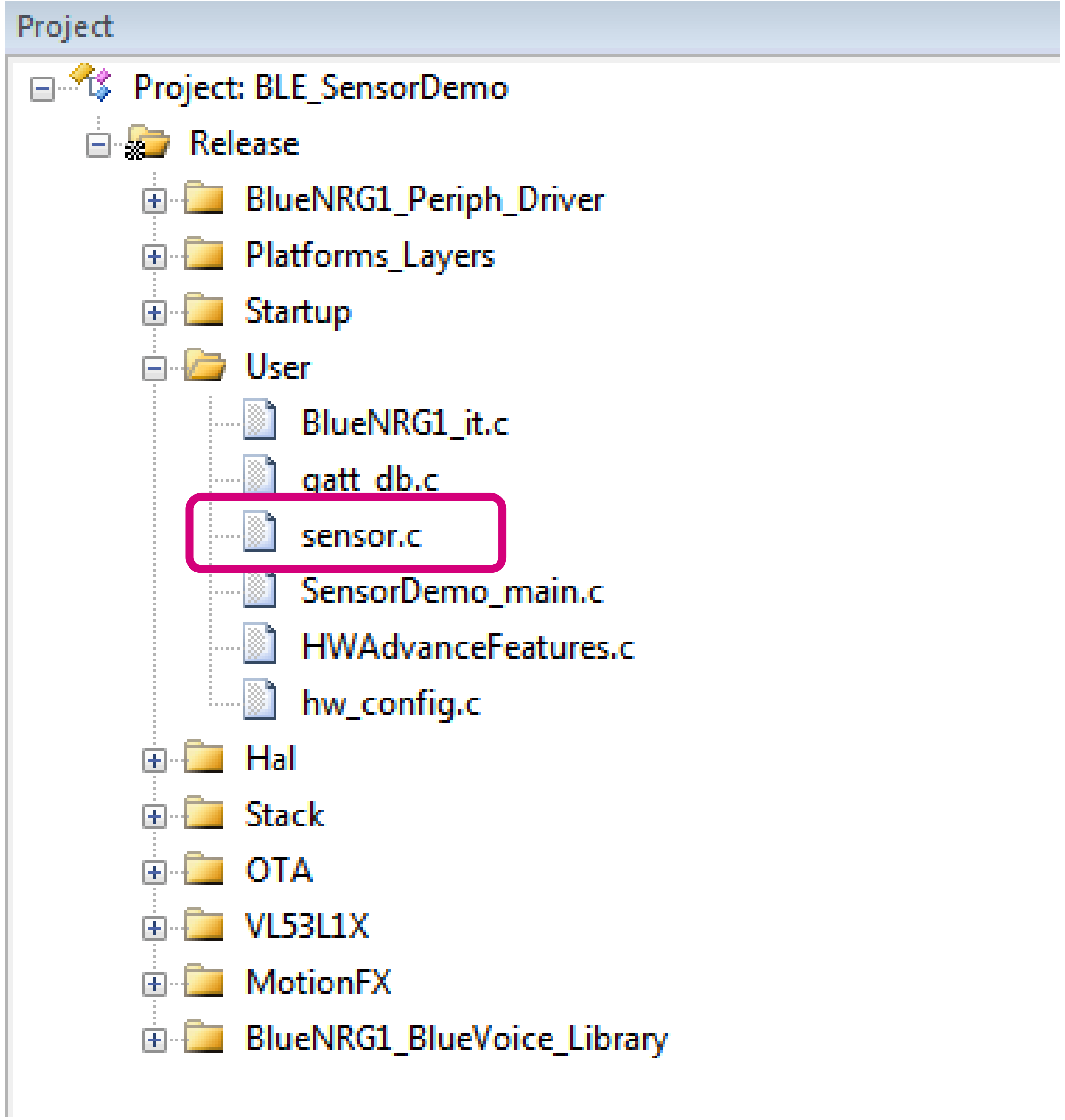
L2 STEP1: Customize your BlueNRG-Tile



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L2 STEP1: Customize your BlueNRG-Tile

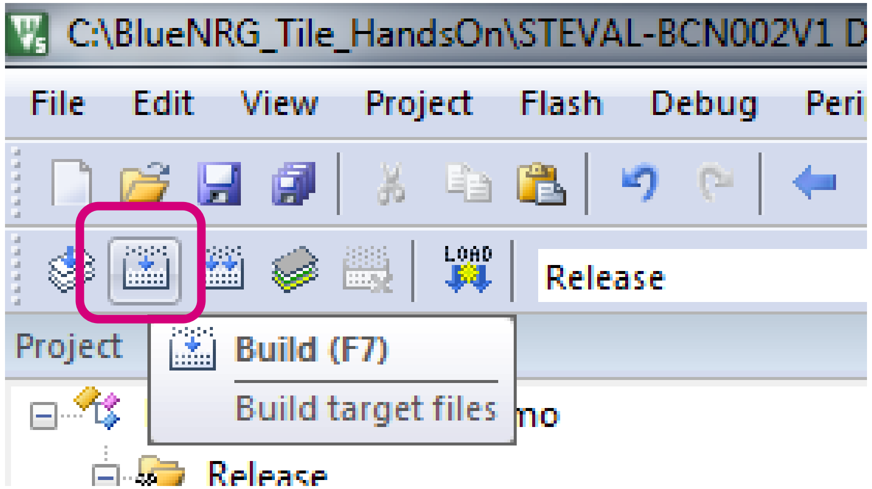
Modify the local name in the advertisement payload

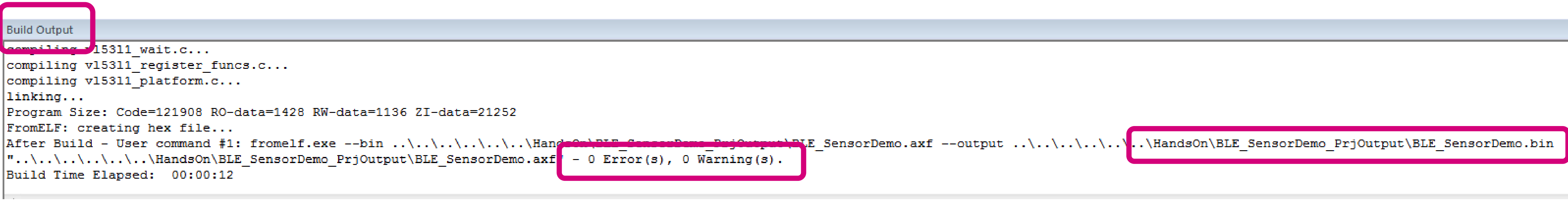
1. In the file **sensor.c** go to **line 51**
2. **Modify X, Y** values in the string
    - **NOTE: COPY THE X,Y VALUES FROM YOUR STEVAL BLISTER**
    - *E.g. if on the box is written **X=3** and **Y=4**, then ‘B’,’C’,’N’,’-’,‘0’,**‘3’**,**‘4’***

```
50  /* Define the BlueNRG-2 Name MUST be 7 char long */
51  #define NAME_ALLMEMS 'B','C','N','-','0','3','4'
```

Build the new code

1. Click on the **Build button** (top left corner) or hit **F7** on your keyboard
2. In the **Build Output** window (bottom) wait for the build to be completed.
   - **BLE_SensorDemo.bin** created
   - "**0 Error(s), 0 Warning(s)**" message appear





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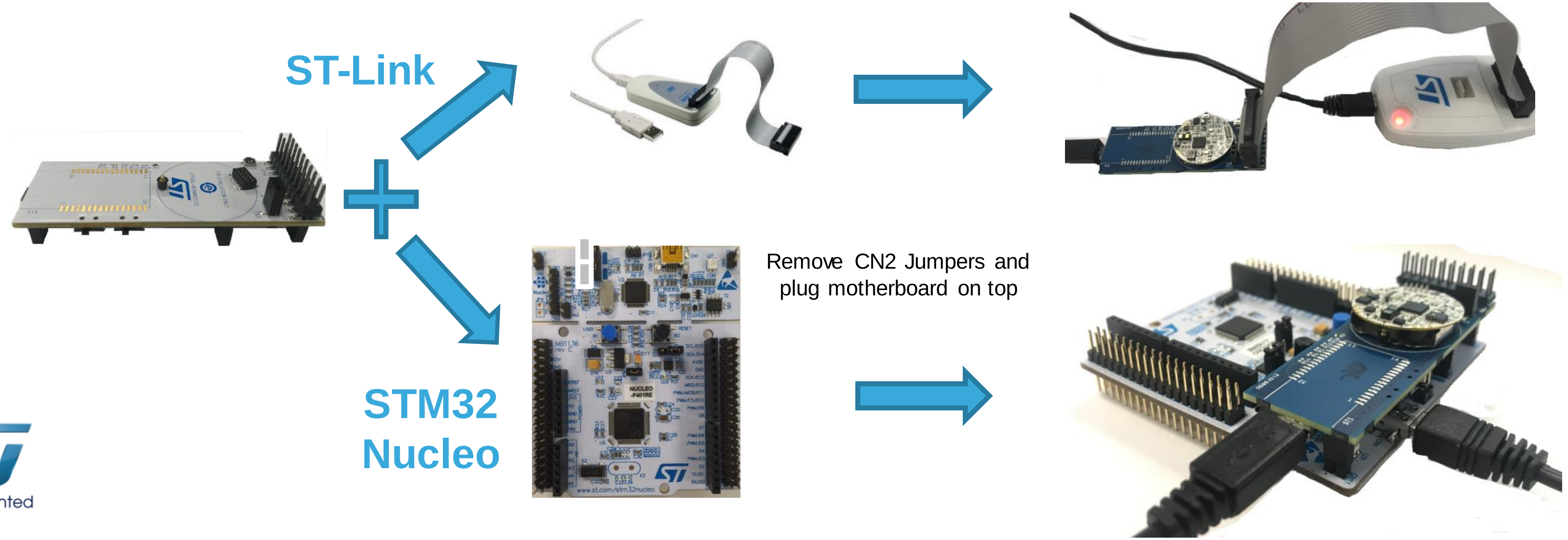
Programming embedded Flash

1. **UART** Bootloader

- ROM bootloader. HW activation through dedicate pin (DIO7) configured for Boot
- PC interface named "**Flasher Utility**" available in the SW package

2. **SWD** interface + ST-LINK

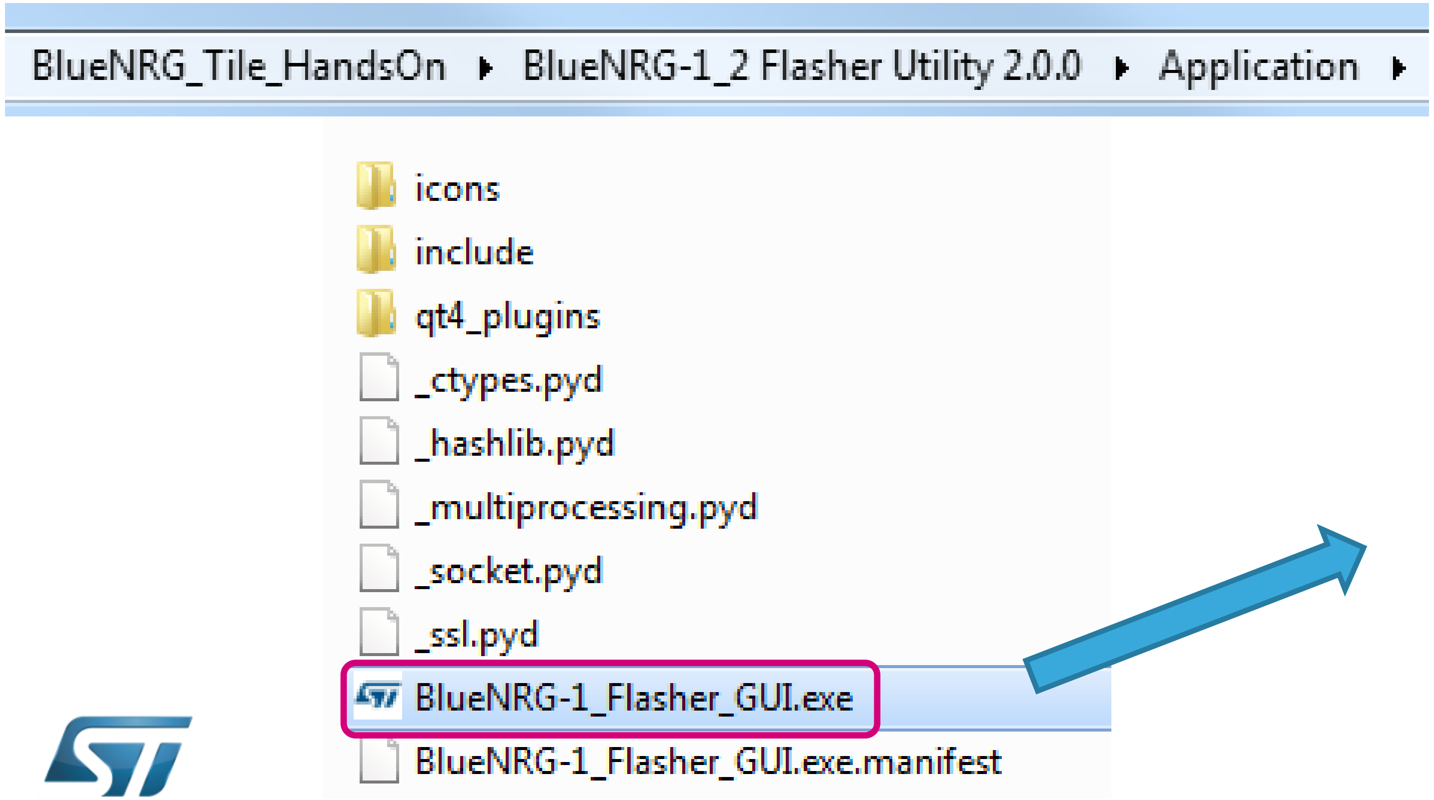
- Interface with the STEVAL-BCN002V1 through the **20-pin JTAG connector**
- Same PC interface **Flasher Utility**

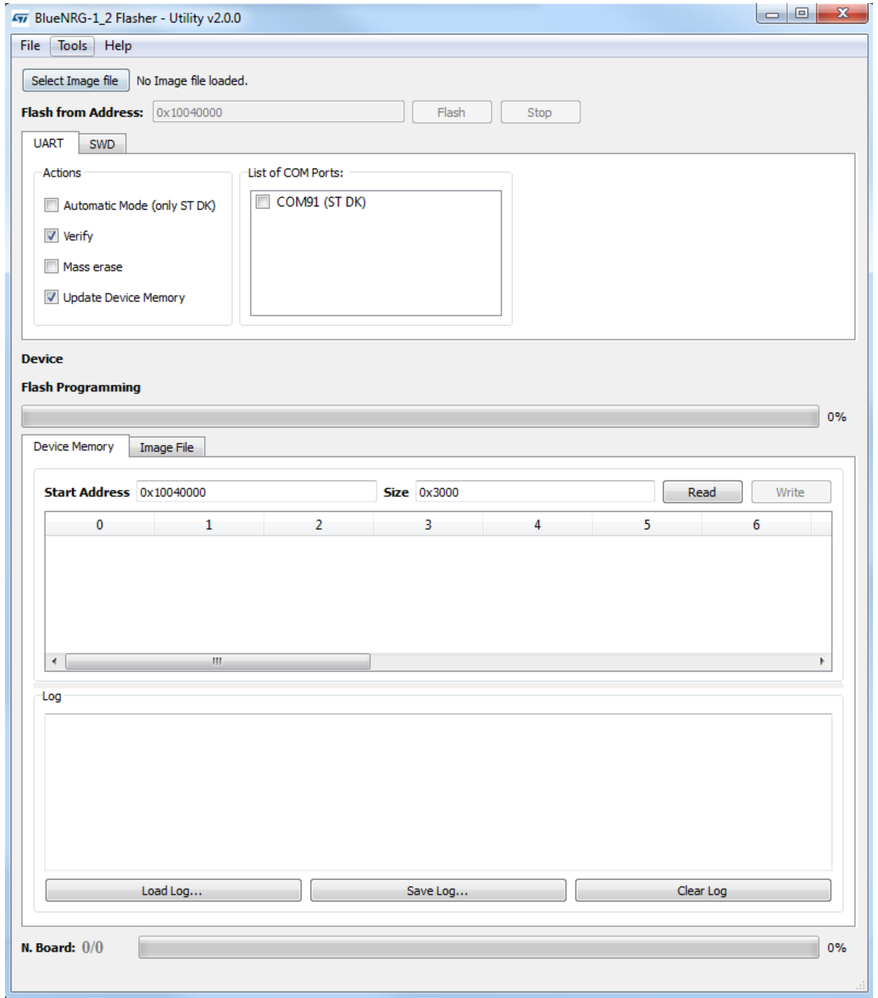


Open the Flasher Utility

1. Go to **\BlueNRG_Tile_HandsOn\BlueNRG-1_2 Flasher Utility 2.0.0\Application**

2. Double click on **BlueNRG-1_Flasher_GUI.exe**





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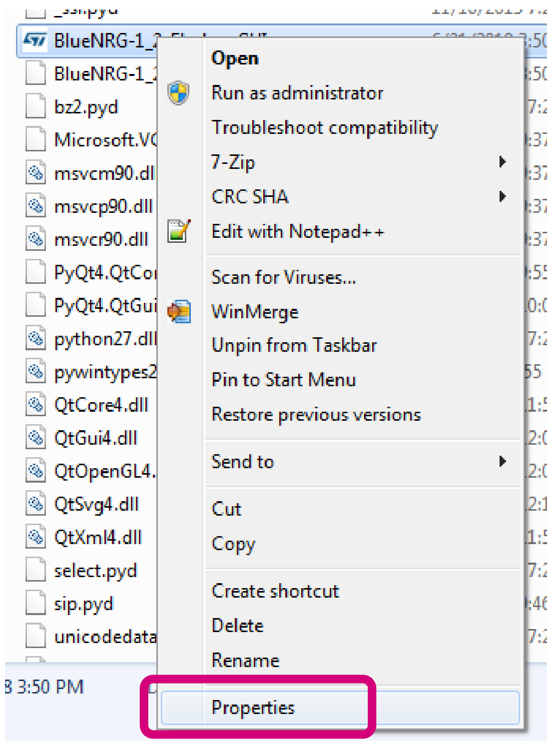
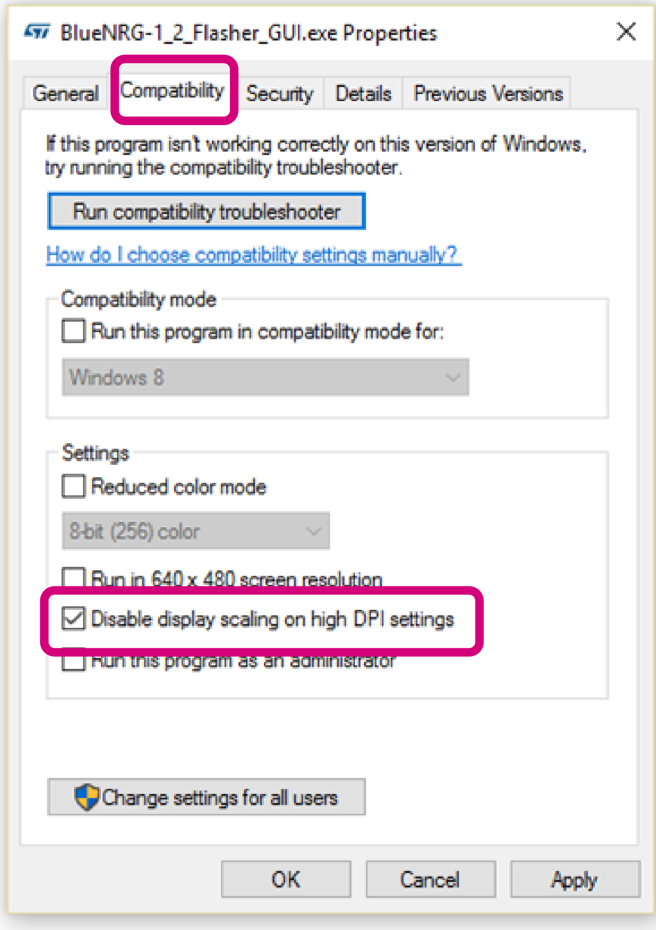
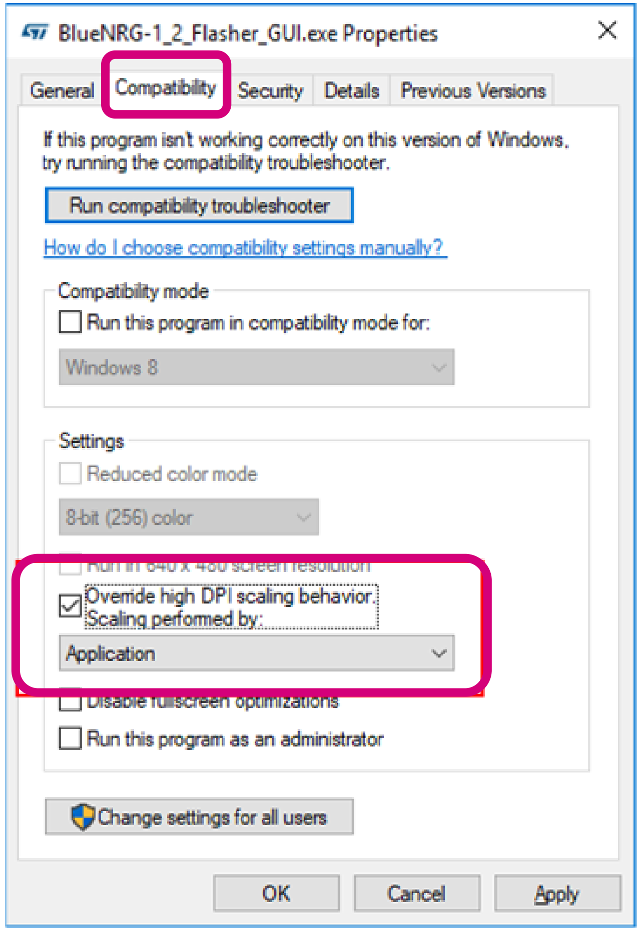
for HD screens…If you've problem with the resolution

- **Right Click** on the .exe file and select **Properties**

- In the **Compatibility** tab select either **Disable display scaling** or **override high DPI scaling**







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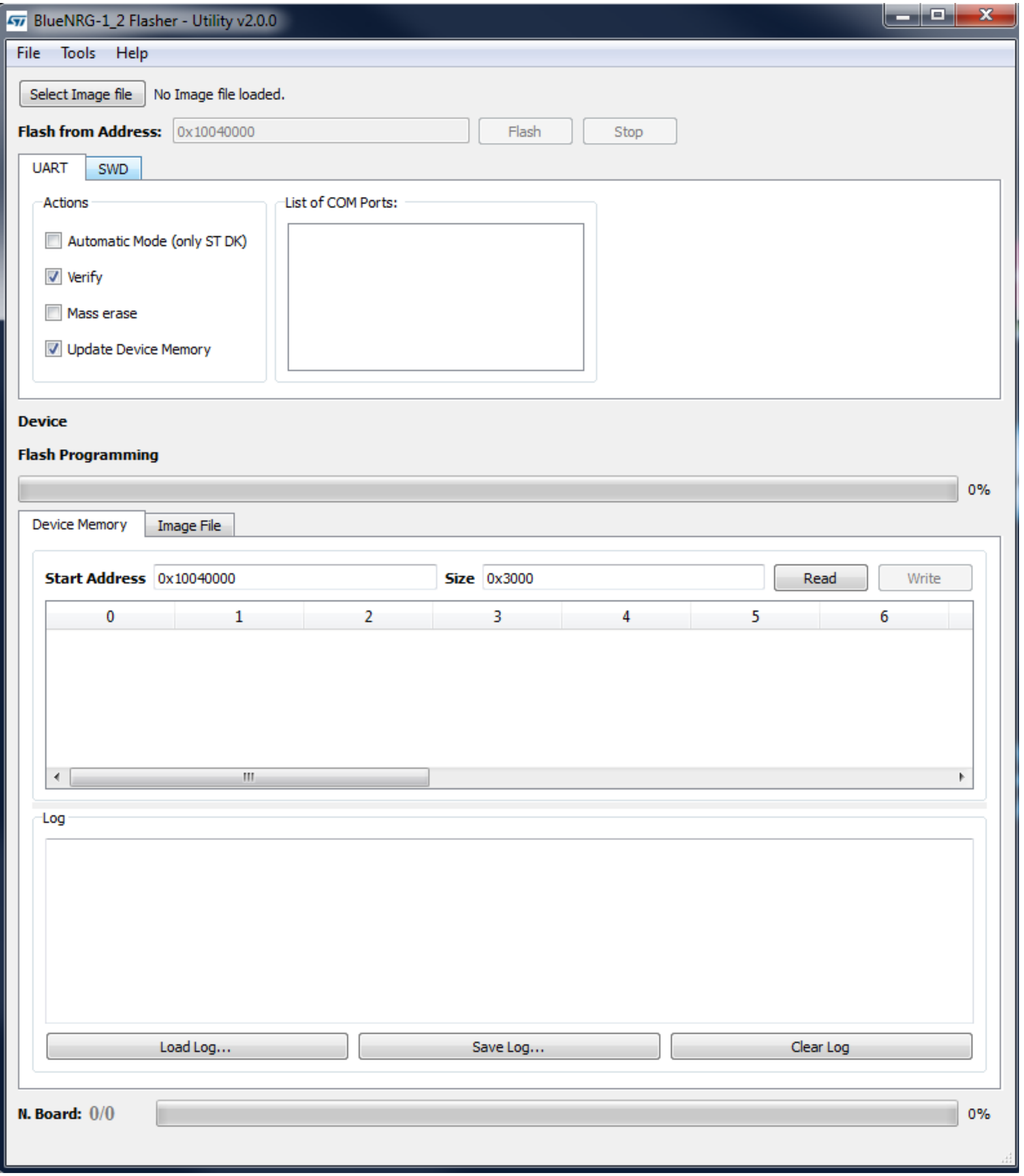
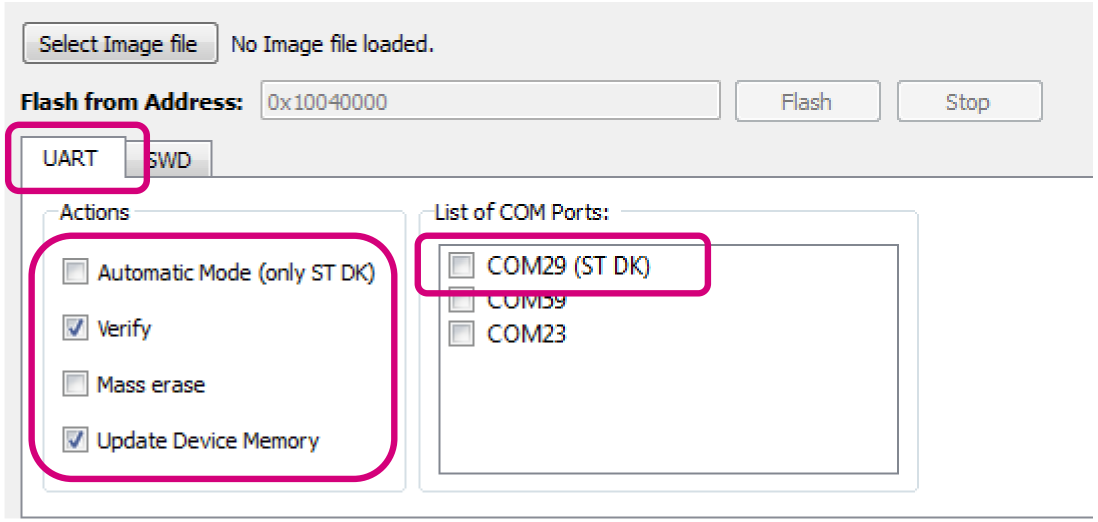
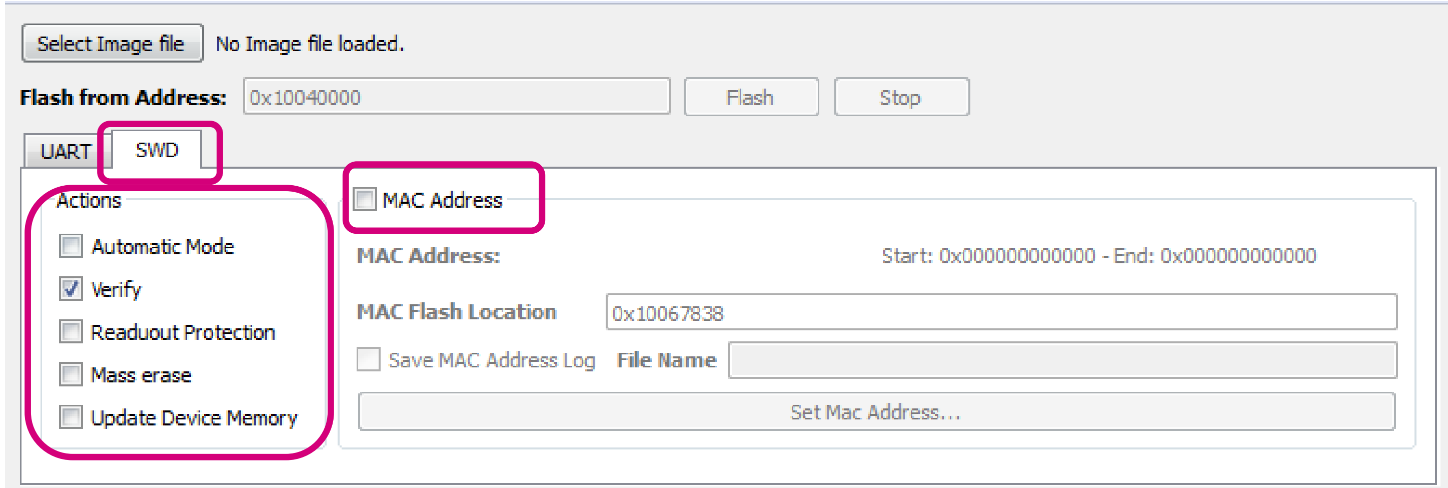
BlueNRG Flasher Utility



UART

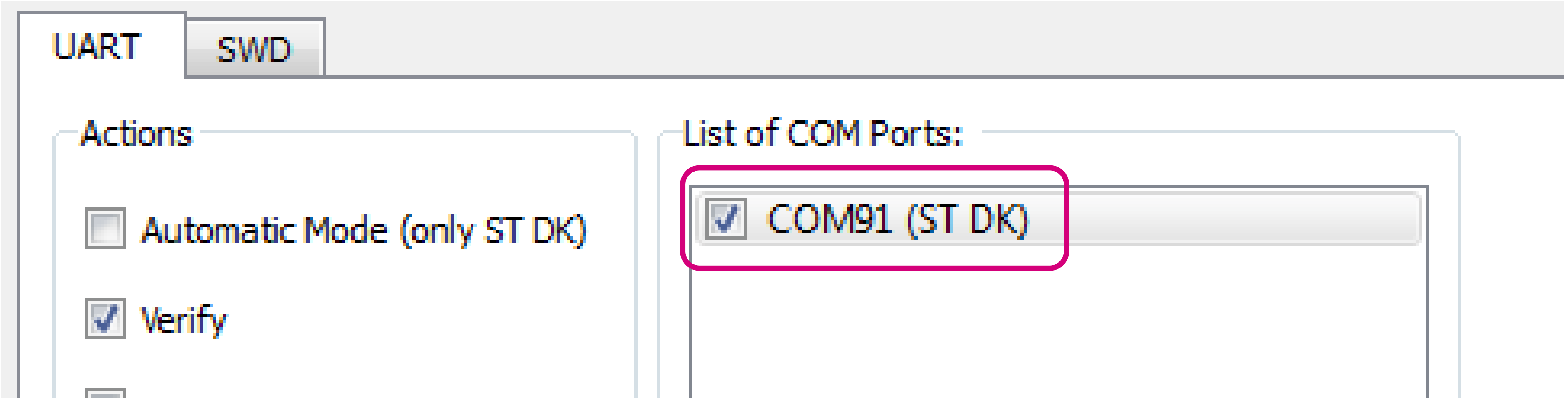
SWD





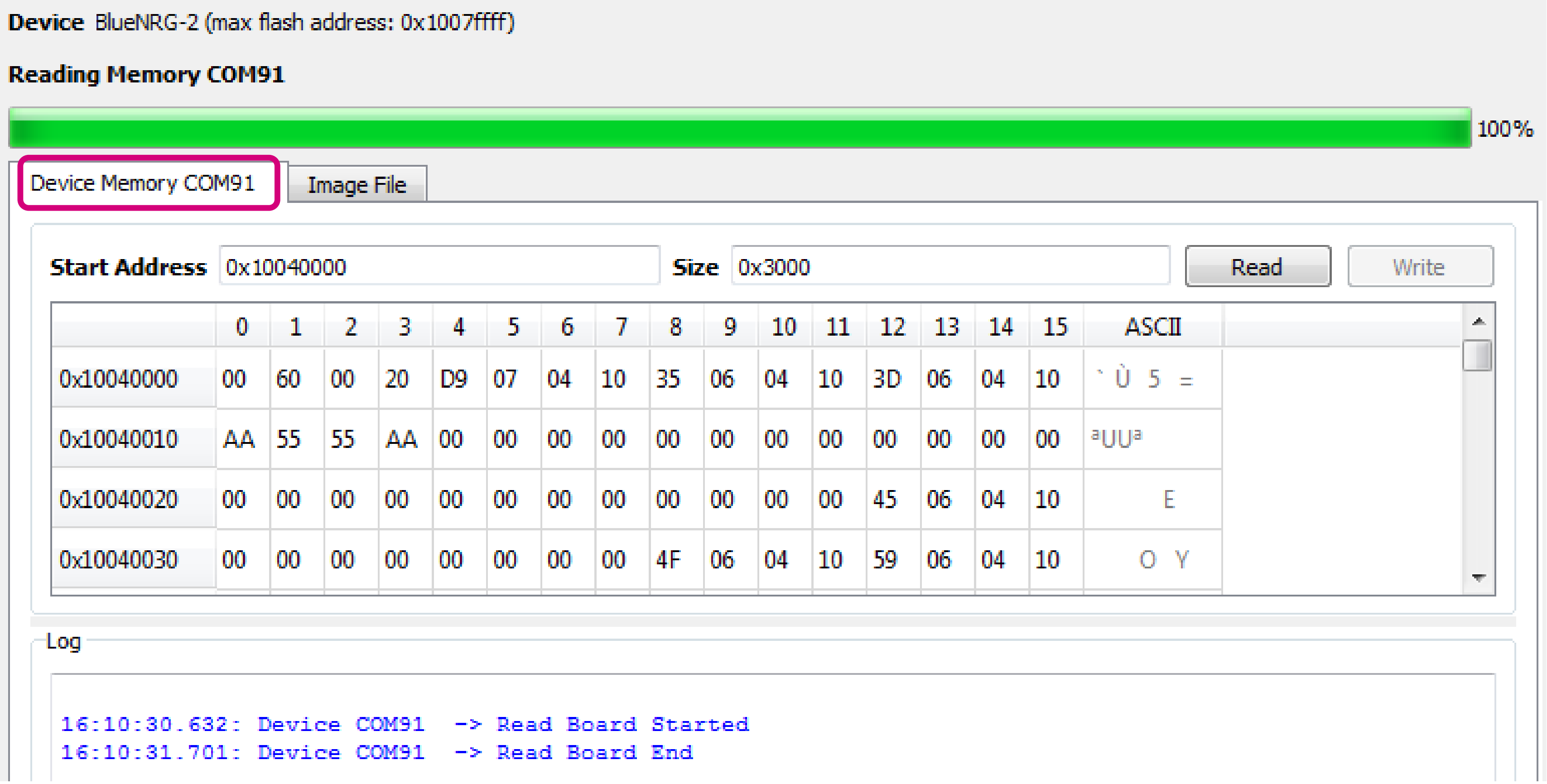
Flash the BlueNRG-2 1/6

1. Select the COM port labeled **(ST DK)**



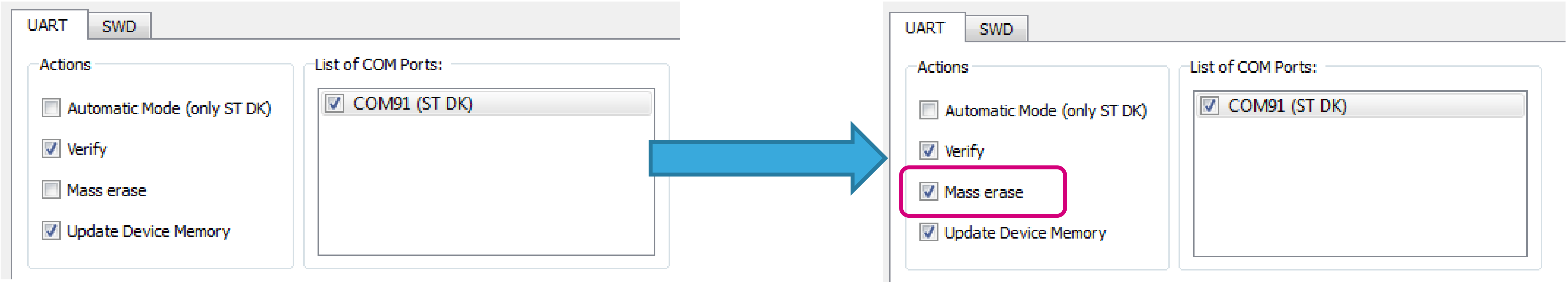
Flash the BlueNRG-2 2/6

1. Device Memory will populate with data



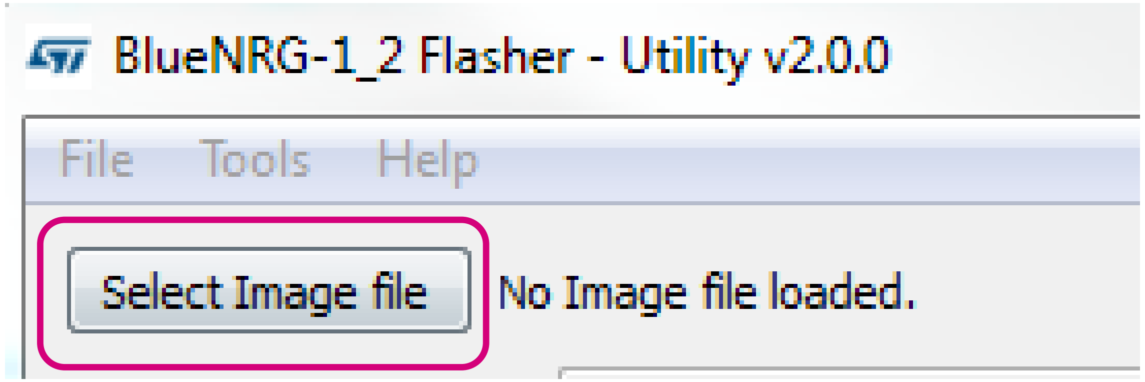
Flash the BlueNRG-2 3/6

1. Click on **Mass Erase**



Flash the BlueNRG-2 4/6

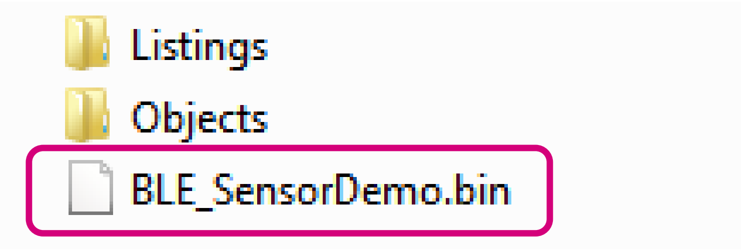
1. Click on **Select Image file** button



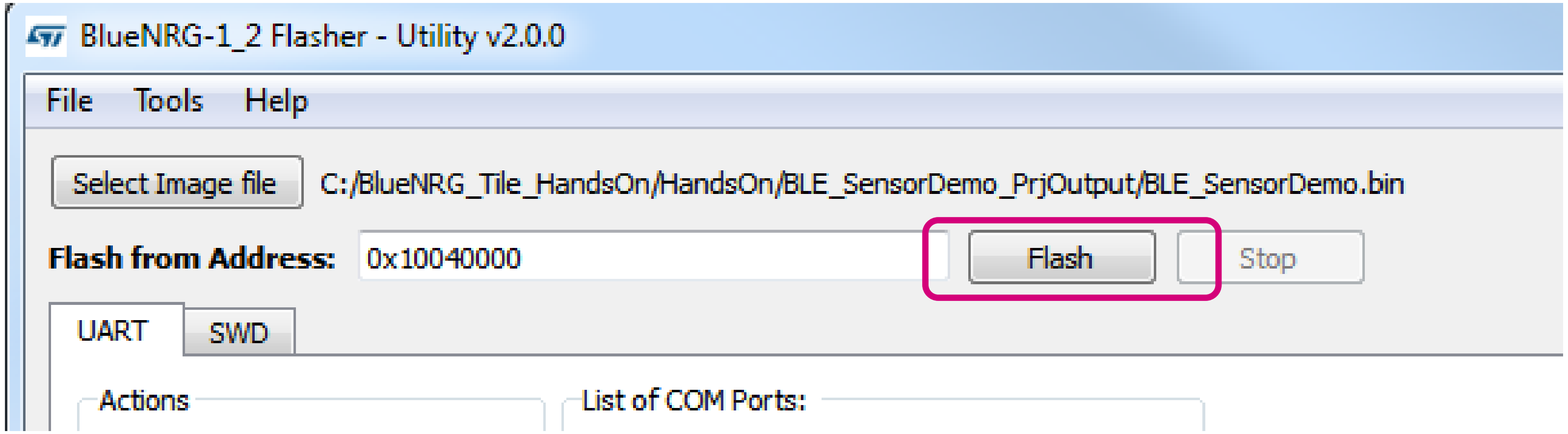
2. And browse the following **path**

Flash the BlueNRG-2 5/6

1. Select **BLE_SensorDemo.bin**



2. Click on the **Flash** button



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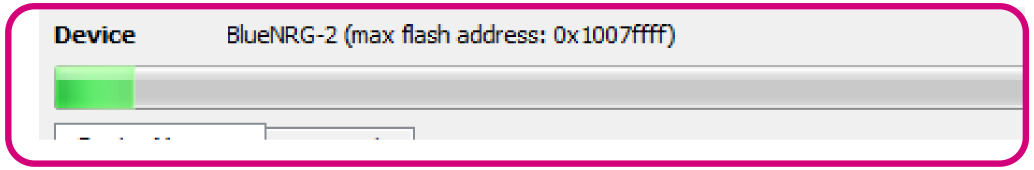
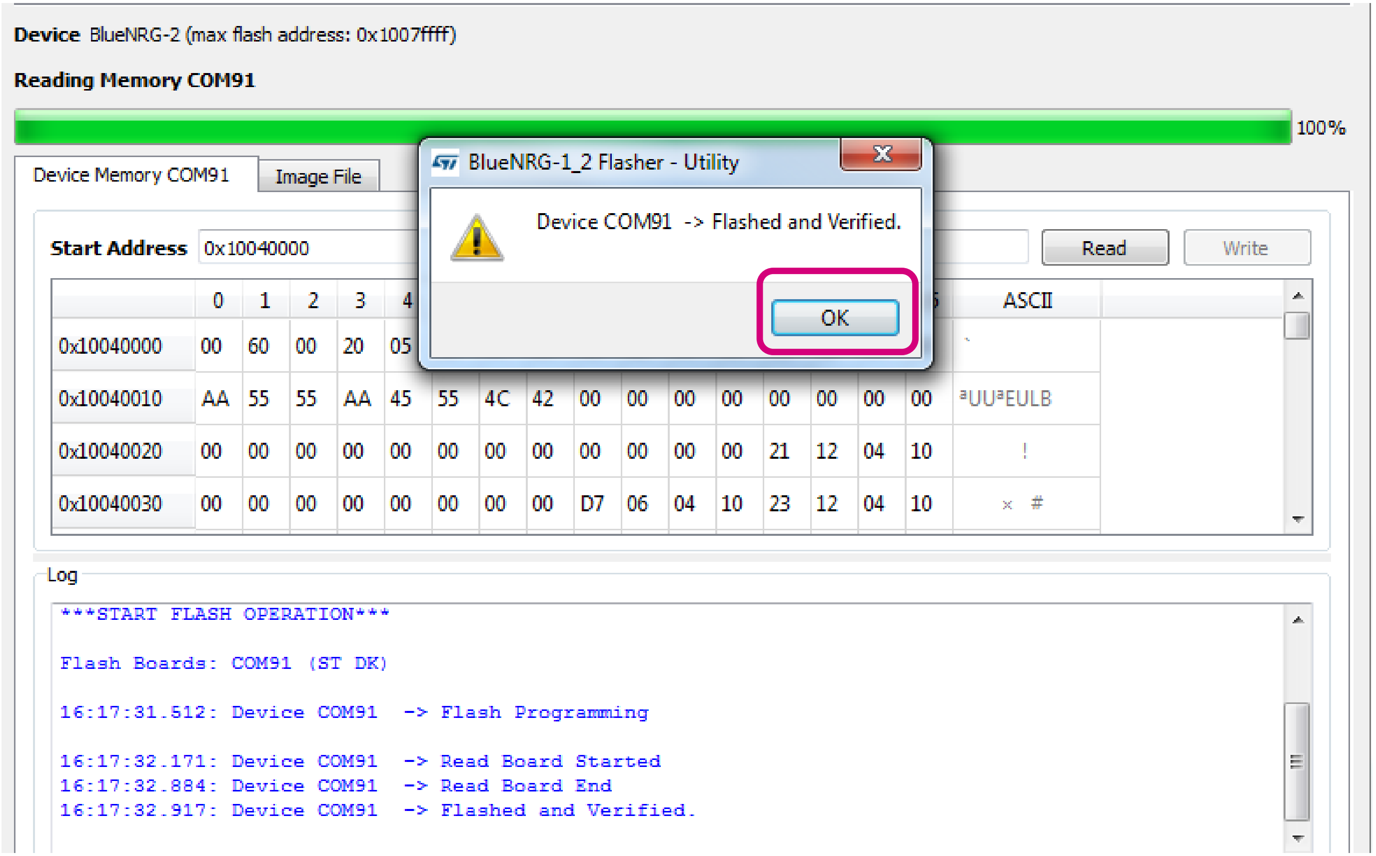
Flash the BlueNRG-2 6/6

1. Flashing starts: **green bar** proceeding



2. Wait for the **pop-up** window and click on **OK**



Do NOT close the Utility!

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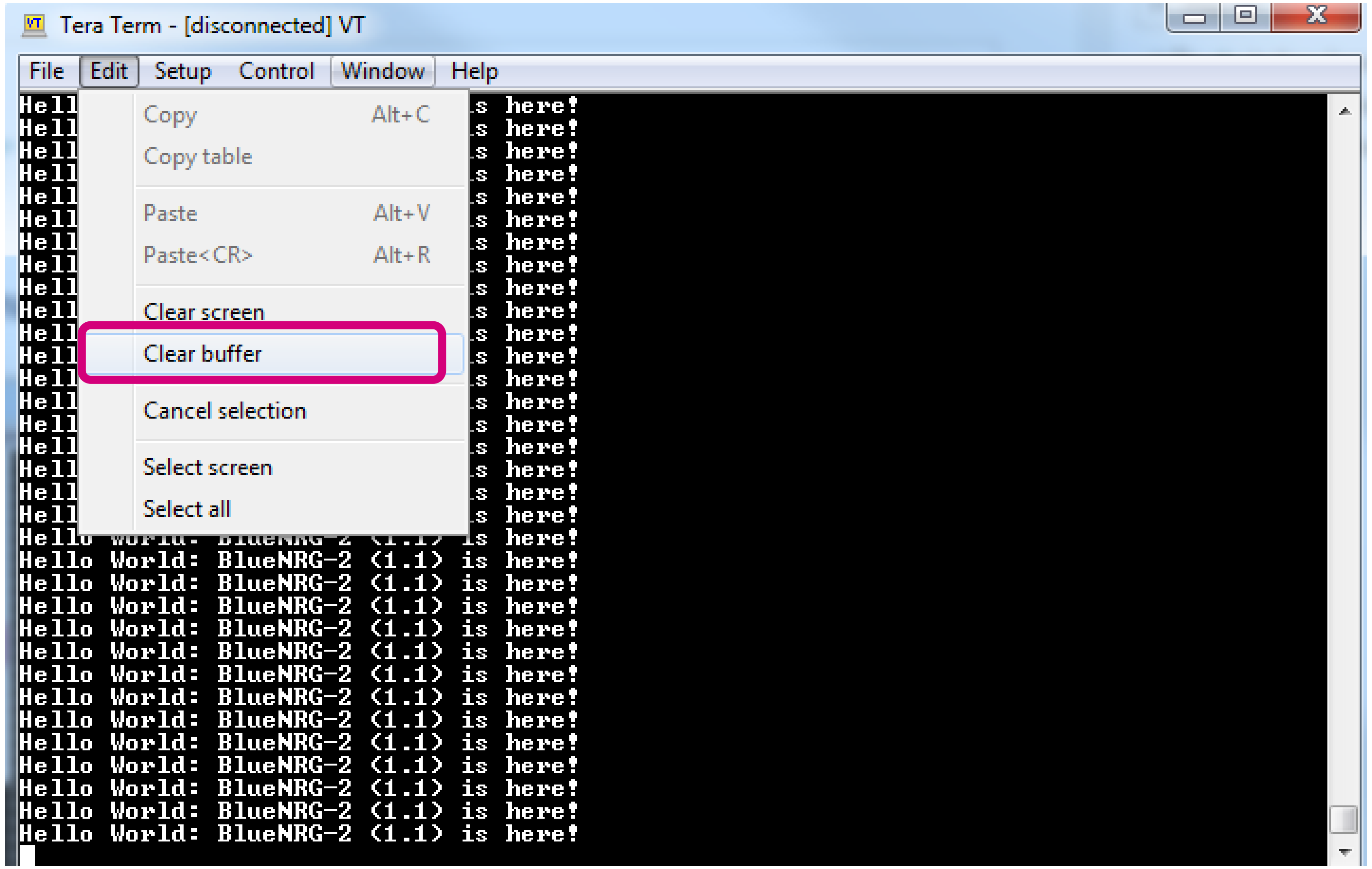
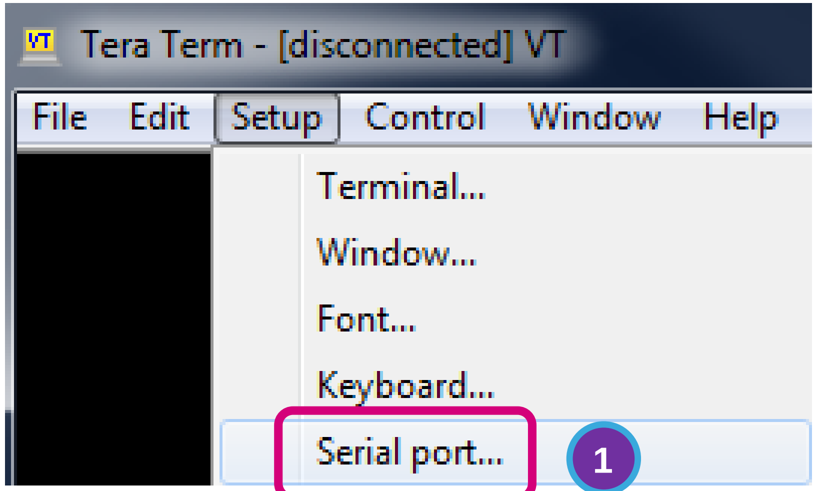
Clean Buffer in the serial terminal

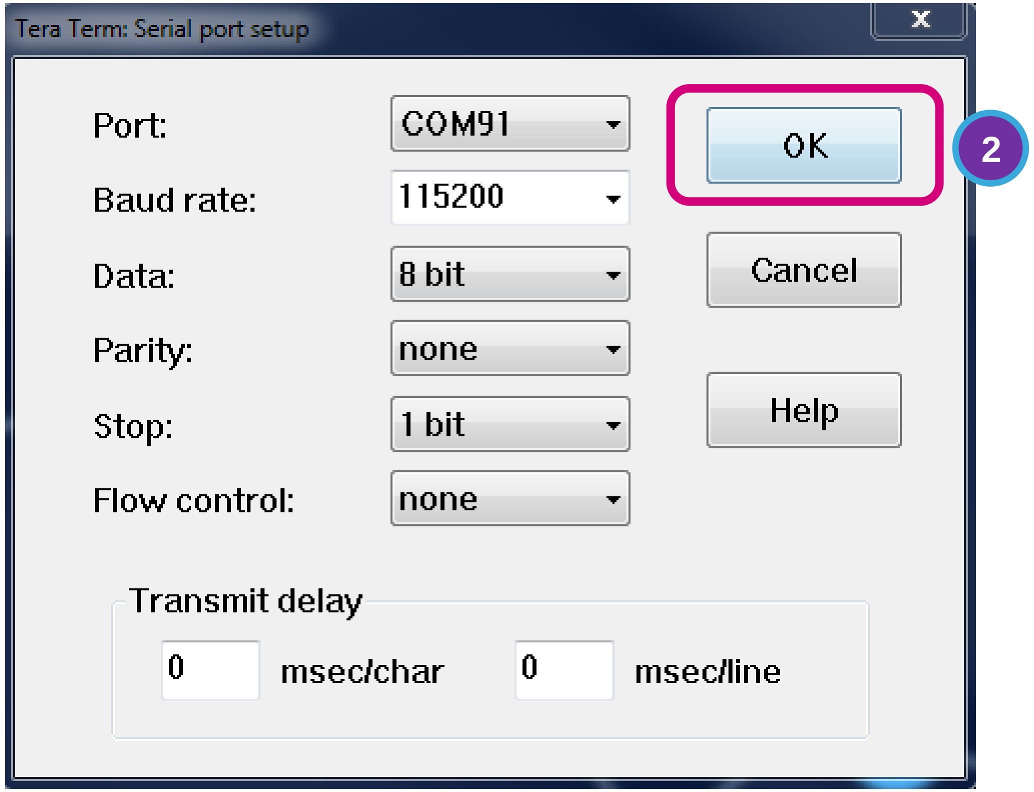
1. In Tera Term in order to have the terminal clean, go to **Edit -> Clear buffer**



Reconnect the serial terminal

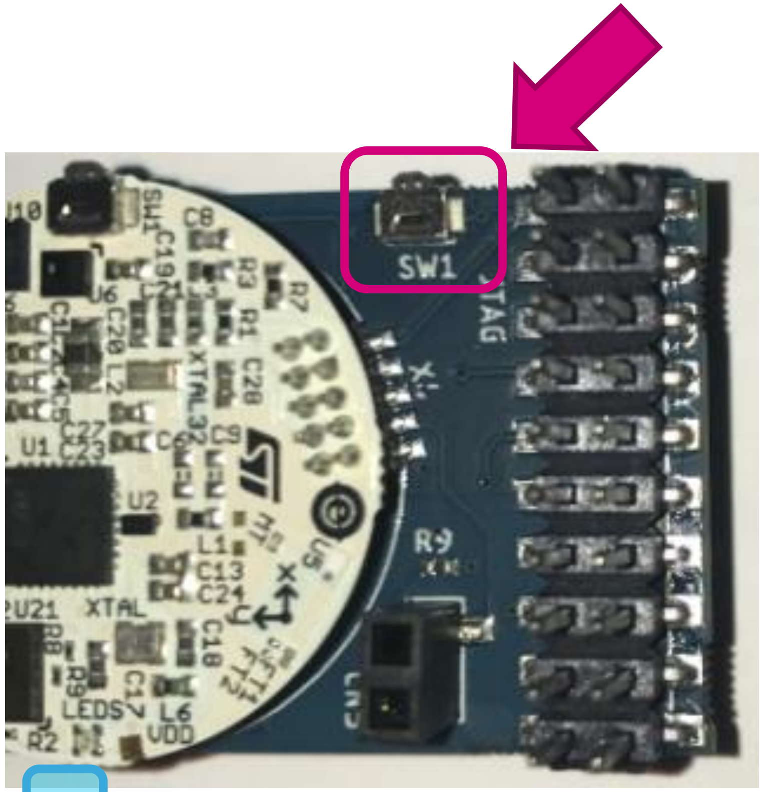
1. Click **Setup** -> **Serial port…**
2. Serial port should already configured. Just need to click on **OK**

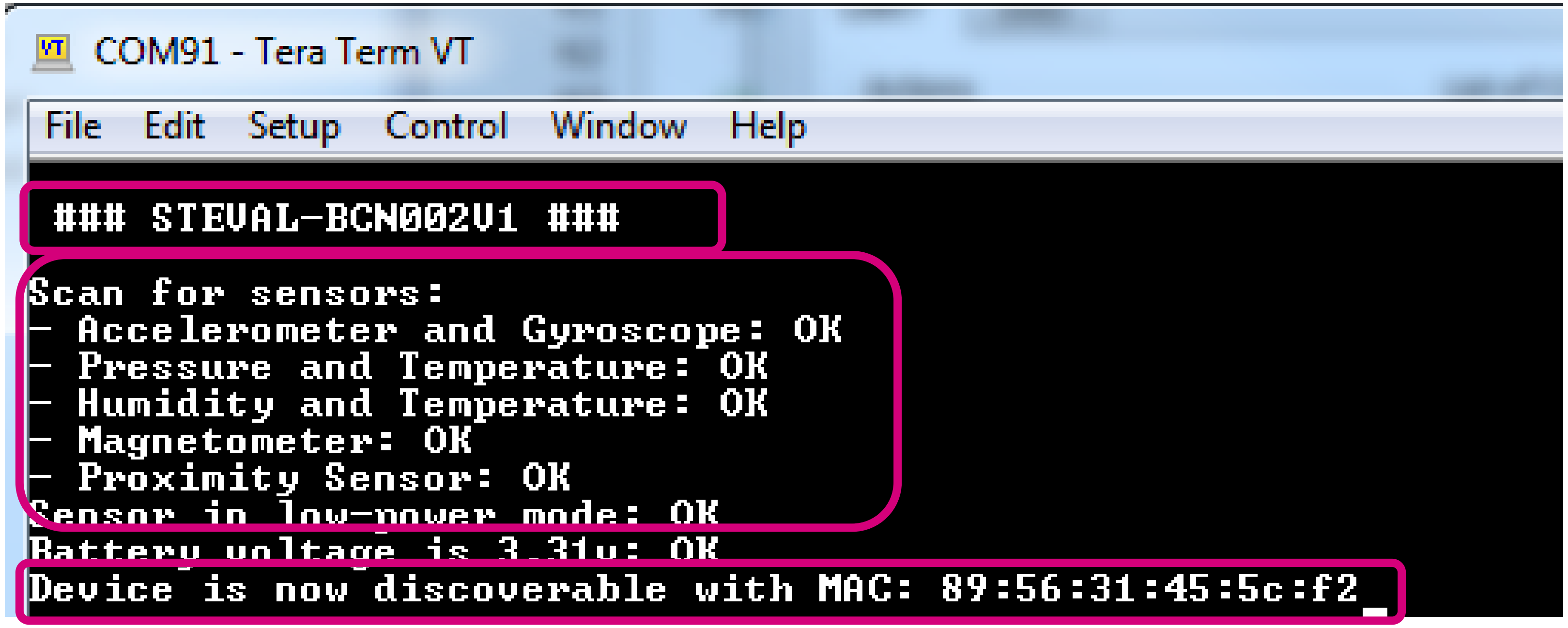




Sanity Check on serial port

Push **SW1 button** on the blue motherboard -> **LED blinking Blue**





Open the BlueMS App

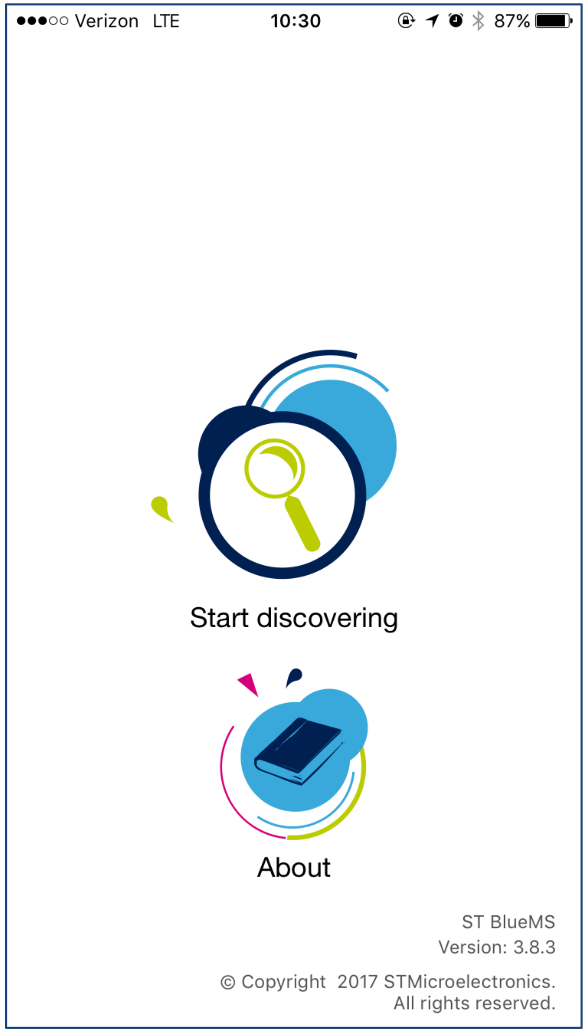
Download on the App Store

GET IT ON Google Play

ST BlueMS

STMICROELECTRONICS INC

Launch the ST BlueMS app previously installed



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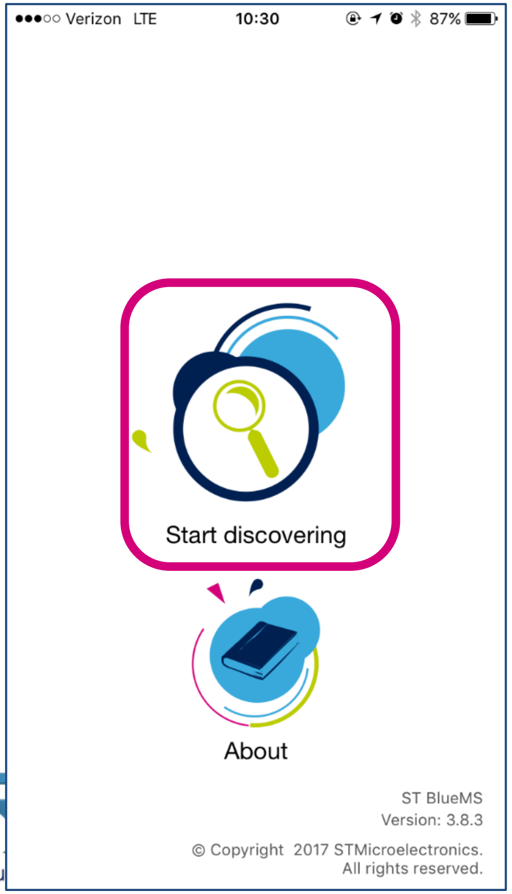
Connect using the BlueMS App

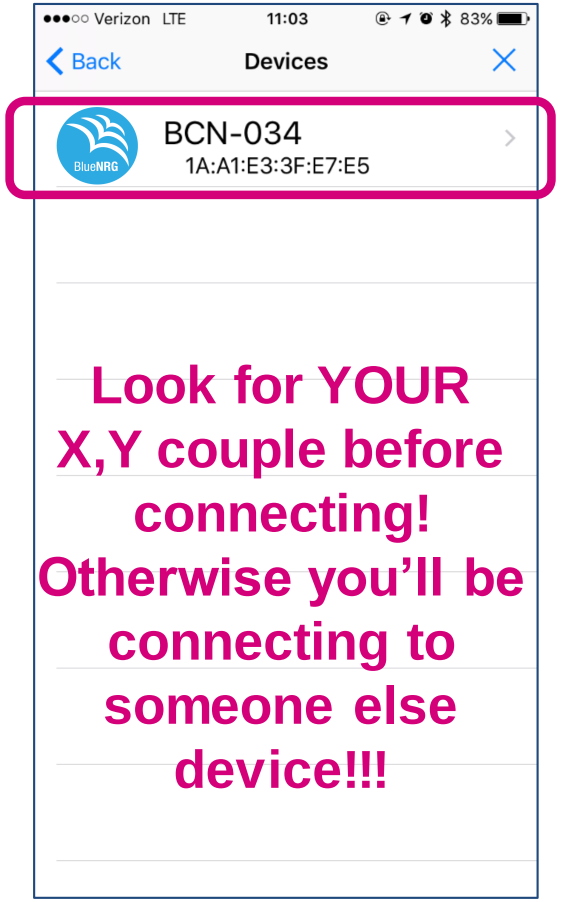
1

Touch "Start discovering"



2

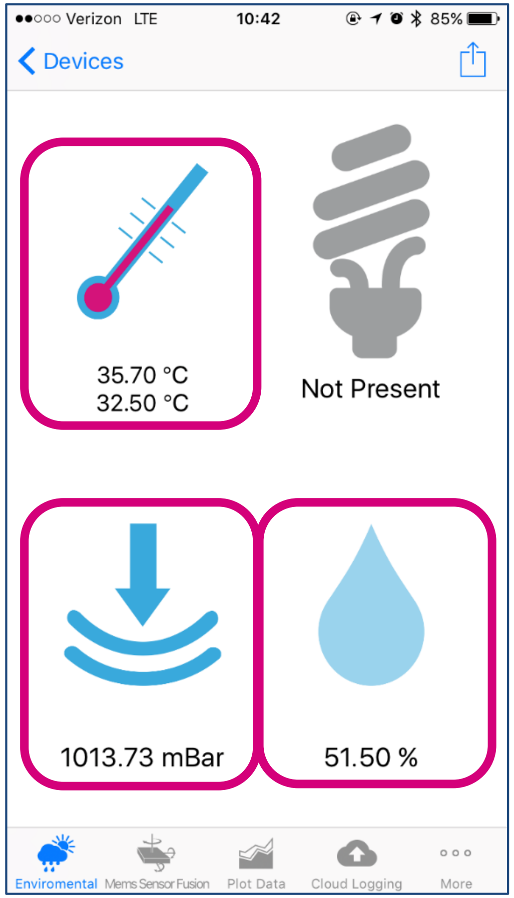
Select your STEVAL-BCN002V1



Look for YOUR X,Y couple before connecting! Otherwise you'll be connecting to someone else device!!!

3

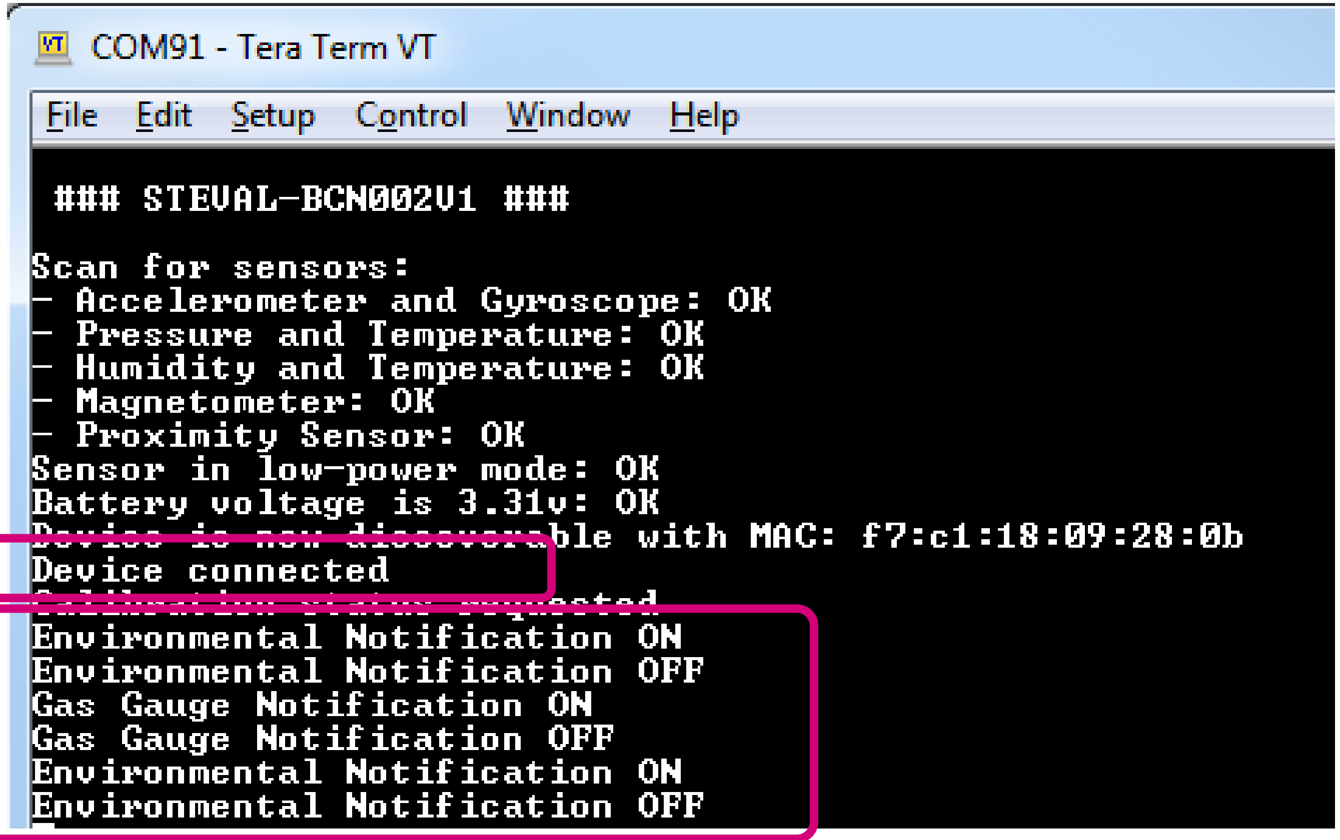
You are connected



Blow on the Temperature sensor to change the temperature and humidity values

TeraTerm output

- "*Device connected*" will appear as connection is created
- Each time user moves on different tabs/screens in the app BLE notifications on different BLE characteristics are enabled. Here Environmental and Gas Gauge characteristics are involved



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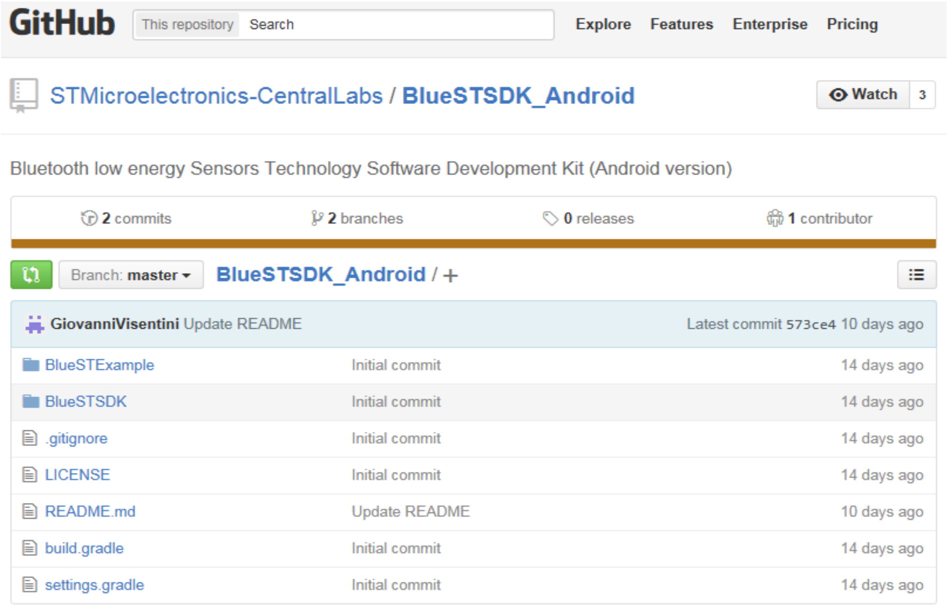
BlueST SDK for Android and iOS

Android

https://github.com/stmicroelectronics-centrallabs/bluestsdk_android

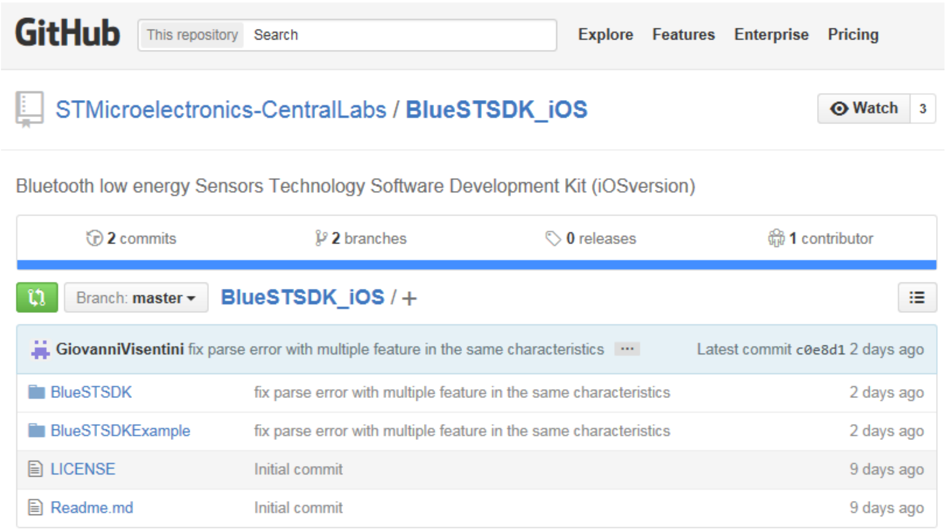


Source code for iOS and Android

available online and maintained on Github repos

iOS

https://github.com/stmicroelectronics-centrallabs/bluestsdk_ios



ST BlueMS Protocol

In file **sensor.c** at line **413**

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

SensorDemo_main.c | sensor.c

```
411 void Set_DeviceConnectable(void) {
412
413   uint8_t manuf_data[26] = {
414   2,                      /* Length of AD type Transmission Power */
415   0x0A, 0x00,             /* Transmission Power = 0 dBm */
416   8,                      /* Length of AD type Complete Local Name */
417   0x09,                   /* AD type Complete Local Name */
418   NAME_ALLMEMS,           /* Local Name */
419   13,                     /* Length of AD type Manufacturer info */
420   0xFF,                   /* AD type Manufacturer info */
421   0x01,                   /* Protocol version */
422   0x04,                   /* Device ID: 0x04 = STEVAL-BCN002V1 Board */
423   0x00,                   /* Feature Mask byte#1: LAB3 0x20 (Led) / LAB5 0x22 (Led+Prox) / LAB7 0x6A (Led+Prox+ADPCM Sync+ADPCM Audio) */
424   0x1F,                   /* Feature Mask byte#2: LAB4 0x9F (Acc+Press+Hum+Temp+Batt+Temp2) / LAB5 0xFF (Acc+Gyro+Mag+Press+Hum+Temp+Batt+Temp2)*/
425   0x00,                   /* Feature Mask byte#3: LAB4 0x04 (AccEvents) / LAB5 0x05 (AccEvents+iNemo Compact) */
426   0x00,                   /* Feature Mask byte#4: LAB5 0x40 (eCompass) */
427   0x00,                   /* BLE MAC start */
428   0x00,
429   0x00,
430   0x00,
431   0x00,
432   0x00                    /* BLE MAC stop */
433   };
```

3 bytes Tx output power

9 bytes Local Name

13 bytes Manufacturer Specific

Feature Mask

BlueMS

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X00

23	22	21	20	19	18	17	16	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0X1E

15	14	13	12	11	10	9	8	
RFU	RFU	RFU	RFU	Beamform	AccEvent	FreeFall	SensFusC	0X00

7	6	5	4	3	2	1	0	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X00

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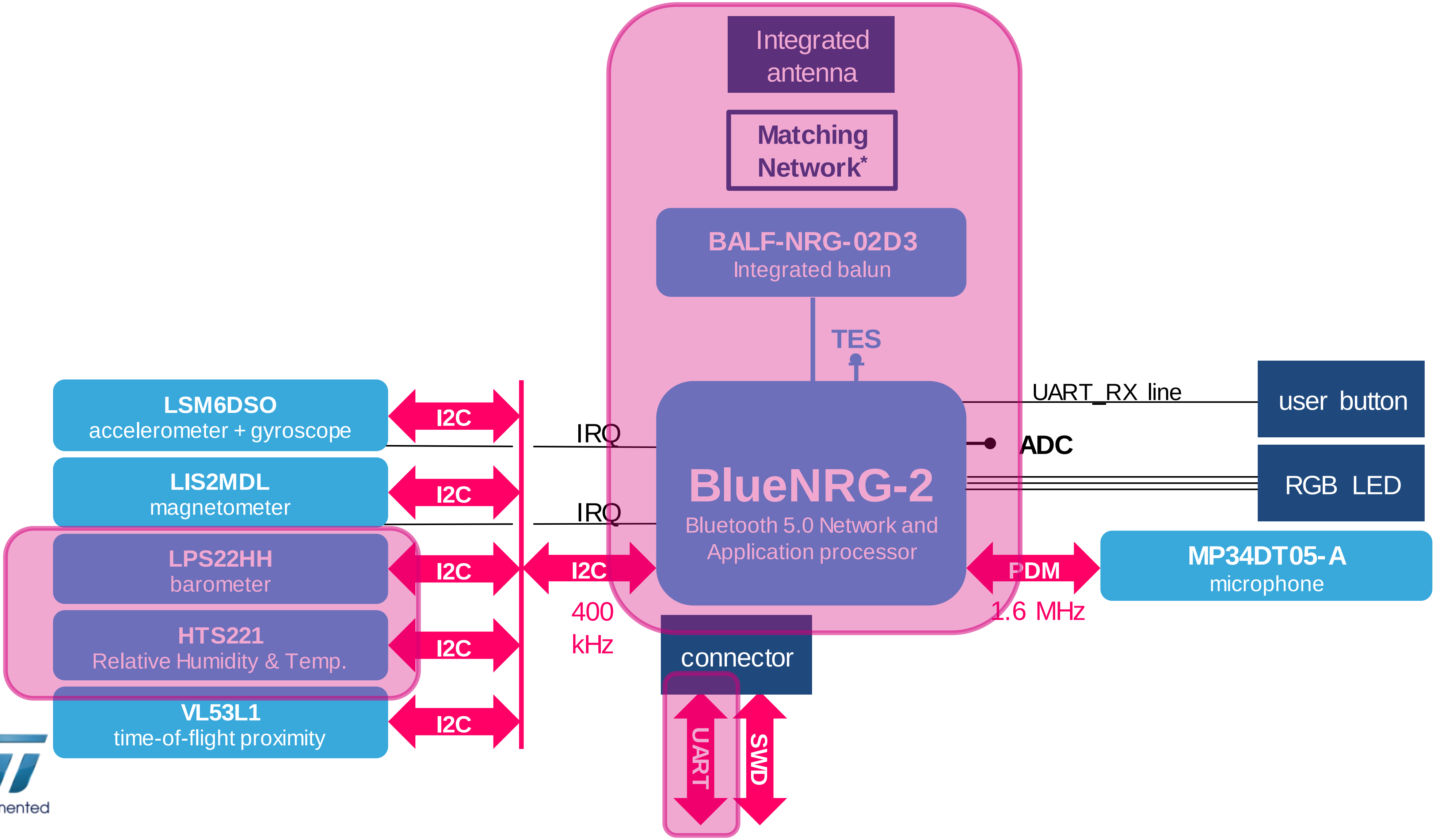
STEVAL-BCN002V1 Block Diagram



BlueMS Protocol – complete Feature Mask

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X6A
23	22	21	20	19	18	17	16	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0XFE
15	14	13	12	11	10	9	8	
RFU	RFU	RFU	RFU	BeamForm	AccEvent	FreeFall	SensFusC	0X05
7	6	5	4	3	2	1	0	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X40

After all labs

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Advertising Data

- In file **sensor.c** at line **413**, this is how the Feature Mask will look like

```c
411 void Set_DeviceConnectable(void) {
412
413     uint8_t manuf_data[26] = {
414     2,                          /* Length of AD type Transmission Power */
415     0x0A, 0x00,                 /* Transmission Power = 0 dBm */
416     8,                          /* Length of AD type Complete Local Name */
417     0x09,                       /* AD type Complete Local Name */
418     NAME_ALLMEMS,               /* Local Name */
419     13,                         /* Length of AD type Manufacturer info */
420     0xFF,                       /* AD type Manufacturer info */
421     0x01,                       /* Protocol version */
422     0x05,                       /* Device ID: 0x05 = STEVAL-BCN002V1 Board */
423     0x6A,                       /* Feature Mask byte#1: LAB3 0x20 (LED) / LAB5 0x22 (Led+Pr
424     0xFE,                       /* Feature Mask byte#2: LAB4 0x9E (Acc+Press+Hum+Temp+Batt)
425     0x05,                       /* Feature Mask byte#3: LAB4 0x04 (AccEvents) / LAB5 0x05 (
426     0x40,                       /* Feature Mask byte#4: LAB5 0x40 (eCompass) */
427     0x00,                       /* BLE MAC start */
428     0x00,
429     0x00,
430     0x00,
431     0x00,
432     0x00                        /* BLE MAC stop */
433     };
```

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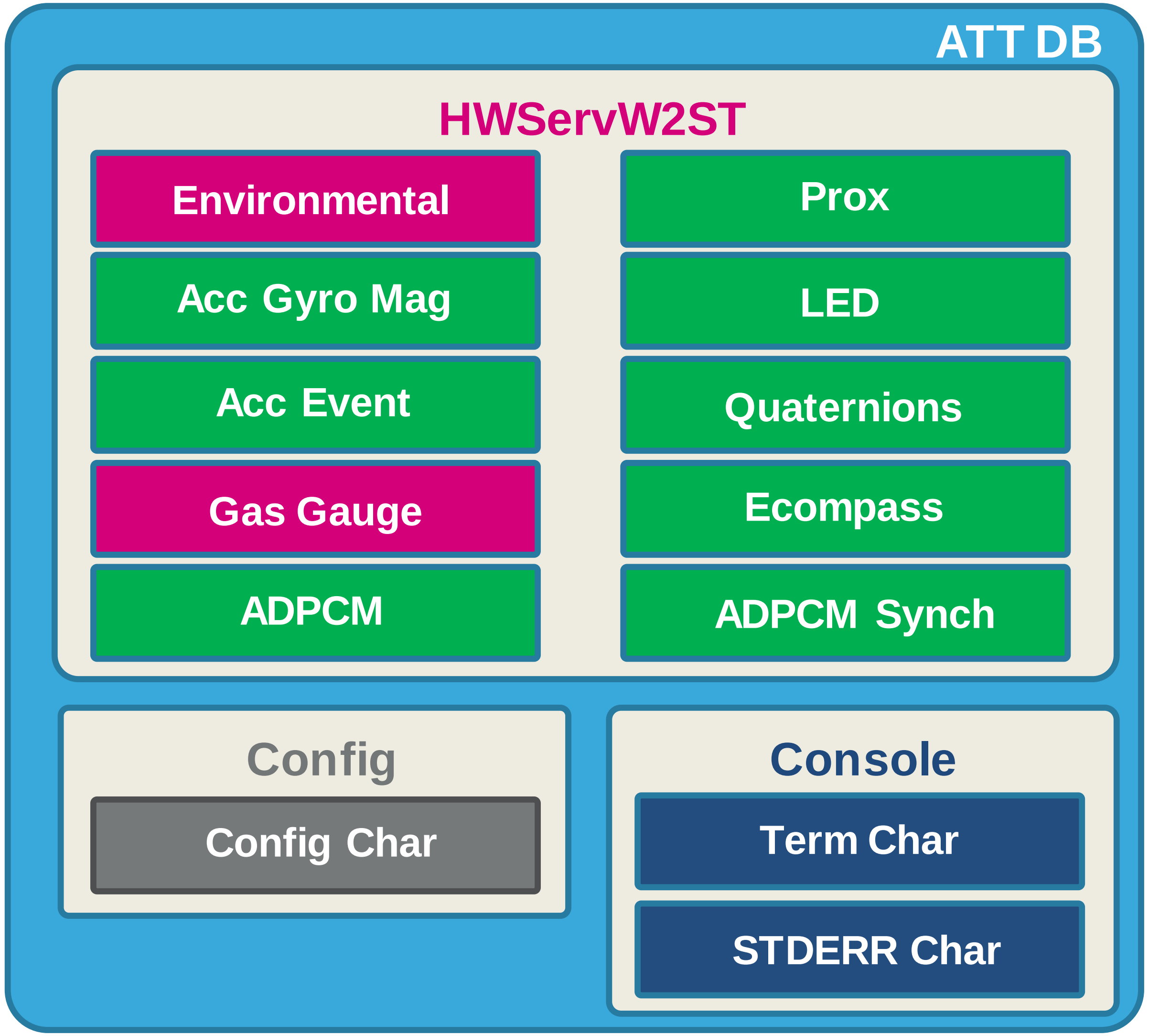
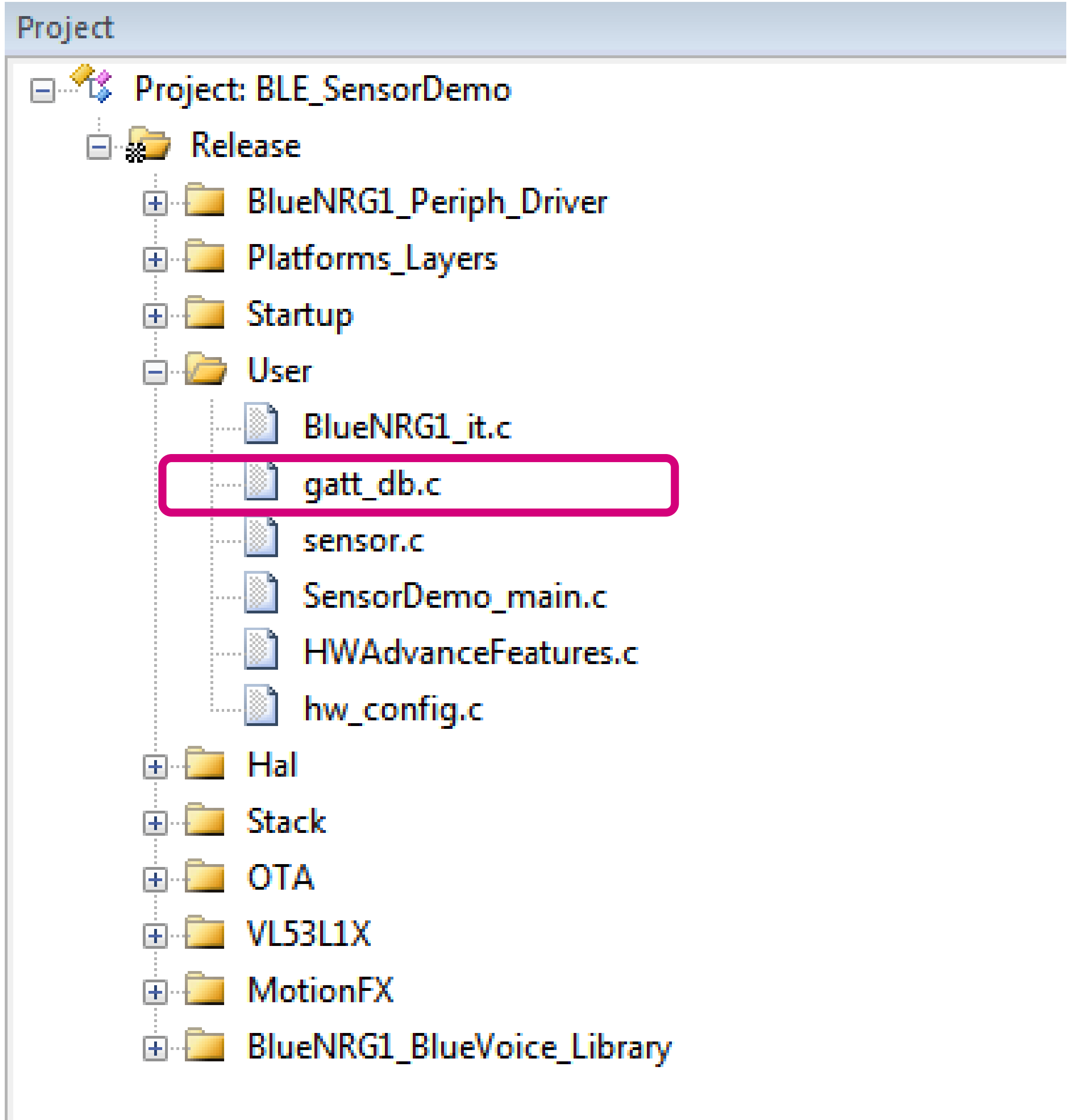
How Feature Mask is mapped onto ATT DB?

- Each bit in the 4-byte Feature Mask in the Advertising packet corresponds to an HW feature
- In the Server ATT DB a BLE Characteristic needs to be added corresponding to each bit in the Advertising Feature Mask

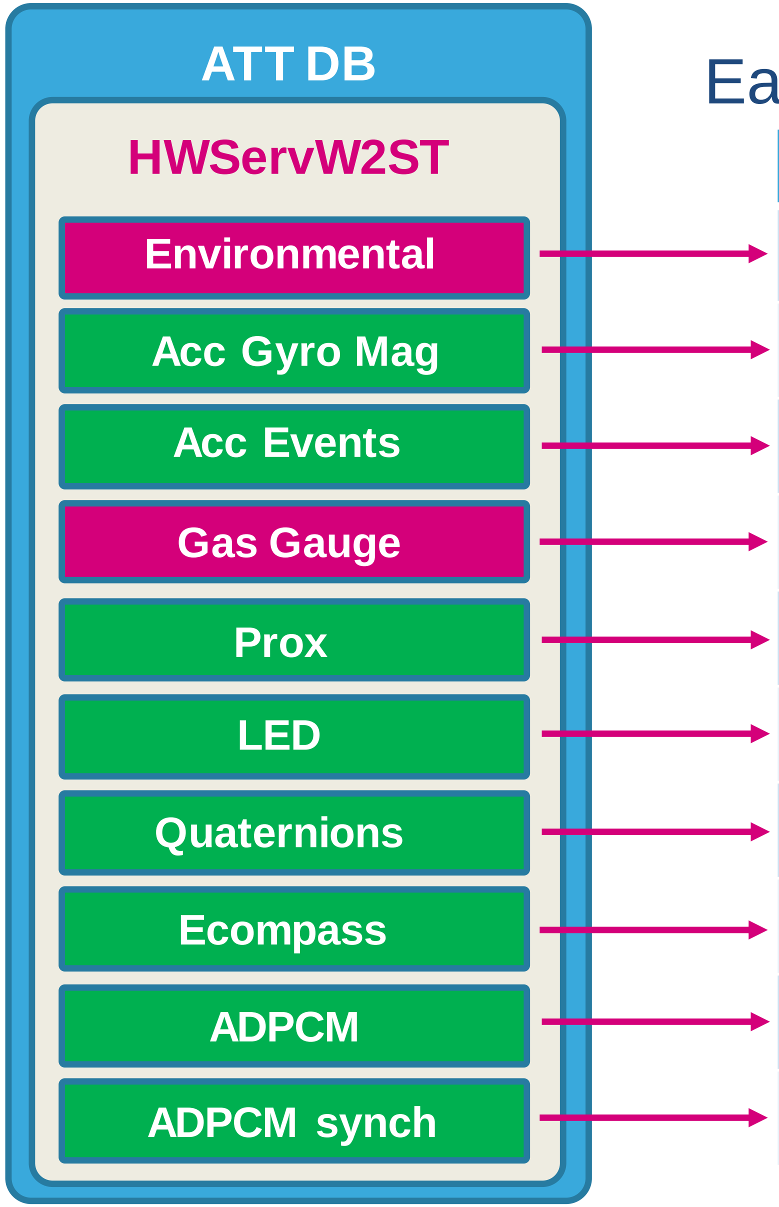


BLE_SensorDemo ATT DB



The ATT DB is defined and created in the file **gatt_db.c**

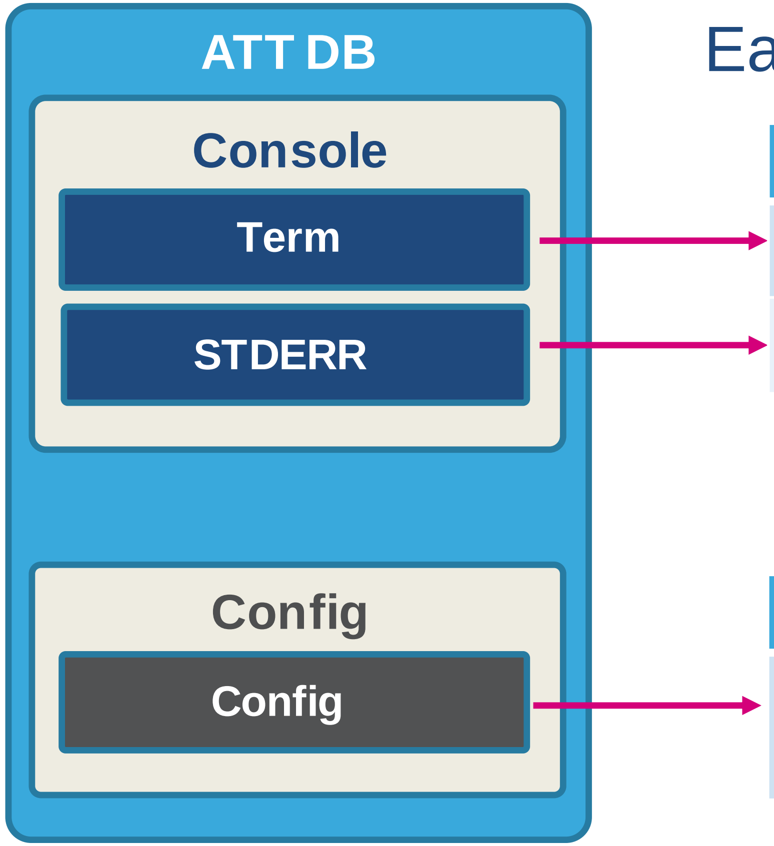
BLE_SensorDemo ATT DB



Each characteristic is defined by the following key parameters

Len	PROPERTIES	UUID TYPE	UUID VALUE
12	N,R	128-bit	001D0000000111e1ac360002a5d5c51b
20	N	128-bit	00E00000000111e1ac360002a5d5c51b
5	N,R	128-bit	00000400000111e1ac360002a5d5c51b
9	N,R	128-bit	00020000000111e1ac360002a5d5c51b
4	N,R	128-bit	02000000000111e1ac360002a5d5c51b
3	N,R	128-bit	20000000000111e1ac360002a5d5c51b
8	N	128-bit	00000100000111e1ac360002a5d5c51b
4	N	128-bit	00000040000111e1ac360002a5d5c51b
20	N	128-bit	08000000000111e1ac360002a5d5c51b
6	N	128-bit	40000000000111e1ac360002a5d5c51b

BLE_SensorDemo ATT DB



Each characteristic is defined by the following key parameters

Len	PROPERTIES	UUID TYPE	UUID VALUE
20	N,R	128-bit	**00000001**000**E**11e1ac360002a5d5c51b
20	N,R	128-bit	**00000002**000**E**11e1ac360002a5d5c51b

Len	PROPERTIES	UUID TYPE	UUID VALUE
20	N, Ww/oR, R,W	128-bit	**00000002**000**F**11e1ac360002a5d5c51b

NOTE 1: UUID values are linked to the Feature Mask in advertising

NOTE 2: 2 additional bytes for a timestamp for each char

BLE_SensorDemo ATT DB

```
tBleStatus Add_HWServW2ST_Service(void)

    aci_gatt_add_service(UUID_TYPE,UUID, … ,MAX_NB_ATTRIBUTES,&ServHandle)

    aci_gatt_add_char(ServHandle,UUID_TYPE,UUID,Length,PROPERTIES,PERMISSIONS, … ,&CharHandle)
```

HWServW2ST**Handle** = 0x000C

Environmental**CharHandle** = 0x000D

AccGyroMag**CharHandle** = 0x0010

ConfigW2ST**Handle** = 0x002B

Config**CharHandle** = 0x002C

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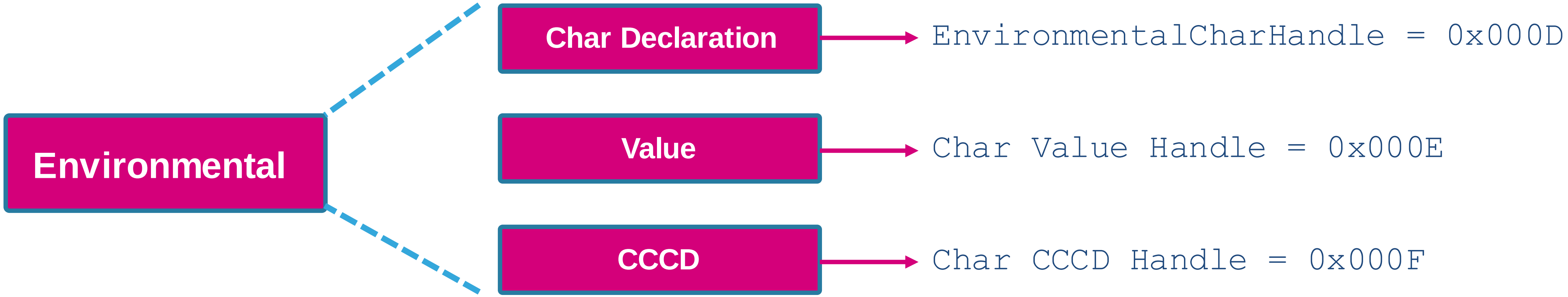
BLE_SensorDemo ATT DB



- Declaration Handle: used by the application to access the Characteristic
- Characteristic Value Handle: used by the Client for Read/Write operations
- **C**lient **C**haracteristic **C**onfigurator **D**escriptor (CCCD): GATT descriptor added by default by the stack if char has Notify/Indicate property. Used by Client to enable notifications/indications on char value.

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Central: Services and Characteristics discovery procedure

This is how ATT DB looks like from the Central

UUIDs **Handles** **Values**

Name	Handle	Property	Value	Value Length
Service User Defined (0x00000000000111E19AB40002A5D5C51B)	0x000C			
Characteristic User Defined (0x001D000000111E1AC360002A5D5C51B)	0x000D	Read, Notify	0x011F0111023C00018B9CA605	0x0C
Client Characteristic Configuration (0x2902)	0x000F		0x0000	0x02
Characteristic User Defined (0x00E00000000111E1AC360002A5D5C51B)	0x0010	Notify		
Client Characteristic Configuration (0x2902)	0x0012		0x0000	0x02
Characteristic User Defined (0x00000400000111E1AC360002A5D5C51B)	0x0013	Read, Notify	0x0000002405	0x05
Client Characteristic Configuration (0x2902)	0x0015		0x0000	0x02
Characteristic User Defined (0x02000000000111E1AC360002A5D5C51B)	0x0016	Read, Notify	0x88A1232E	0x04
Client Characteristic Configuration (0x2902)	0x0018		0x0000	0x02
Characteristic User Defined (0x20000000000111E1AC360002A5D5C51B)	0x0019	Read, Notify	0x0024E6	0x03
Client Characteristic Configuration (0x2902)	0x001B		0x0000	0x02
Characteristic User Defined (0x00020000000111E1AC360002A5D5C51B)	0x001C	Read, Notify	0x0180000CBA03E8AB63	0x09
Client Characteristic Configuration (0x2902)	0x001E		0x0000	0x02
Characteristic User Defined (0x00000100000111E1AC360002A5D5C51B)	0x001F	Notify		
Client Characteristic Configuration (0x2902)	0x0021		0x0000	0x02
Characteristic User Defined (0x00000040000111E1AC360002A5D5C51B)	0x0022	Notify		
Client Characteristic Configuration (0x2902)	0x0024		0x0000	0x02
Characteristic User Defined (0x08000000000111E1AC360002A5D5C51B)	0x0025	Notify		
Client Characteristic Configuration (0x2902)	0x0027		0x0000	0x02
Characteristic User Defined (0x40000000000111E1AC360002A5D5C51B)	0x0028	Notify		
Client Characteristic Configuration (0x2902)	0x002A		0x0000	0x02
Service User Defined (0x00000000000F11E19AB40002A5D5C51B)	0x002B			
Characteristic User Defined (0x0000002000F11E1AC360002A5D5C51B)	0x002C	Write w/o resp, Notify		
Client Characteristic Configuration (0x2902)	0x002E		0x0000	0x02
Service User Defined (0x00000000000E11E19AB40002A5D5C51B)	0x002F			
Characteristic User Defined (0x0000001000E11E1AC360002A5D5C51B)	0x0030	Read, Write w/o resp, Write, Notify	0x0	0x00
Client Characteristic Configuration (0x2902)	0x0032		0x0000	0x02
Characteristic User Defined (0x0000002000E11E1AC360002A5D5C51B)	0x0033	Read, Notify	0x0	0x00
Client Characteristic Configuration (0x2902)	0x0035		0x0000	0x02

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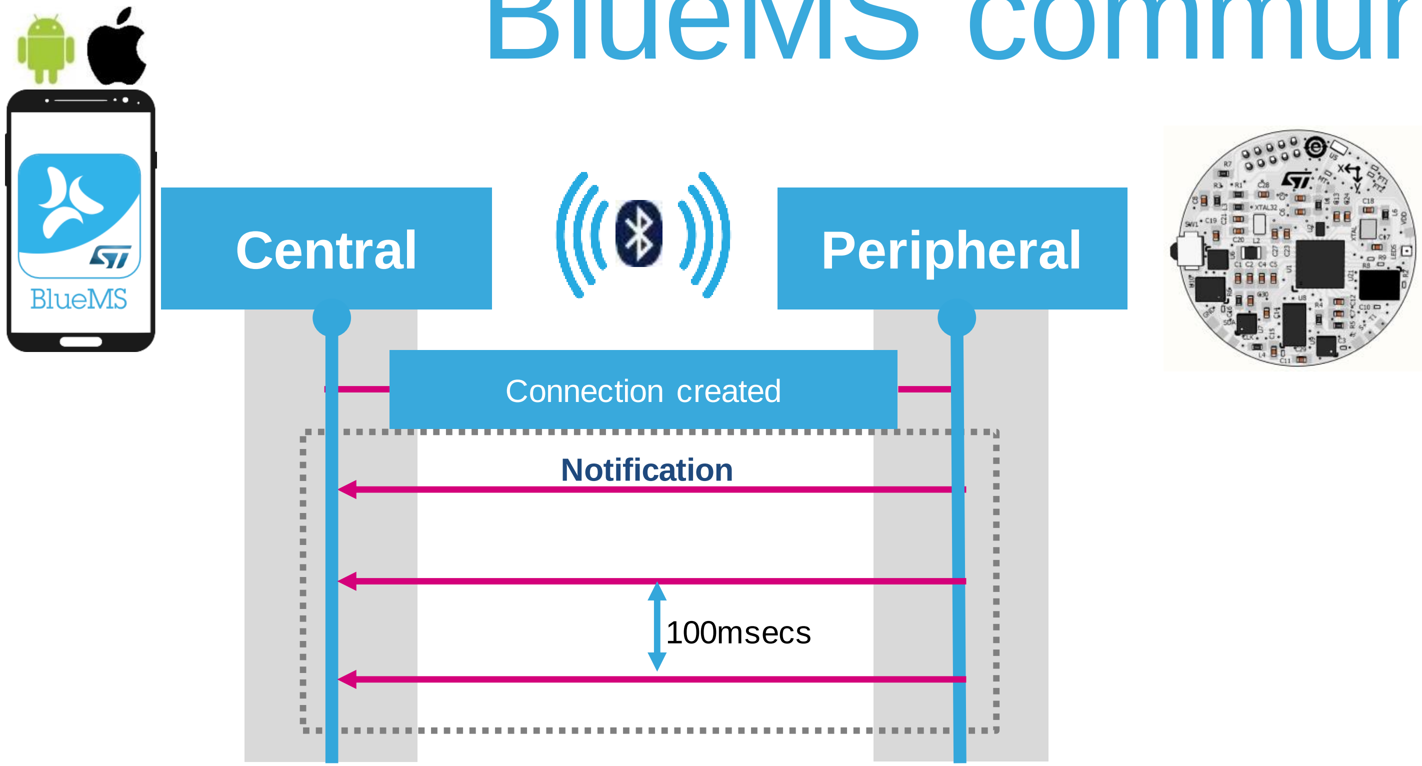
BlueMS communication protocol




```
aci_gatt_update_char_value(ServiceHandle,    0x000C, // HWserv handle
                           CharHandle,       0x000D, // EnvChar handle
                           Offset,           0x00,
                           Length,           0x08,
                           Value)            Data)   // EnvChar Value
```

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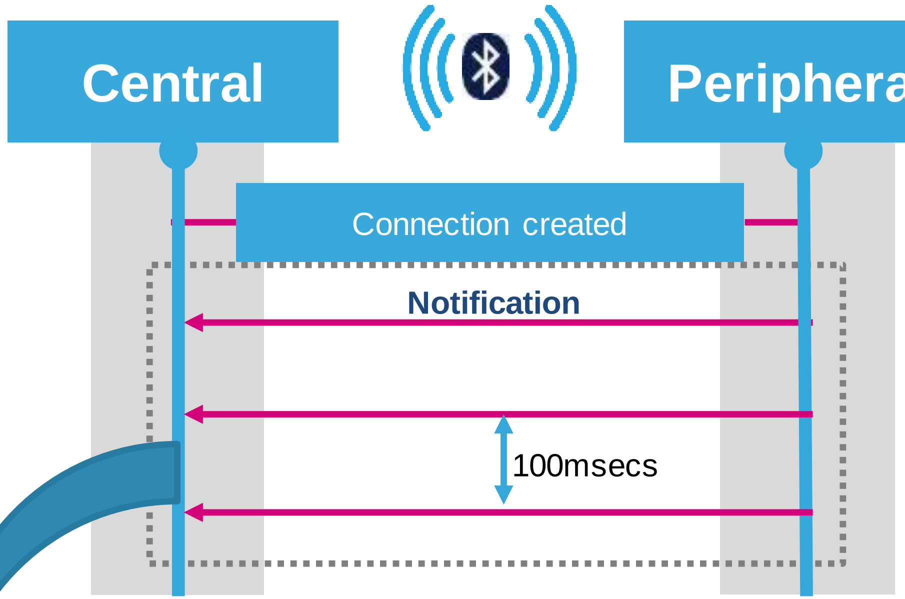
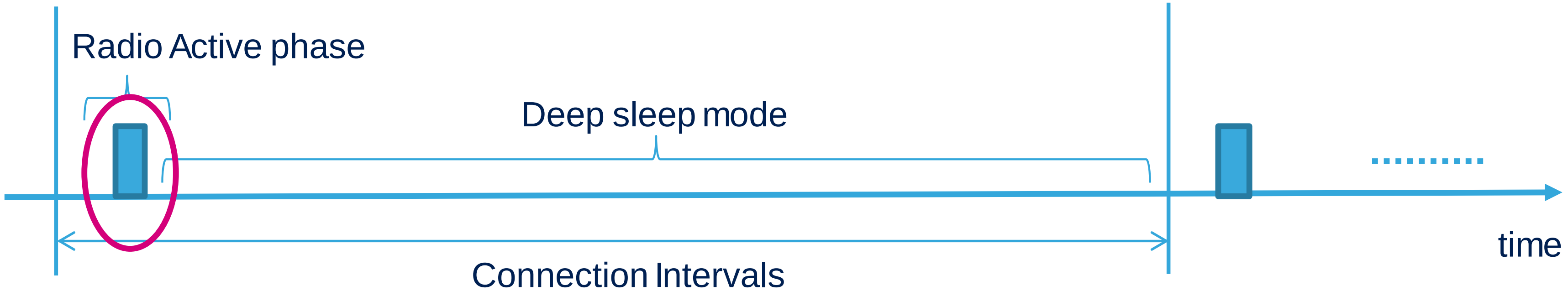
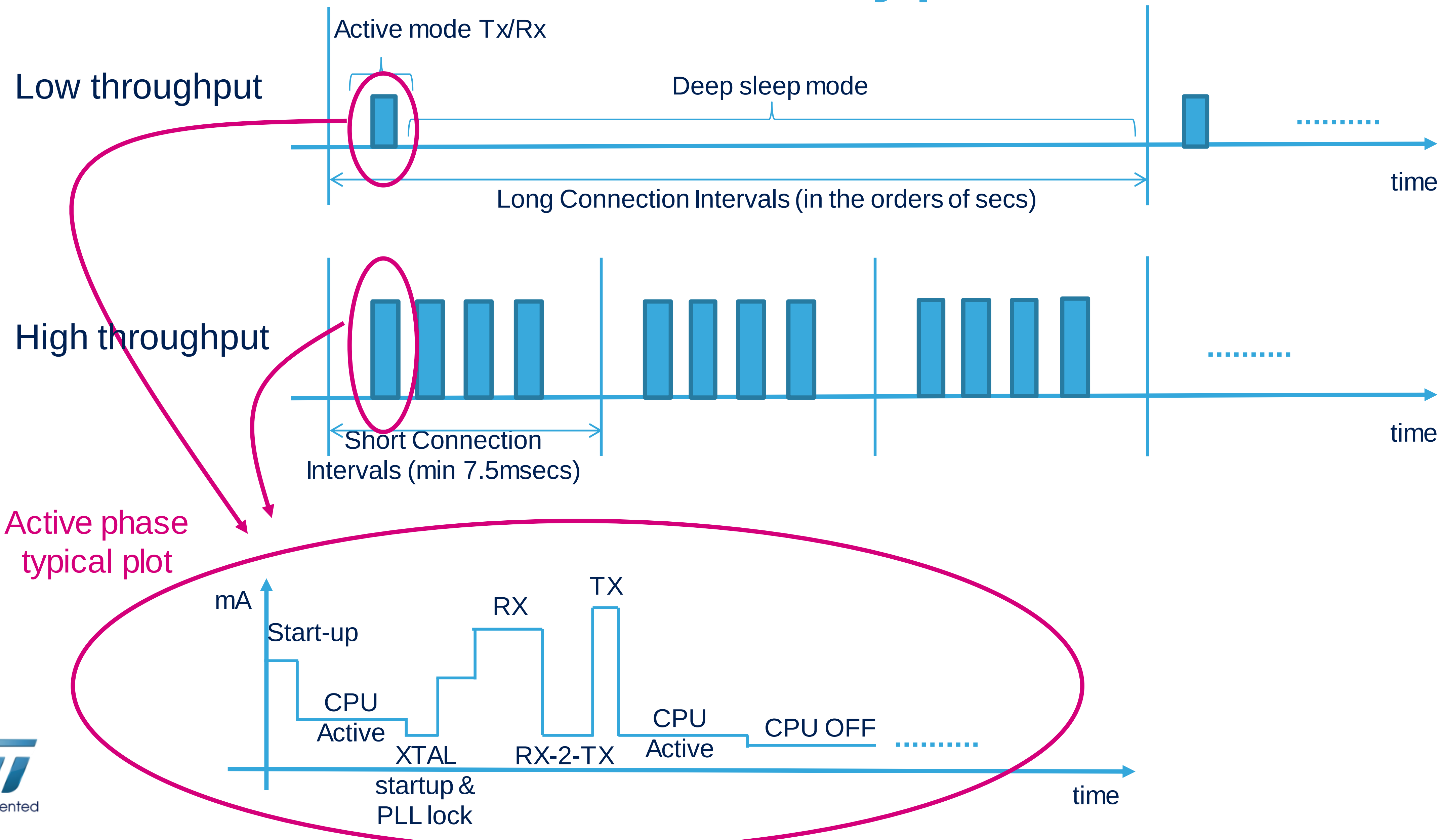
Cortex-M0 Sleep management



- Sleep mode managed through a dedicated sleep library and API
  - *BlueNRG_Sleep(sleepMode, gpioWakeBitMask, gpioWakeLevelMask);*
- 4 wake up sources: timers, DIO11, DIO12 and DIO13
  - Timers: 4 virtual timers mapped on 2 physical timers managed by the radio IP
  - DIO11: Interrupt line from UART RX or SW1 button
  - DIO12: Interrupt line from Magnetometer
  - DIO13: Interrupt line from 6-axis Accelerometer & Gyroscope



Typical scenarios



Low Power Modes

- Deep sleep mode can represent most of the application time.
- Efficient management of sleep modes lowers significantly avg pwr consumption.

BlueNRG-2 flexible low power architecture

Sleeping Mode	Consumption	Notes
RUNNING	1.9mA	Core running
CPU HALT	1.5mA	WFI instruction
WAKETIMER	900nA	GPIOs and Timer Wakeup
NOTIMER	**500nA**	GPIOs only Wakeup

Highest power

Low Power library combines requests coming from the application with the radio operating mode

Lowest power

Context Save/Restore

- BlueNRG-2 Low Power Library manages autonomously entering and exiting to/from sleep mode. **NO need for the application to worries about sleep management and RAM retention!**

- The library saves peripherals configurations and application context before entering deep sleep, and restores the context on exiting from low power state:
  - **CPU returns to execute the next instruction after the low power function call**
  - **No need to re-initialize peripheral and radio stack**
  - **RAM retention is guaranteed**

BlueNRG Current Consumption Estimation Tool

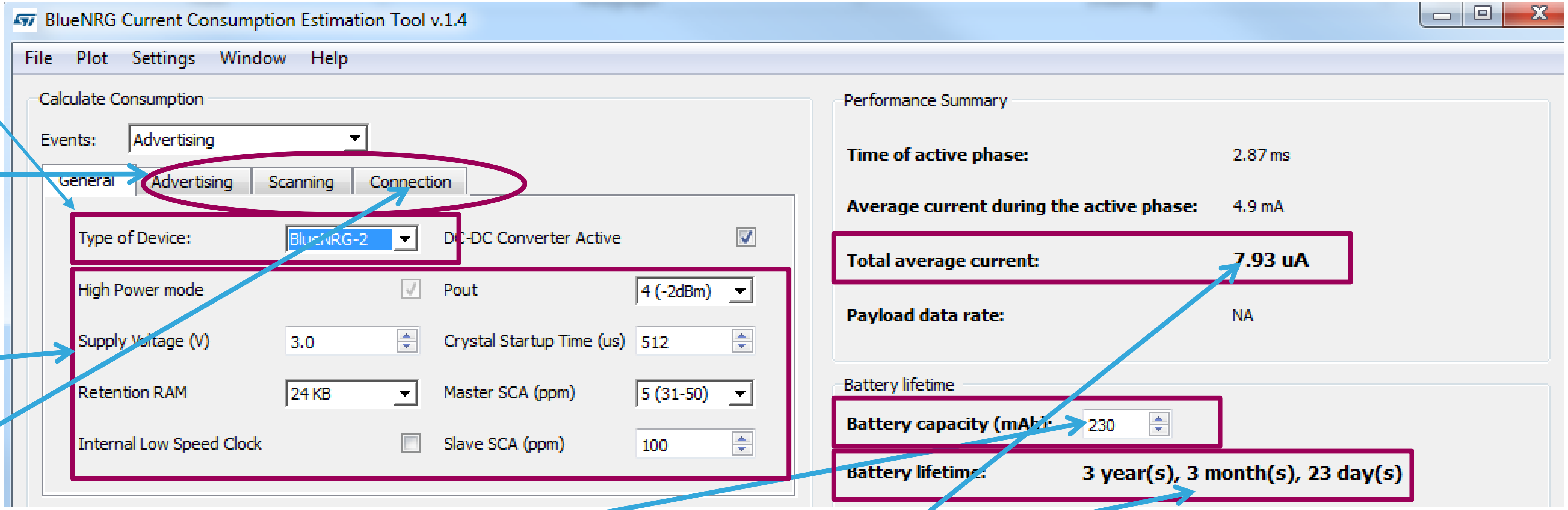
- Accurate estimate of average current consumption and battery lifetime

1. Select the device

2. Select the type of event

3. Configure the HW operating conditions

4. Configure the application use case scenario



5. Specify the Battery capacity

6. Read the average current and the estimated battery lifetime

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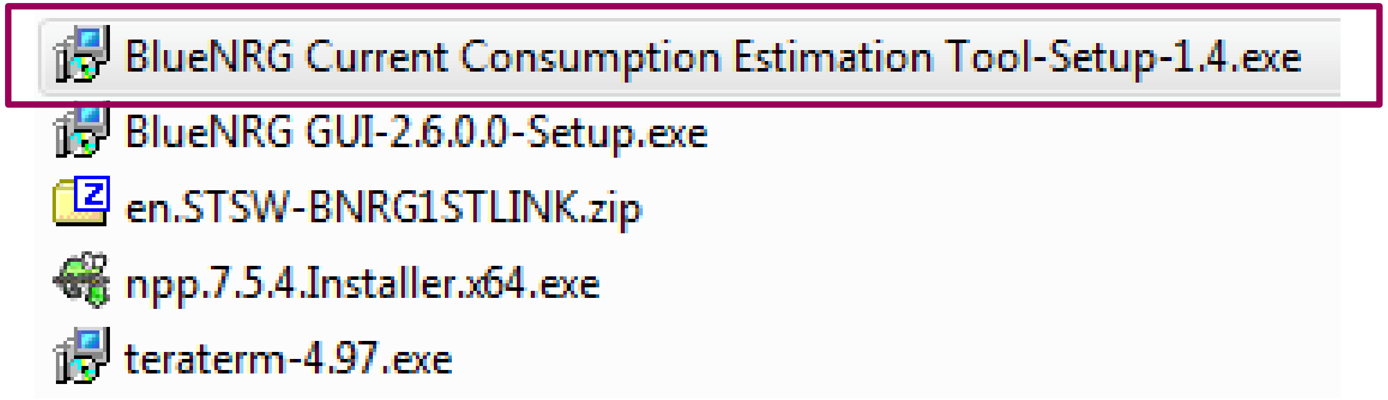
BlueNRG Current Consumption Estimation Tool

- Check on the installation folder in the path "**BlueNRG_Tile_HandsOn/Software**"



- Or on st.com at this link:

http://www.st.com/content/st_com/en/products/embedded-software/wireless-connectivity-software/stsw-bnrg001.html

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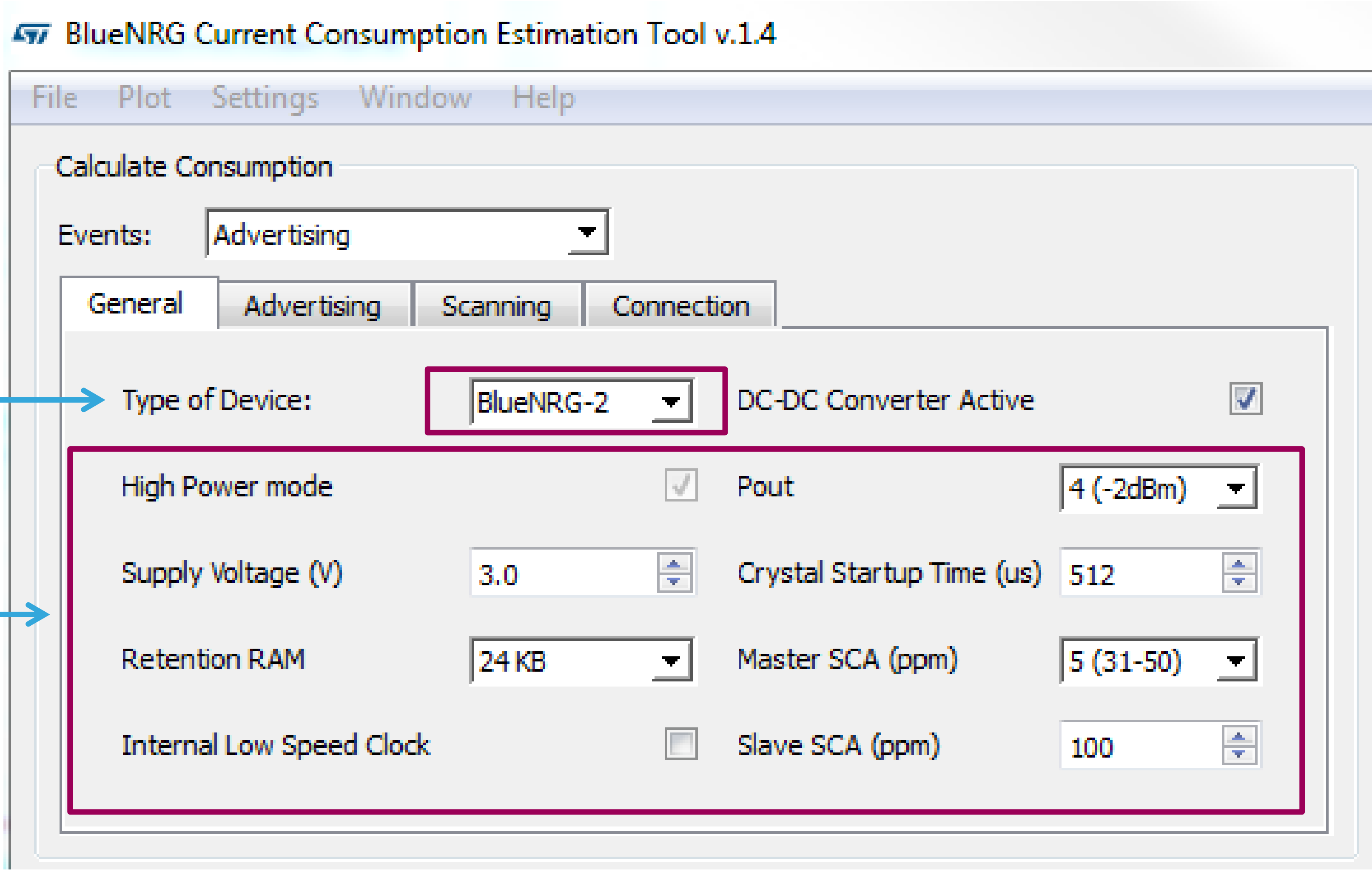
Advertising example 1/3

1. Select the device

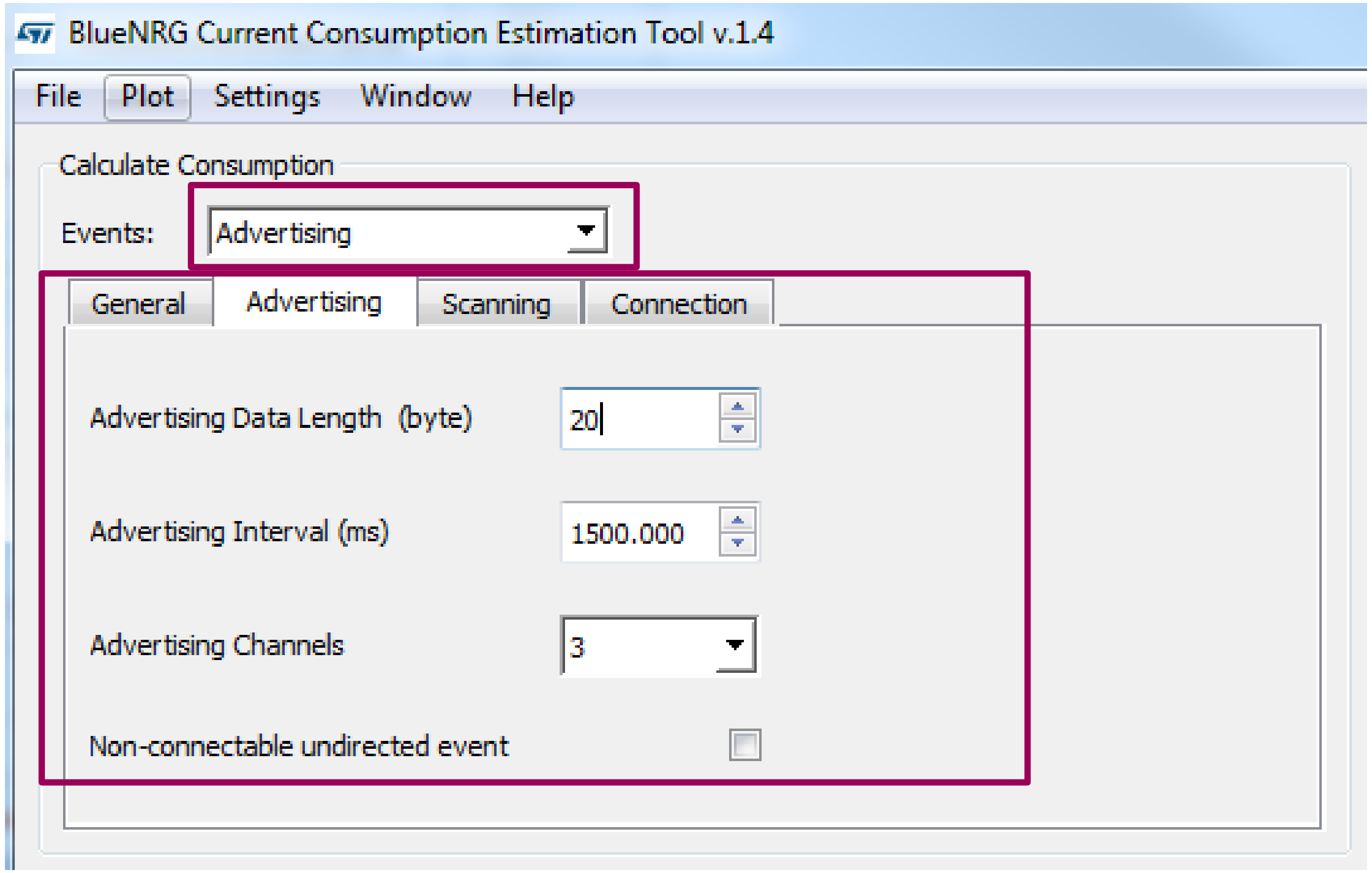
2. Configure the HW operating conditions



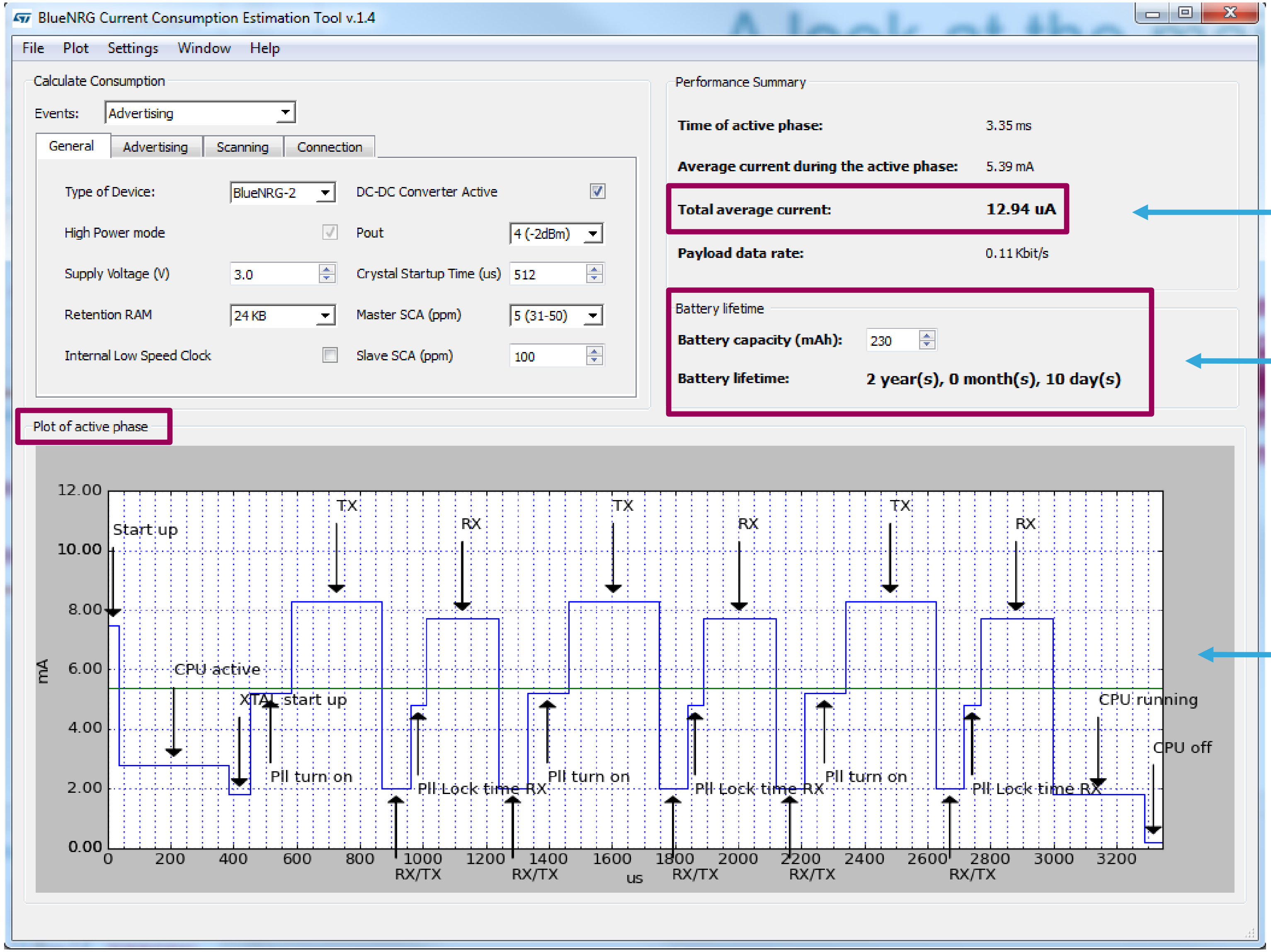
Advertising example 2/3

1. Select the event type

2. Configure the event operating conditions



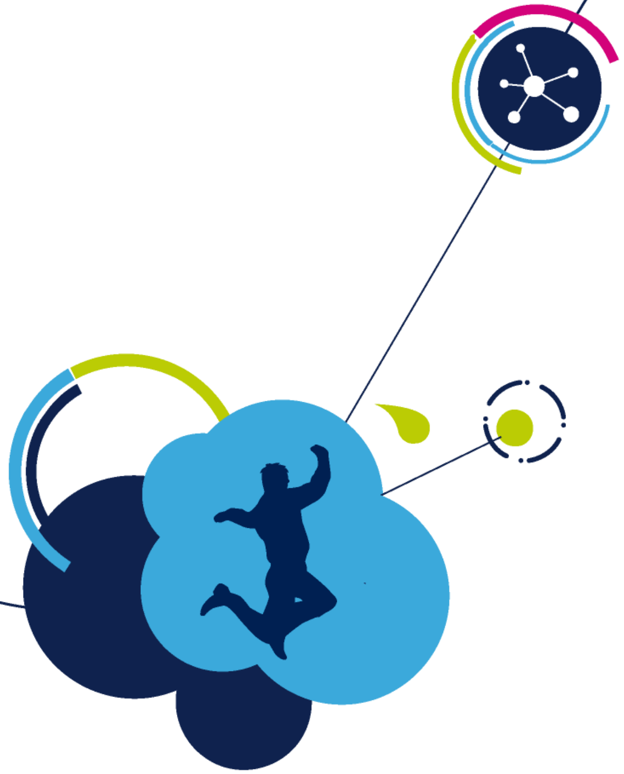
Advertising example 3/3



1. Get average current consumption

2. Get expected battery lifetime

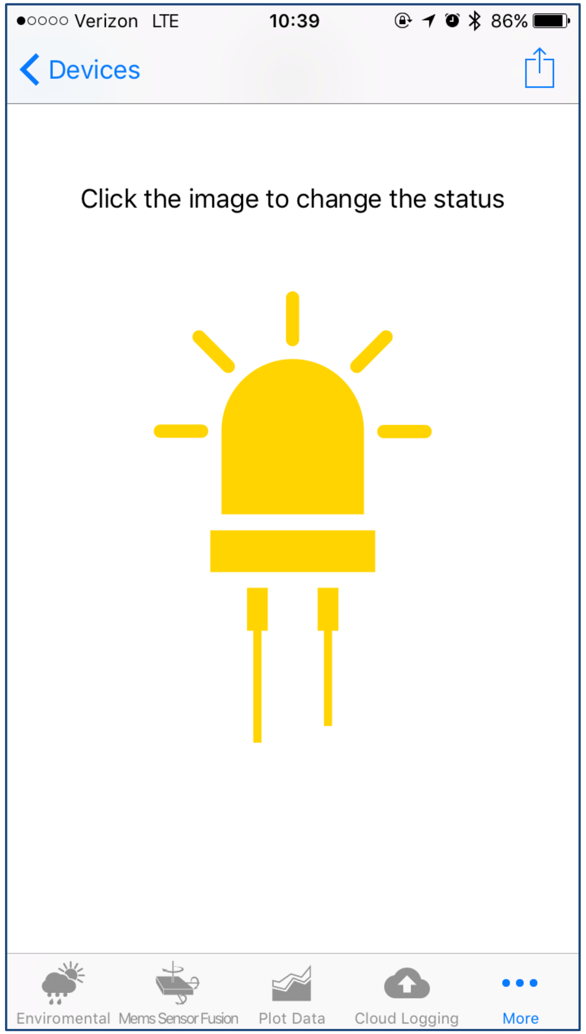
3. Plot of the active phase



Lab 3

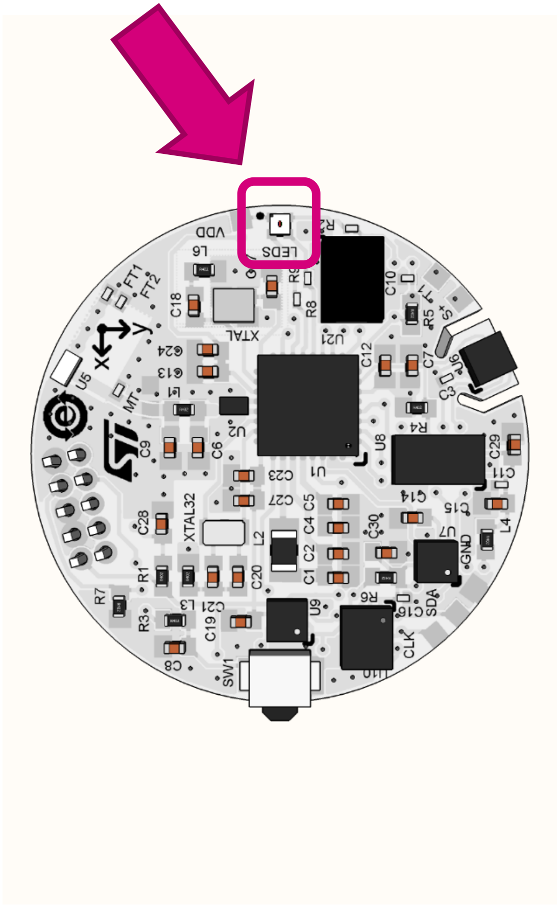
LED characteristic

Enable LED toggling



Write Packet

‘1’ LED ON
‘0’ LED OFF



Notification Packet

‘1’ LED ON
‘0’ LED OFF

1. Click the image on the app
2. Image will change color and **RED LED** toggles
3. Sent **BLE notification packet**

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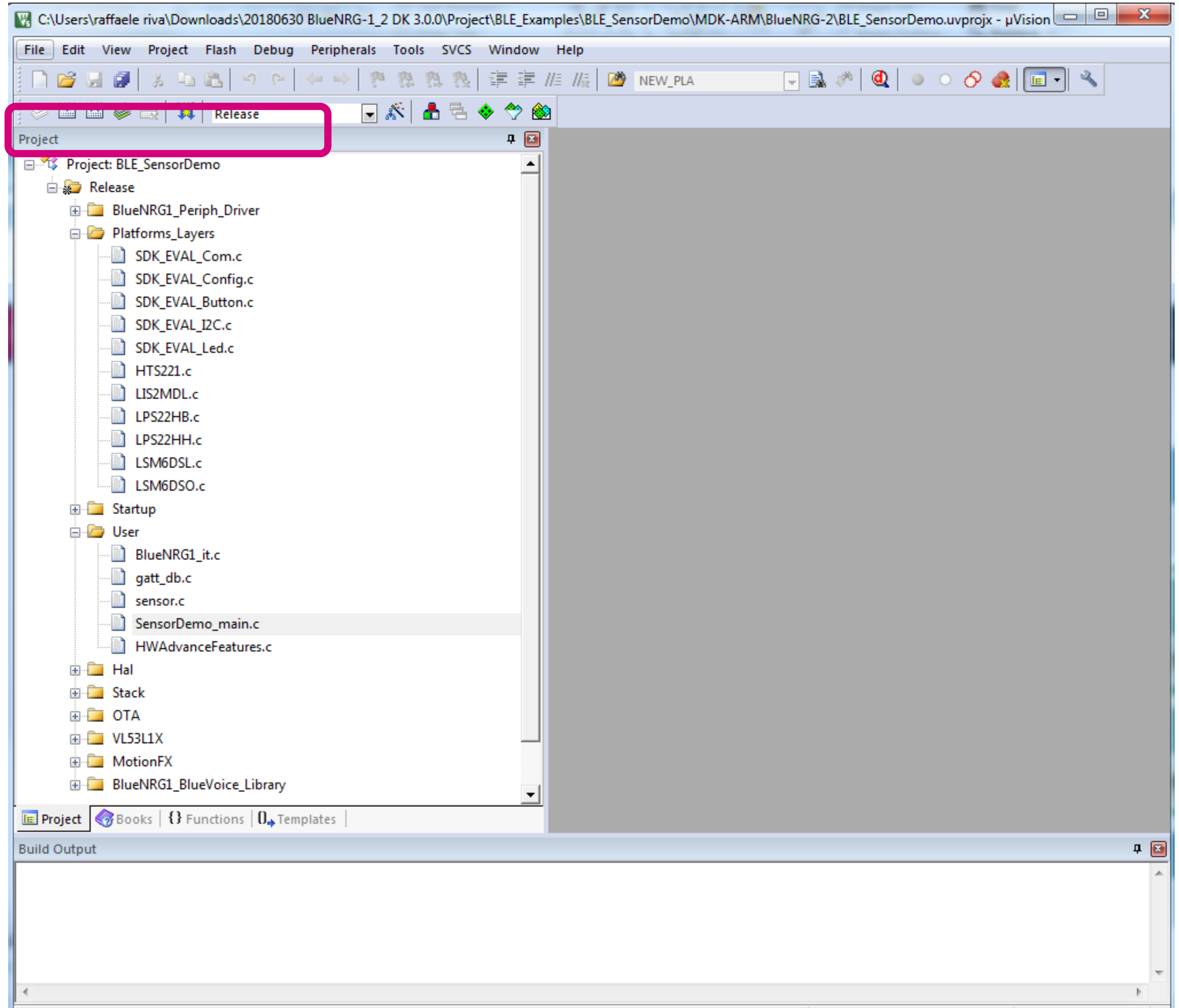
Code flow

1. Modify advertising packet
2. Client enables LED characteristic notifications
3. Client Writes in Config Char
4. Parse write command from the client and send BLE notification on LED status

Sensor Demo reference application

Now we go **back** again to **Keil uVision**



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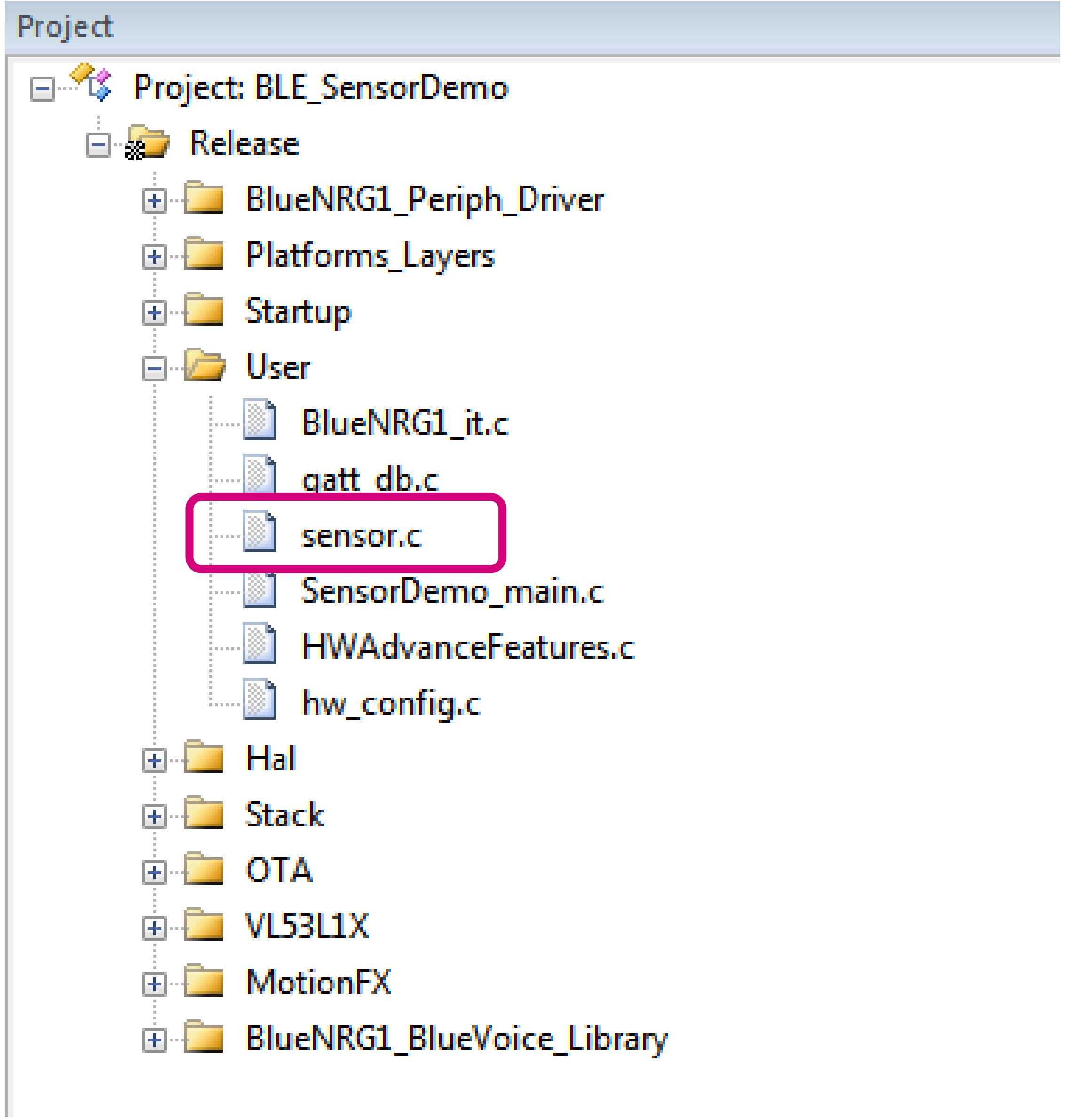
L3 STEP1: Modify advertising packet



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BlueMS

ST BlueMS Protocol

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X20
23	**22**	**21**	**20**	**19**	**18**	**17**	**16**	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0X1E
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	
RFU	RFU	RFU	RFU	Beamform	AccEvent	FreeFall	SensFusC	0X00
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X00

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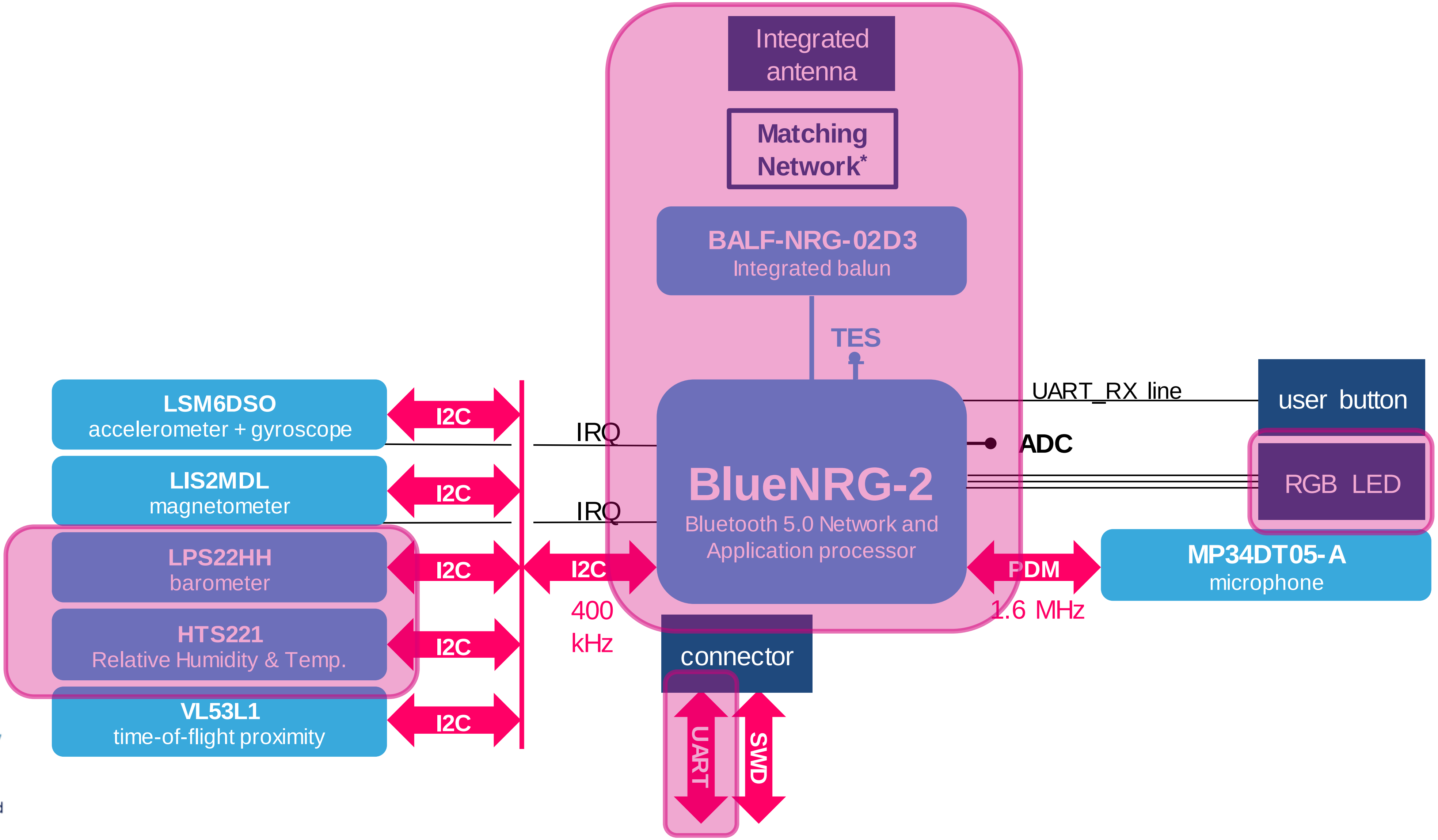
STEVAL-BCN002V1 Block Diagram



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L3 STEP1: Modify advertising packet

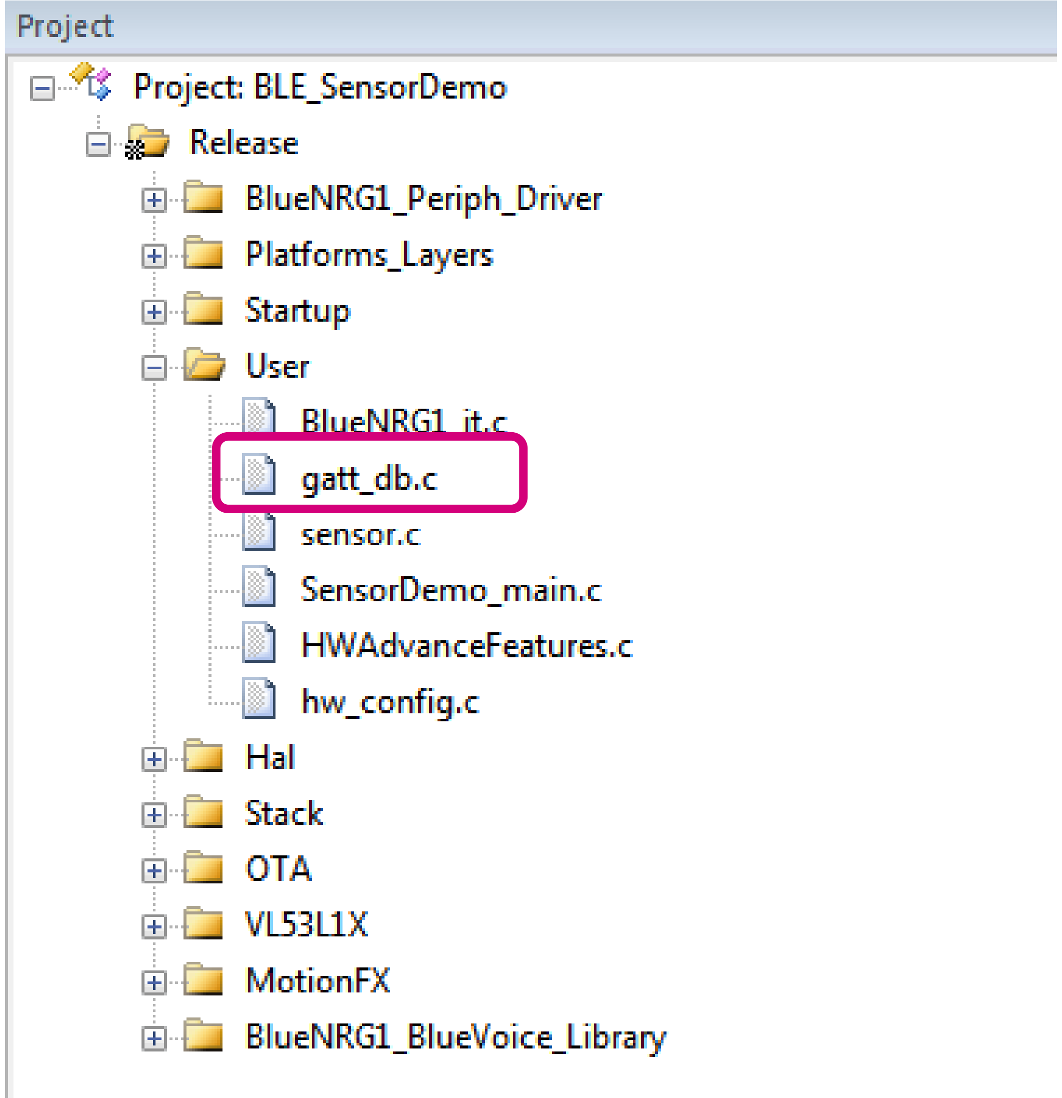
Modify the Feature Mask in the advertisement payload

1. In the file **sensor.c**
2. Go to **line 423**
3. Modify Feature Mask byte#1 from 0x00 to **0x20**

sensor.c

```c
411 void Set_DeviceConnectable(void) {
412
413     uint8_t manuf_data[26] = {
414     2,                          /* Length of AD type Transmission Power */
415     0x0A, 0x00,                 /* Transmission Power = 0 dBm */
416     8,                          /* Length of AD type Complete Local Name */
417     0x09,                       /* AD type Complete Local Name */
418     NAME_ALLMEMS,               /* Local Name */
419     13,                         /* Length of AD type Manufacturer info */
420     0xFF,                       /* AD type Manufacturer info */
421     0x01,                       /* Protocol version */
422     0x05,                       /* Device ID: 0x05 = STEVAL-BCN002V1 Board */
423     0x20,                       /* Feature Mask byte#1: LAB3 0x20 (LED) / LAB5 (
424     0x1E,                       /* Feature Mask byte#2: LAB4 0x9E (Acc+Press+Hum
425     0x00,                       /* Feature Mask byte#3: LAB4 0x04 (AccEvents) /
426     0x00,                       /* Feature Mask byte#4: LAB5 0x40 (eCompass) */
427     0x00,                       /* BLE MAC start */
```

L3 STEP2: Client enables LED characteristic notifications



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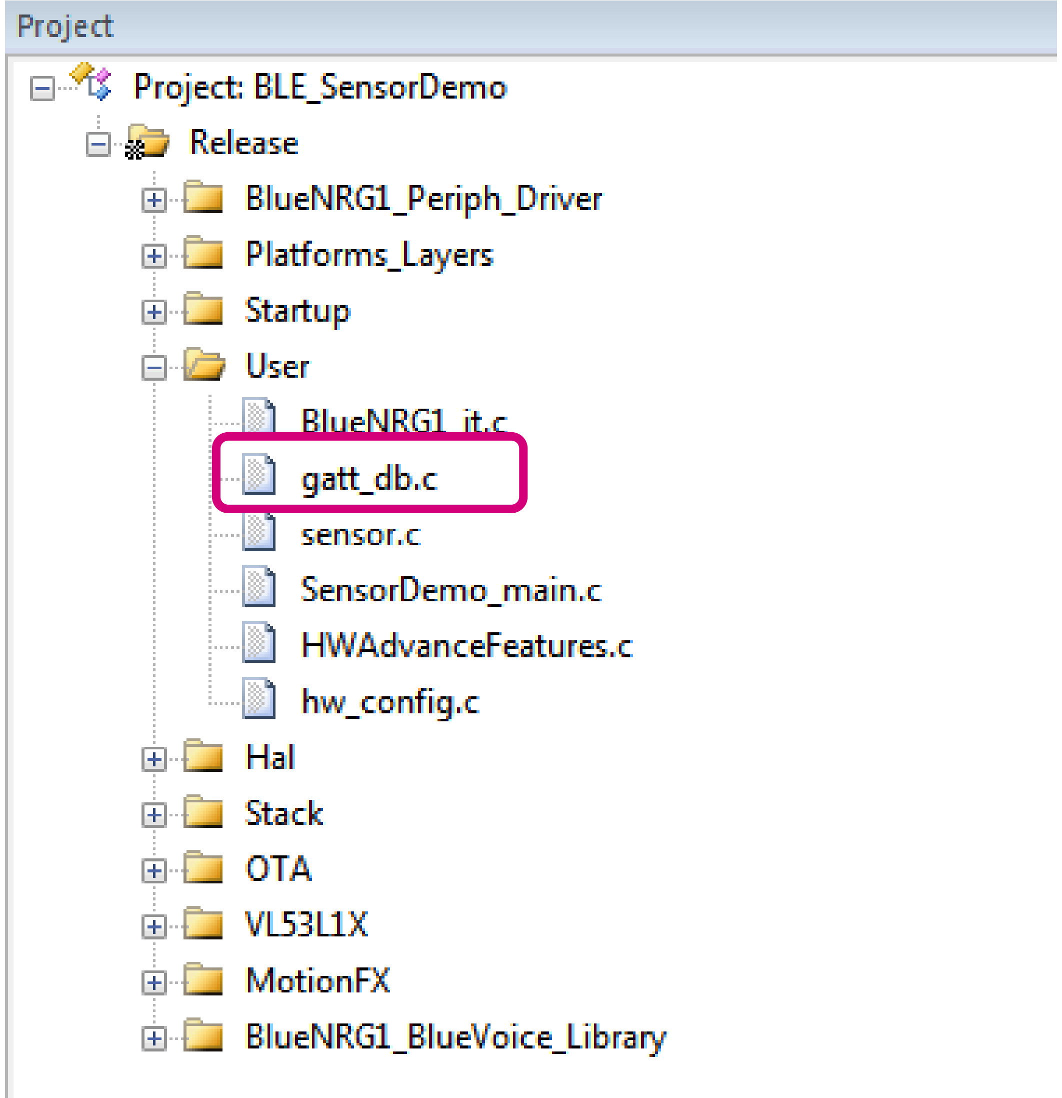
L3 STEP2: Client enables LED characteristic notifications

1. In the file **gatt_db.c** go to the **line 686**
2. Client writes in the LED Characteristics Client Configurator Descriptor (CCCD) and Server enables notifications through the ***xFeatureNotification*** structure in **line 689** by ***xFeatureNotification.LedNotification = true;***

```
686   } else if (attr_handle == (LedCharHandle + 2)) {
687
688     if (att_data[0] == 01) {
689       xFeatureNotification.LedNotification = true;
690       PRINTF("Led Notification ON\n\r");
691     } else if (att_data[0] == 0) {
692       xFeatureNotification.LedNotification = false;
693       PRINTF("Led Notification OFF\n\r");
694     }
```

L3 STEP3: Client Writes in Config Char



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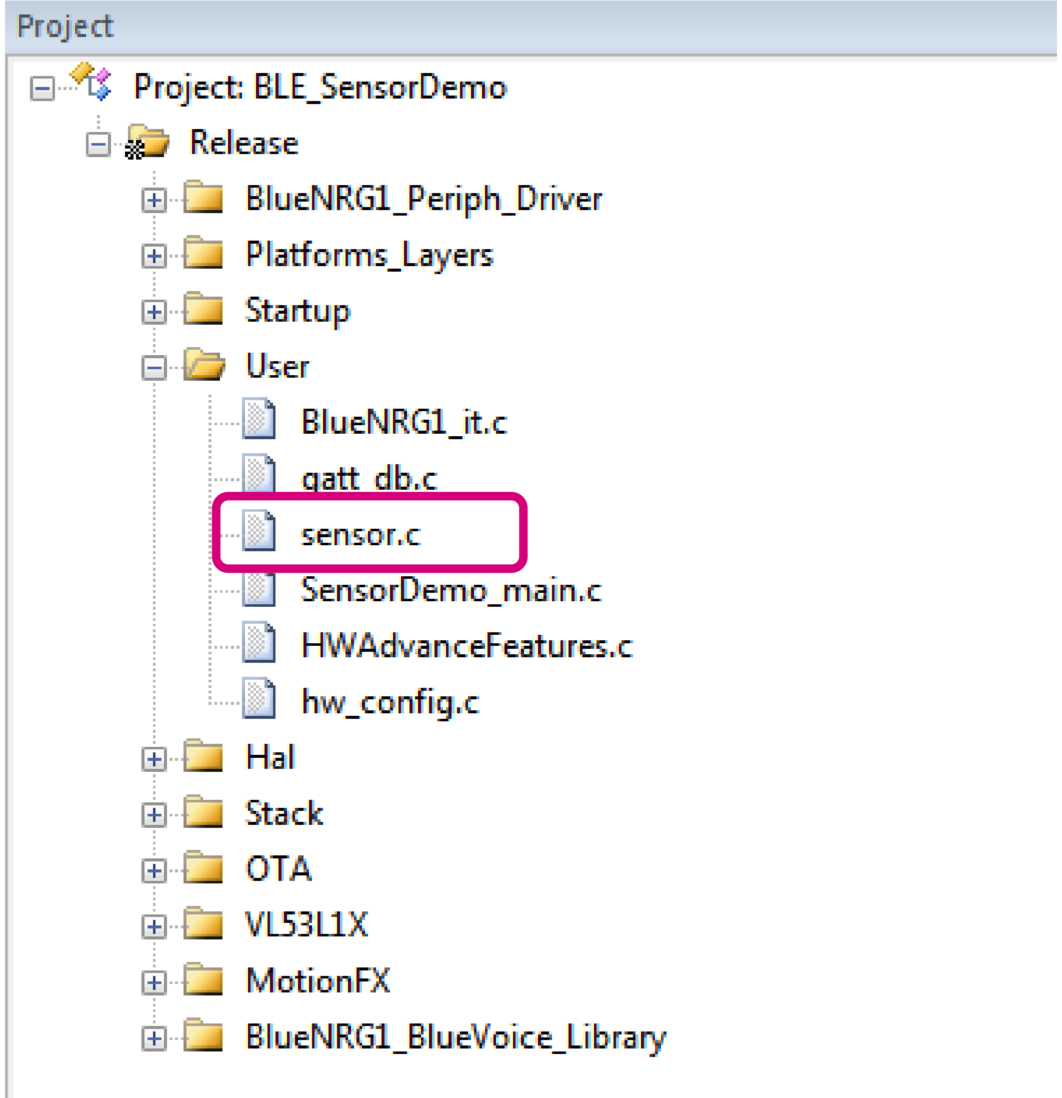
L3 STEP3: Client Writes in Config Char

1. In the file **gatt_db.c** go to the **line 816**
2. Client writes in the Config Char and Server parses the command through the function ***ConfigCommandParsing(att_data, data_length);***

```
816    } else if (attr_handle == ConfigCharHandle + 1) {
817
818      /* Received one write command from Client on Configuration characteristic */
819      ConfigCommandParsing(att_data, data_length);
820
821    }
```

L3 STEP4: Parse write command and send BLE notification on LED status



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L3 STEP4: Parse write command and send BLE notification on LED status

1. Line **941**: **ConfigCommandParsing**
2. Check on the FeatureMask (line **947**)
3. If it's the LED feature mask (line **1125**)
4. Check on the command value. If 0x01
5. Turn ON LED3
6. Send Notification on the Config char on the command received and parsed
7. Send Notification on the LED char with the LED status

```
941  uint32_t ConfigCommandParsing(uint8_t *
942    FeatureMask = (att_data[3]) | (att_da
943    uint8_t Command = att_data[4];
944    uint8_t Data = att_data[5];
945    uint32_t SendItBack = 1;
946
947    switch (FeatureMask) {
```

```
1125  case FEATURE_MASK_LED:
1126    switch (Command) {
1127      case 1:
1128        SdkEvalLedOn(LED1);
1129        PRINTF("Enabled: RGB led\n\r");
1130        Config_Notify(FEATURE_MASK_LED, Command, Data);
1131        break;
1132      case 0:
1133        SdkEvalLedOff(LED1);
1134        PRINTF("Disabled: RGB led\n\r");
1135        Config_Notify(FEATURE_MASK_LED, Command, Data);
1136        break;
1137    }
1138
1139    if (xFeatureNotification.LedNotification) {
1140      if (SdkEvalLedGetState(LED1))
1141        Led_Update(ENABLE);
1142      else
1143        Led_Update(DISABLE);
1144    }
1145  break;
```

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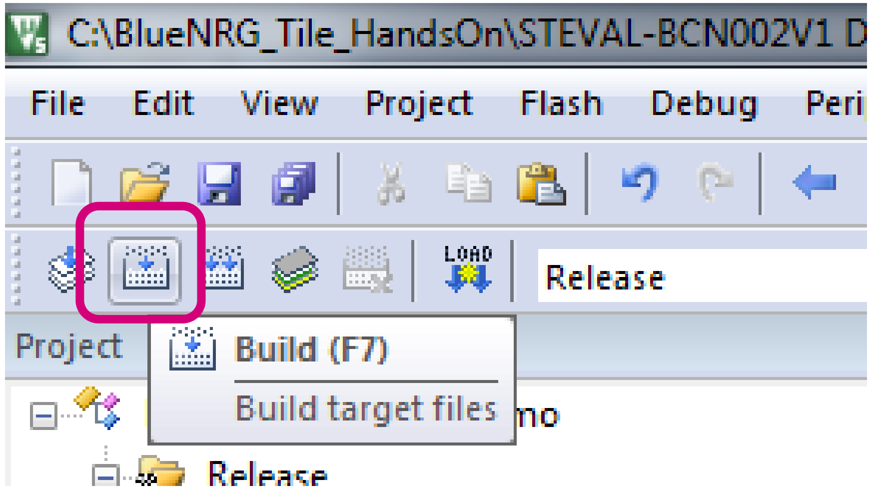
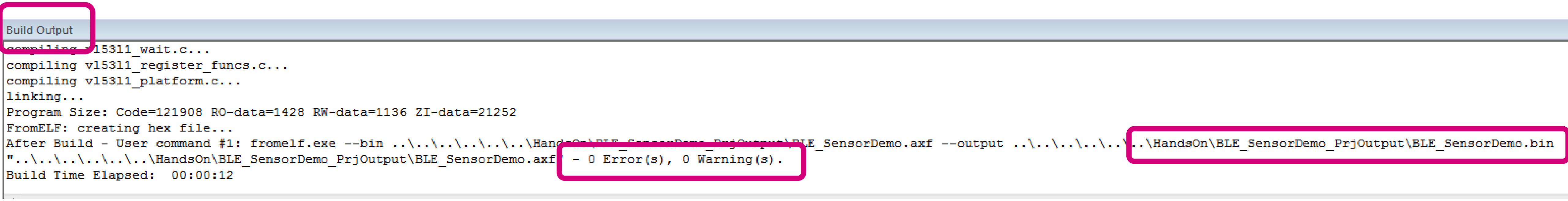
Build the new code

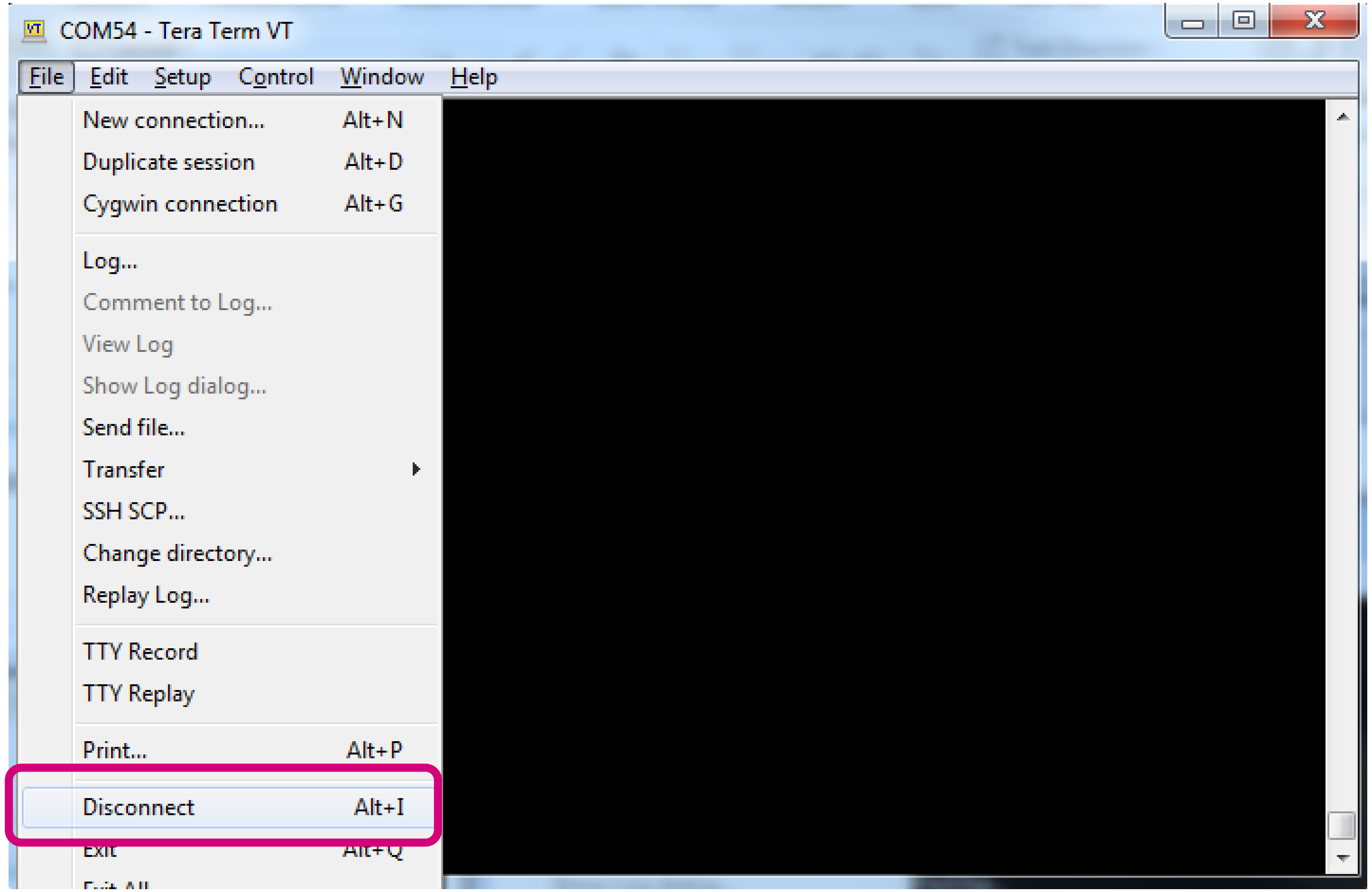
1. Click on the **Build button** (top left corner) or hit **F7** on your keyboard
2. In the **Build Output** window (bottom) wait for the build to be completed.
   - **BLE_SensorDemo.bin** created
   - "**0 Error(s), 0 Warning(s)**" message appear





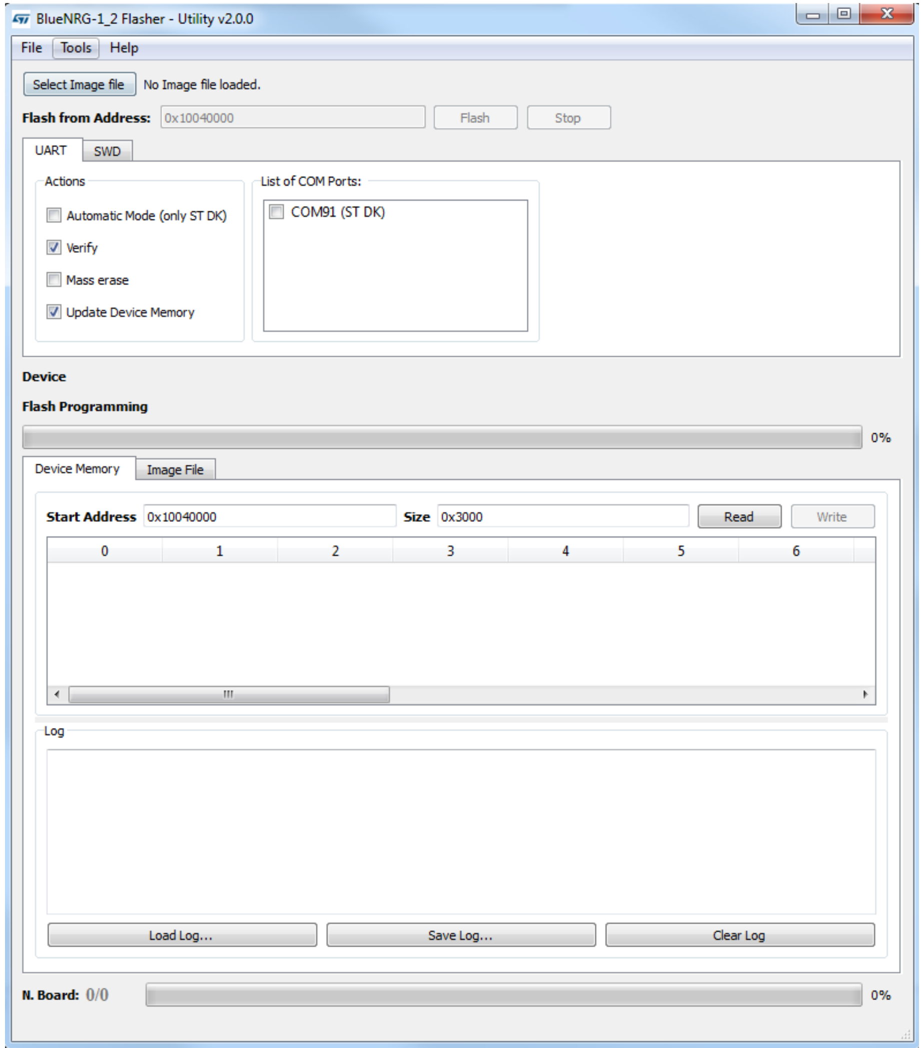
Disconnect the serial terminal

1. Go back to TeraTerm
2. Click on the **File->Disconnect**



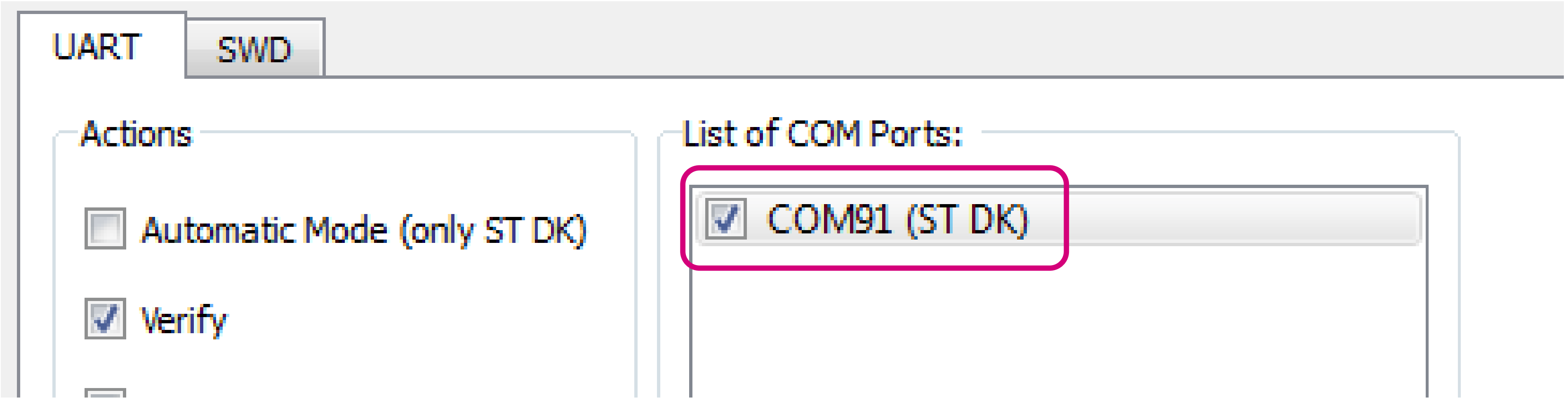
Re-flash the BlueNRG-2

1. Go back to the BlueNRG-2 Flasher Utility



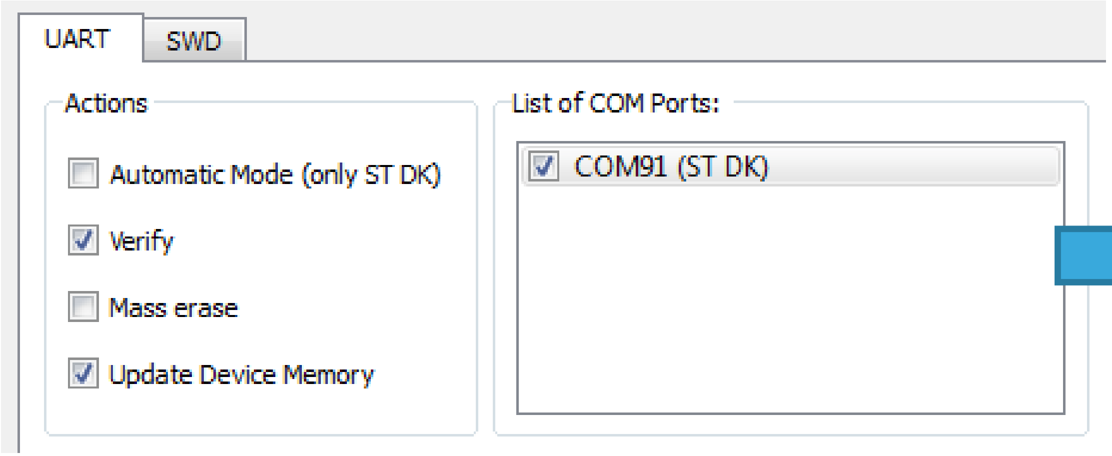
Flash the BlueNRG-2 1/5

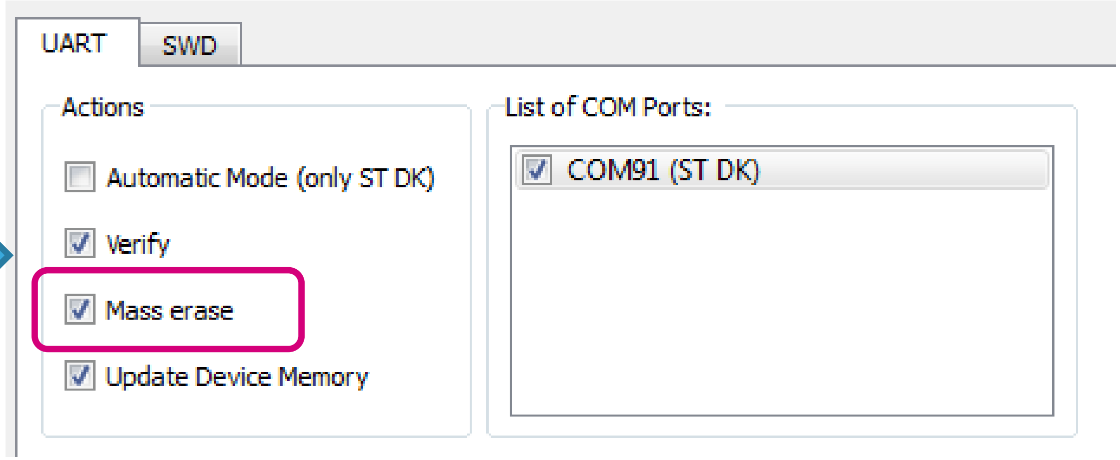
1. Select the COM port labeled **(ST DK)**



Flash the BlueNRG-2 2/5

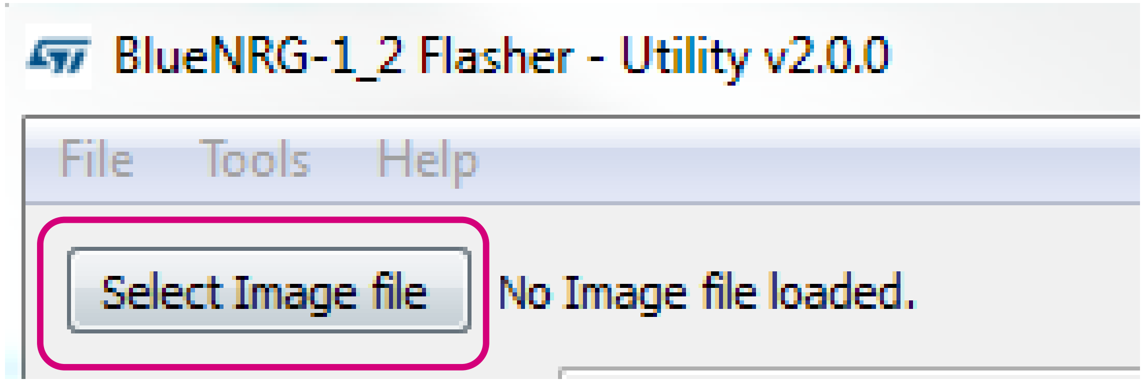
1. Click on **Mass Erase**





Flash the BlueNRG-2 3/5

1. Click on **Select Image file** button



2. And browse the following **path**

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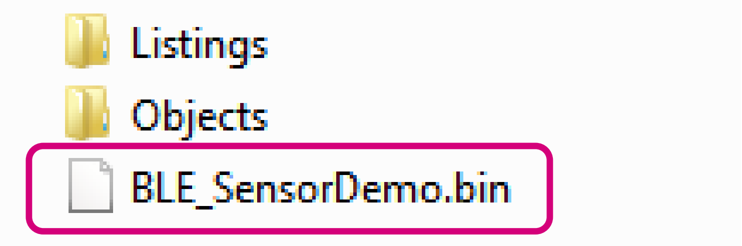
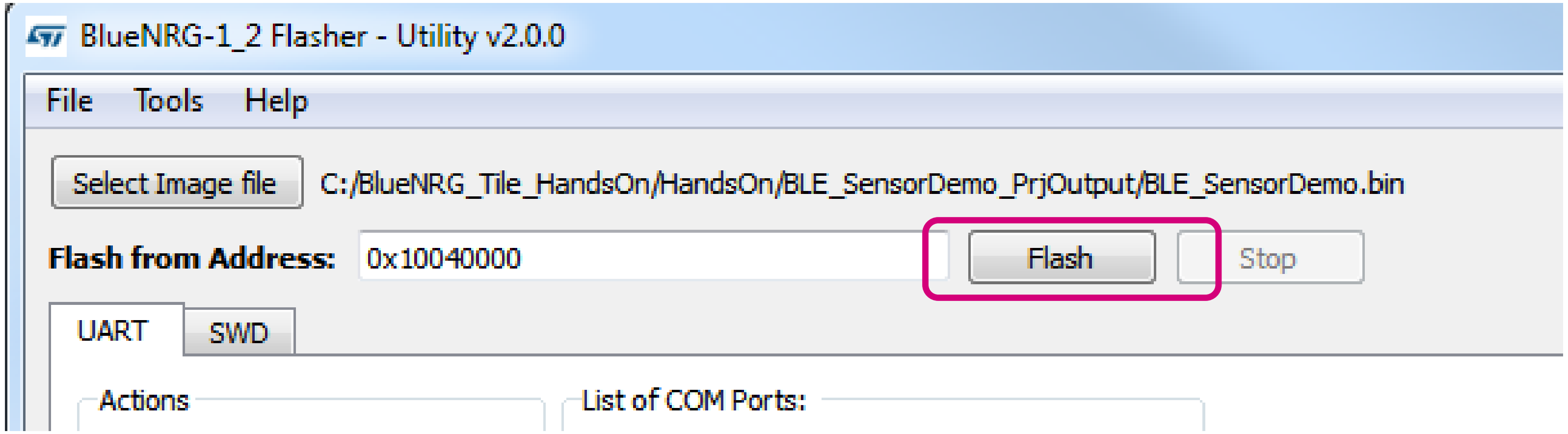
Flash the BlueNRG-2 4/5

1. Select **BLE_SensorDemo.bin**



2. Click on the **Flash** button



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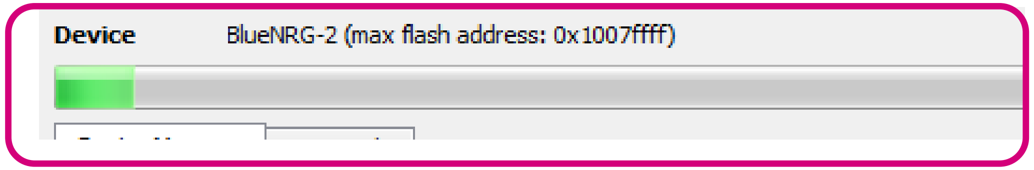
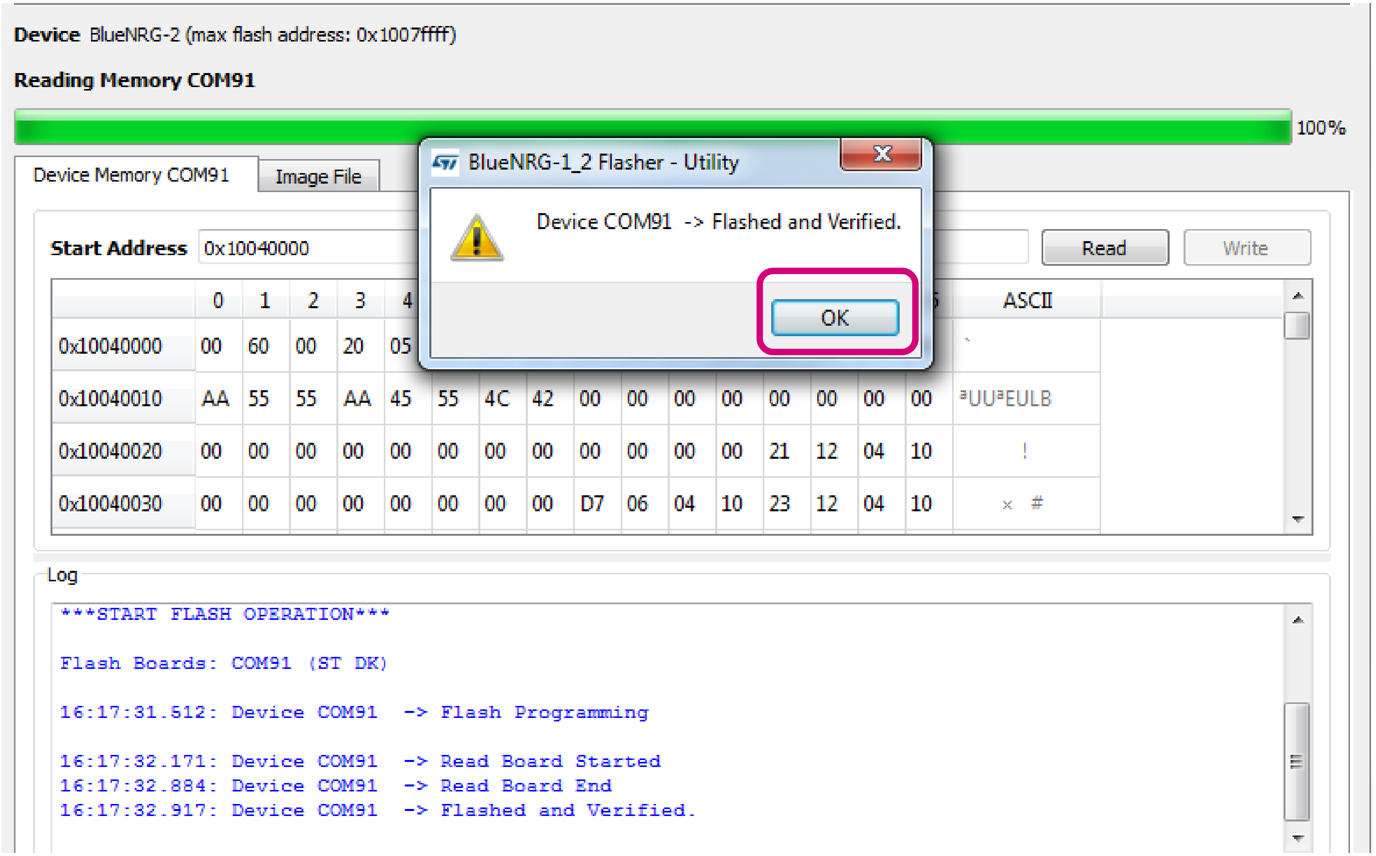
Flash the BlueNRG-2 5/5

1. Flashing starts: **green bar** proceeding



2. Wait for the **pop-up** window and click on **OK**



Do NOT close the Utility!

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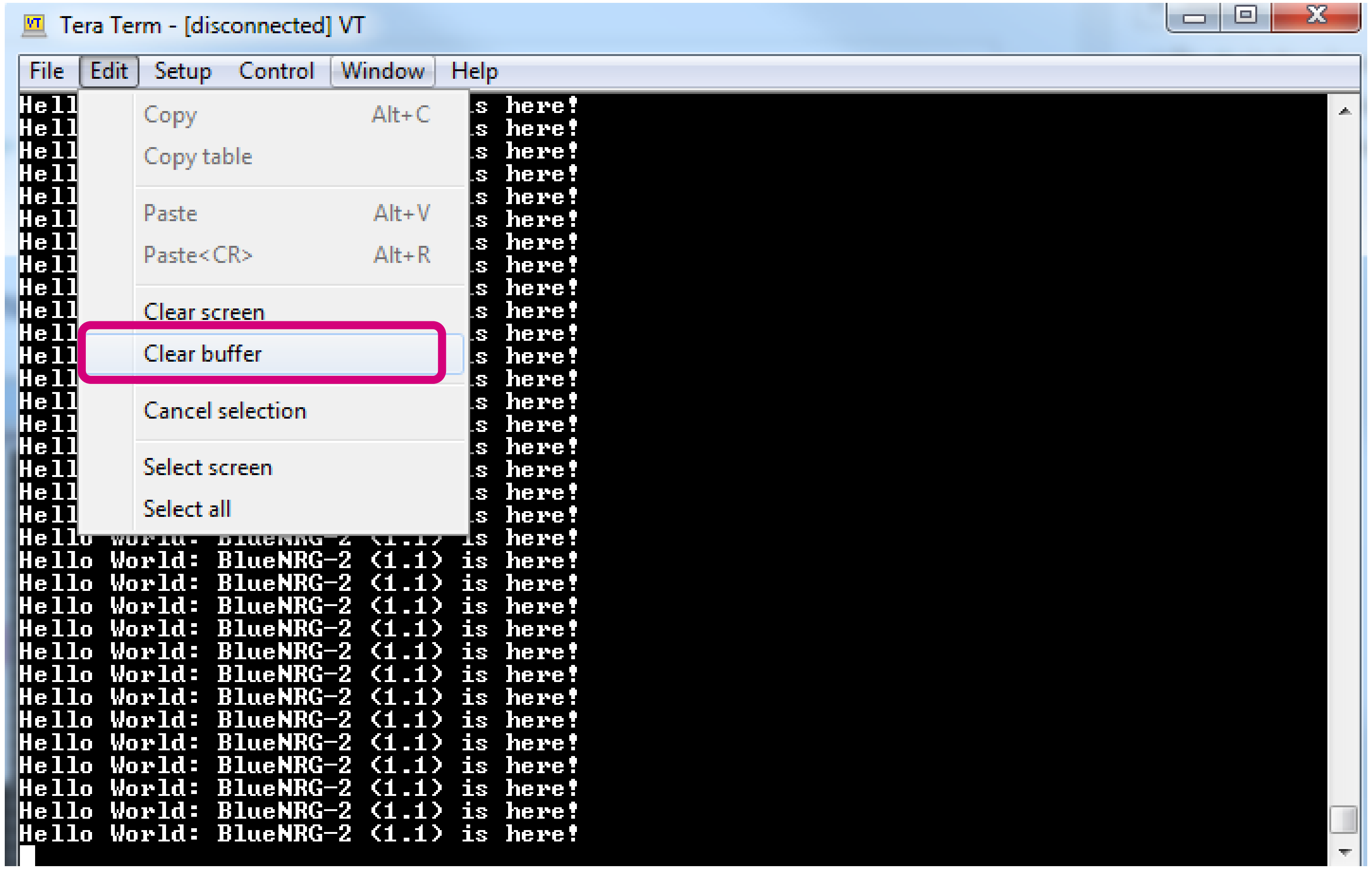
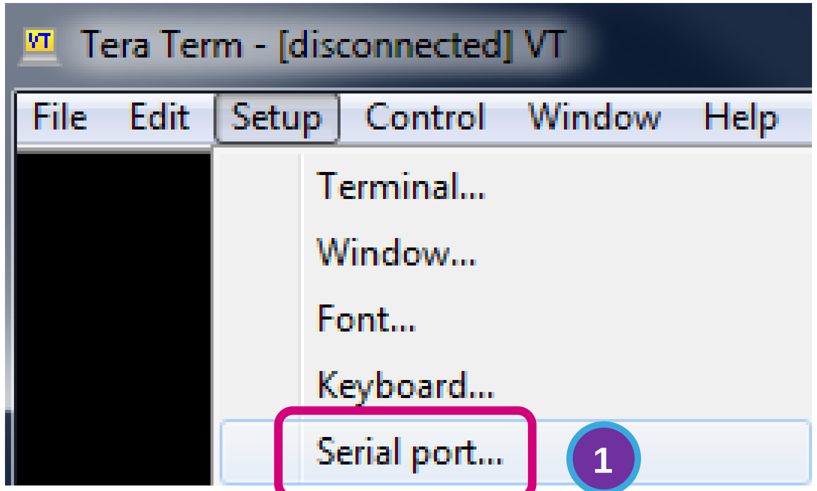
Clean Buffer in the serial terminal

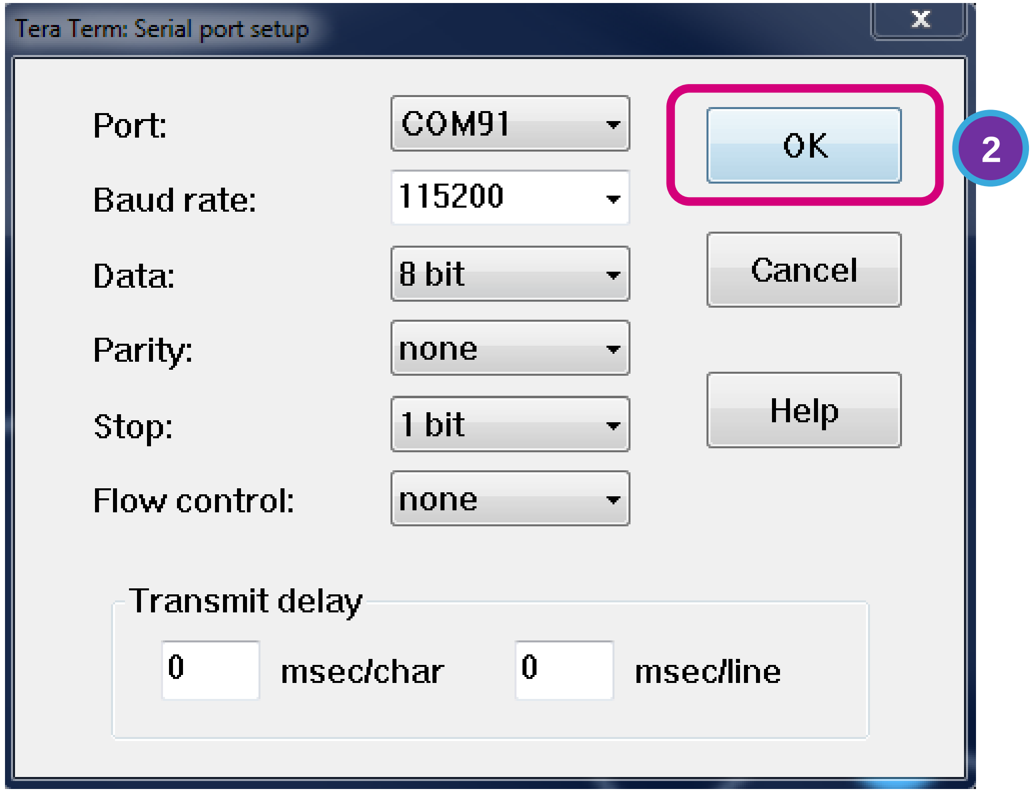
1. In Tera Term in order to have the terminal clean, go to **Edit -> Clear buffer**



Reconnect the serial terminal

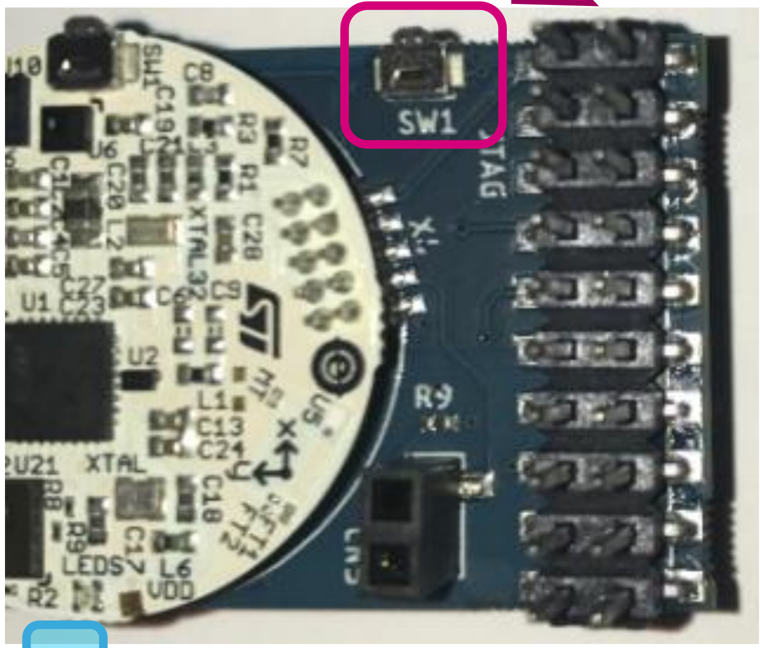
1. Click **Setup** -> **Serial port…**
2. Serial port should already configured. Just need to click on **OK**

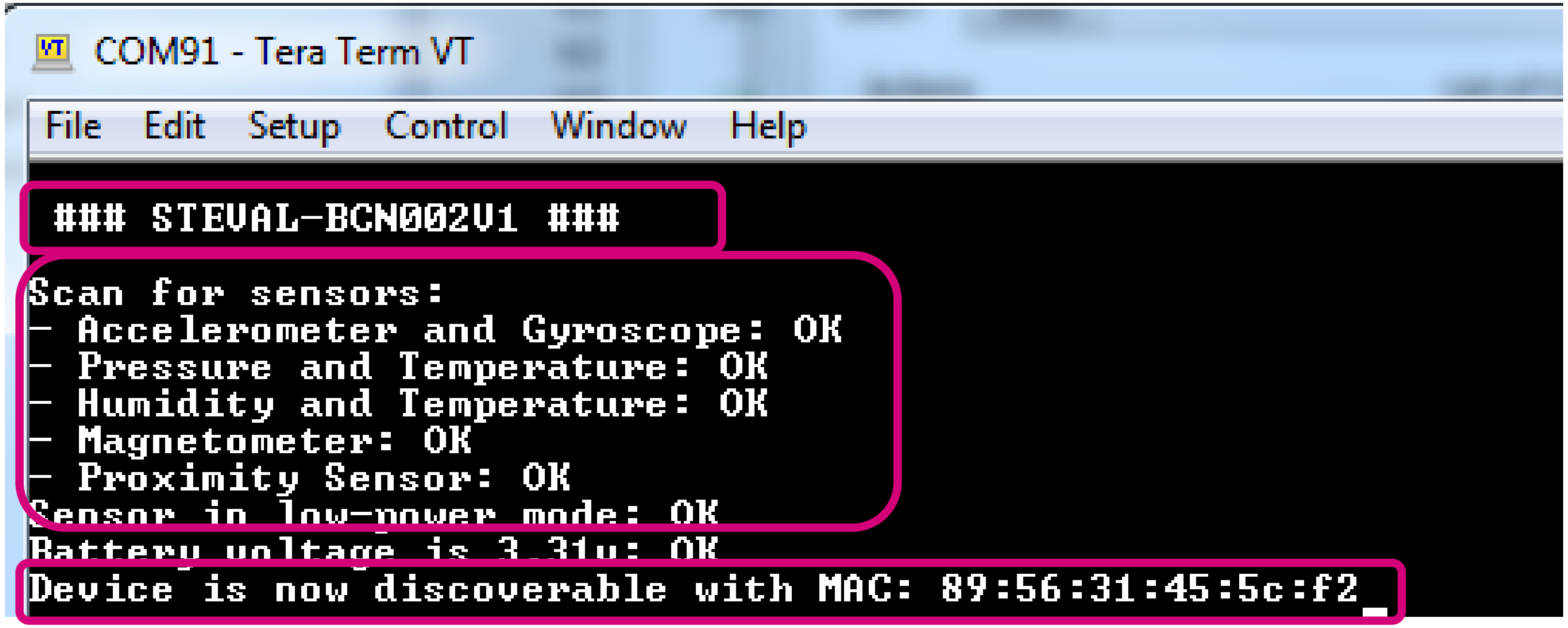




Sanity Check on serial port

Push **SW1 button** on the blue motherboard -> **LED blinking Blue**





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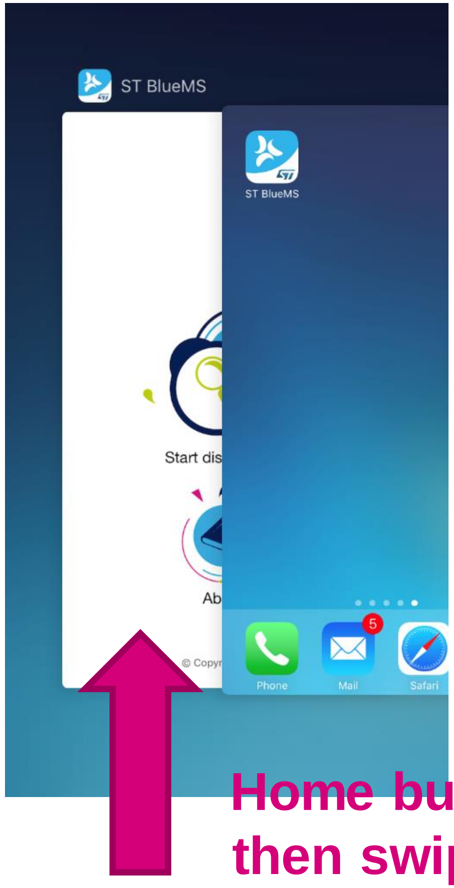
Connect using the BlueMS App

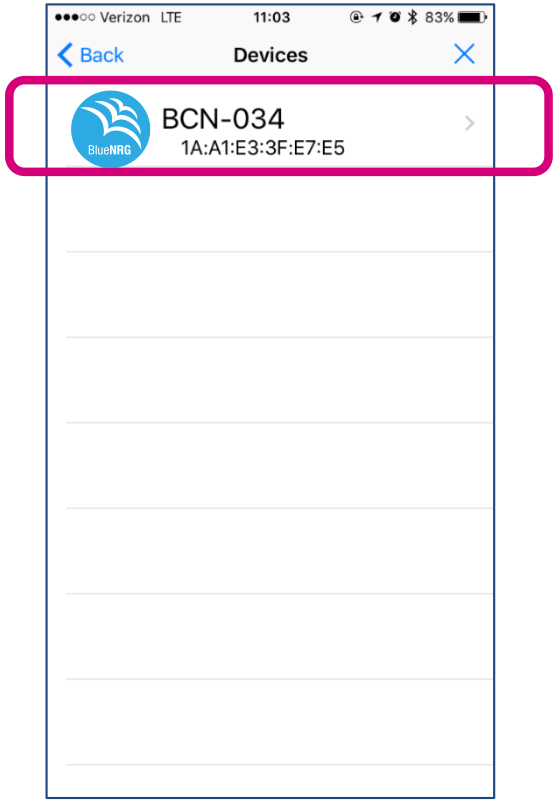
1 **“Kill” the BlueMS app**



Home button and then swipe to top

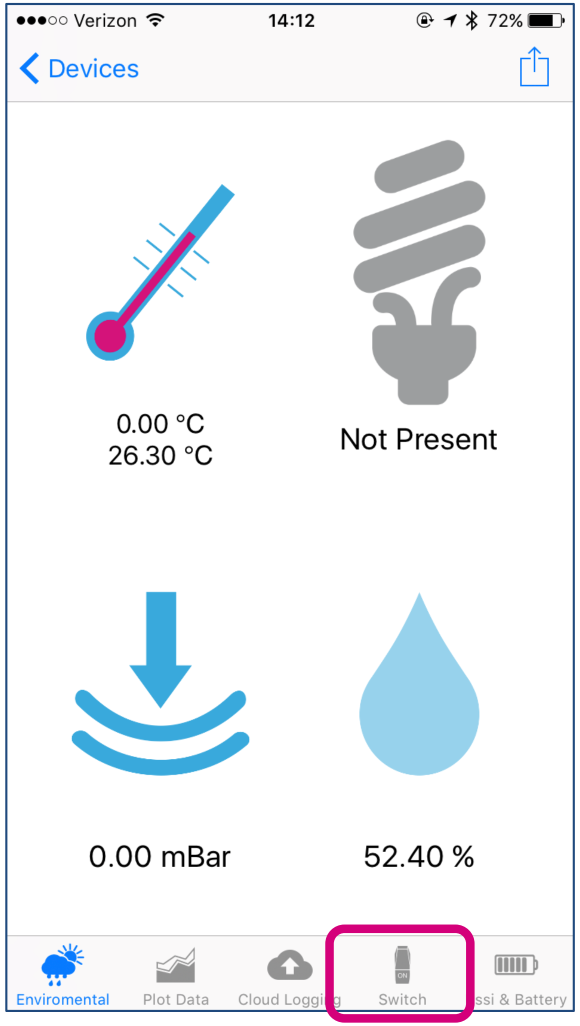
2 **Touch “Start discovering”**

3 **Select your STEVAL-BCN002V1**

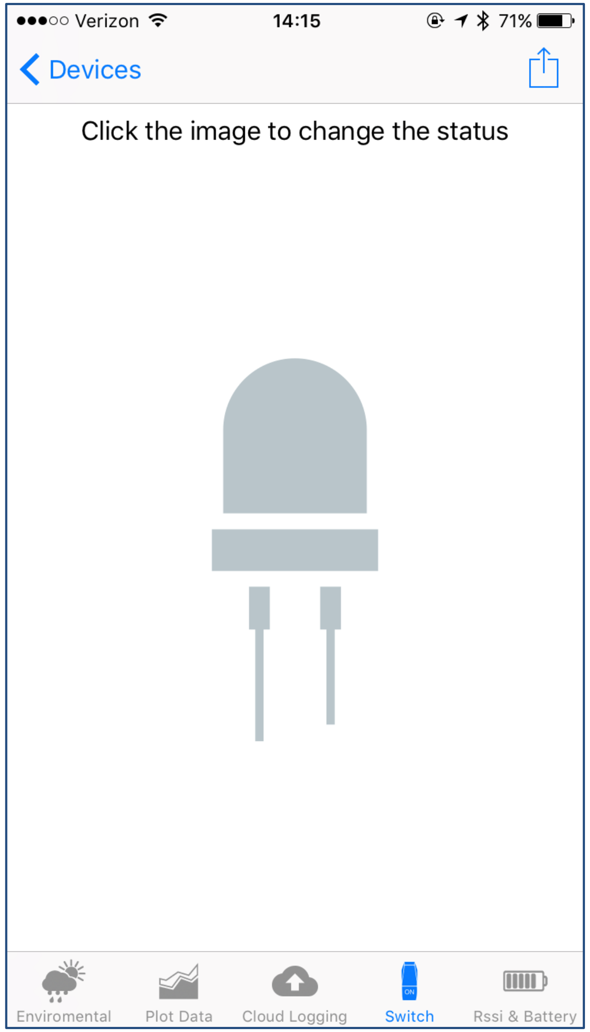


enabling LED toggling

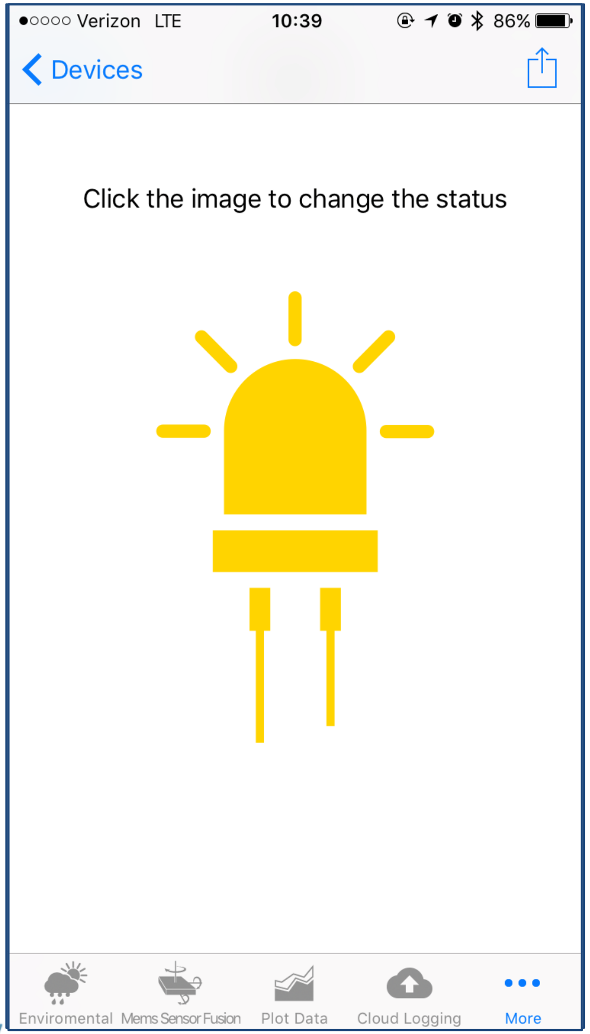
Click on “Switch”



A new page will appear



Enable LED toggling

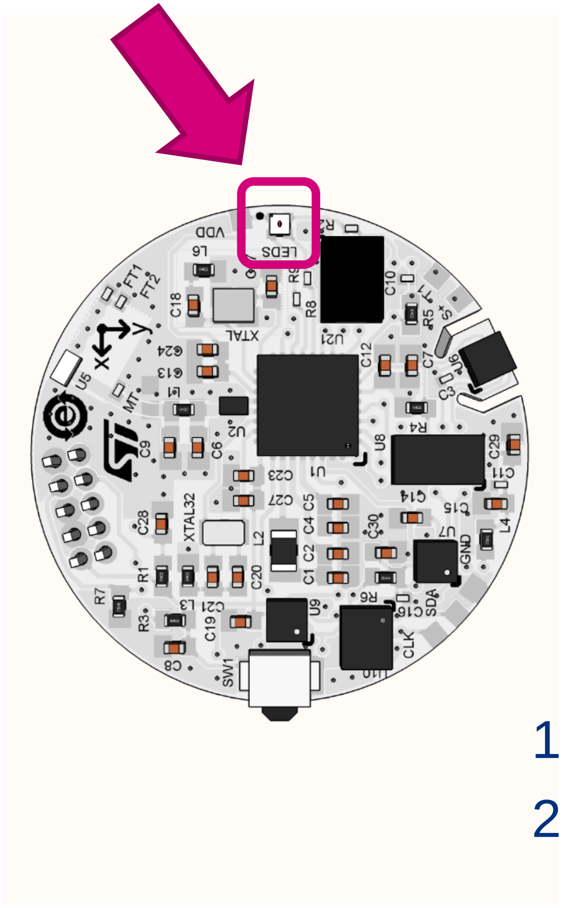


Write Packet

‘1’ LED ON
‘0’ LED OFF

Notification Packet

‘1’ LED ON
‘0’ LED OFF



1. Click the image on the app
2. Image will change color and **RED LED** toggles
3. Sent **BLE notification packet**

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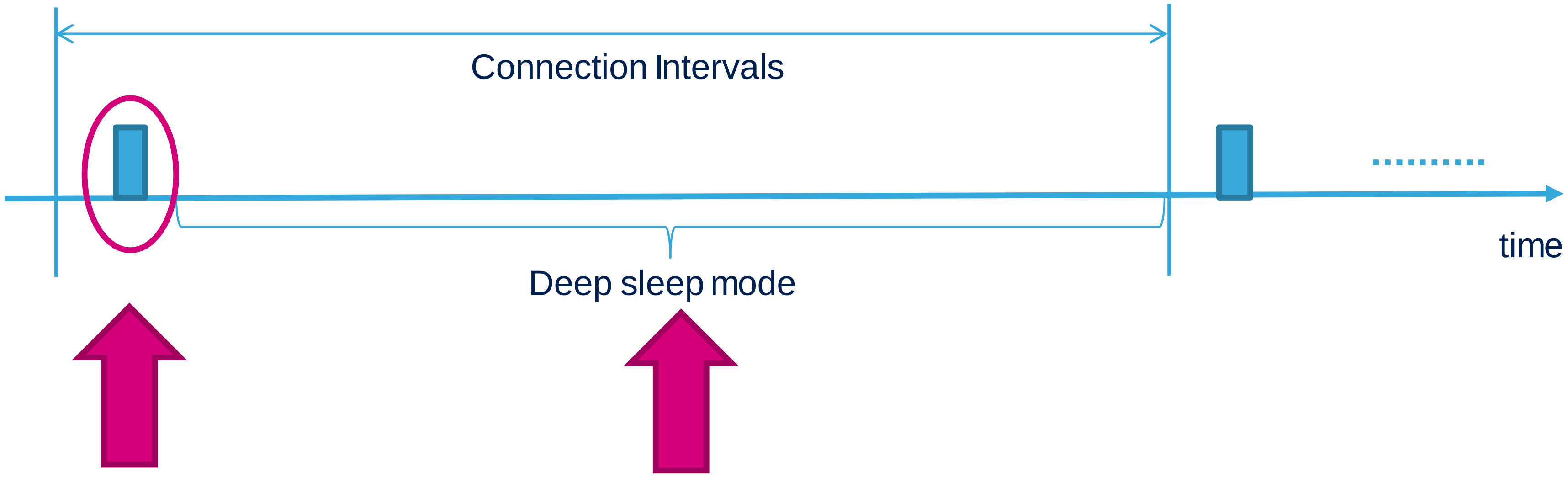
LED toggling

- **Red LED** fast toggling shows the entering/exiting to/from Sleep mode



In Active Phase
LED is **ON**

In Sleep Phase
LED is **OFF**

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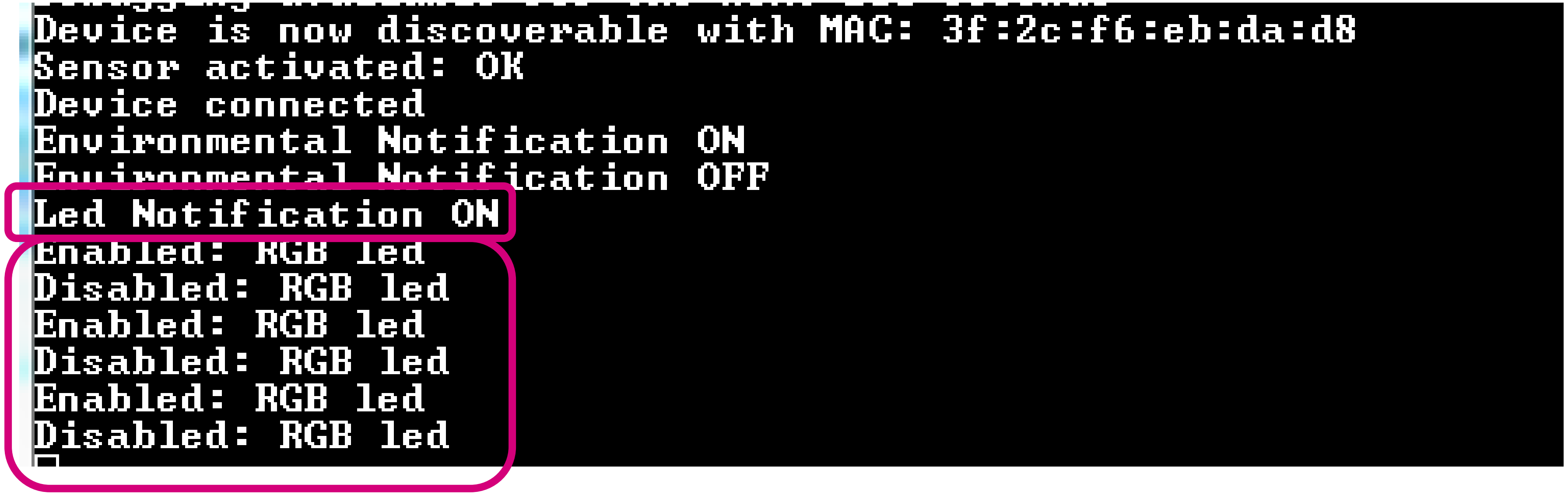
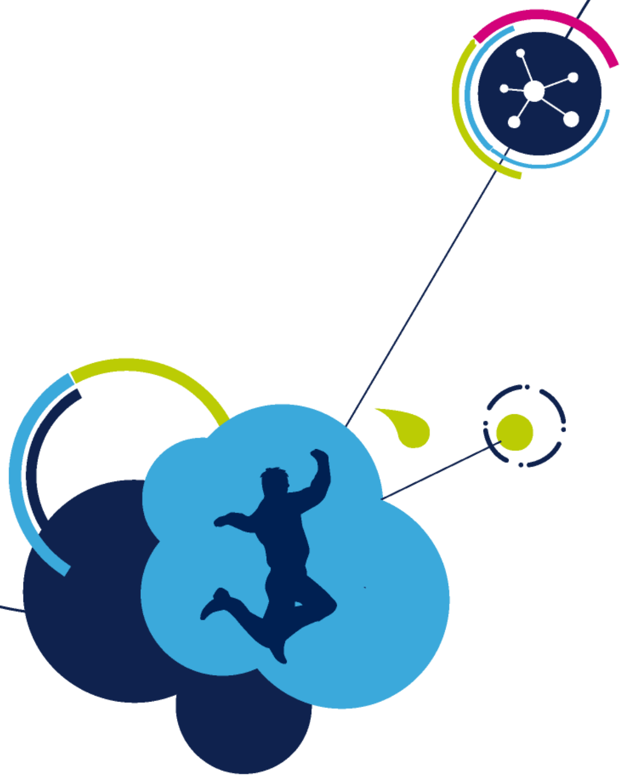
TeraTerm output

- String “*LED Notification ON*” will appear as the app tab will be enabled
- Each time user click on the LED icon in the BlueMS app, the Write command is sent to the board and the LED will toggle accordingly (“Enabled: RGB led” = ON, “Disabled: RGB led” = OFF)





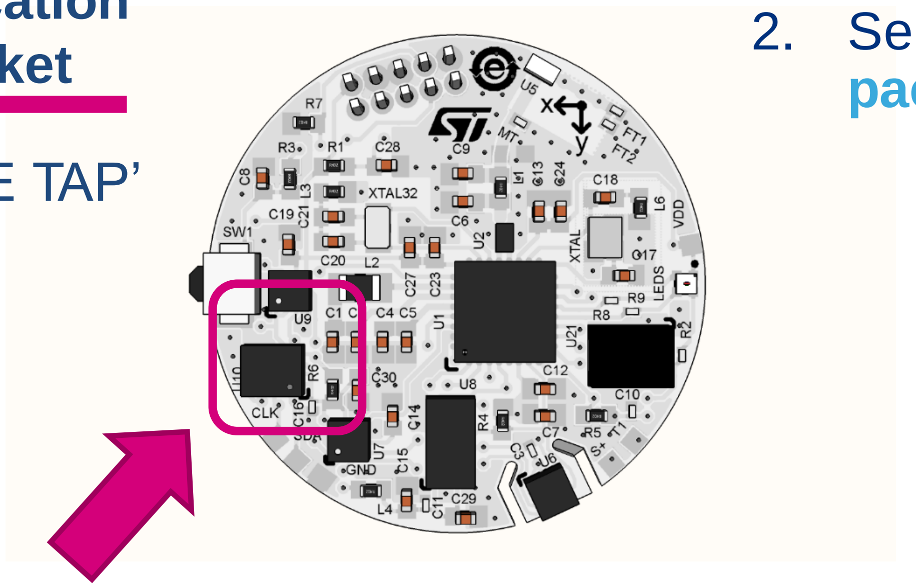
Lab 4

Accelerometer embedded events detection

Example - Single Tap

Notification Packet

'SINGLE TAP'



1. On the board perform a Single Tap
2. Send **BLE notification packet**

NOTE: this is just an example for SingleTap. Other events will be displayed later in the lab!

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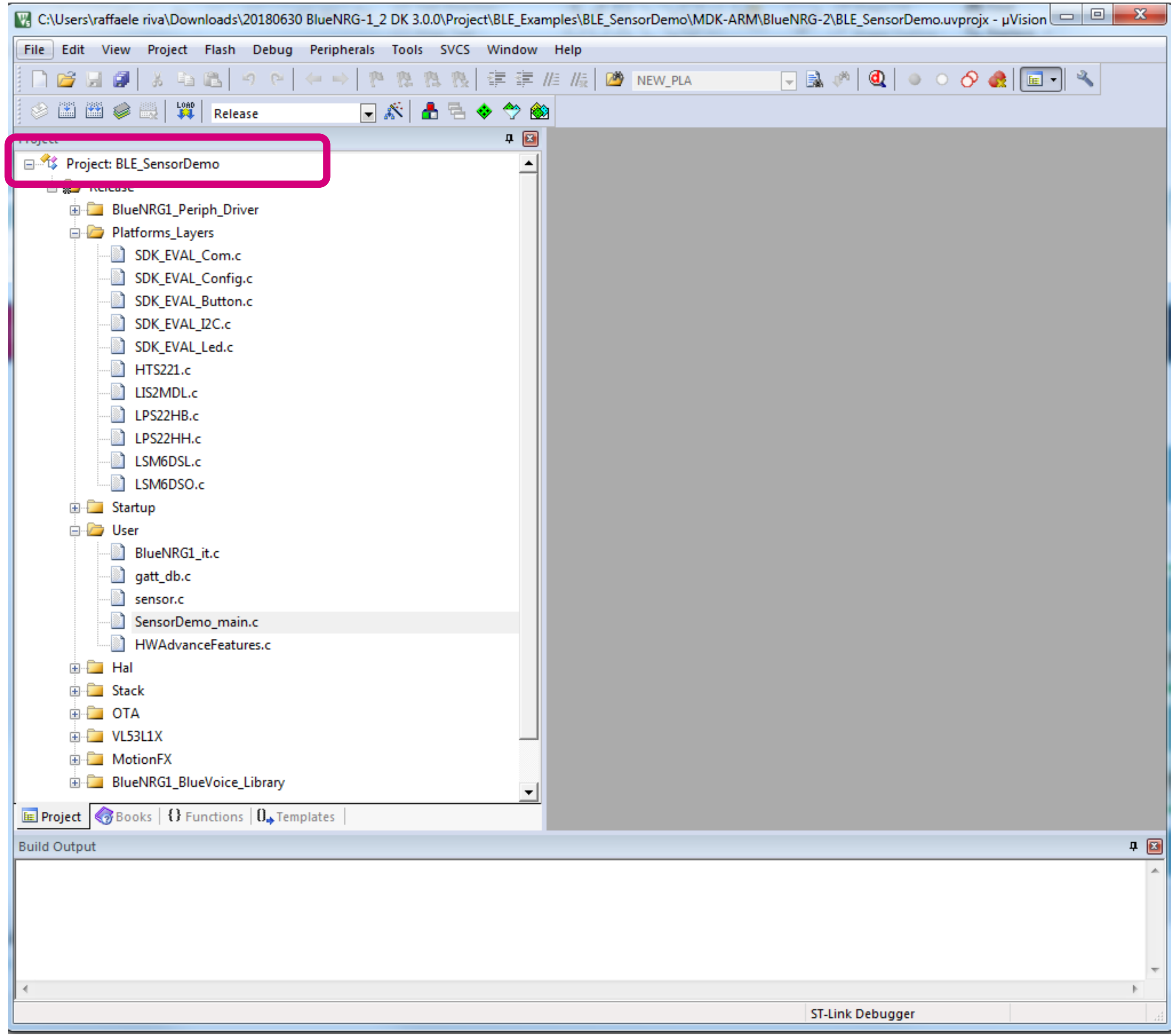
Code modifications

1. Modify advertising packet
2. Enable Accelerometer events detection feature
3. Read Event Status and send BLE notification through an update on the Accelerometer Event characteristic value

Sensor Demo reference application

Now we go **back** again to **Keil uVision**



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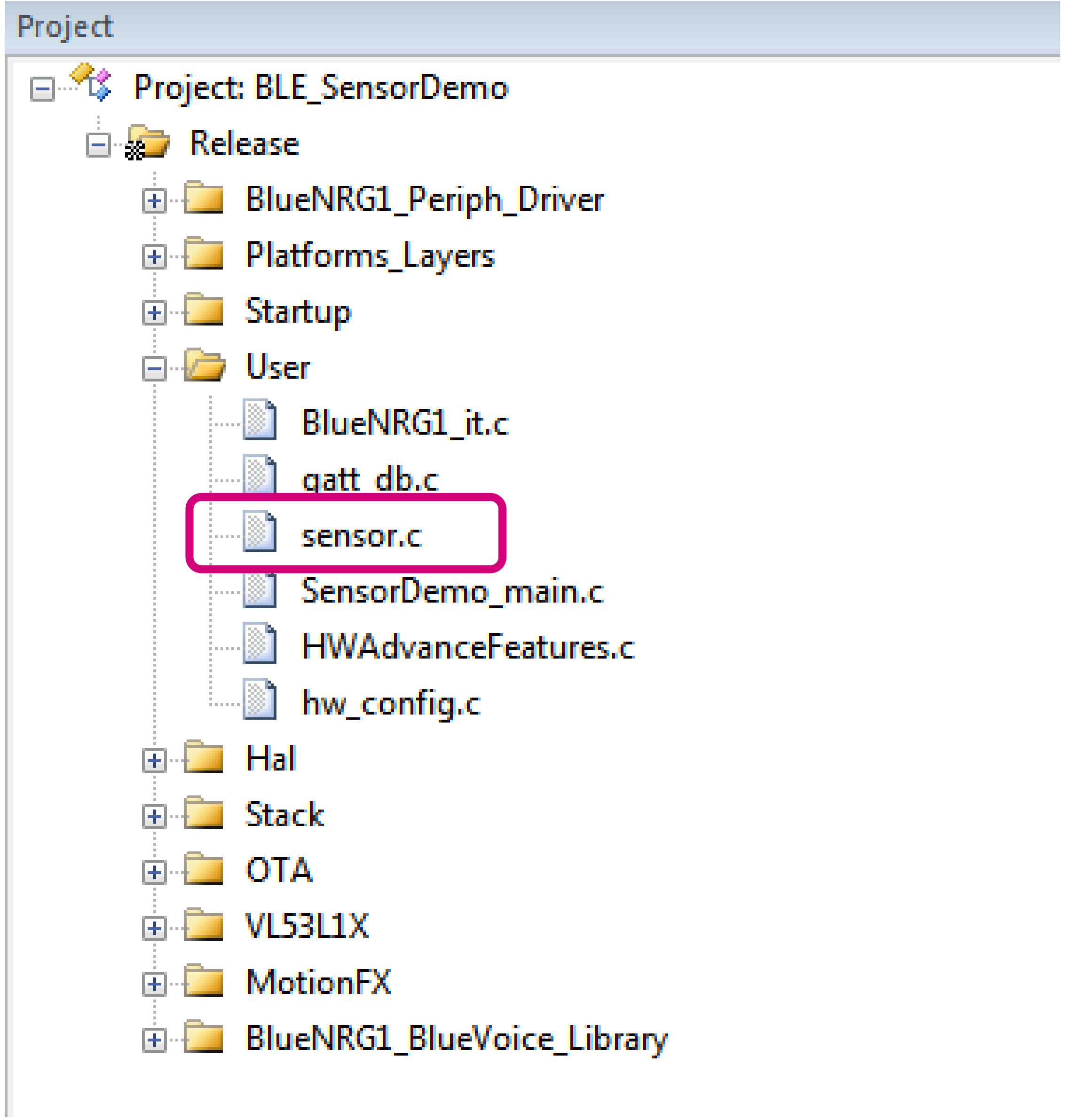
L4 STEP1: Modify advertising packet



ST BlueMS Protocol

BlueMS

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X20
23	**22**	**21**	**20**	**19**	**18**	**17**	**16**	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0X9E
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	
RFU	RFU	RFU	RFU	Beamform	AccEvent	FreeFall	SensFusC	0X04
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X00

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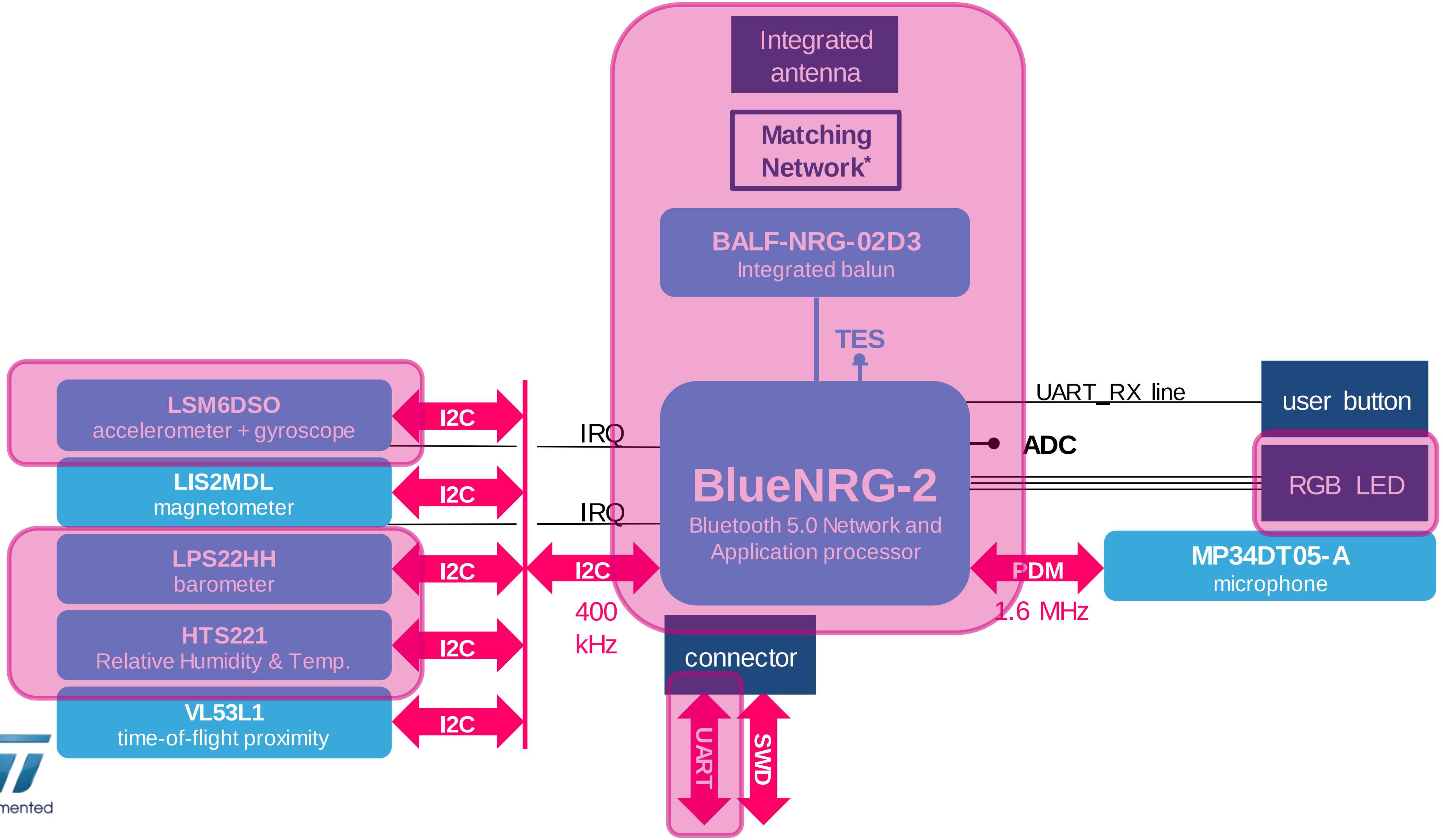
STEVAL-BCN002V1 Block Diagram



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L4 STEP1: Modify advertising packet

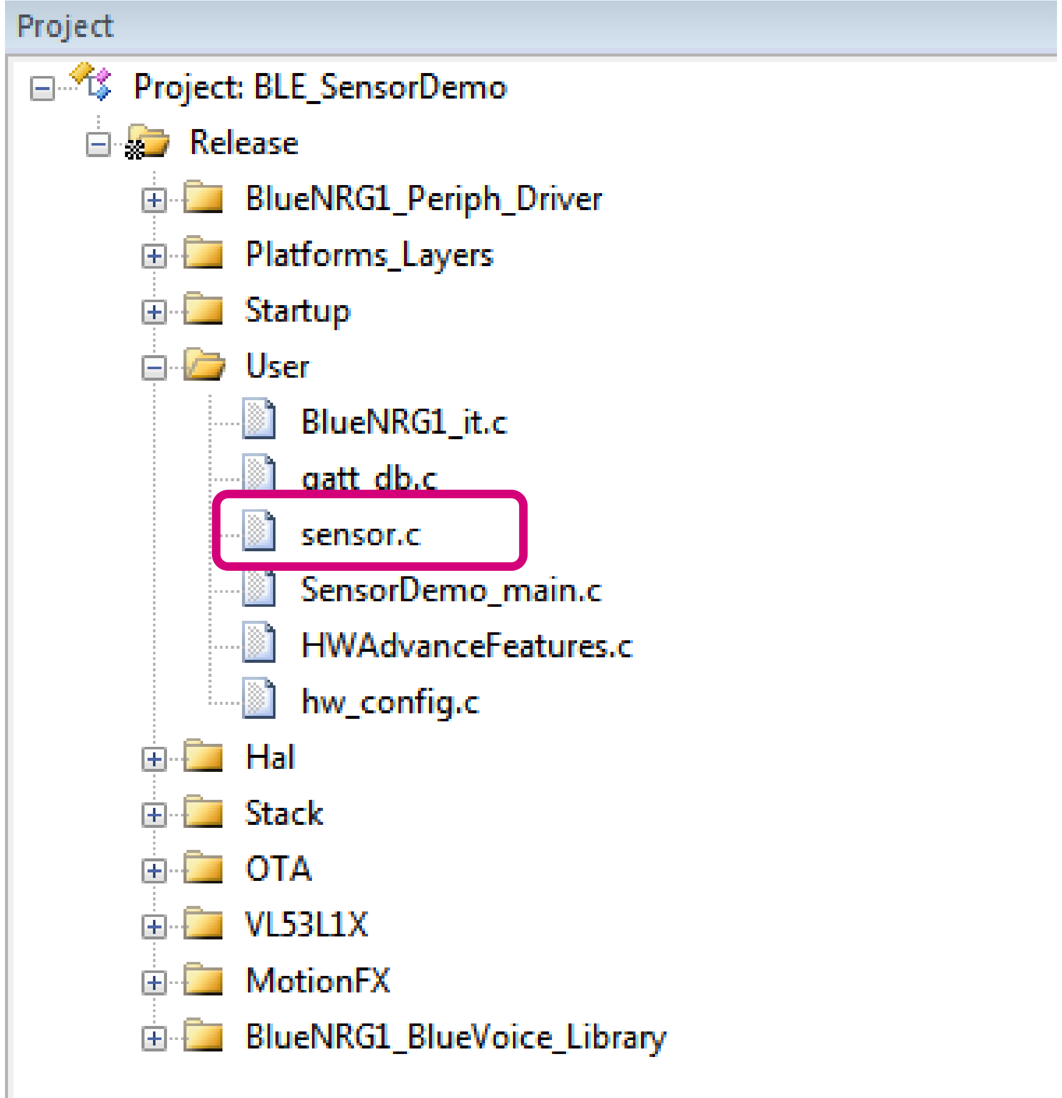
Modify the Feature Mask in the advertisement payload

1. In the file **sensor.c**
2. Go to **line 424 and 425**
3. Modify the Feature Mask byte#2 from 0x1E to **0x9E**
4. Modify the Feature Mask byte#3 from 0x00 to **0x04**

sensor.c

```
411 void Set_DeviceConnectable(void) {
412
413     uint8_t manuf_data[26] = {
414     2,                        /* Length of AD type Transmission Power */
415     0x0A, 0x00,               /* Transmission Power = 0 dBm */
416     8,                        /* Length of AD type Complete Local Name */
417     0x09,                     /* AD type Complete Local Name */
418     NAME_ALLMEMS,             /* Local Name */
419     13,                       /* Length of AD type Manufacturer info */
420     0xFF,                     /* AD type Manufacturer info */
421     0x01,                     /* Protocol version */
422     0x05,                     /* Device ID: 0x05 = STEVAL-BCN002V1 Board */
423     0x20,                     /* Feature Mask byte#1: LAB3 0x20 (LED) / LAB5
424     0x9E,                     /* Feature Mask byte#2: LAB4 0x9E (Acc+Press+Hu
425     0x04,                     /* Feature Mask byte#3: LAB4 0x04 (AccEvents) /
426     0x00,                     /* Feature Mask byte#4: LAB5 0x40 (eCompass) */
427     0x00,                     /* BLE MAC start */
```

L4 STEP2: Enable Accel events feature



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L4 STEP2: Enable Accel events feature

Enable multiple accelerometer embedded events detection

1. In the same file **sensor.c**
2. Go to **line 54** to **line 58**
3. Set the defines **from line 54 to line 58** from 0 to **1**

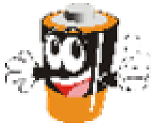
sensor.c*

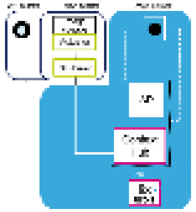
```
53 /* ACCELEROMETER EVENTS */
54 #define ENABLE_FREE_FALL      1
55 #define ENABLE_SINGLE_TAP     1
56 #define ENABLE_HW_WAKEUP      1
57 #define ENABLE_TILT           1
58 #define ENABLE_PEDOMETER      1
```

LSM6DSO at a glance

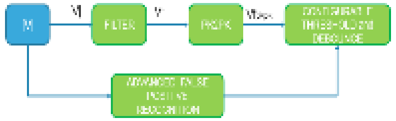
1. PERFORMANCE AND FEATURE

- **Accuracy:** Tango and Daydream compliance
- **0.55mA** current consumption is **HP combo**
  - -15% vs. LSM6DSL/M @ same performance
- New **ultra low power mode: 14uA (@100Hz ODR) Axl only**

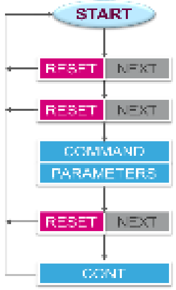




2. FLEXIBILITY: algorithm @ silicon level



- **Pedometer 2.x**
  WeChat Precision



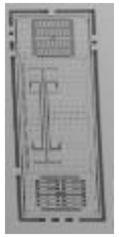
- **FSM** build custom sensors for XL and Gyro

3. NEW STANDARD

- **I3C**

- **FIFO tag**

4. INNOVATION



- MEMS: **Axl T-structure** for mechanical shock robustness
- **Compressed FIFO (3x)**
- **10 patents protecting LSM6DSO innovation**

Spring designed to absorb shocks and reduce mechanical stress in critical areas

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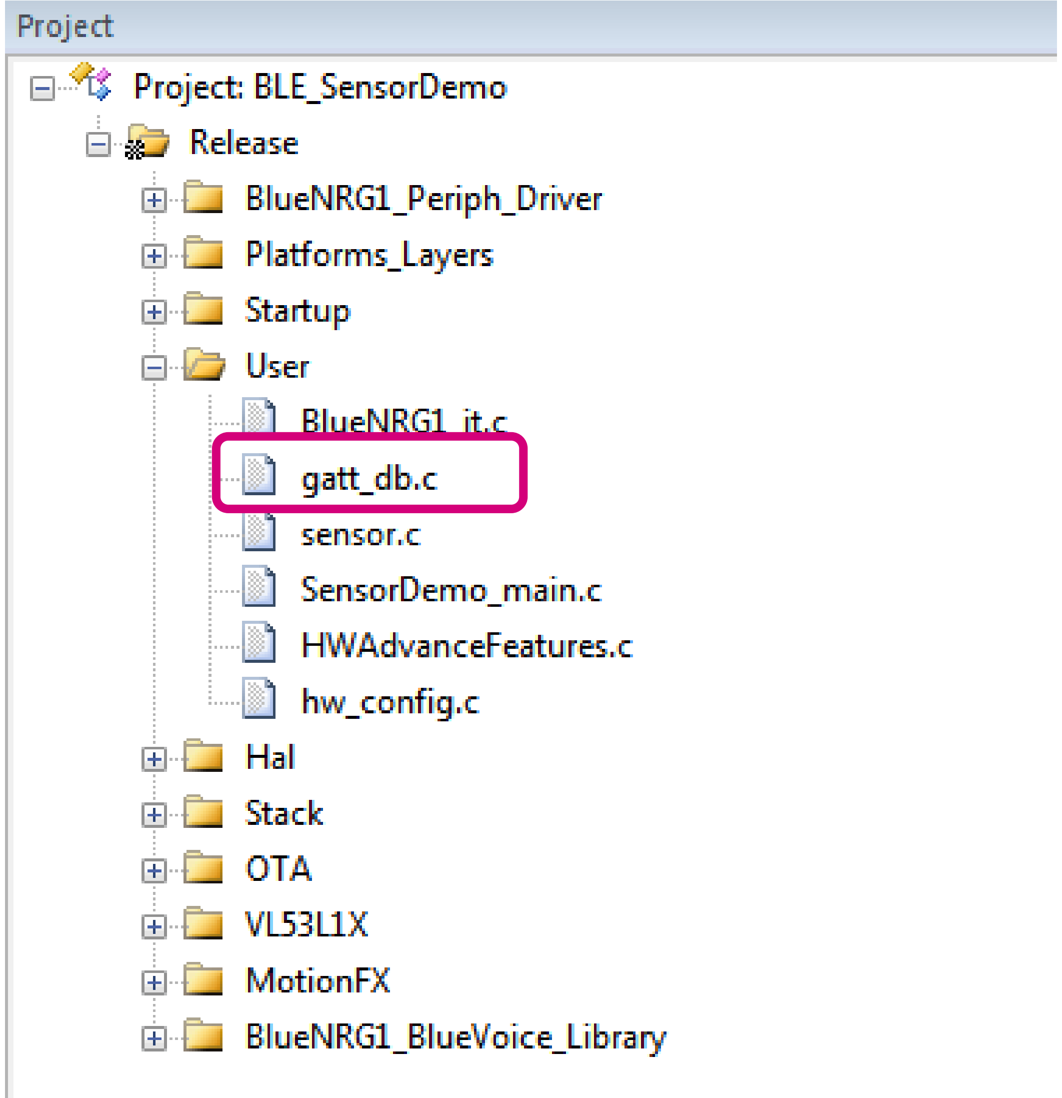
L4 STEP3: Client enables Acc Event characteristic notifications



L4 STEP3: Client enables Acc Event characteristic notifications

1. In the file **gatt_db.c** go to the **line 717**
2. Client writes in the Acc Event Characteristic Client Configurator Descriptor (CCCD) and Server enables notifications through the ***xFeatureNotification*** structure in **line 728** by ***xFeatureNotification.AccEventNotification = true;***

```
717 } else if (attr_handle == (AccEventCharHandle + 2)) {
718
719   if (xFeatureNotification.MotionNotification == false && xFeatureNotification.iNemoEngineNotification == false) {
720     if (att_data[0] == 01) {
721       lsm6dso_xl_data_rate_set(0, LSM6DSO_XL_ODR_52Hz);
722       GPIO_WriteBit(GPIO_Pin_7, Bit_RESET); // Proximity OFF
723       EnableHWMultipleEvents();
724       ResetHWPedometer();
725       GPIO_EXTICmd(GPIO_Pin_13, ENABLE);
726       Config_Notify(FEATURE_MASK_ACC_EVENTS, 'm', 1);
727       AccEvent_Notify(0, 2);
728       xFeatureNotification.AccEventNotification = true;
729       PRINTF("AccEvent Notification ON\n\r");
730
731     } else if (att_data[0] == 0) {
732       lsm6dso_xl_data_rate_set(0, LSM6DSO_XL_ODR_OFF);
733       xFeatureNotification.AccEventNotification = false;
734       GPIO_EXTICmd(GPIO_Pin_13, DISABLE);
735       DisableHWMultipleEvents();
736       PRINTF("AccEvent Notification OFF\n\r");
737
```

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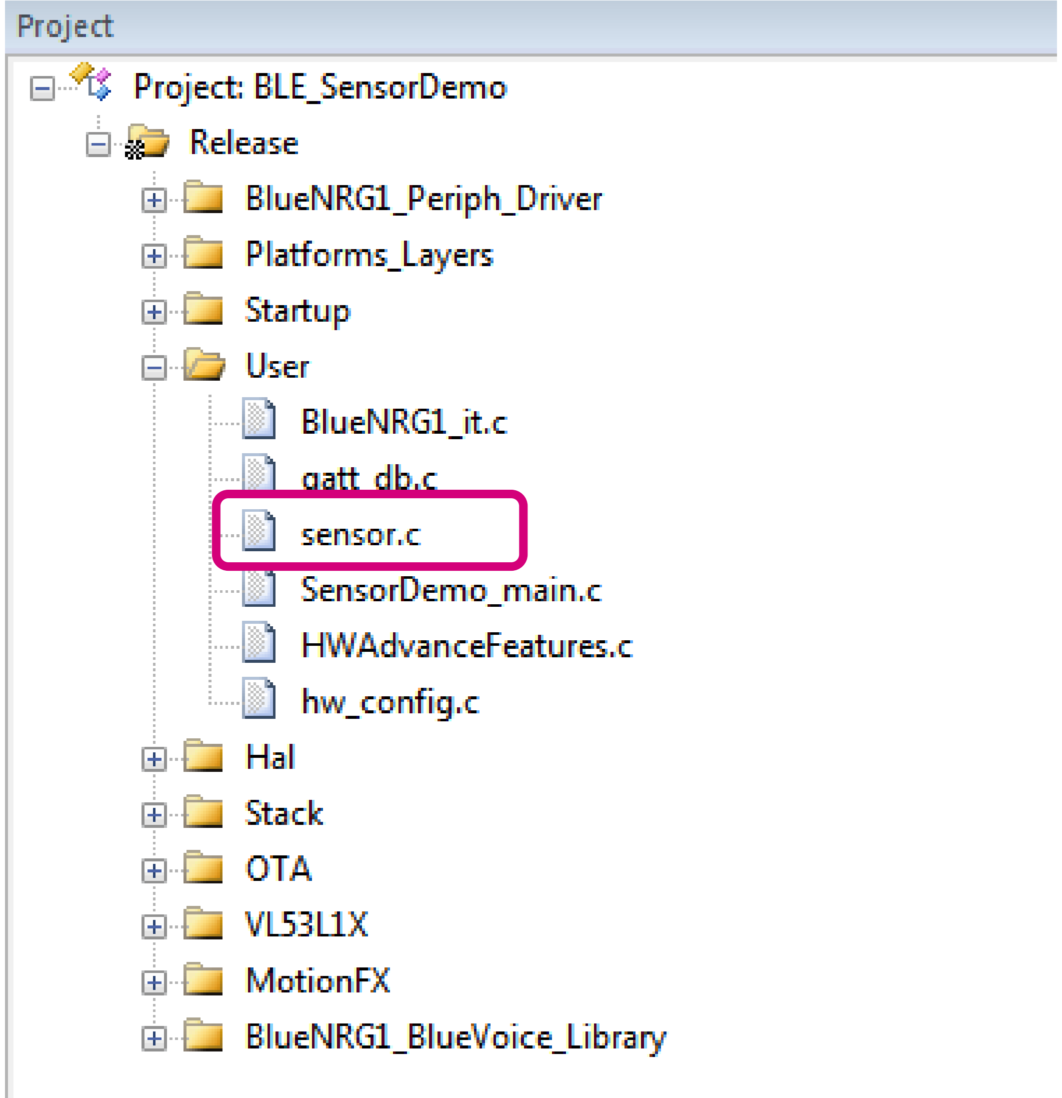
L4 STEP4: Read Event Status and send BLE notification



L4 STEP4: Read Event Status and send BLE notification


```
1179 void MEMSCallback(void) {
1180
1181   lsm6dso_all_sources_get(0, &all_source);
1182
1183   /* Check if the interrupt is due to Single Tap */
1184   if (xHardwareFeaturePresence.HwSingleTAP || xHardwareFeaturePresence.MultipleEvent) {
1185     if (all_source.reg.all_int_src.single_tap) {
1186       SdkEvalLedOn(LED1);
1187       SdkEvalLedOn(LED3);
1188       PRINTF("Event: Single Tap\n\r");
1189 #if ENABLE_SINGLE_TAP
1190       AccEvent_Notify(ACC_SINGLE_TAP, 2);
1191 #endif
1192     }
1193   }
```

In the file **sensor.c**

1. **line 1179 *void MEMSCallback(void)***

   Callback triggered by IO13
2. **line 1181 *lsm6dso_all_sources_get***

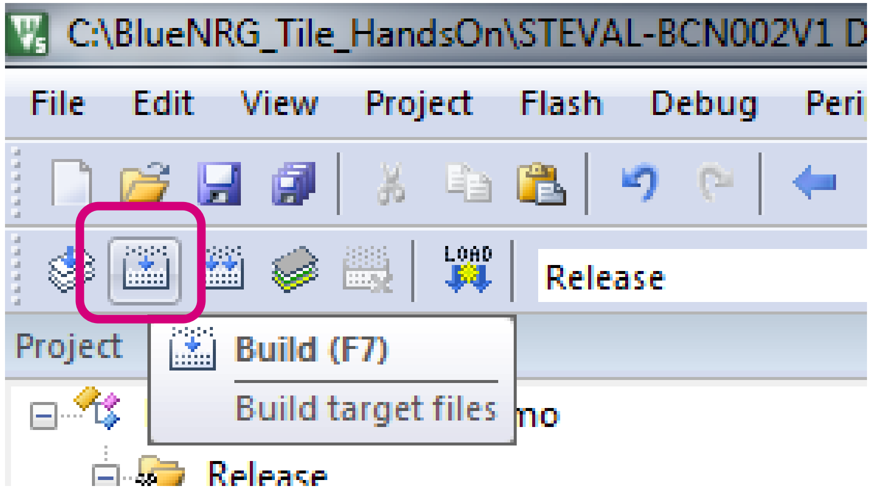
   Read accelerometer status registers
3. **line 1185 *if (all_source.reg.all_int_src.single_tap)***

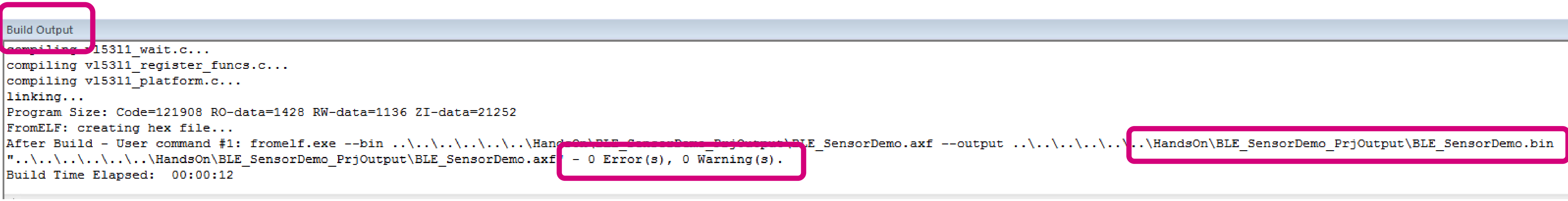
   Check vs. single tap event
4. **line 1190 *AccEvent_Notify***

   Send BLE notification

Build the new code

1. Click on the **Build button** (top left corner) or hit **F7** on your keyboard
2. In the **Build Output** window (bottom) wait for the build to be completed.
   - **BLE_SensorDemo.bin** created
   - "**0 Error(s), 0 Warning(s)**" message appear





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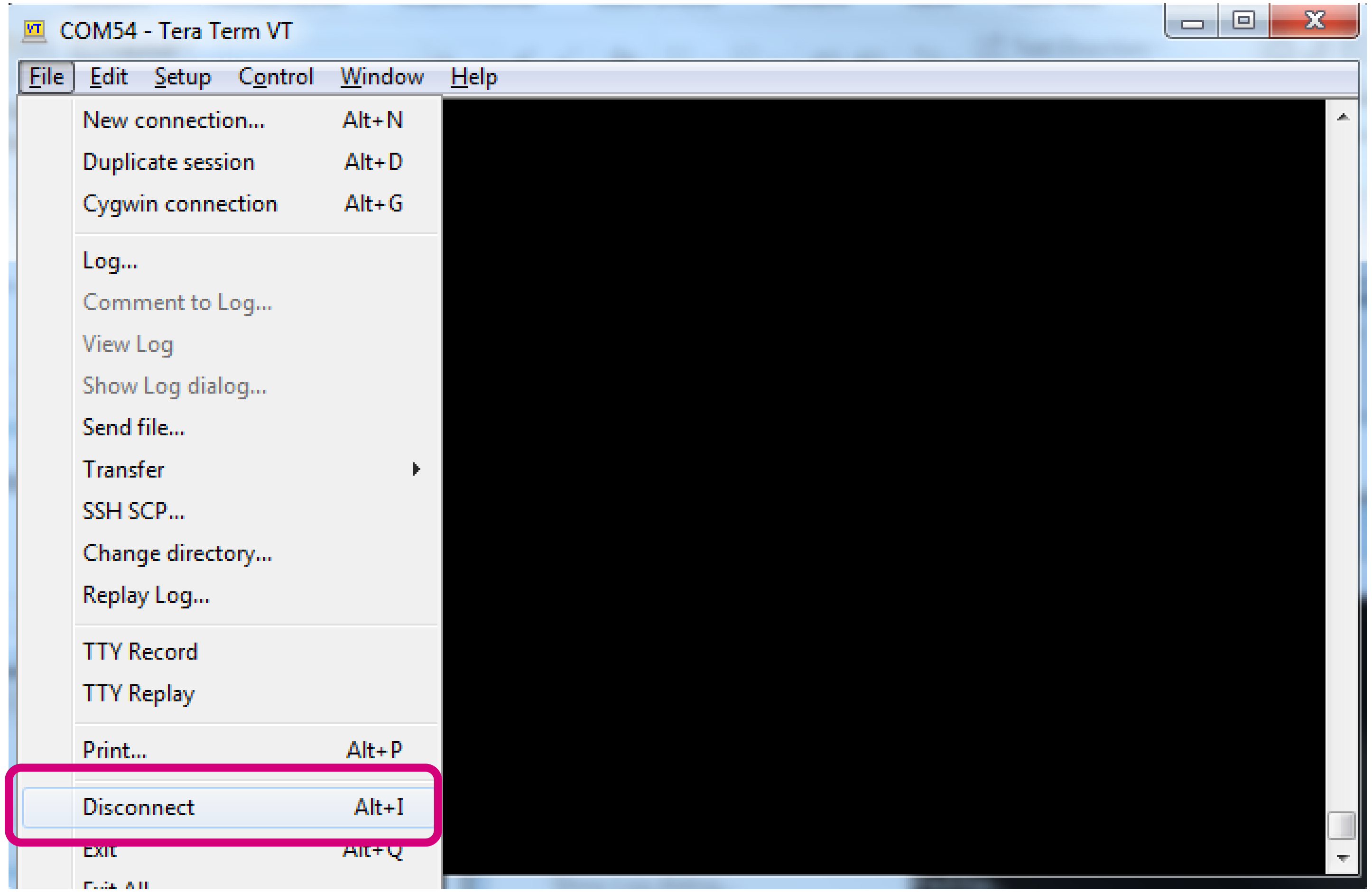
Disconnect the serial terminal

1. Go back to TeraTerm
2. Click on the **File->Disconnect**



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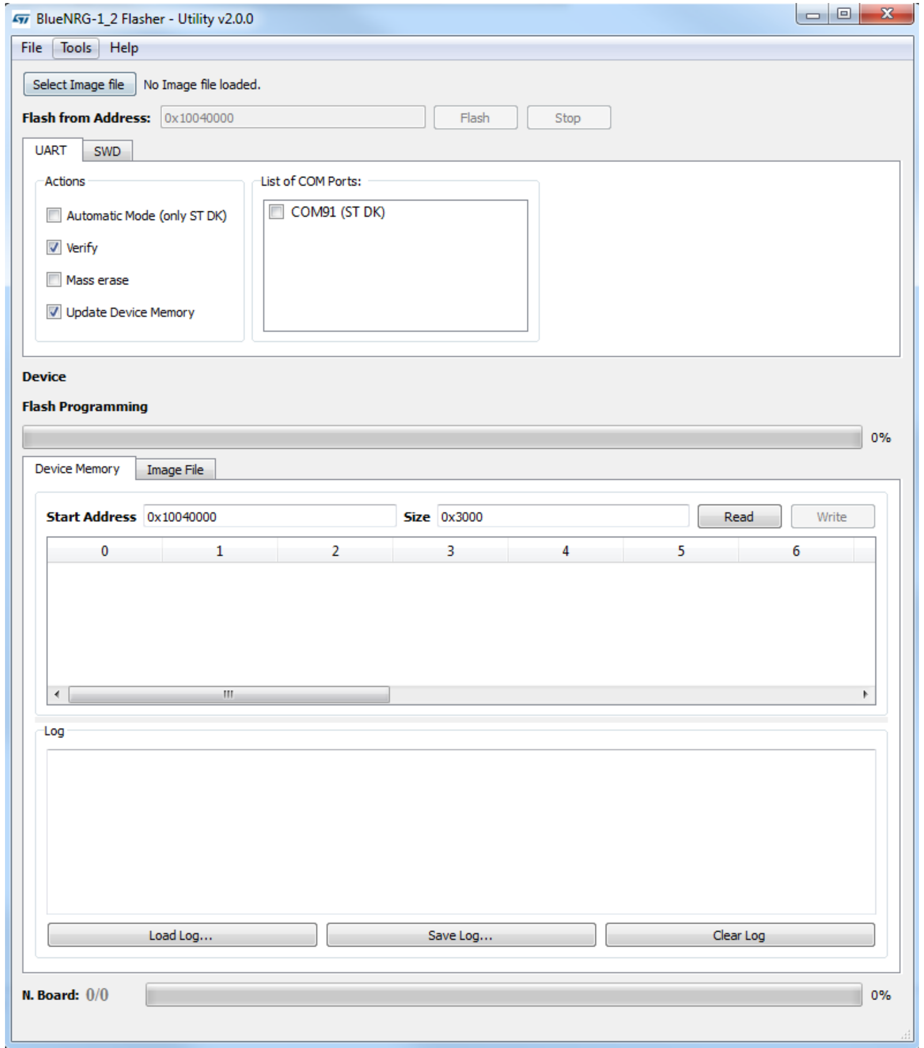
Re-flash the BlueNRG-2

1. Go back to the BlueNRG-2 Flasher Utility



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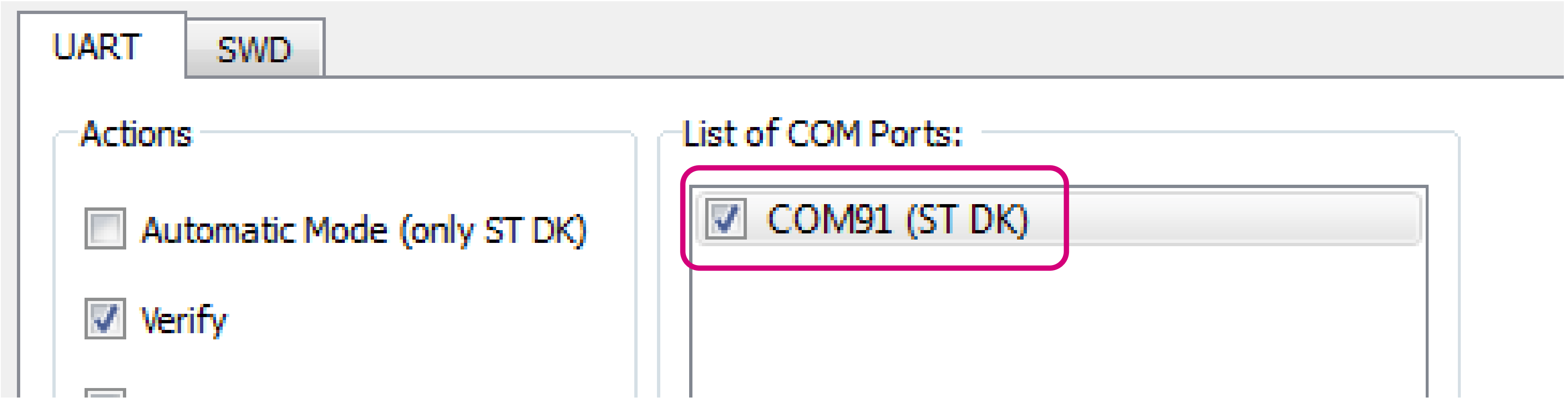
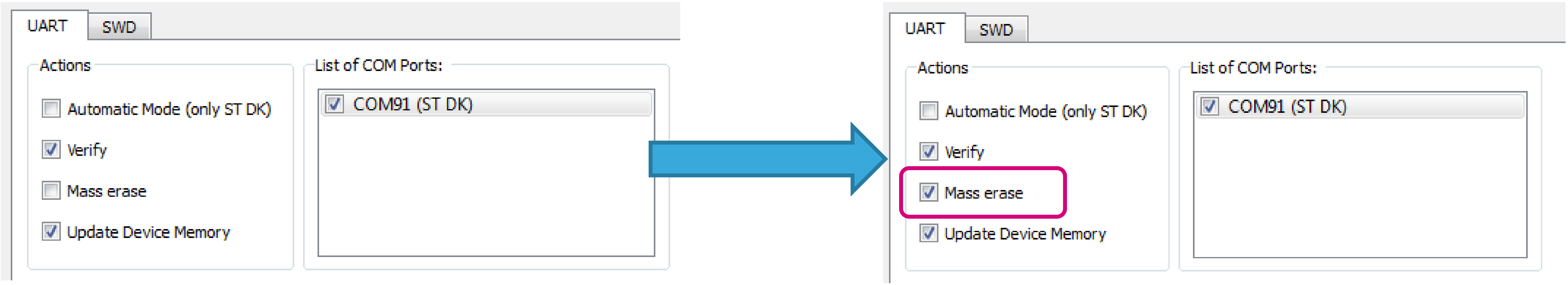
Flash the BlueNRG-2 1/5

1. Select the COM port labeled **(ST DK)**



Flash the BlueNRG-2 2/5

1. Click on **Mass Erase**



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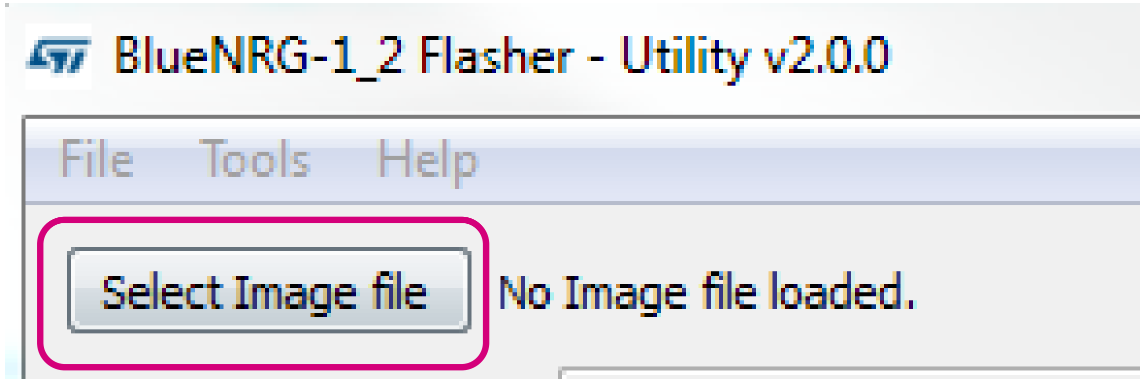
Flash the BlueNRG-2 3/5

1. Click on **Select Image file** button



2. And browse the following **path**

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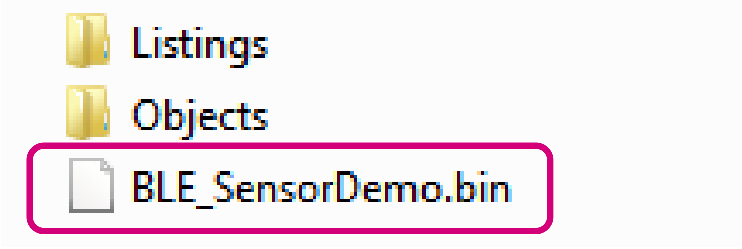
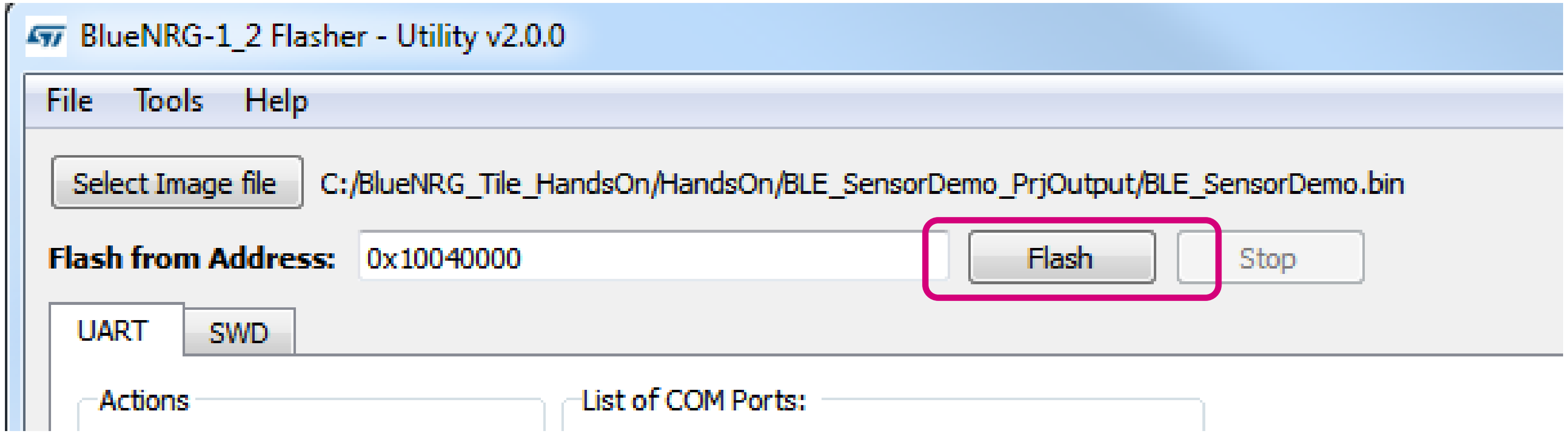
Flash the BlueNRG-2 4/5

1. Select **BLE_SensorDemo.bin**

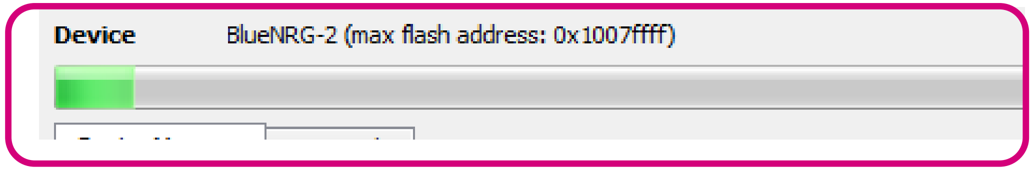


2. Click on the **Flash** button

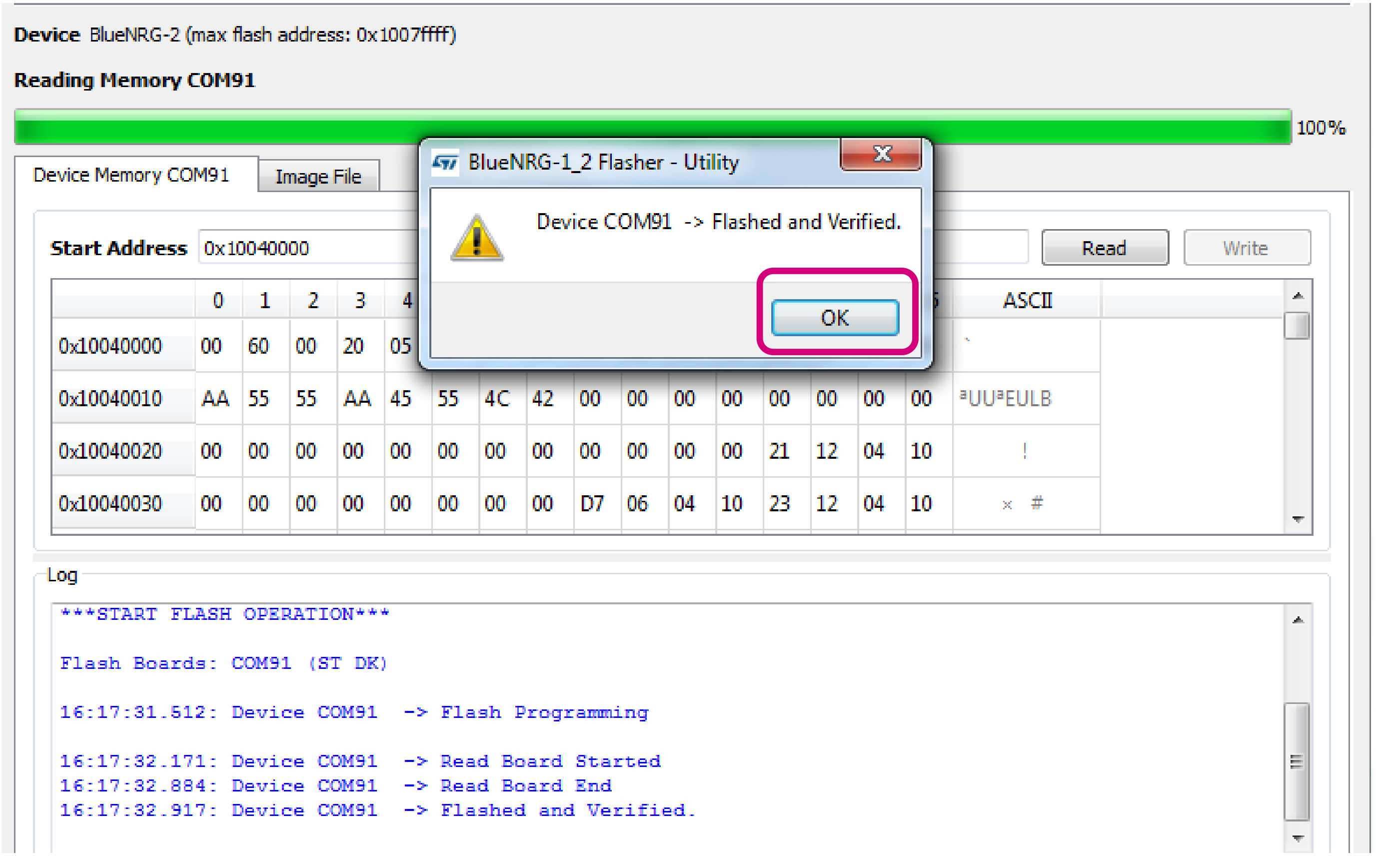


Flash the BlueNRG-2 5/5

1. Flashing starts: **green bar** proceeding



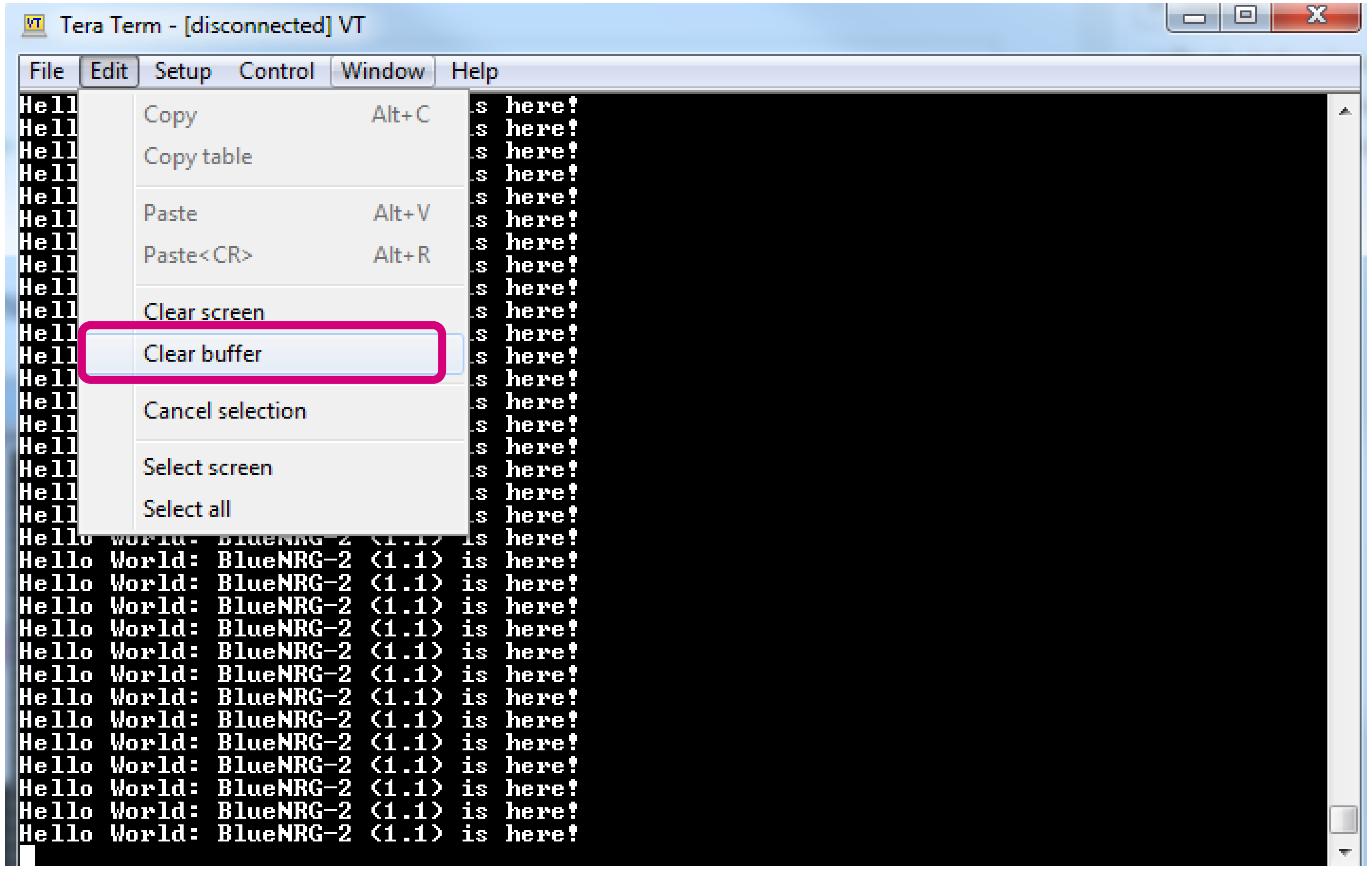
2. Wait for the **pop-up** window and click on **OK**



Do NOT close the Utility!

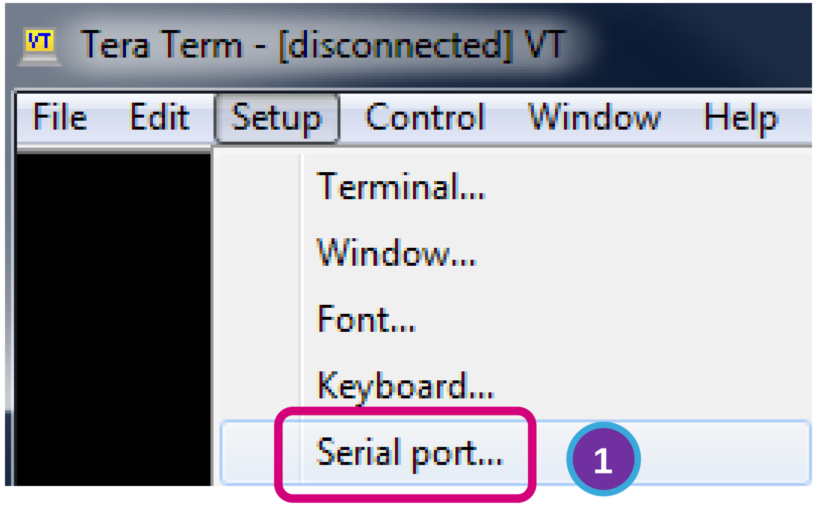
Clean Buffer in the serial terminal

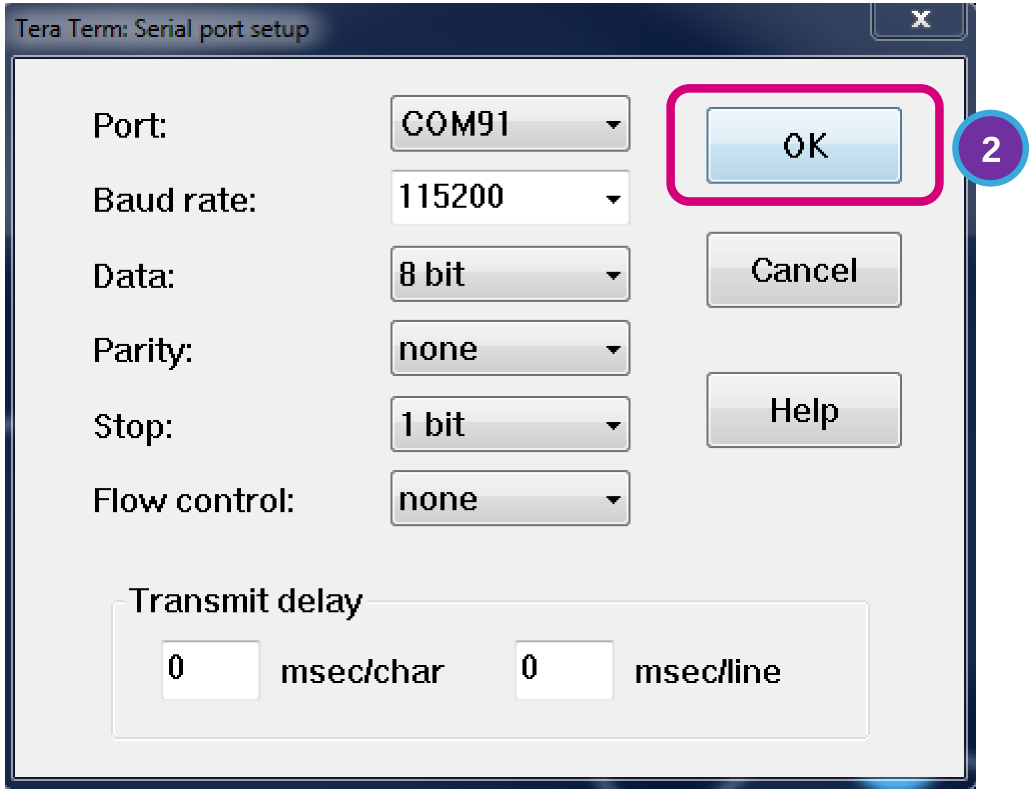
1. In Tera Term in order to have the terminal clean, go to **Edit -> Clear buffer**



Reconnect the serial terminal

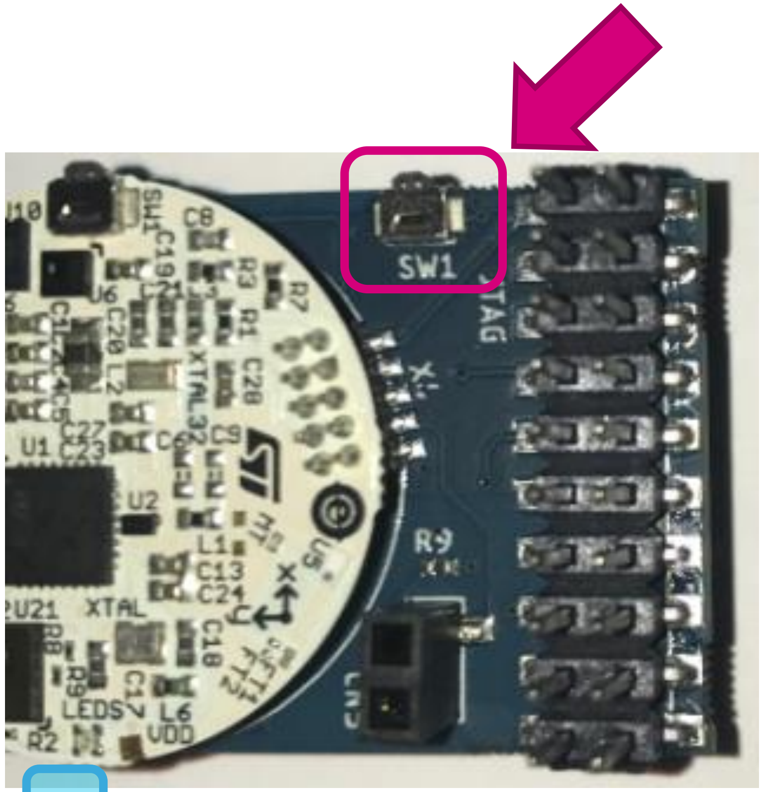
1. Click **Setup** -> **Serial port…**
2. Serial port should already configured. Just need to click on **OK**

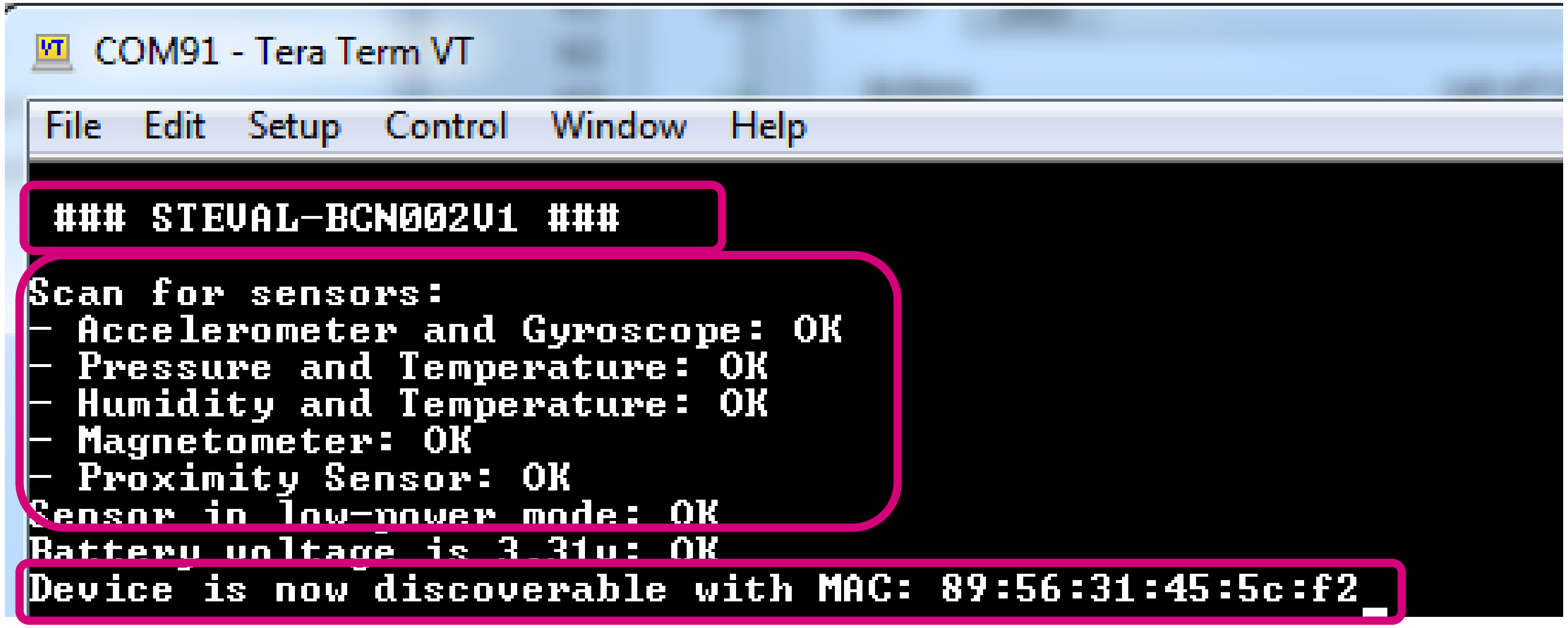




Sanity Check on serial port

Push **SW1 button** on the blue motherboard -> **LED blinking Blue**





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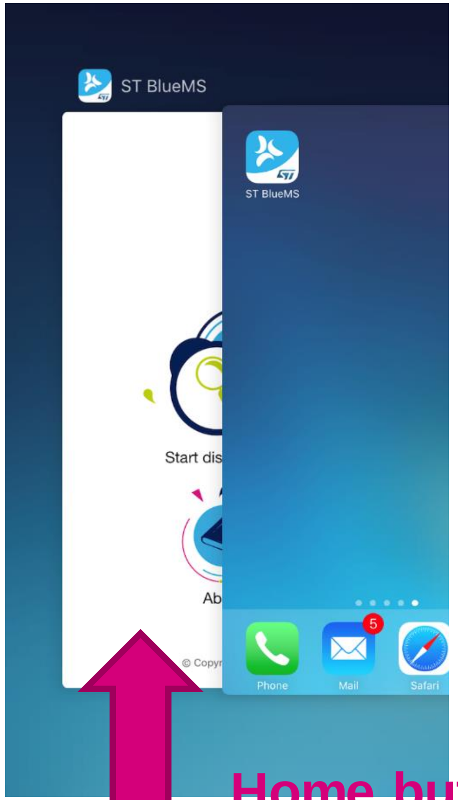
Connect using the BlueMS App

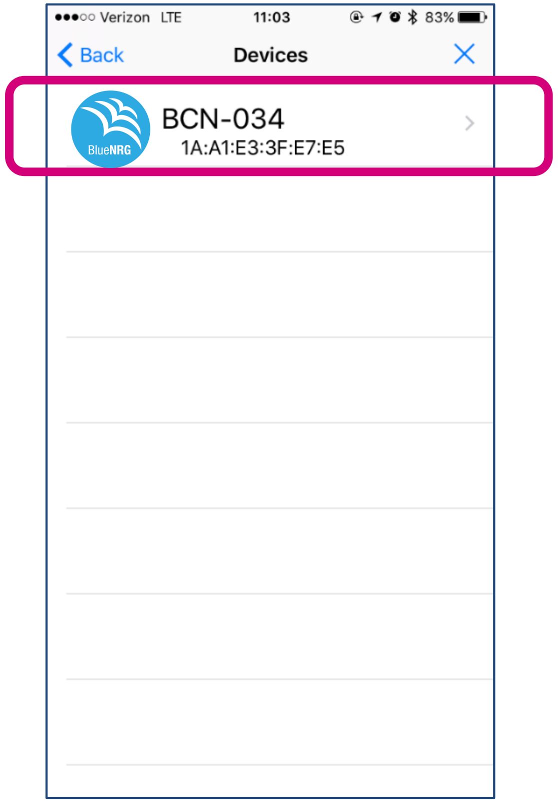
1 “Kill” the BlueMS app



Home button and then swipe to top

2 Touch “Start discovering”

3 Select your STEVAL-BCN002V1



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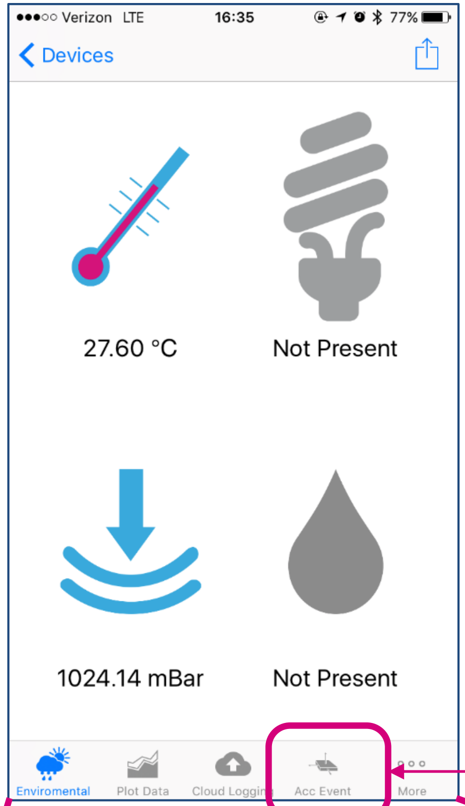
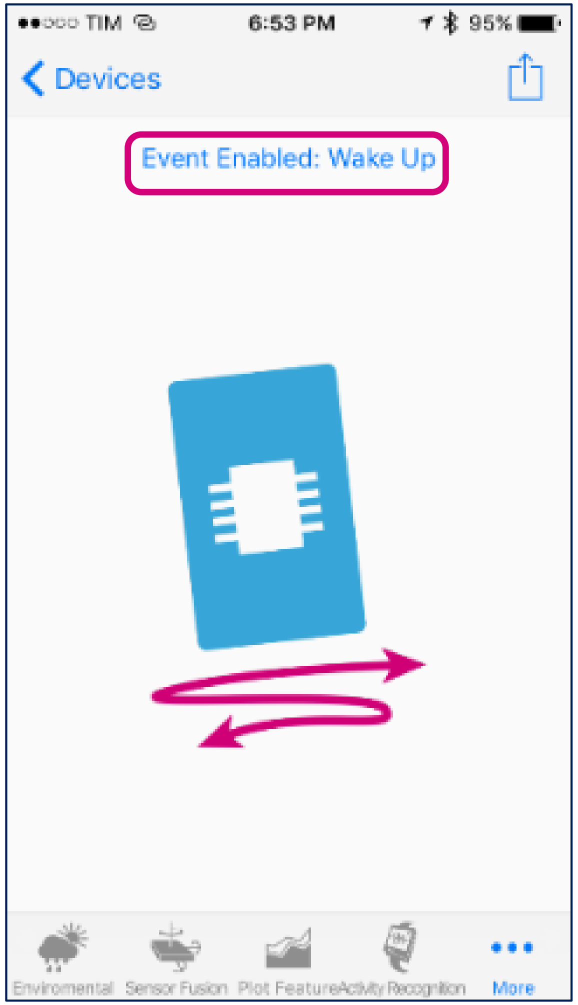
Visualize Hardware Wakeup Event in BlueMS

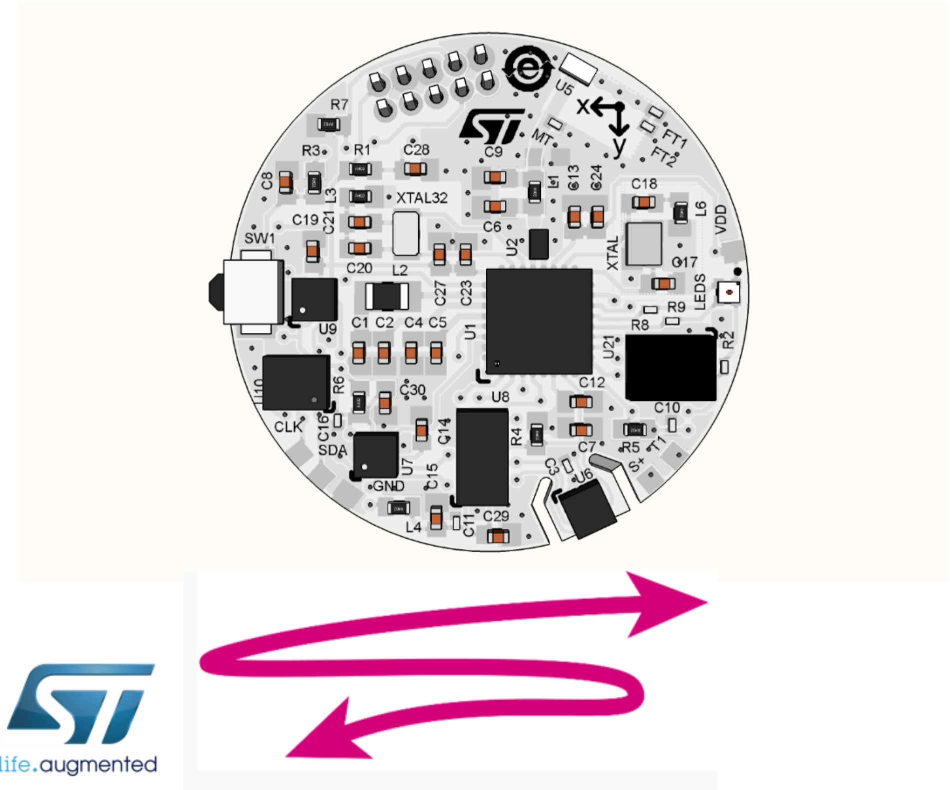


Select
“**Acc Event**”



Event Detection

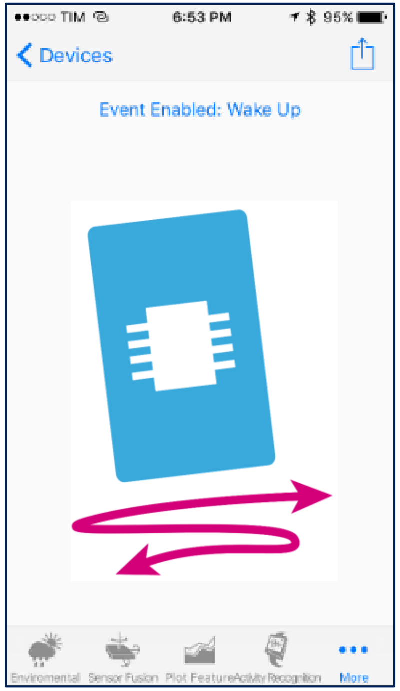
1. Leave the board still for a few seconds
2. Shake the board
3. Send **BLE notification packet**



Notification Packet

'WAKE UP'

Wake Up



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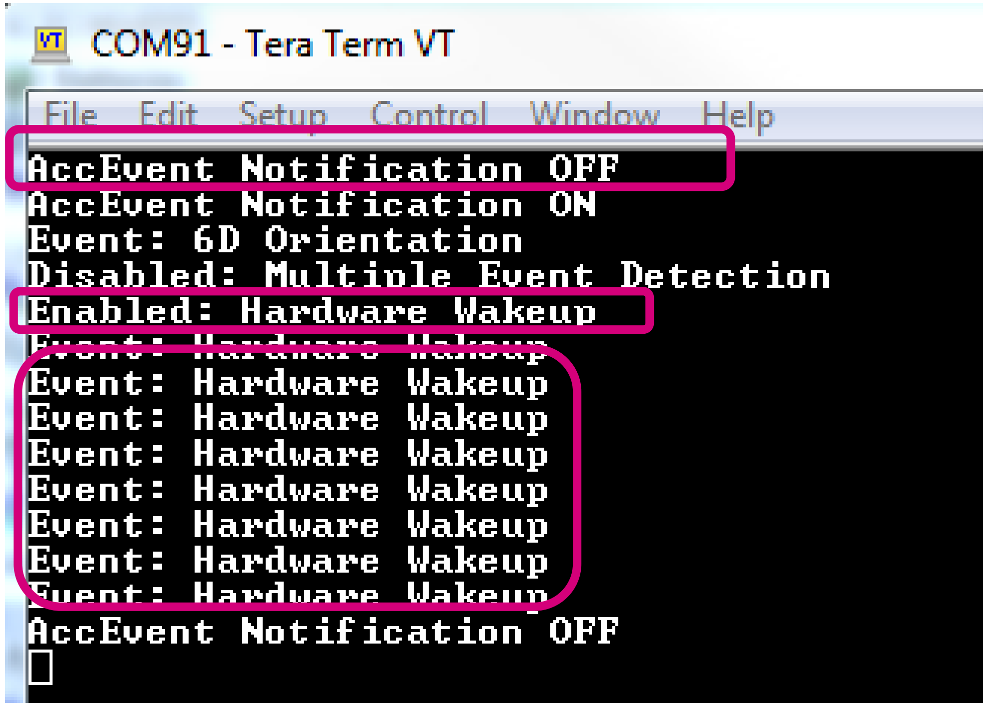
TeraTerm output

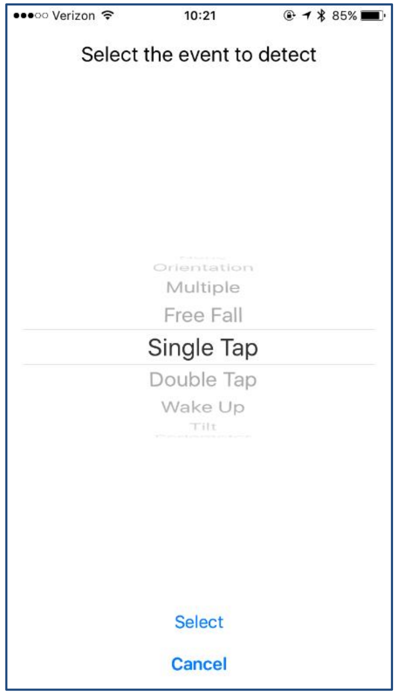
- "*AccEvent Notification ON*": enable notifications on the Accellerometer Event characteristic
- "*Enabled Harware Wakeup*": user enable hardware wakeup event detection
- "*Event: Hardware Wakeup*": the actual BLE notification packet sent upon detection of the Hardware Wakeup event.



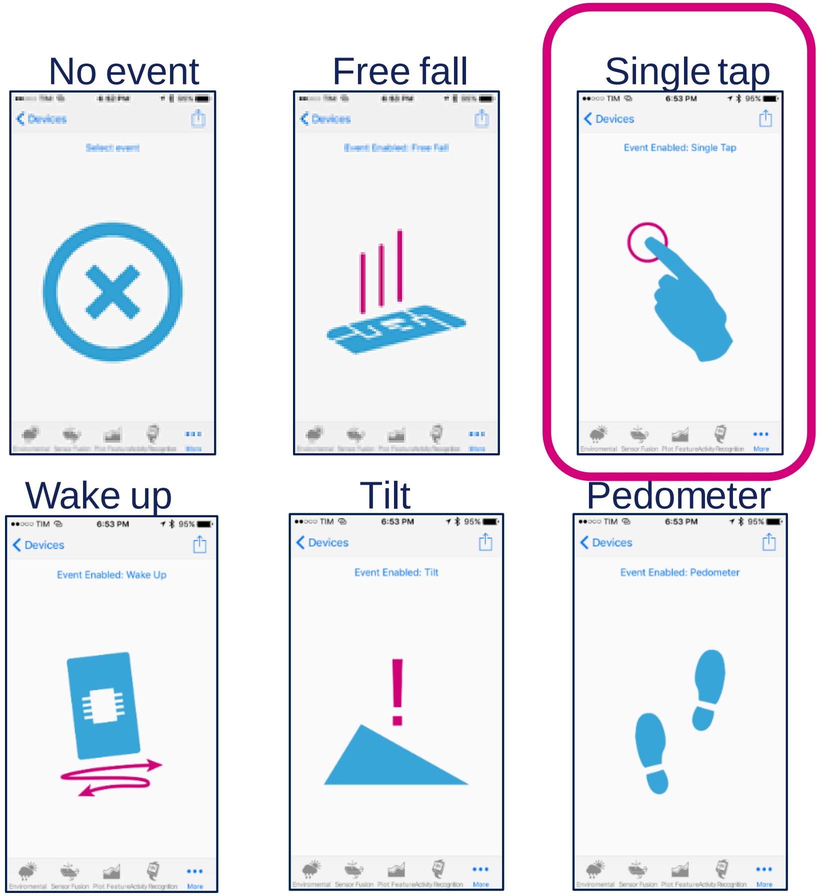
NOTE: if the phone display enters sleep mode, notifications are not sent

LSM6DSO Embedded Events

Other possible embedded events



Single Tap example



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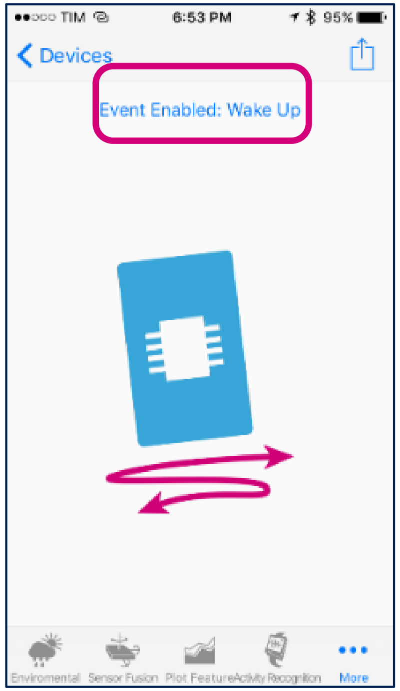
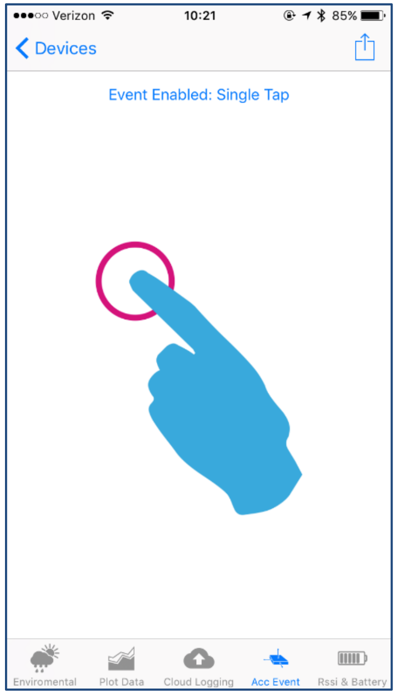
Visualize Single Tap Event in BlueMS

Touch
“**Event Enabled**”



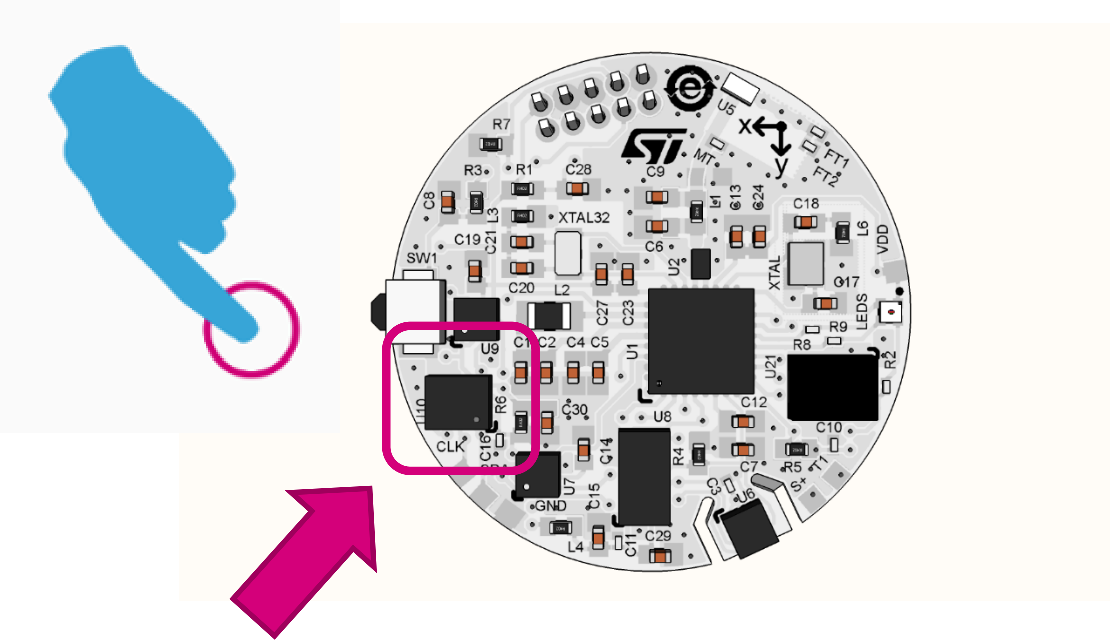
Select
“**Single Tap**”
and hit
“**Select**”

Enabled
“**Single Tap**”



Event Detection

1. On the board perform a Single Tap
2. Send **BLE notification packet**

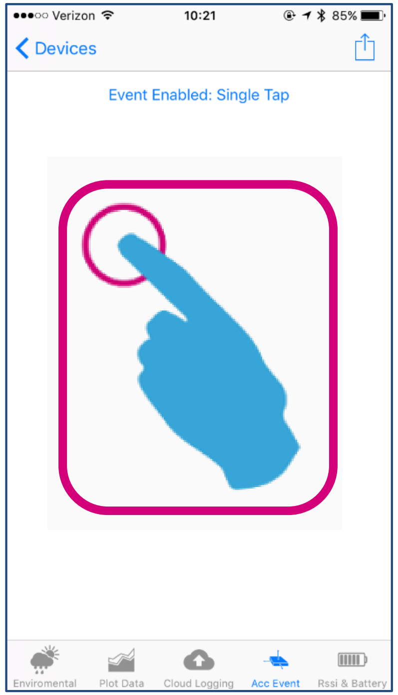


Tap **gently** on the board

Notification Packet

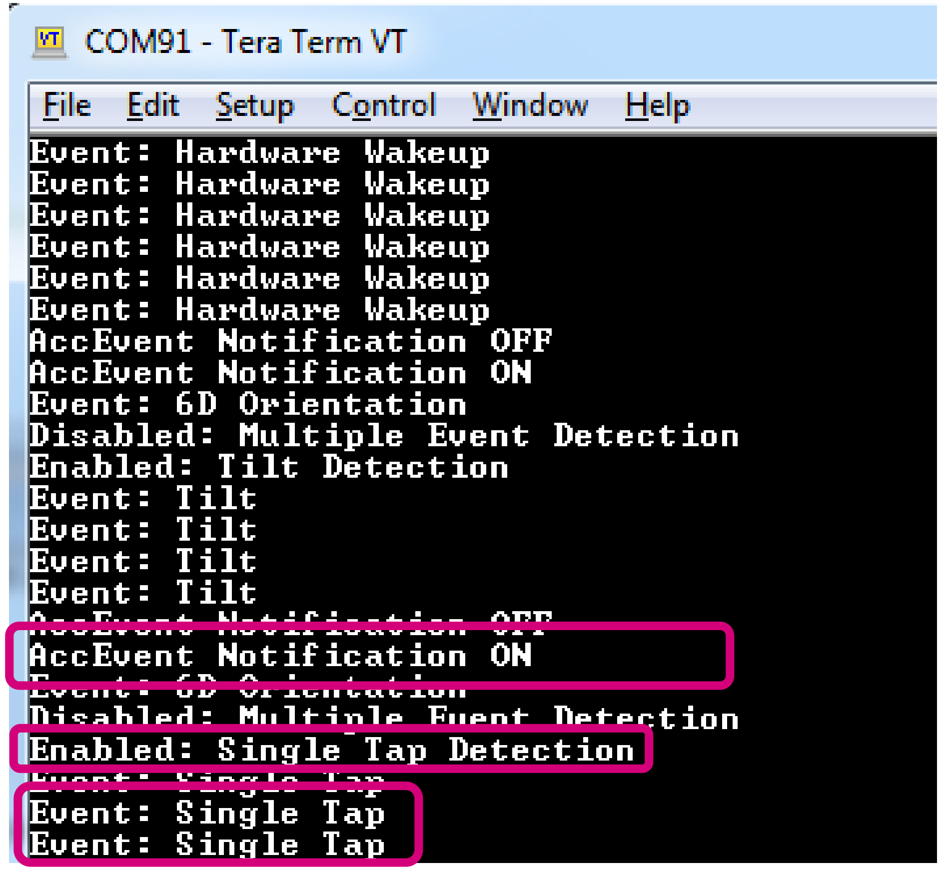
‘SINGLE TAP’

Single Tap



TeraTerm output

- "*AccEvent Notification ON*": enable notifications on the Accellerometer Event characteristic
- "*Enabled Single Tap Detection*": user enable Single Tap event detection
- "*Event: Single Tap*": the actual BLE notification packet sent upon detection of the Single Tap event.



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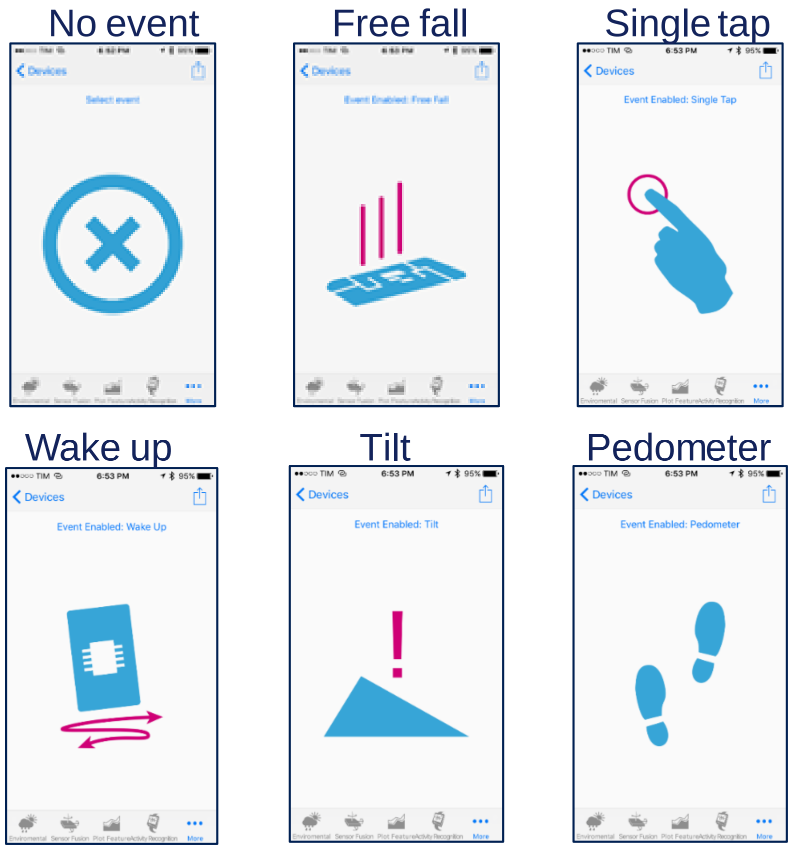
NOTE: if the phone display enters sleep mode, notifications are not sent

LSM6DSO Embedded Events

You can go ahead later and test other events…

Other possible embedded events



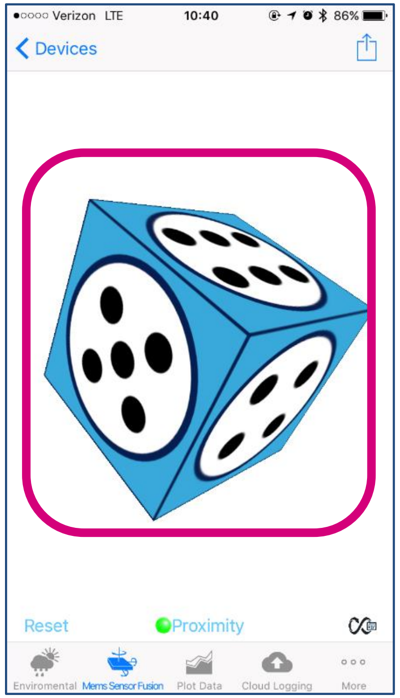
Lab 5

9-axis Acc+Gyro+Mag Sensor Data Fusion

Goal

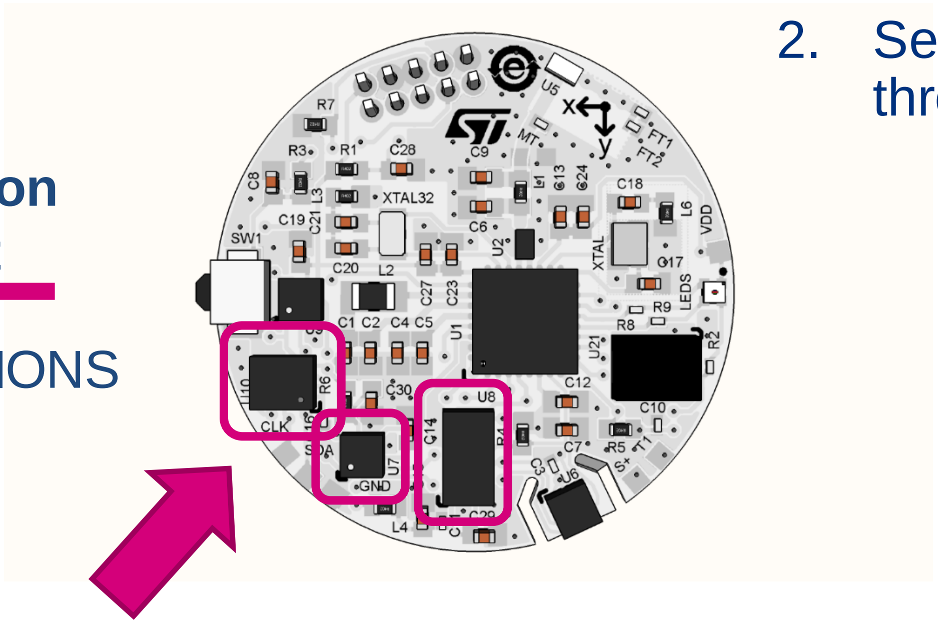
- In this example we are going to demonstrate how to:
  - Enable the embedded sensor data fusion library
    - Input: raw Acc+Gyro+Mag sensor data
    - Output: quaternions
  - Scale the quaternions value by a scaling factor proportional to proximity detection
  - Send scaled data fusion information through BLE notifications packets to the ST BlueMS client

Sensor Data Fusion

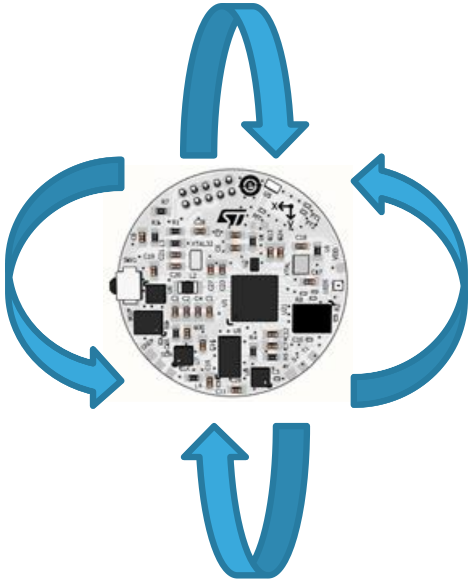


Notification Packet

QUATERNIONS



1. Enable Sensor Fusion library
2. Send quaternions information through **BLE notification packet**



Sensors used by data fusion:
Acc+Gyro+Mag and Proximity

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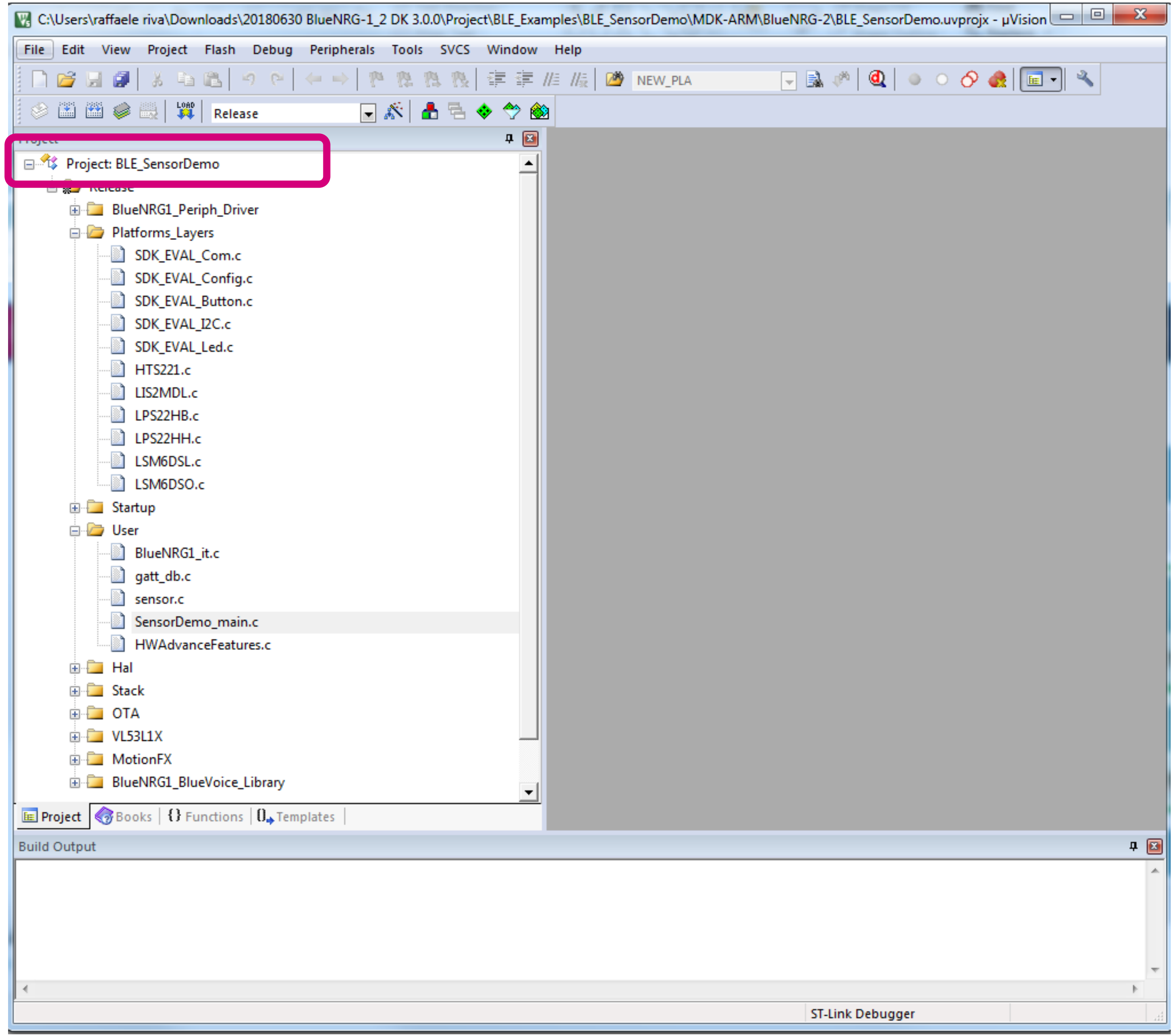
Code modifications

1. Modify advertising packet
2. Enable Sensor Data fusion library
3. Enable proximity sensor
4. Send quaternions data – scaled by proximity sensor data - through BLE notifications packets

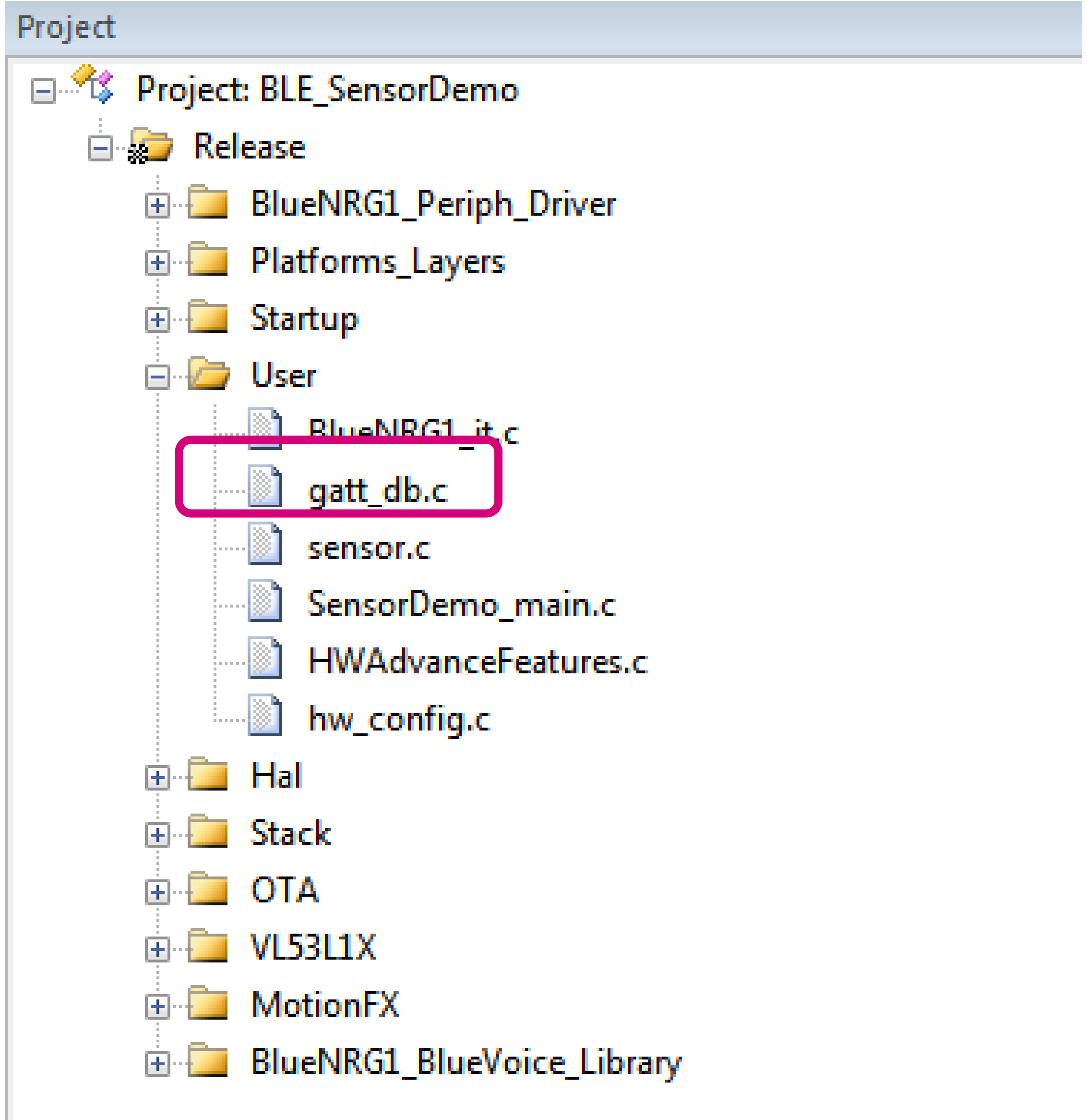
Sensor Demo reference application

Now we go **back** again to **Keil uVision**



life.augmented

L5 STEP1: Modify advertising packet



ST BlueMS Protocol

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X22
23	22	21	20	19	18	17	16	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0XFE
15	14	13	12	11	10	9	8	
RFU	RFU	RFU	RFU	Beamform	AccEvent	FreeFall	SensFusC	0X05
7	6	5	4	3	2	1	0	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X40

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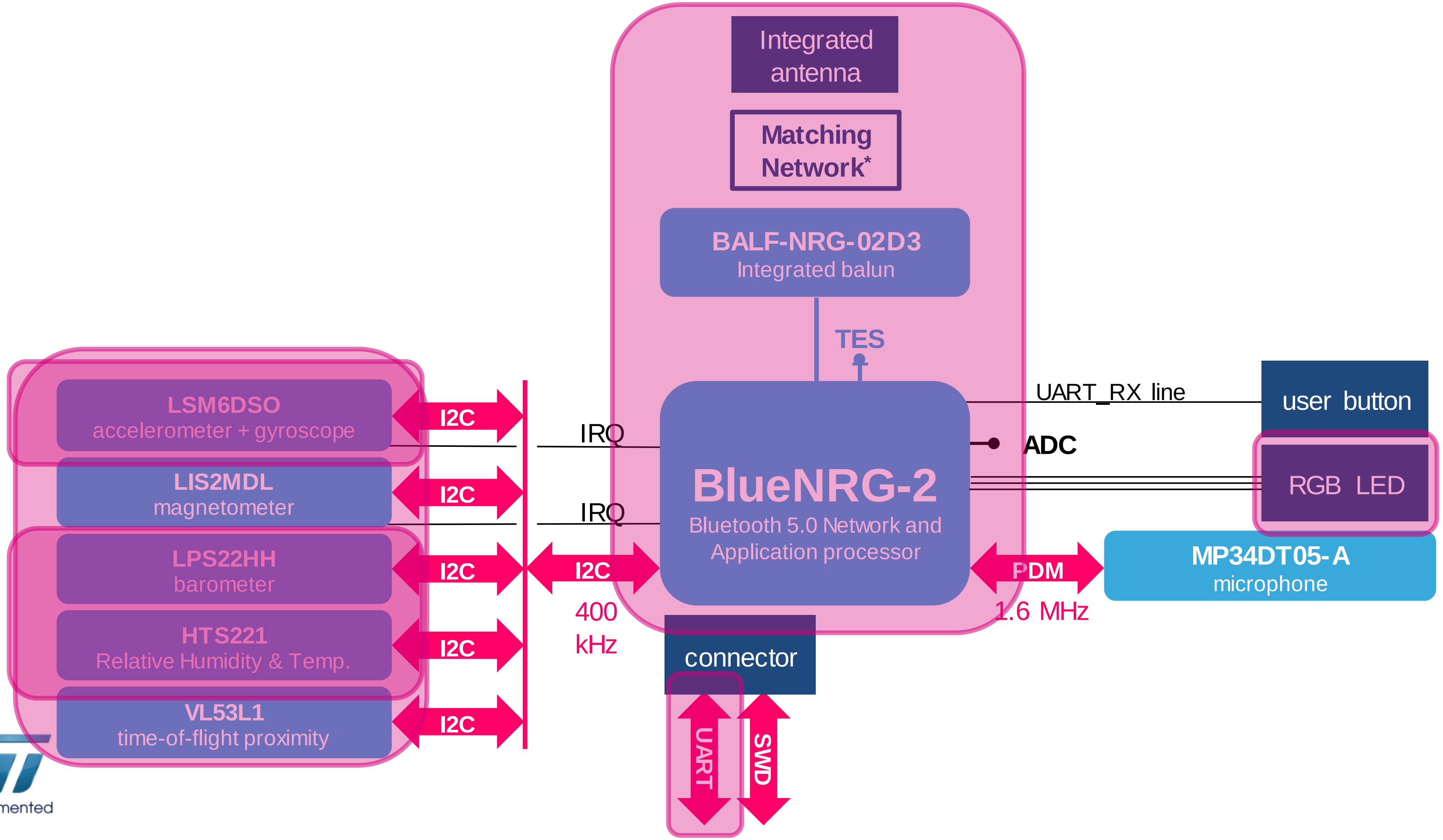
STEVAL-BCN002V1 Block Diagram



L5 STEP1: Modify advertising packet

Modify the Feature Mask in the advertisement payload

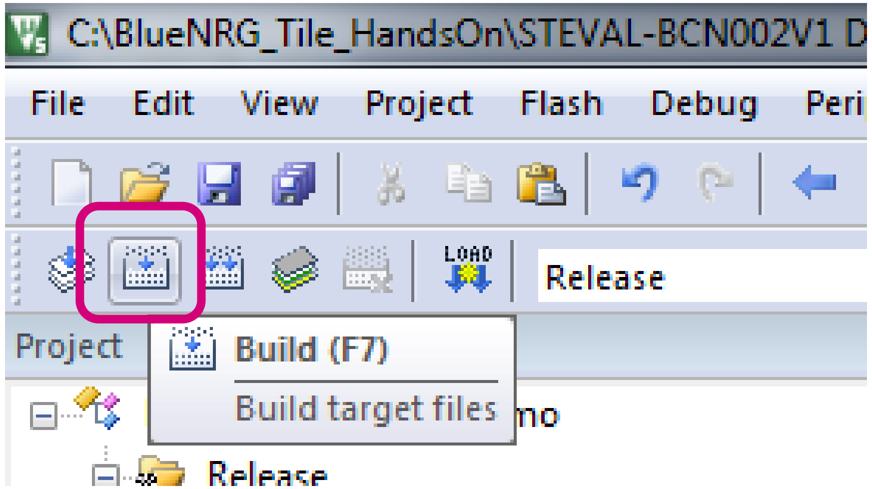
1. In the file **sensor.c** and go to **line 423, 424, 425 and 426**
2. Modify **line 423** Feature Mask byte#1 from 0x20 to **0x22**
3. Modify **line 424** Feature Mask byte#2 from 0x9E to **0xFE**
4. Modify **line 425** Feature Mask byte#3 from 0x04 to **0x05**
5. Modify **line 426** Feature Mask byte#4 from 0x00 to **0x40**

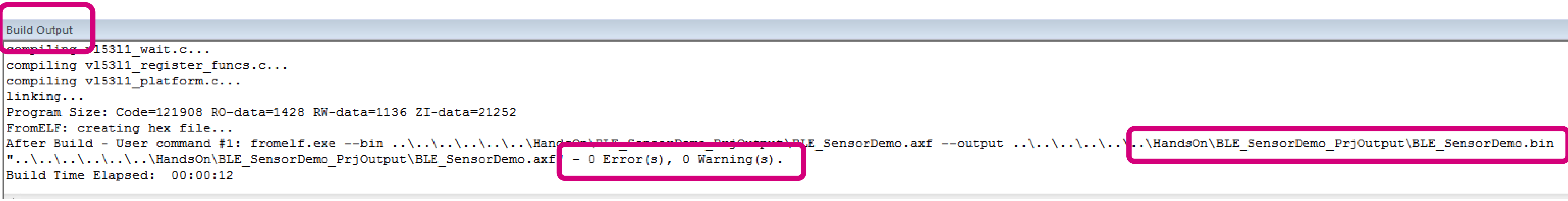
sensor.c

```c
411 void Set_DeviceConnectable(void) {
412
413   uint8_t manuf_data[26] = {
414   2,                      /* Length of AD type Transmission Power */
415   0x0A, 0x00,             /* Transmission Power = 0 dBm */
416   8,                      /* Length of AD type Complete Local Name */
417   0x09,                   /* AD type Complete Local Name */
418   NAME_ALLMEMS,           /* Local Name */
419   13,                     /* Length of AD type Manufacturer info */
420   0xFF,                   /* AD type Manufacturer info */
421   0x01,                   /* Protocol version */
422   0x05,                   /* Device ID: 0x05 = STEVAL-BCN002V1 Board */
423   0x22,                   /* Feature Mask byte#1  LAB3 0x20 (LED) / LAB5
424   0xFE,                   /* Feature Mask byte#2  LAB4 0x9E (Acc+Press+Hu
425   0x05,                   /* Feature Mask byte#3  LAB4 0x04 (AccEvents) /
426   0x40,                   /* Feature Mask byte#4  LAB5 0x40 (eCompass) */
427   0x00,                   /* BLE MAC start */
```

Build the new code

1. Click on the **Build button** (top left corner) or hit **F7** on your keyboard
2. In the **Build Output** window (bottom) wait for the build to be completed.
   - **BLE_SensorDemo.bin** created
   - "**0 Error(s), 0 Warning(s)**" message appear





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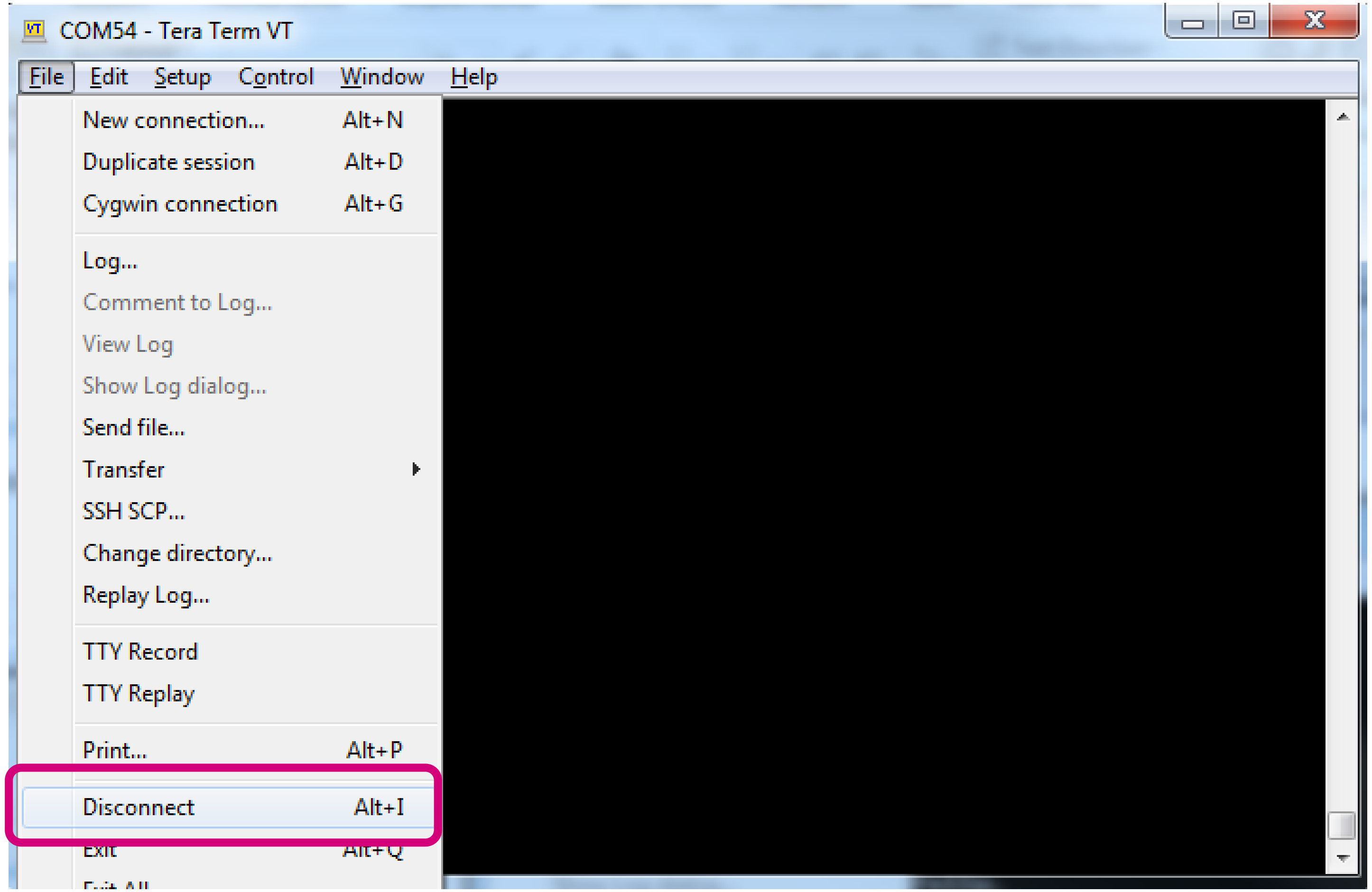
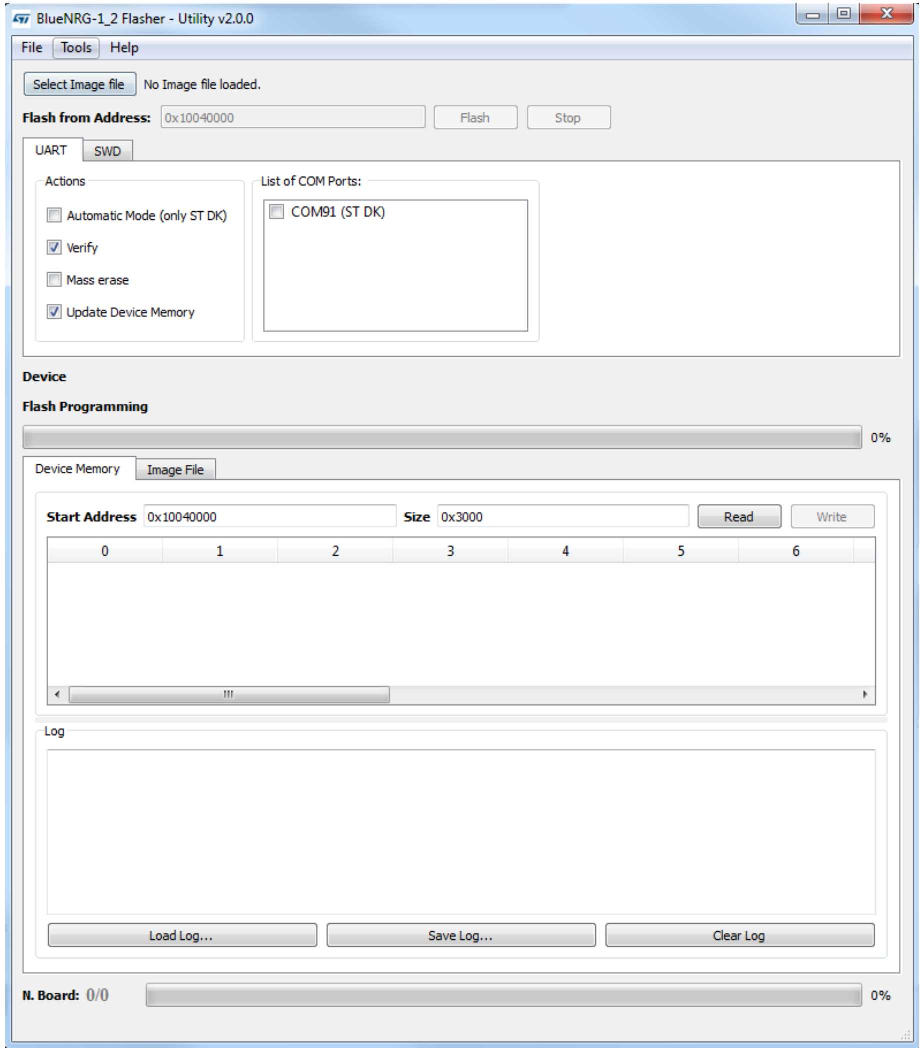
Disconnect the serial terminal

1. Go back to TeraTerm
2. Click on the **File->Disconnect**



Re-flash the BlueNRG-2

1. Go back to the BlueNRG-2 Flasher Utility



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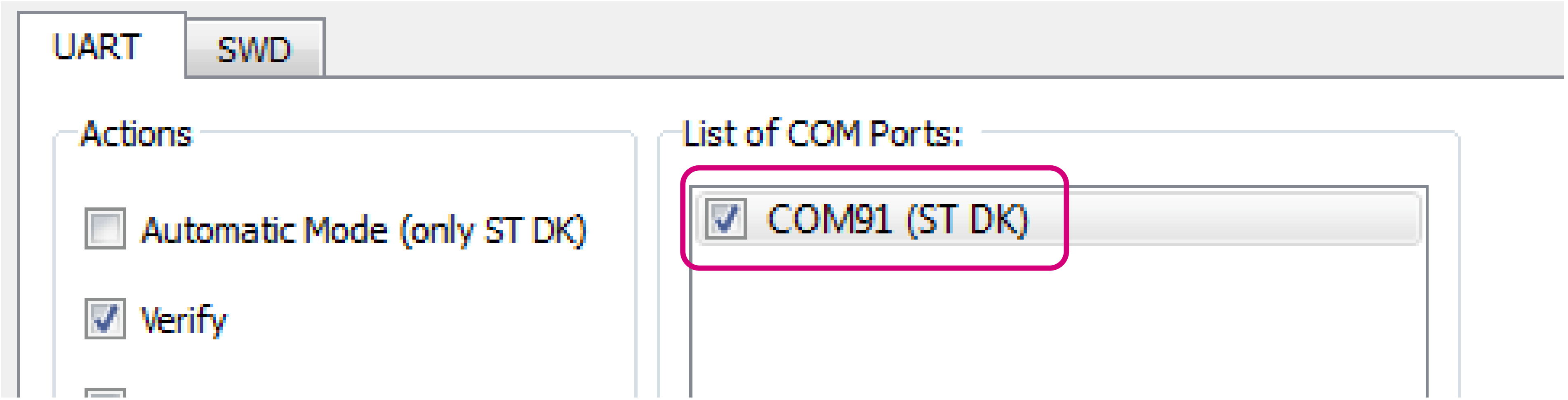
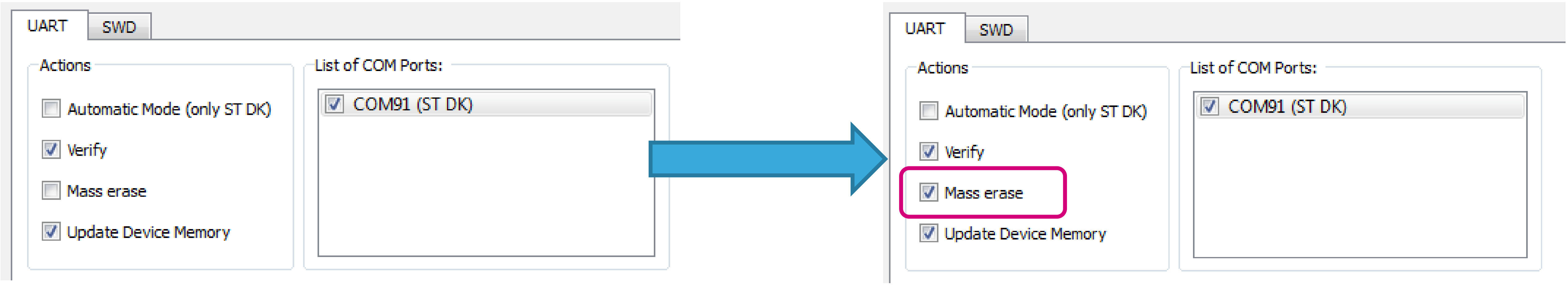
Flash the BlueNRG-2 1/5

1. Select the COM port labeled **(ST DK)**



Flash the BlueNRG-2 2/5

1. Click on **Mass Erase**



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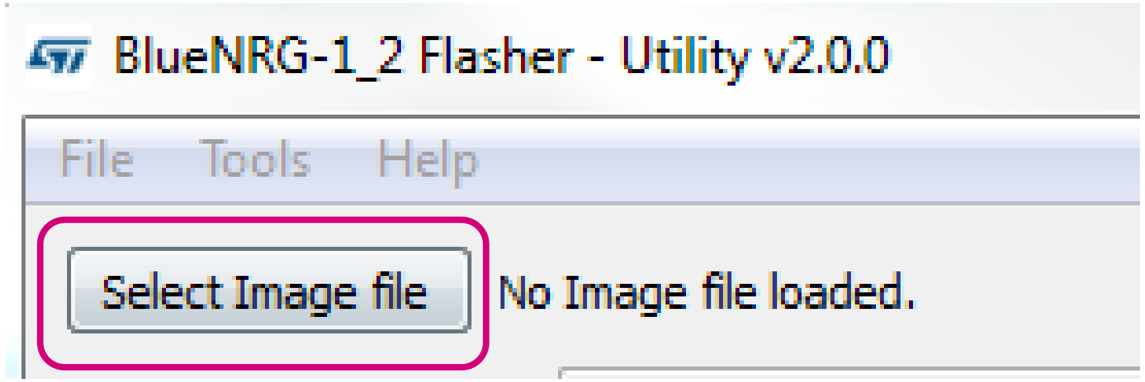
Flash the BlueNRG-2 3/5

1. Click on **Select Image file** button



2. And browse the following **path**

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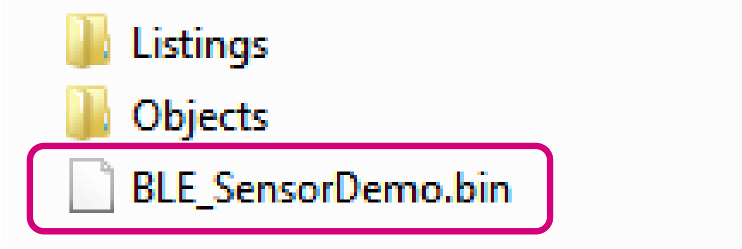
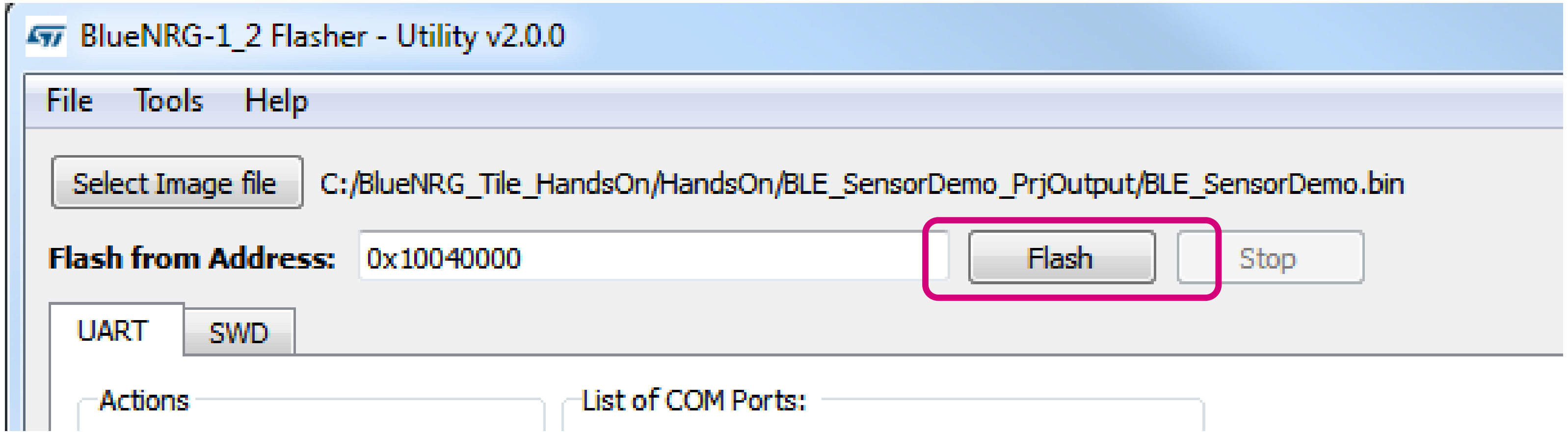
Flash the BlueNRG-2 4/5

1. Select **BLE_SensorDemo.bin**

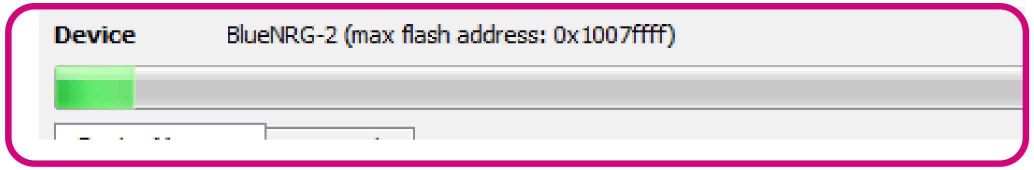


2. Click on the **Flash** button

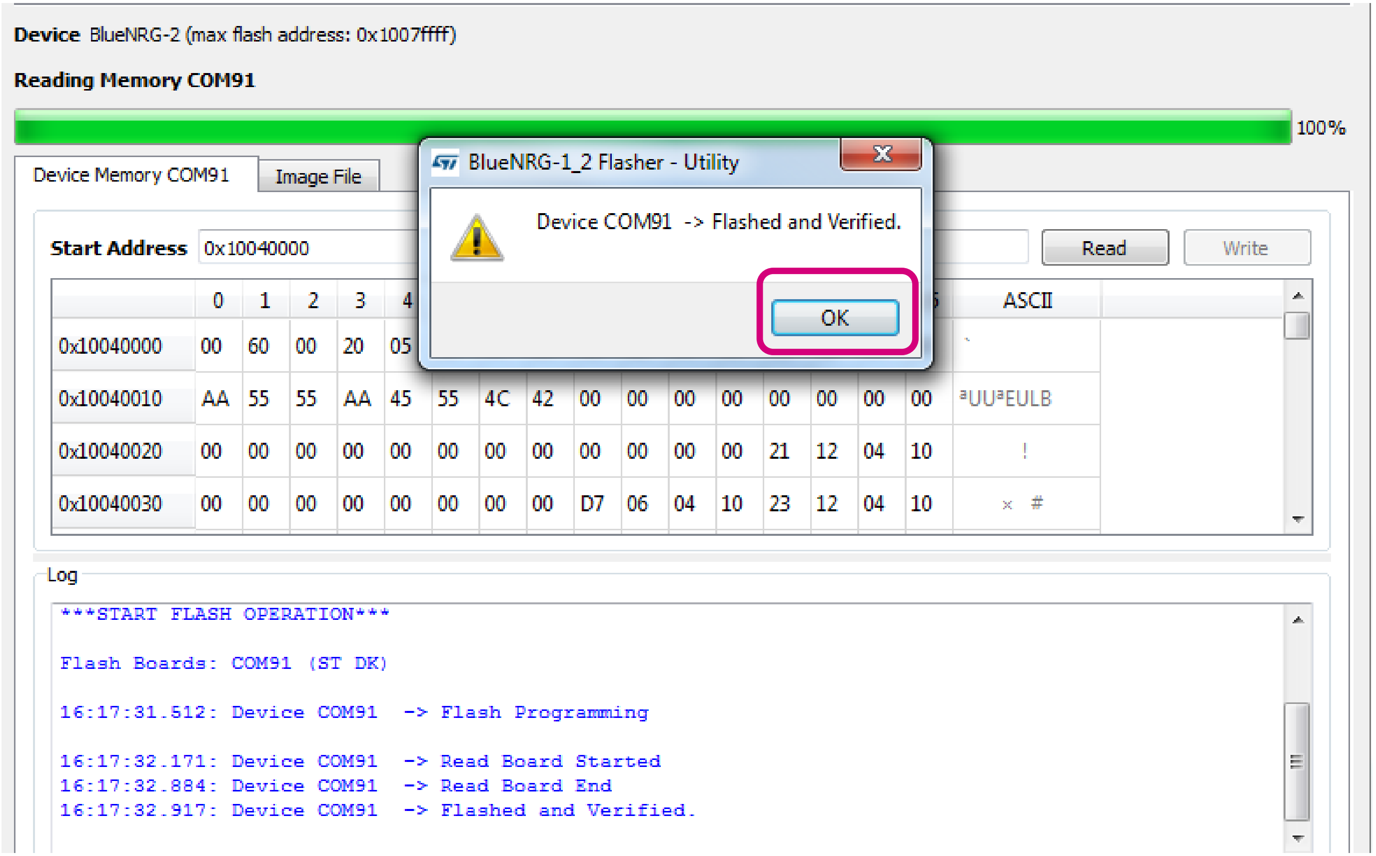


Flash the BlueNRG-2 5/5

1. Flashing starts: **green bar** proceeding



2. Wait for the **pop-up** window and click on **OK**



Do NOT close the Utility!

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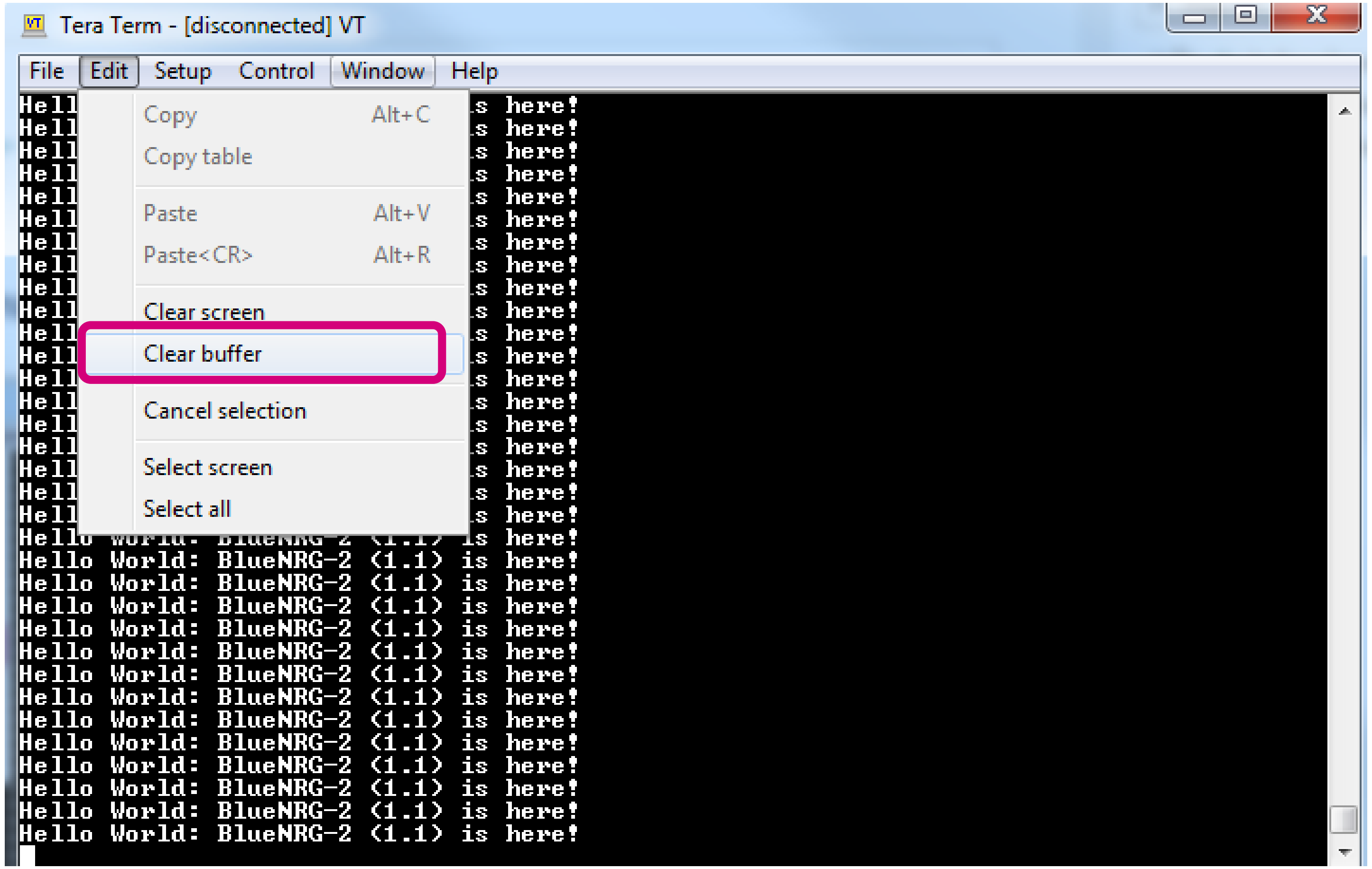
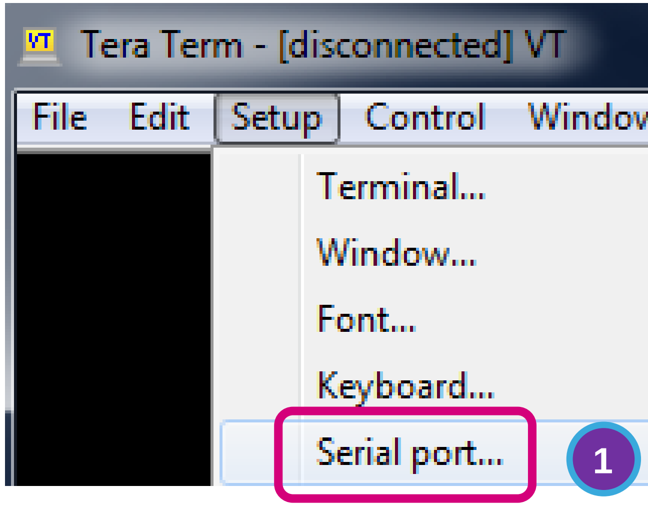
Clean Buffer in the serial terminal

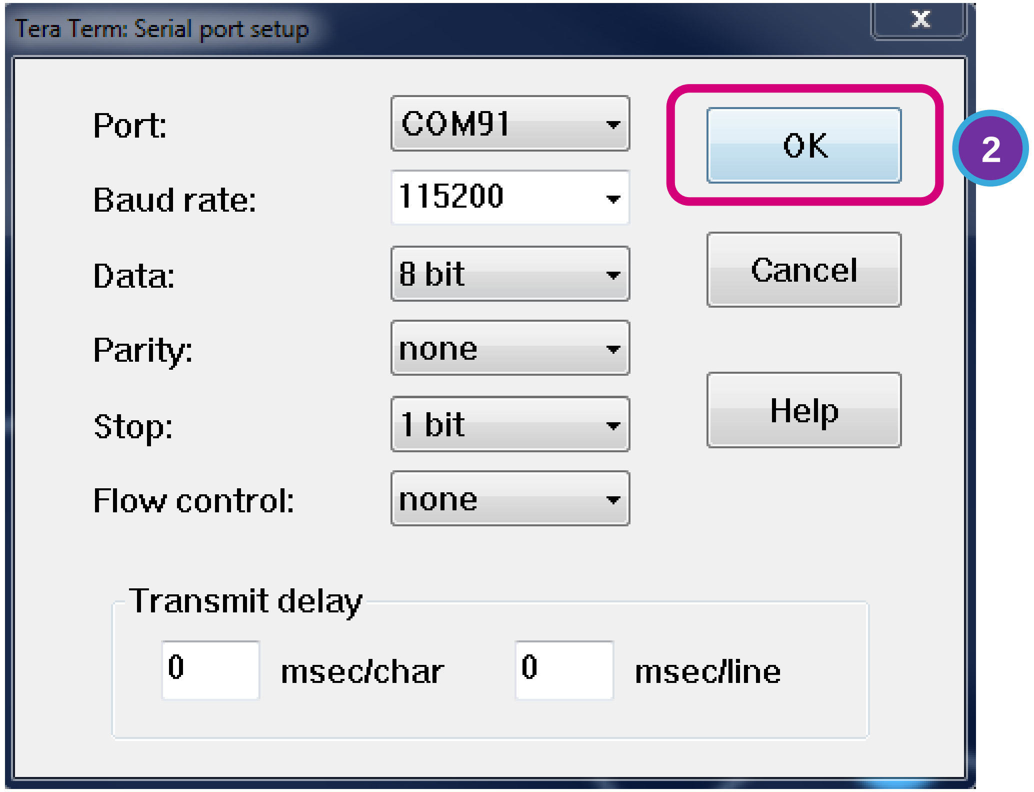
1. In Tera Term in order to have the terminal clean, go to **Edit -> Clear buffer**



Reconnect the serial terminal

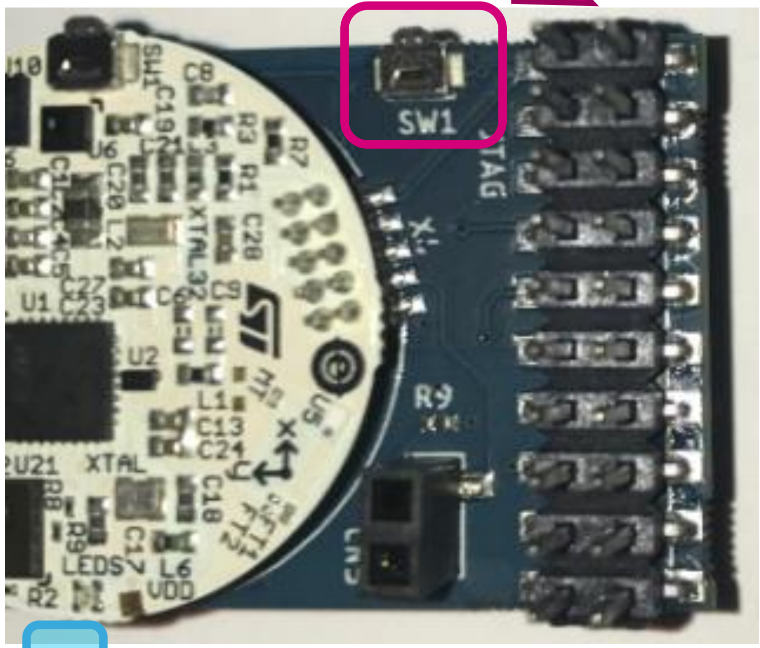
1. Click **Setup** -> **Serial port…**
2. Serial port should already configured. Just need to click on **OK**

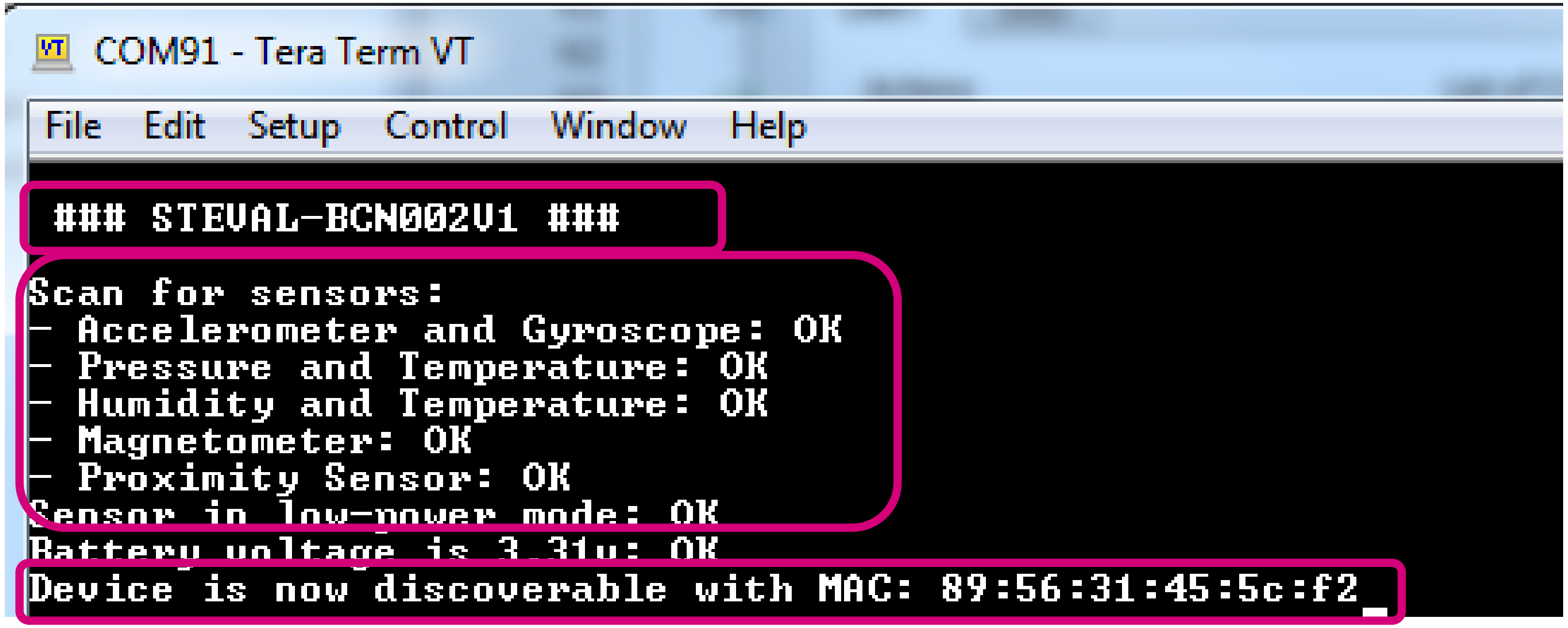




Sanity Check on serial port

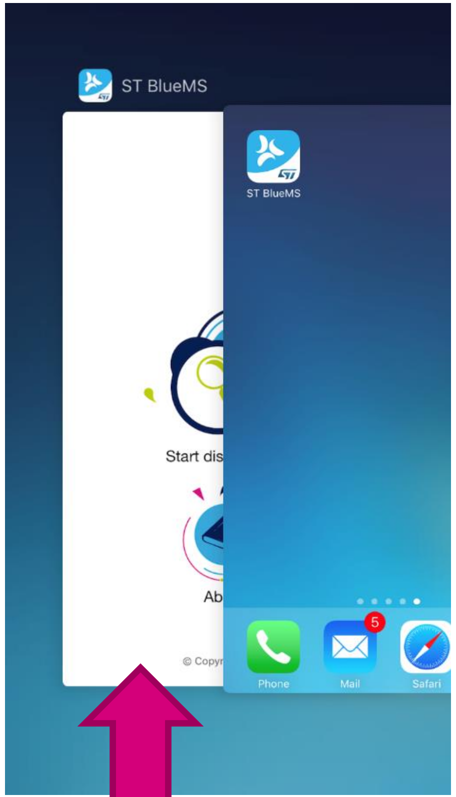
Push **SW1 button** on the blue motherboard -> **LED blinking Blue**





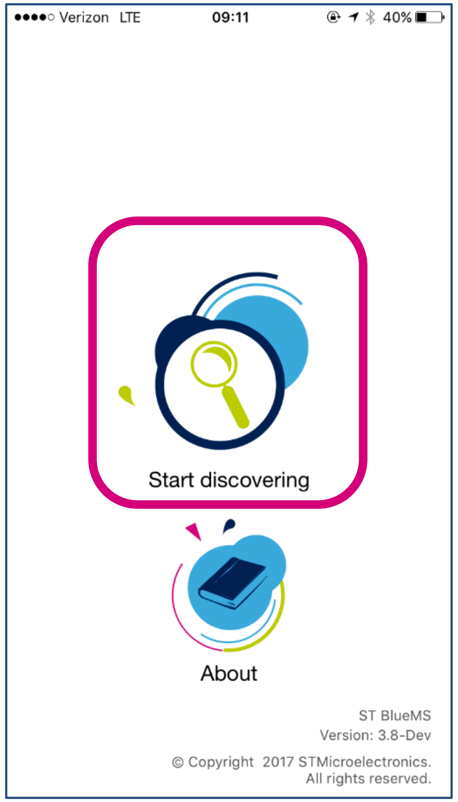
Connect using the BlueMS App

1 **“Kill” the BlueMS app**

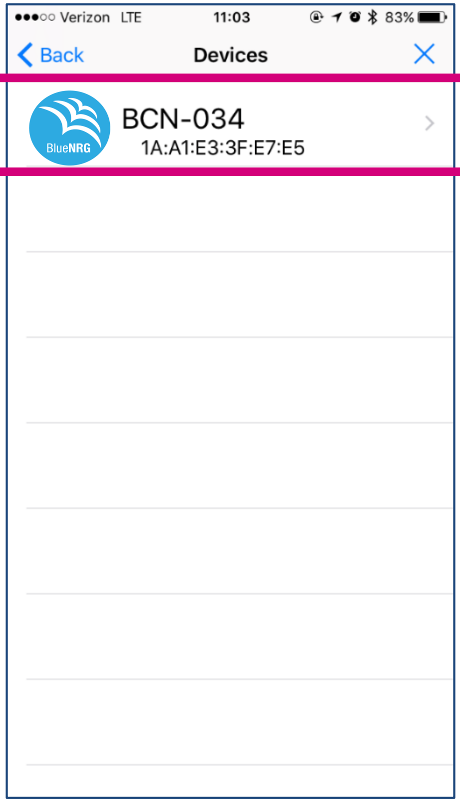


Home button and then swipe to top

2 **Touch “Start discovering”**



3 **Select your STEVAL-BCN002V1**



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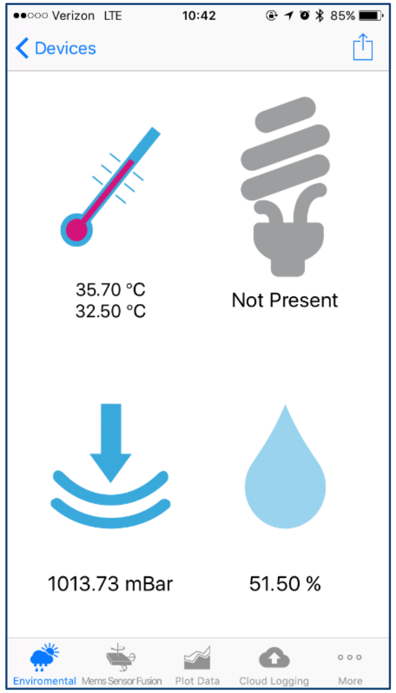
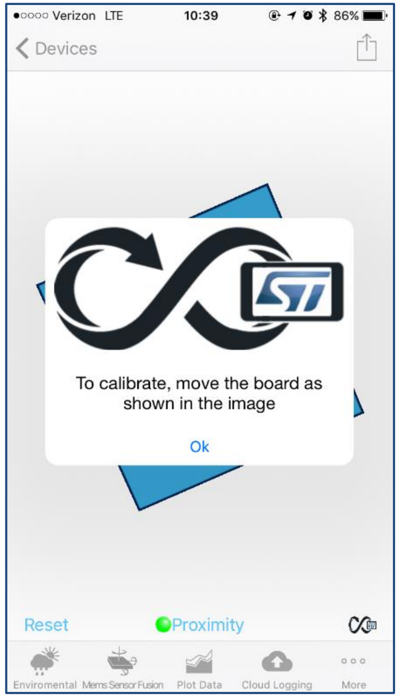
Sensor Data Fusion

Swipe left to view the real-time data plot



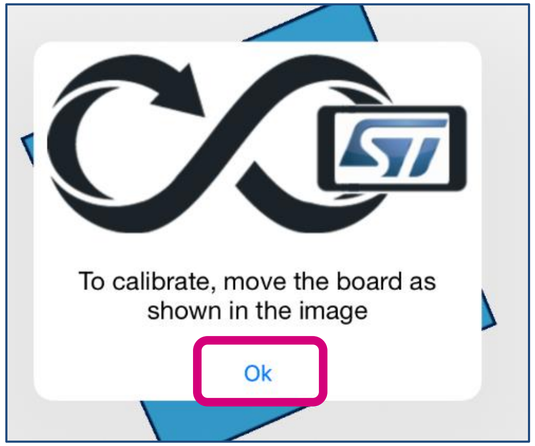
1

"**Sensor Fusion**" tab



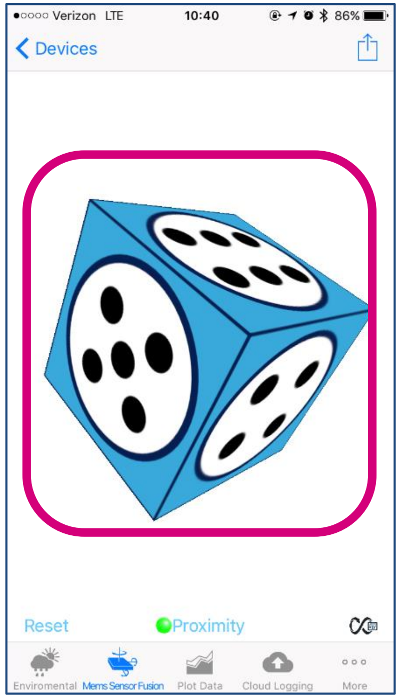
2

Click on **OK**



3

Sensor Fusion **enabled**



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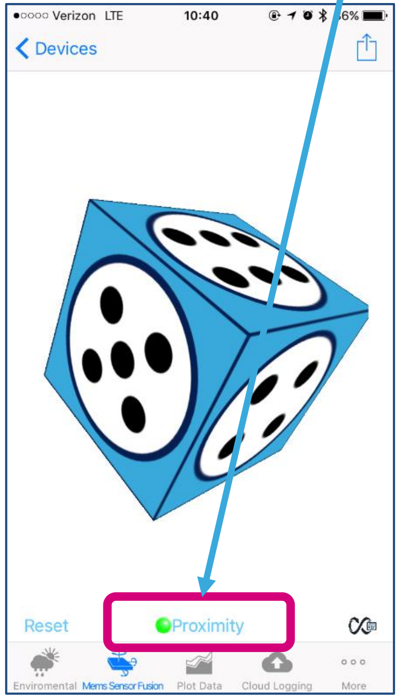
Proximity Sensor

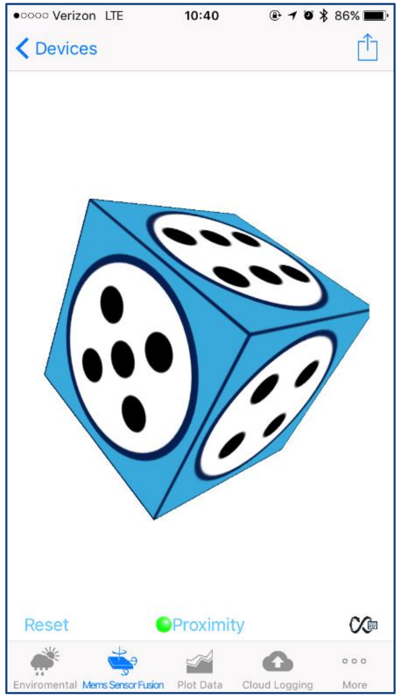
ON Proximity
OFF Proximity

Enable **Proximity** Sensor

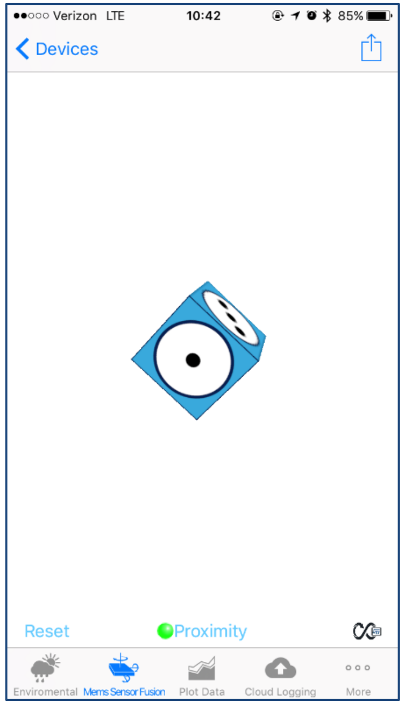


If you move your hand far and close to the BlueNRG-Tile

1 Far from BlueNRG-Tile



2 Near to BlueNRG-Tile



Note: ONLY for rendering purposes, the cube is scaled proportional to a clipped 30 cm distance

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Proximity Sensor - VL53L1X

3rd gen ToF sensor with lens for **long distance** ranging & ROI selection

Product highlights

OLGA: **4.9 x 2.5 x 1.56 mm**
FoV : 27°
Compatible footprint with VL53L0X

Enhanced performances:

- Full FoV ranging : **400cm+** (white target, no IR)
- **Programmable FOV:** SPAD zone selection – full-screen to 4x4

Cutting-edge module and silicon :

- **Fastest miniature ToF product in the market** up to 50Hz
- **Integrated lens** for longer range and better ambient light immunity
- **Programmable settings** to best fit customer's application:
  - Low power with interrupts for user / object detection
  - Long distance ranging
  - High accuracy for small movement detection

Applications

Presence user detection

- Autonomous mode with interrupts
- Low-power
- Long distance 400cm+
- PC, tablets, IoT, portable handsets, security

Obstacle detection:

- Robots: Obstacle avoidance
- Vacuum cleaners: Wall following, cliff detection
- Drones: Take-off and landing, Ceiling detection

Accurate objects distance scanning

- Vending machines: control of objects in racks
- Coins dispensers: coins counting
- Smart shelves: Consumer scanning

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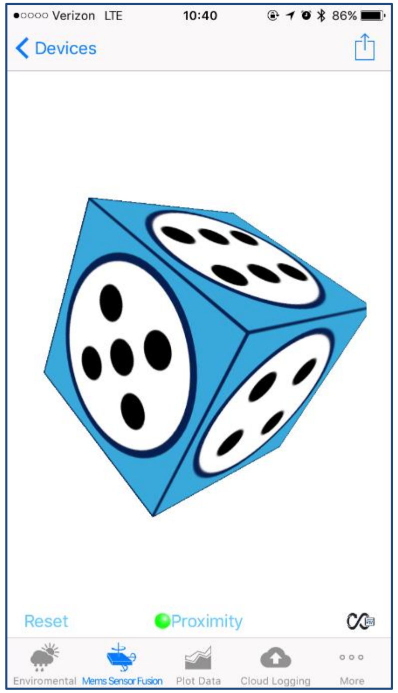
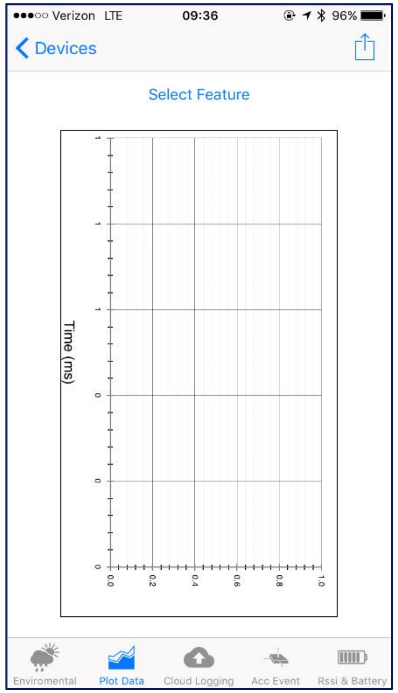
Full-range Proximity Real-time Data Plot

Swipe left to view the real-time data plot



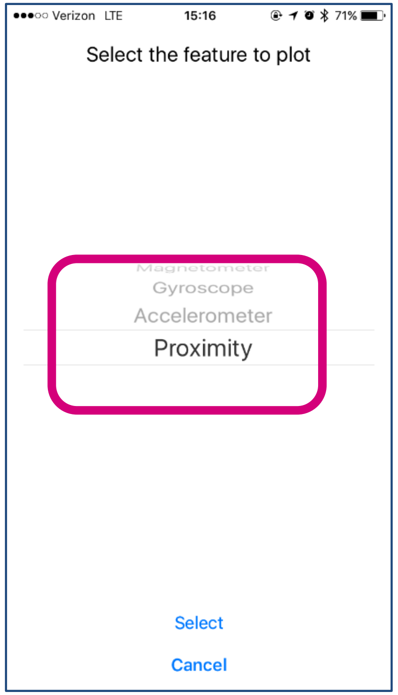
1

"**Plot Feature**" tab



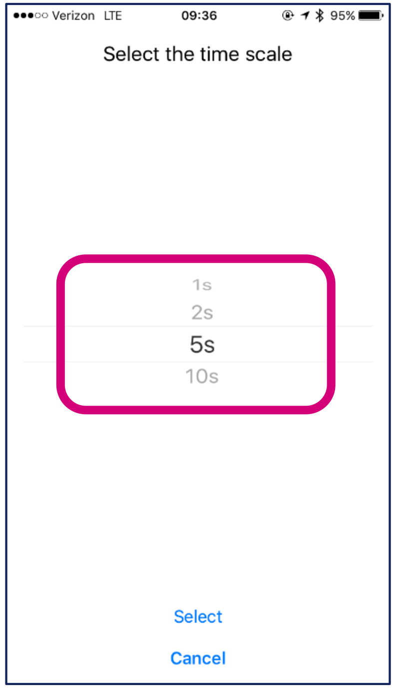
2

Select **Proximity**



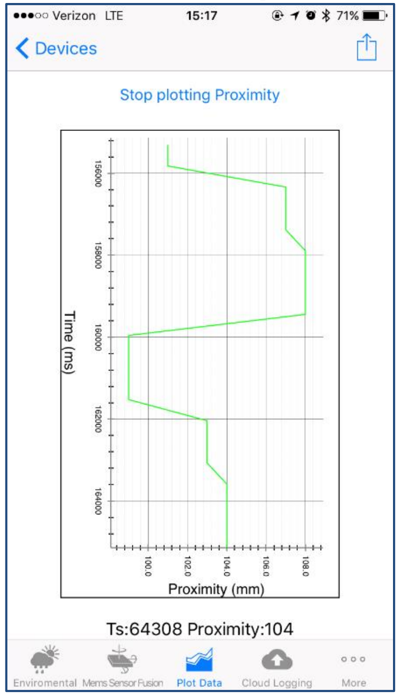
3

Select the **time frame**



4

View the real-time data plot



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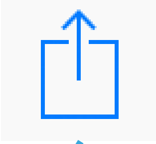
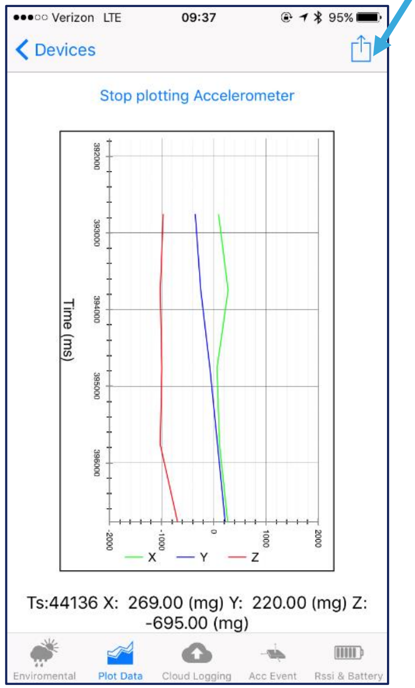
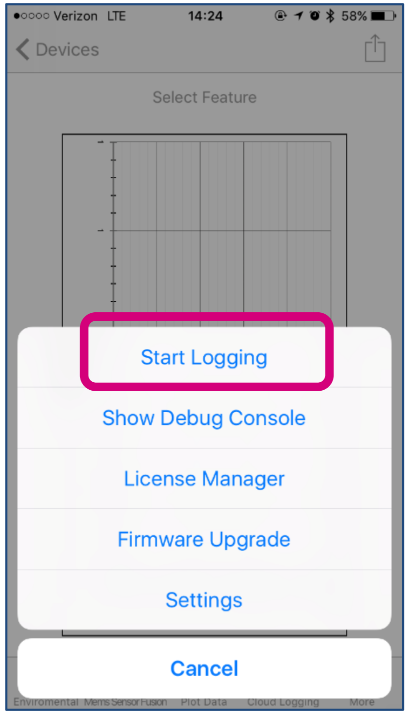
Logging Real-time Data Plot

Click on top right cornerv

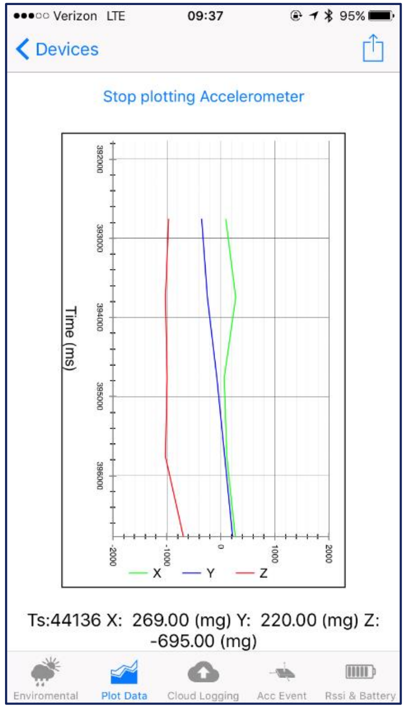




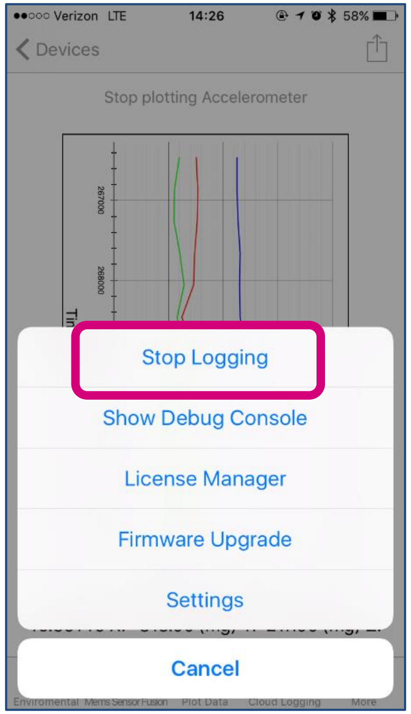
1. Select **"Start logging"**



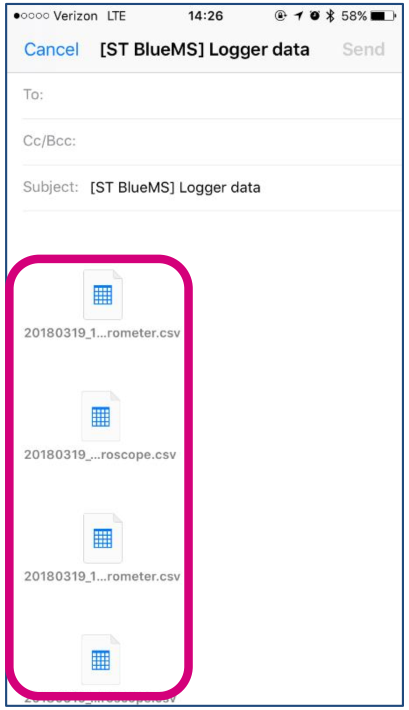
2. After some time re-click on the right-top corner



3. Select **"stop logging"**



4. App opens your email client



.csv files attached to the email

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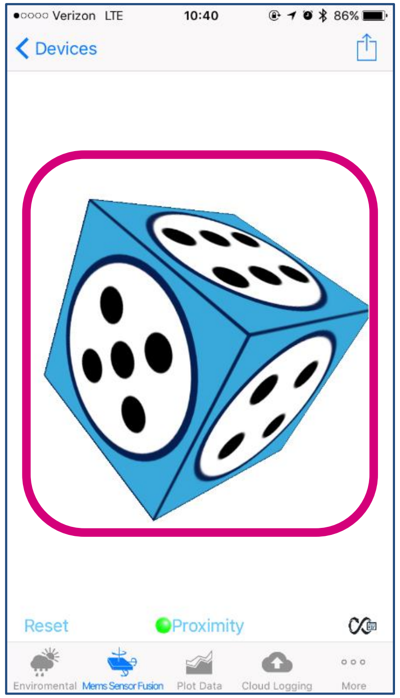
Sensor Data Fusion

Sensor Fusion
enabled



Try **static** position: no drift, the cube is perfectly still

- In steady static position the **acc** and **mag** enable an accurate orientation estimation
- acc vibrations and mag bias and interferences are rejected or compensated by the **motionFX** library

Try highly **dynamic** motion: perfect tracking[note1]

- In high dynamic motion the acc cannot be used, therefore the **gyro** is utilized to update the orientation[note 2]
- gyro bias is estimated and compensated by the **motionFX** library

- Note 1: very high rotation speed will result in gyro signal clipping, causing a higher integration error, hence motionFX will take longer to converge to actual orientation
- Note 2: the small residual bias will cause some integration error which is recovered quickly when the motion ends exploiting the acc and mag

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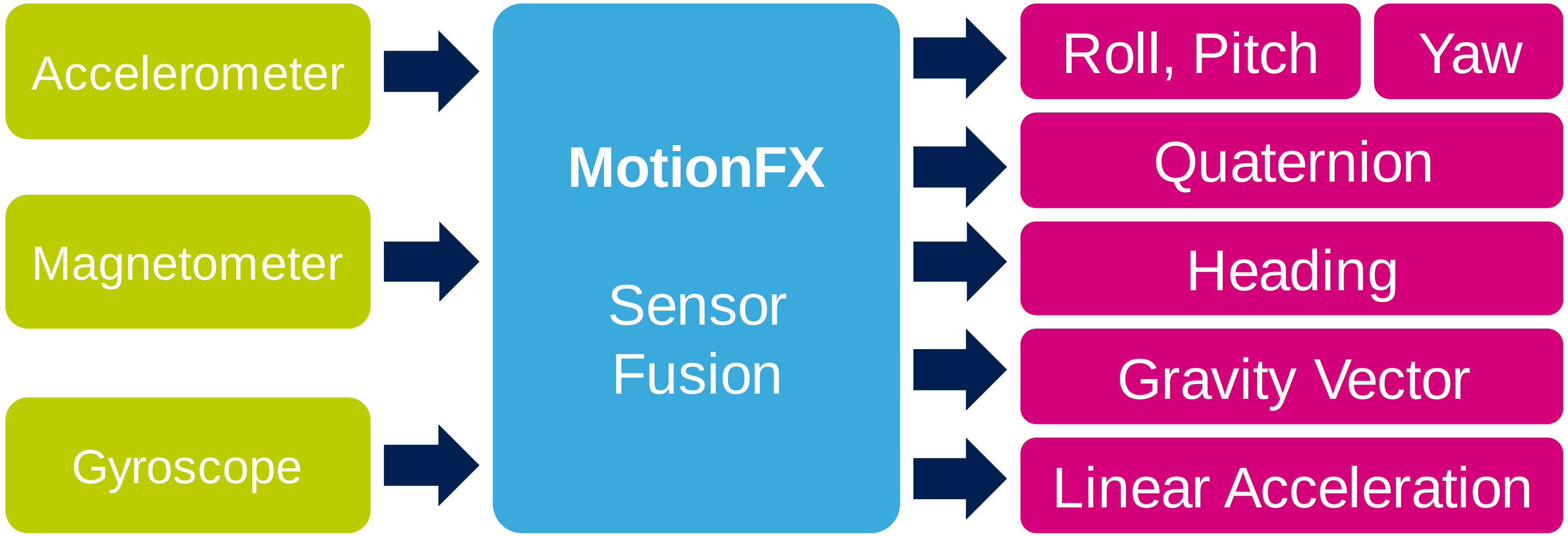
Sensor Data Fusion

MotionFX library

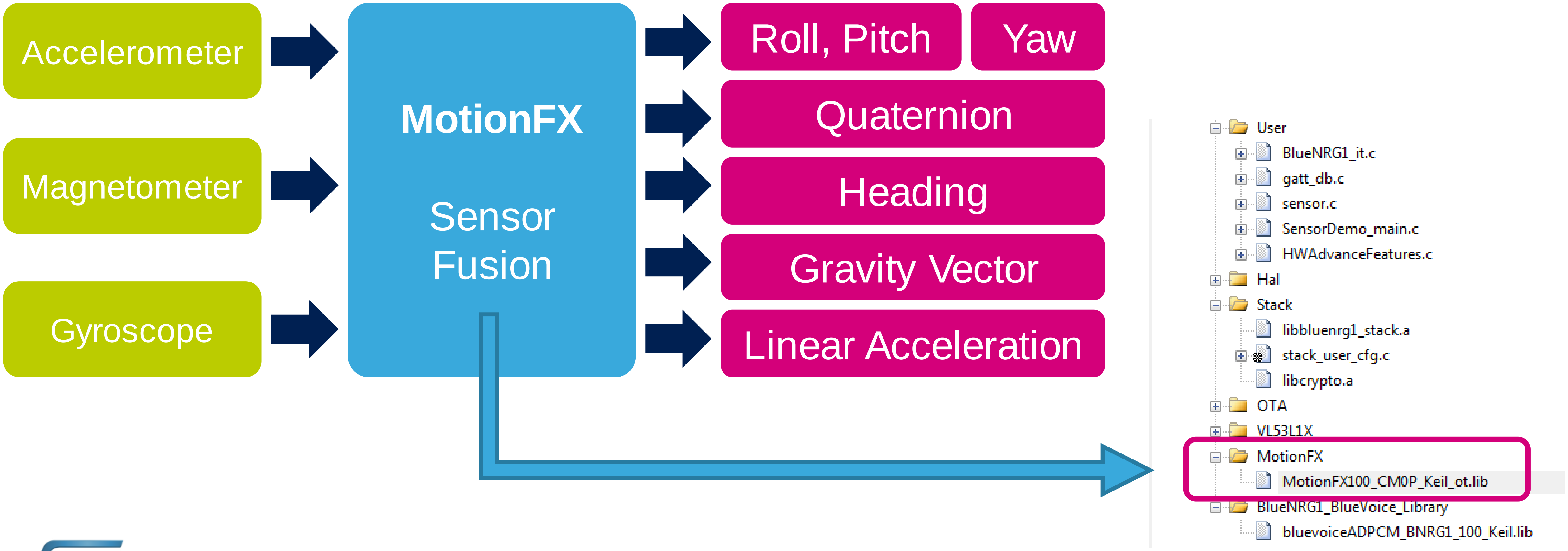


Motion FX library provides orientation estimation plus:

- Magnetometer bias compensation and anomaly rejection.
- Accelerometer vibrations rejection.
- Gyroscope bias offset compensation.

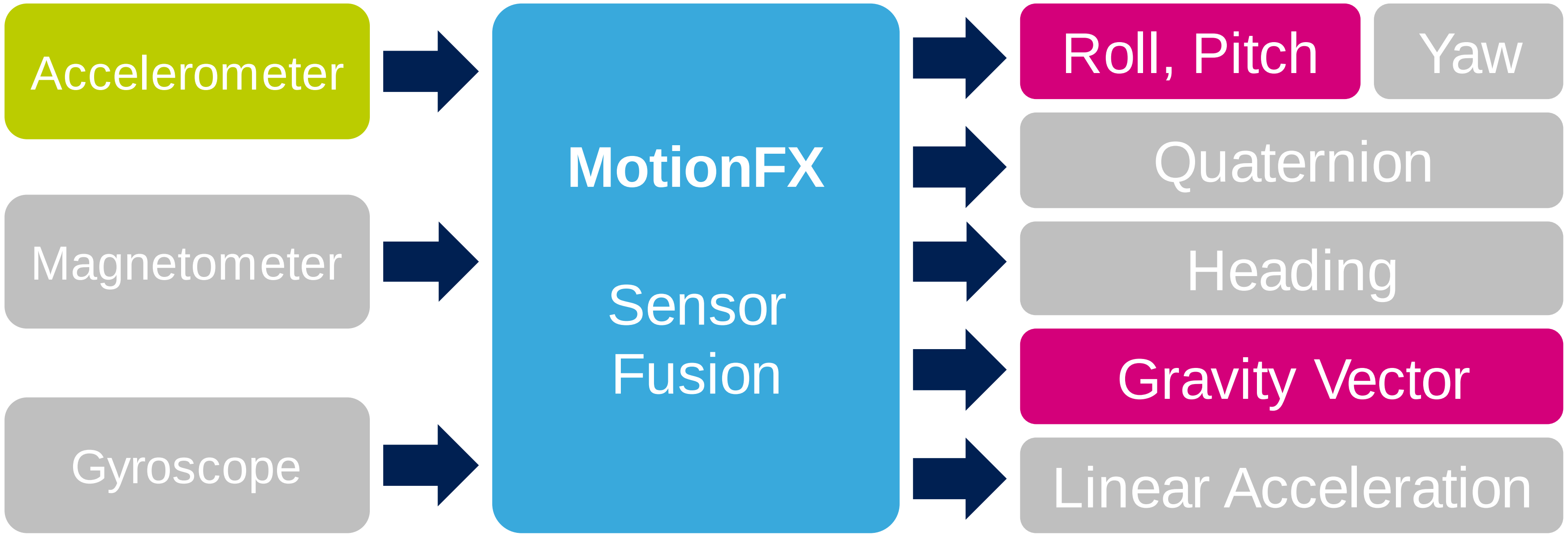
Sensor Data Fusion

MotionFX library



Sensor Data Fusion

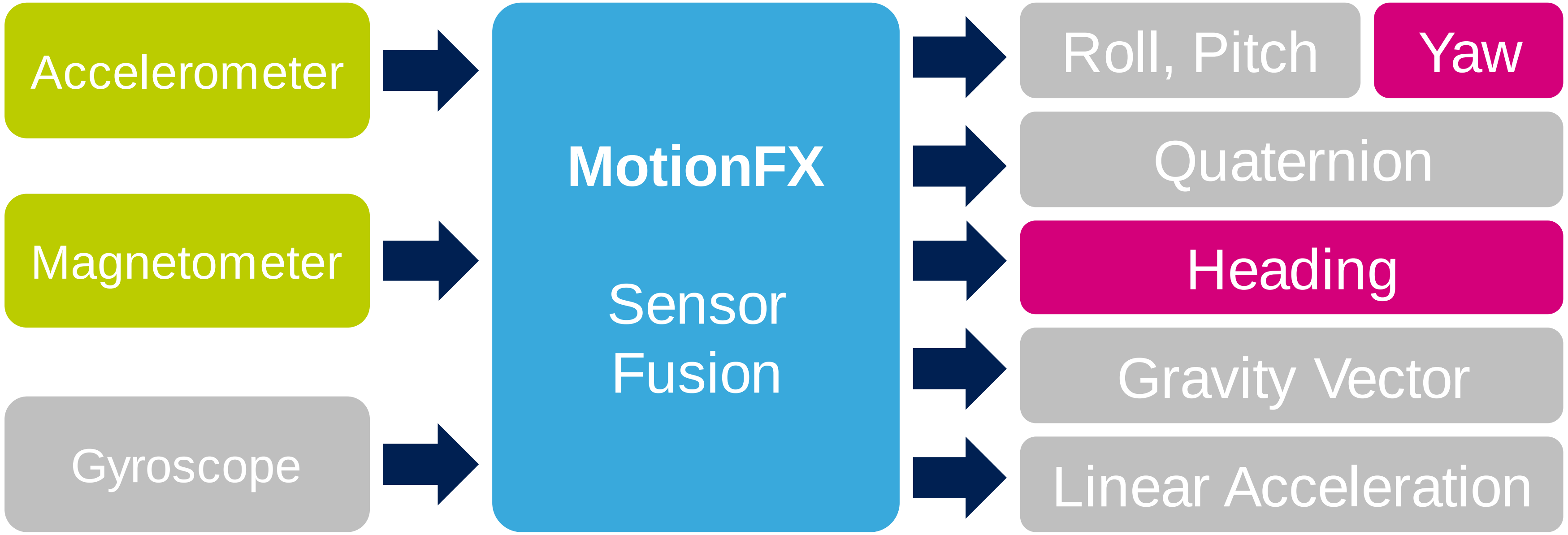
MotionFX library



- **Accelerometer** gives roll and pitch angles and the gravity vector …but **only in static conditions**! (or low dynamics, such as, glance gesture)

Sensor Data Fusion

MotionFX library



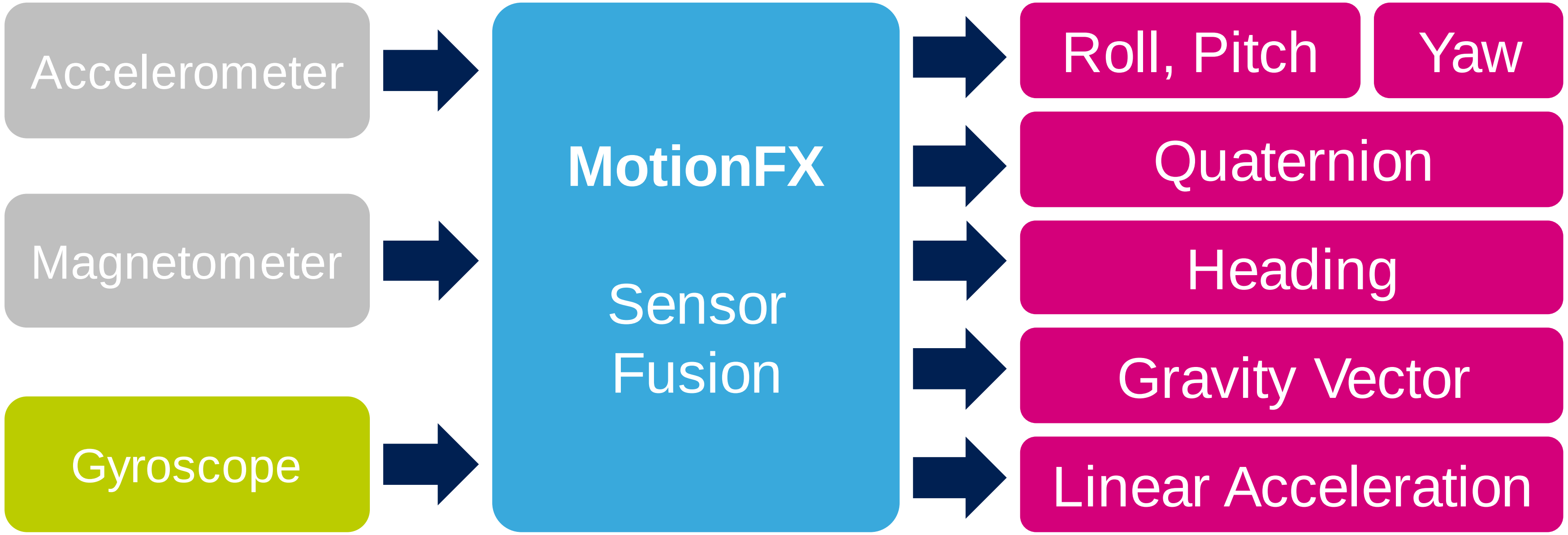
- **Magnetometer** gives yaw angle and heading

…but **only if tilt is compensated**: the accelerometer is needed!

…and mag bias **(hard-iron) must be compensated!**

Sensor Data Fusion

MotionFX library



- **Gyroscope** gives the new orientation based on previous orientation

…but gyro bias **offset needs to be compensated** for accuracy!

Sensor Data Fusion

MotionFX library

Accelerometer → Magnetometer → Gyroscope → **MotionFX** Sensor Fusion → Roll, Pitch | Yaw; Quaternion; Heading; Gravity Vector; Linear Acceleration

Motion FX library provides orientation estimation plus:

- Magnetometer hard-iron offset compensation.
- Accelerometer vibrations rejection.
- Gyroscope bias offset compensation.

Gyroscope

The gyroscope is the most important sensor in the system
…works in highly dynamic conditions when the Acc cannot be used
…works with magnetic anomalies when the Mag cannot be used

LSM6DSO is an inertial module
with **Acc** and **Gyro**

- **Exceptional noise performance** for maximum accuracy in orientation estimation
  - 90 ug/sqrtHz acc noise density
  - **3.8 mdps/sqrtHz gyro noise density**
- **Extremely low-power**
  - **650 uA peak power** at ODR 6.66kS/sec Acc+Gyro in high performance mode!

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LSM6DSO

iNEMO inertial module:
always-on 3D accelerometer and 3D gyroscope

Data brief

LGA-14L
(2.5 x 3 x 0.83 mm) typ.

Features

- Power consumption: 0.55 mA in combo high-performance mode
- "Always-on" experience with low power consumption for both accelerometer and gyroscope
- Smart FIFO up to 9 kbyte
- Android compliant
- ±2/±4/±8/±16 *g* full scale
- ±125/±250/±500/±1000/±2000 dps full scale
- Analog supply voltage: 1.71 V to 3.6 V
- Independent IO supply (1.62 V)
- Compact footprint: 2.5 mm x 3 mm x 0.83 mm
- SPI / I²C & MIPI I3C[SM] serial interface with main processor data synchronization
- Auxiliary SPI for OIS data output for gyroscope and accelerometer
- Advanced pedometer, step detector and step counter
- Significant Motion Detection, Tilt detection
- Standard interrupts: free-fall, wakeup, 6D/4D orientation, click and double-click
- Programmable finite state machine: accelerometer, gyroscope and external sensors
- Embedded temperature sensor
- ECOPACK®, RoHS and "Green" compliant

Description

The LSM6DSO is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope boosting performance at 0.55 mA in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer.

The LSM6DSO supports main OS requirements, offering real, virtual and batch sensors with 9 kbytes for dynamic data batching. ST's family of MEMS sensor modules leverages the robust and mature manufacturing processes already used for the production of micromachined accelerometers and gyroscopes. The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DSO has a full-scale acceleration range of ±2/±4/±8/±16 *g* and an angular rate range of ±125/±250/±500/±1000/±2000 dps.

The LSM6DSO fully supports EIS and OIS applications as the module includes a dedicated configurable signal processing path for OIS and auxiliary SPI, configurable for both the gyroscope and accelerometer.

High robustness to mechanical shock makes the LSM6DSO the preferred choice of system designers for the creation and manufacturing of reliable products. The LSM6DSO is available in a plastic land grid array (LGA) package.

Table 1. Device summary

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Magnetometer

LIS2MDL is digital Mag

- **Exceptional noise performance and dynamic range** for maximum accuracy in orientation estimation
  - 50 Gauss dynamic range
  - **3 mgauss RMS noise**
- **Embedded offset compensation**
  - **Intrinsic offset is estimated and compensated automatically**
  - Extrinsic offset (hard-iron) must be estimated by host and can be compensated internally

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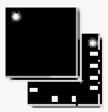
LIS2MDL

Digital output magnetic sensor:
ultra-low-power, high-performance 3-axis magnetometer

Datasheet - production data



LGA-12 (2.0x2.0x0.7 mm)

Features

- 3 magnetic field channels
- ±50 gauss magnetic dynamic range
- 16-bit data output
- SPI/I²C serial interfaces
- Analog supply voltage 1.71 V to 3.6 V
- Selectable power mode/resolution
- Single measurement mode
- Programmable interrupt generator
- Embedded self-test
- Embedded temperature sensor
- ECOPACK®, RoHS and "Green" compliant

Applications

- Tilt-compensated compasses
- Map rotation
- Intelligent power saving for handheld devices
- Gaming and virtual reality input devices

Description

The LIS2MDL is an ultra-low-power, high-performance 3-axis digital magnetic sensor.

The LIS2MDL has a magnetic field dynamic range of ±50 gauss.

The LIS2MDL includes an I²C serial bus interface that supports standard, fast mode, fast mode plus, and high-speed (100 kHz, 400 kHz, 1 MHz, and 3.4 MHz) and an SPI serial standard interface.

The device can be configured to generate an interrupt signal for magnetic field detection.

The LIS2MDL is available in a plastic land grid array package (LGA) and is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

Table 1. Device summary

Part number	Temp. range [°C]	Package	Packaging
LIS2MDL	-40 to +85	LGA-12	Tray
LIS2MDLTR	-40 to +85	LGA-12	Tape and reel

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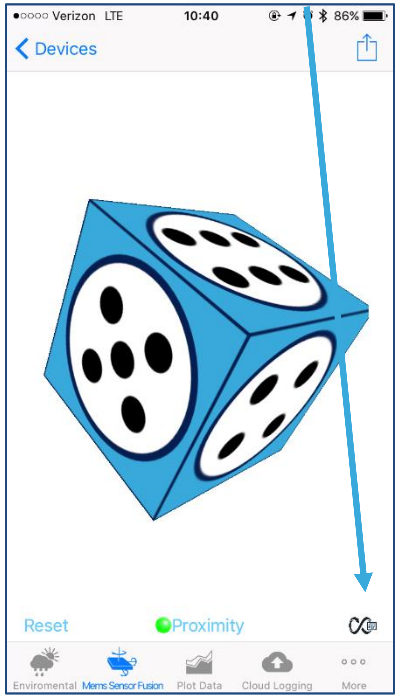
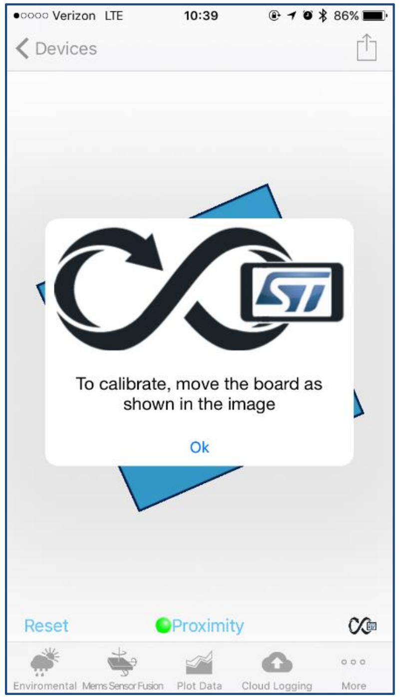
Magnetometer

Calibration

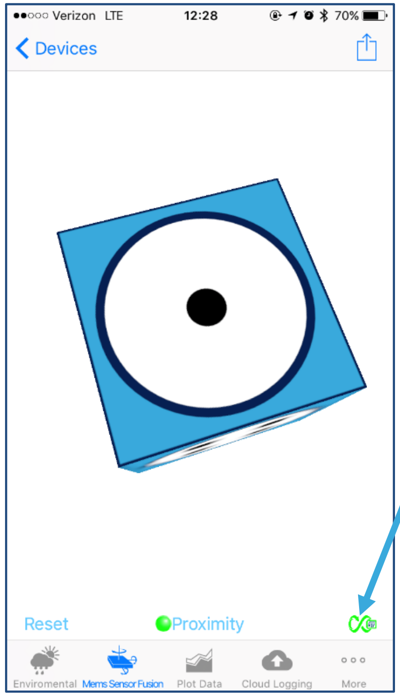
Touch 



Move the BlueNRG-Tile with the "**8 pattern**" shown in the figure to calibrate the magnetometer



Calibration is **Completed** when the icon becomes **green**.



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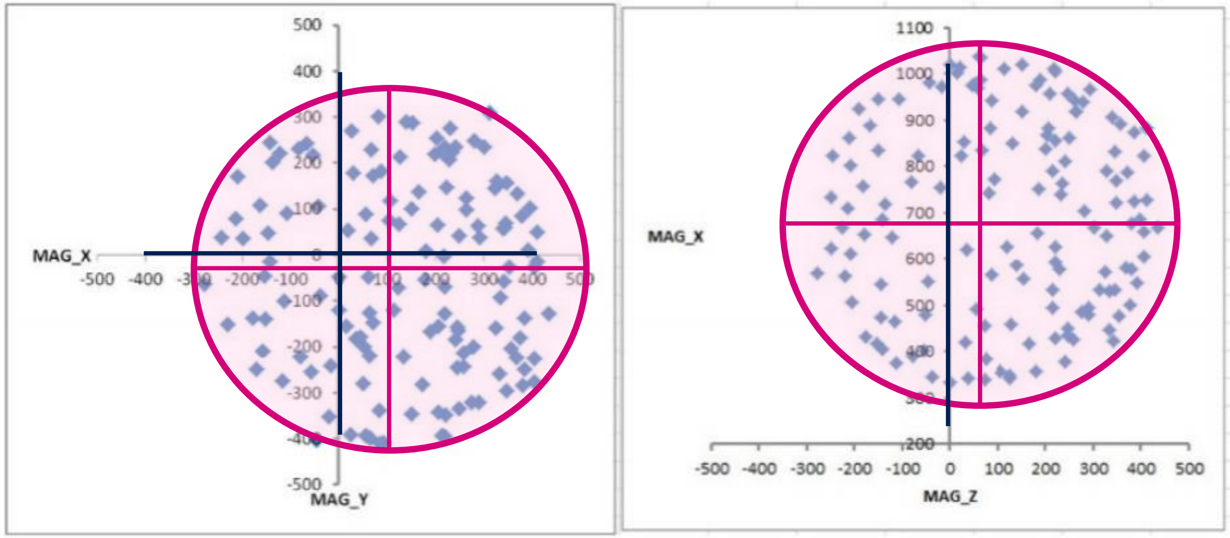
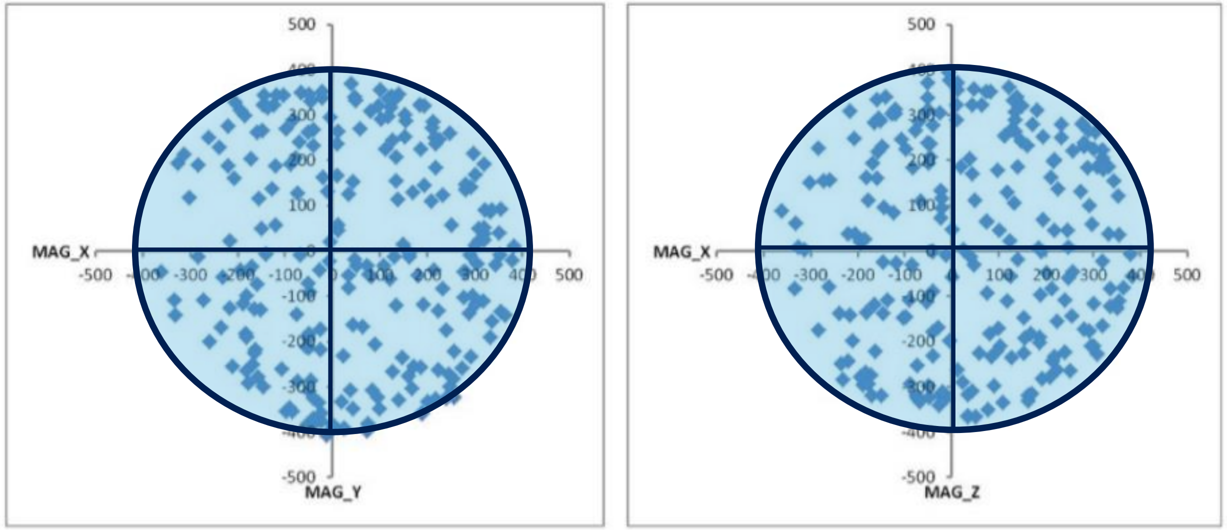
Magnetometer

Calibration



Before calibration,
data not centered

Each magnetometer has **intrinsic offset:** this is compensated **internally**



After calibration,
data centered:
hard-iron offset
subtracted

Higher precision in the compensation!

What if magnetometer is NOT calibrated?
Not accurate eCompass

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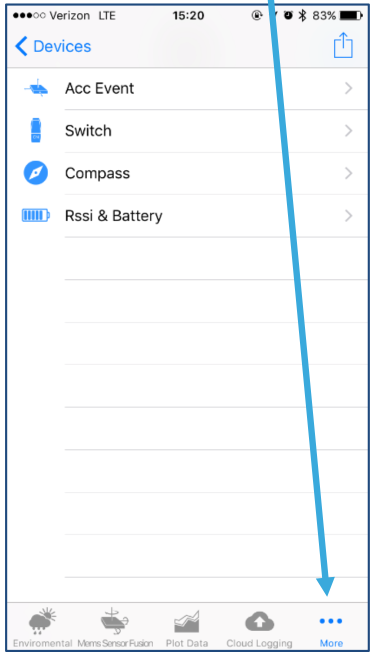
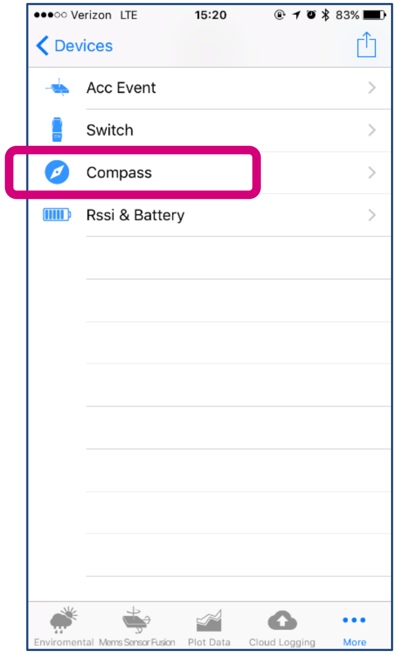
Magnetometer eCompass

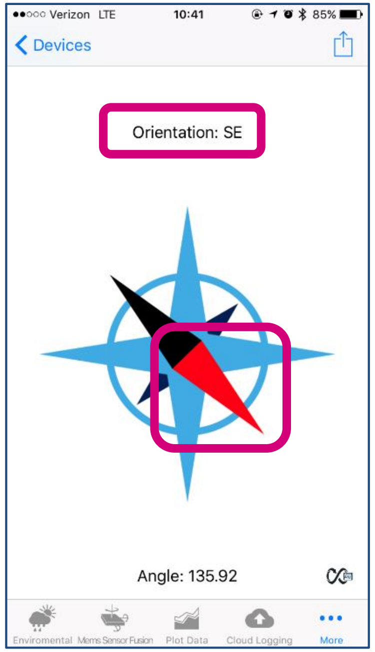
Touch



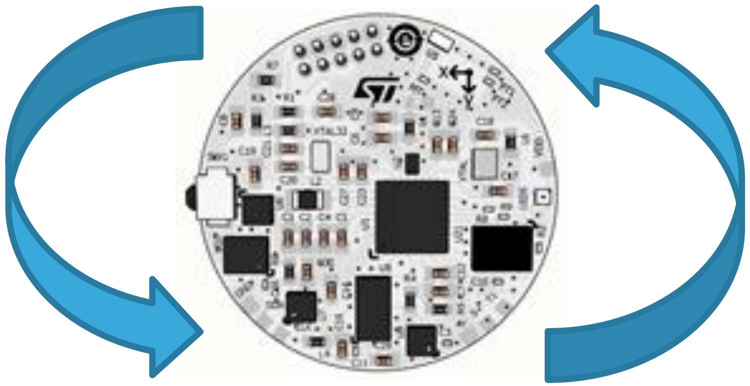
Select "**Compass**"



Red arrow is related to the current orientation of the BlueNRG-Tile



Rotate the BlueNRG-Tile



(you can check against the phone eCompass)

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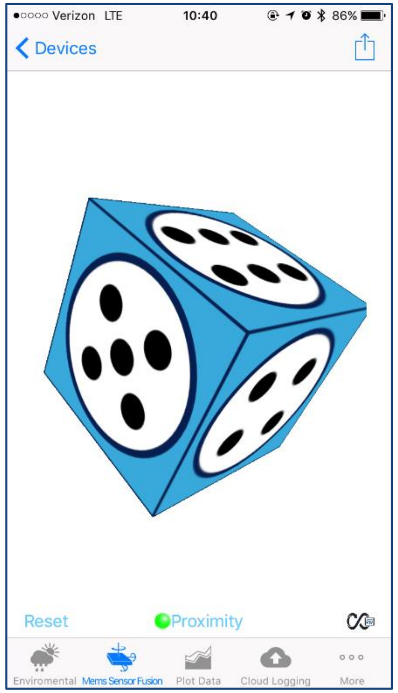
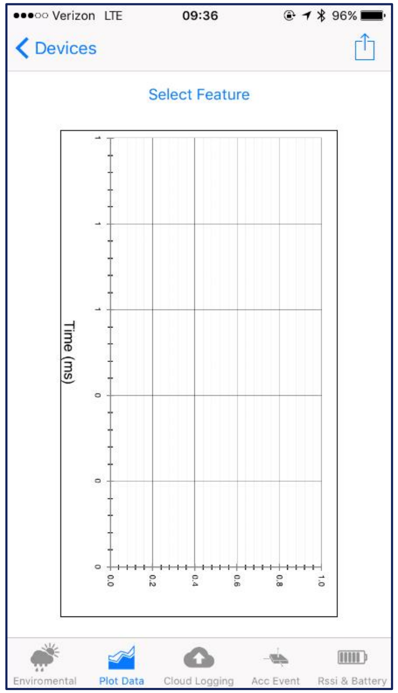
Real-time Data Plot

Swipe left to view the real-time data plot



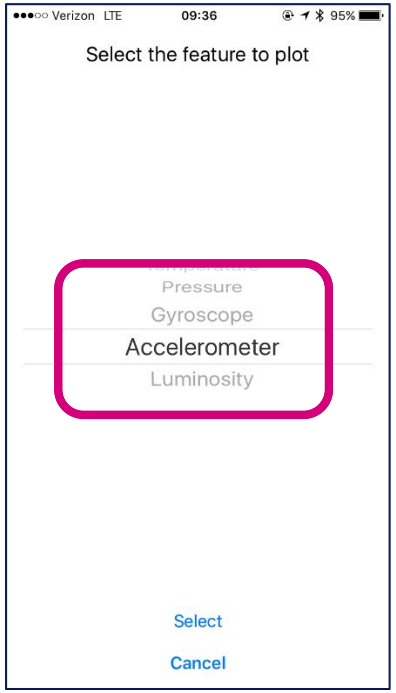
1

"**Plot Feature**" tab



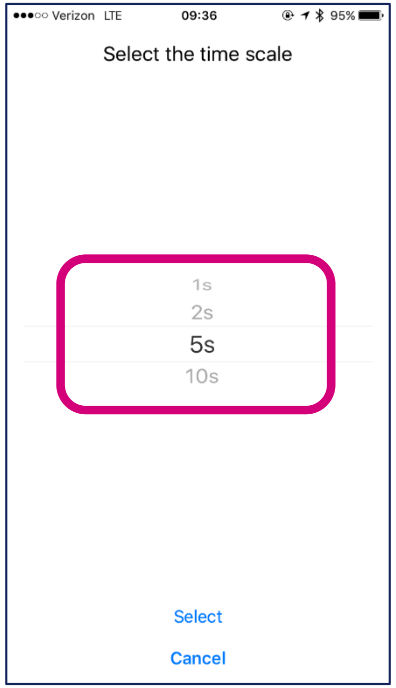
2

Select the **sensor device**



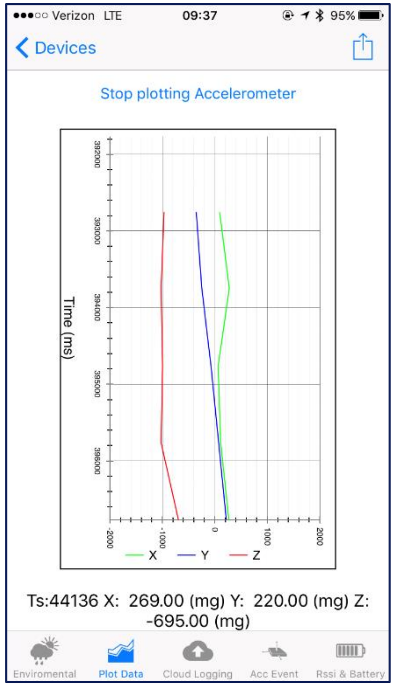
3

Select the **time frame**



4

View the real-time data plot



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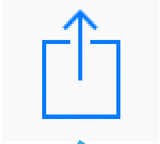
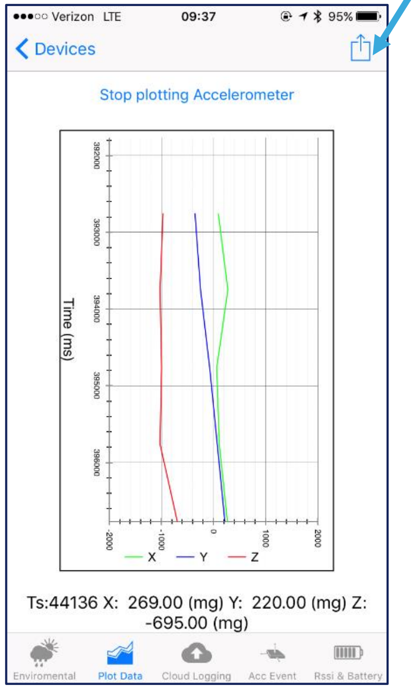
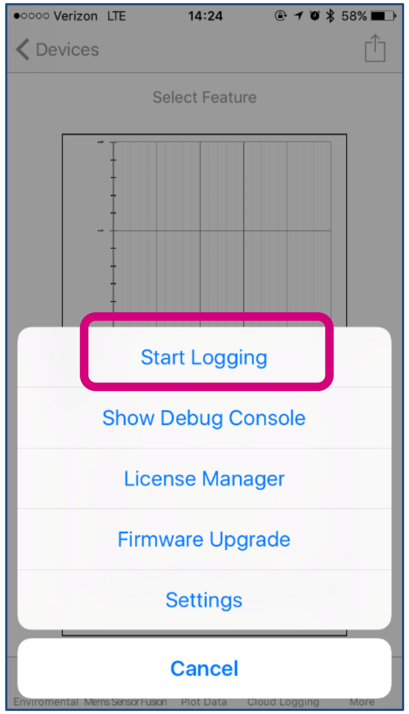
Logging Real-time Data Plot

Click on top right cornerv

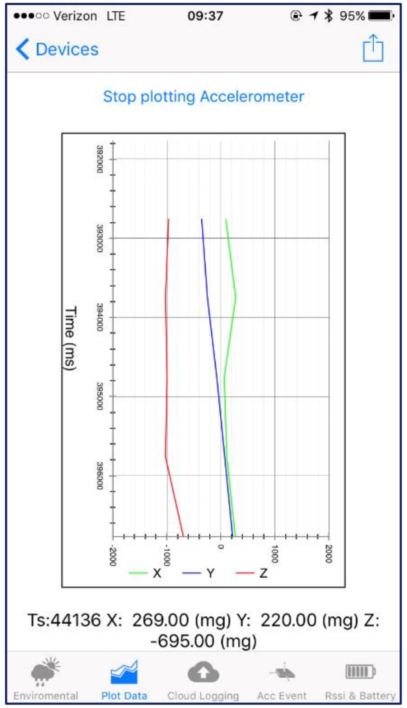




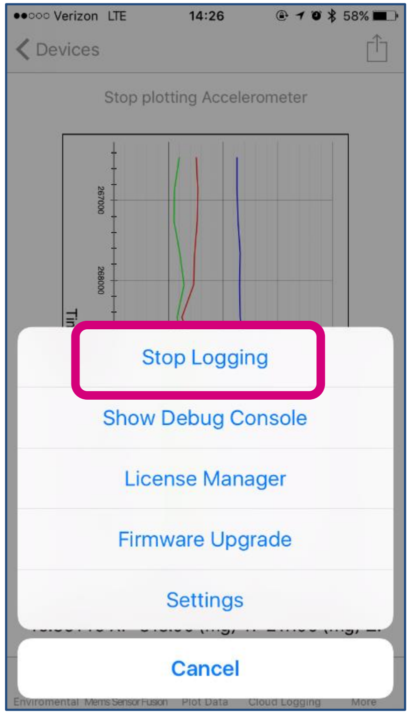
1 Select **"Start logging"**



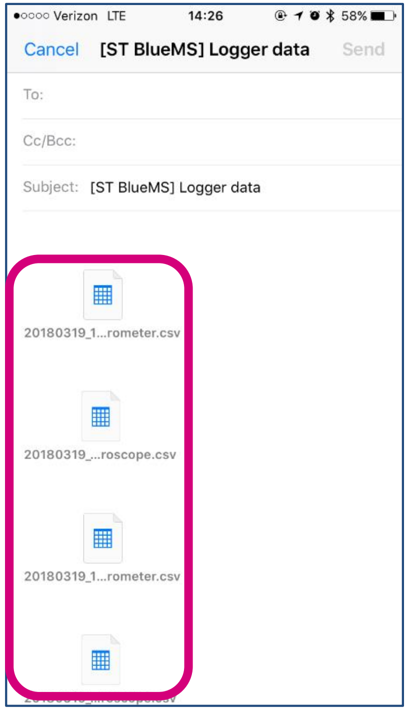
2 After some time re-click on the right-top corner



3 Select **"stop logging"**



4 App opens your email client



.csv files attached to the email

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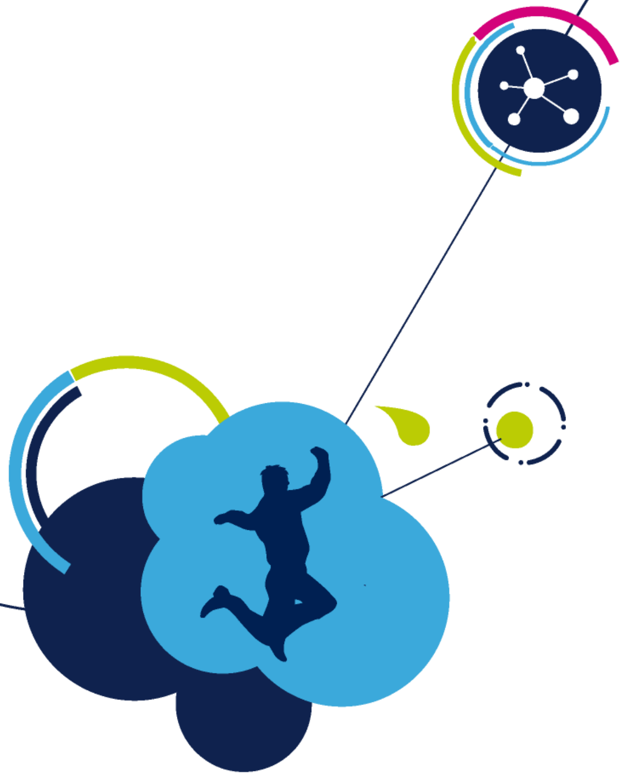
Do NOT disconnect!
Just stay connected for the next lab…



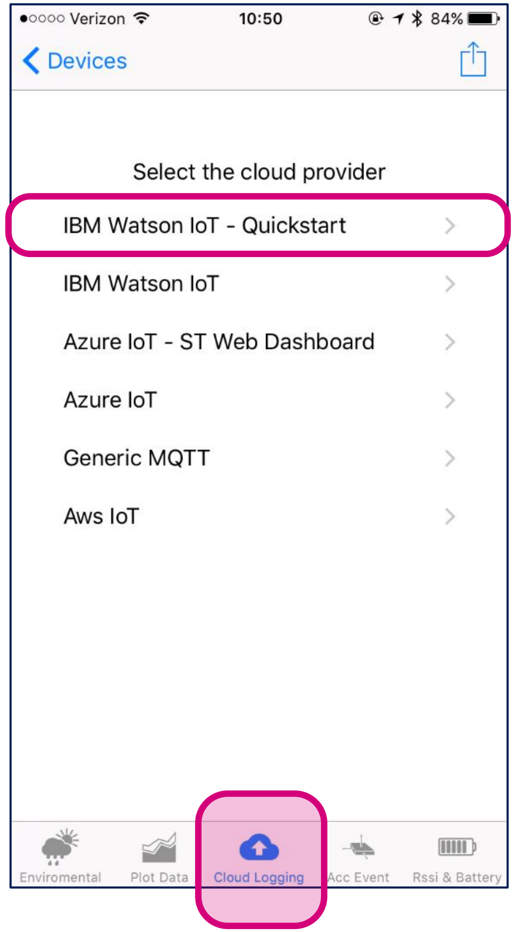
Lab 6

Cloud data logging on IBM Watson

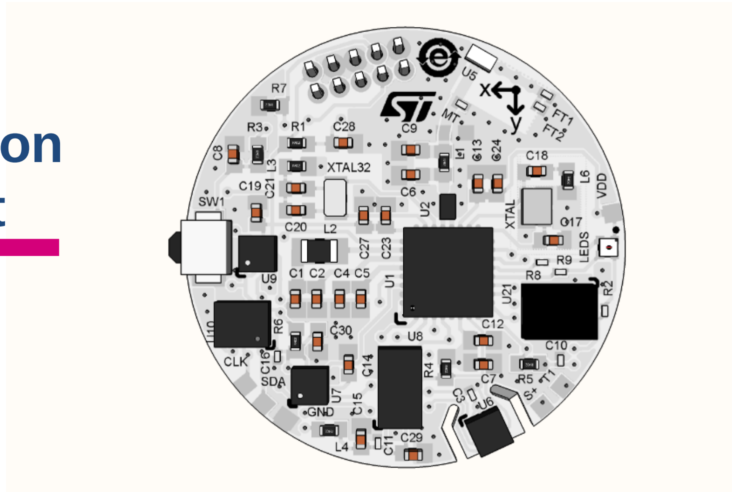
Cloud Logging

1. Enable **IBM Watson IoT** in **BlueMS** client
2. Send **BLE notification packets on Sensor status**
3. **Visualize** the data

IBM Watson



Notification Packet



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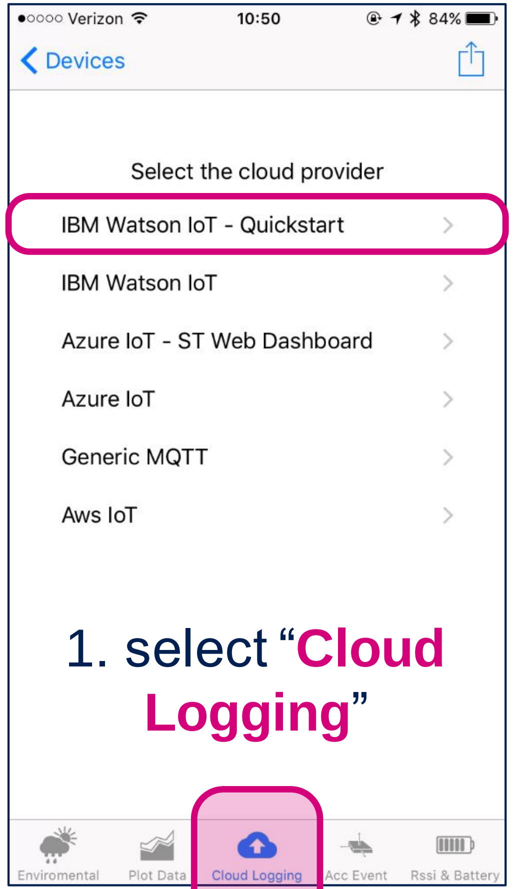
Code modifications

NO MODIFICATIONS NEEDED!

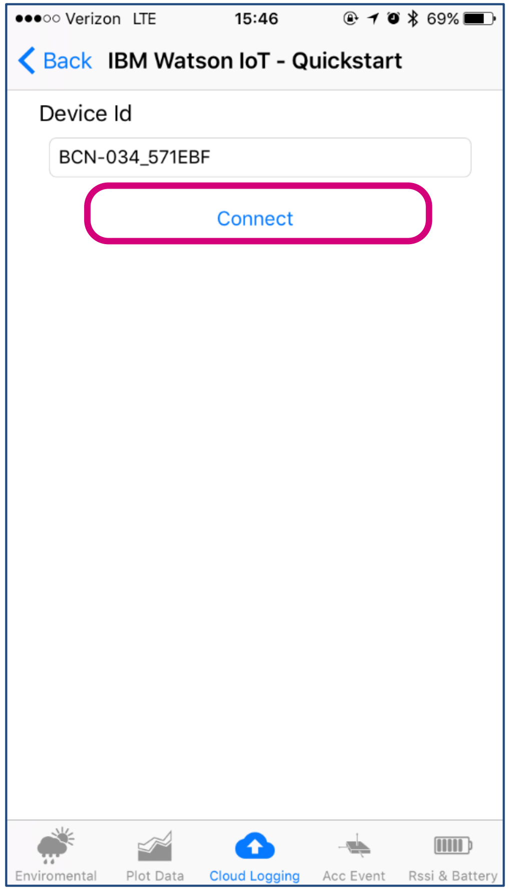
IBM Watson IoT Quickstart

2. select “**IBM Watson IoT - Quickstart**”

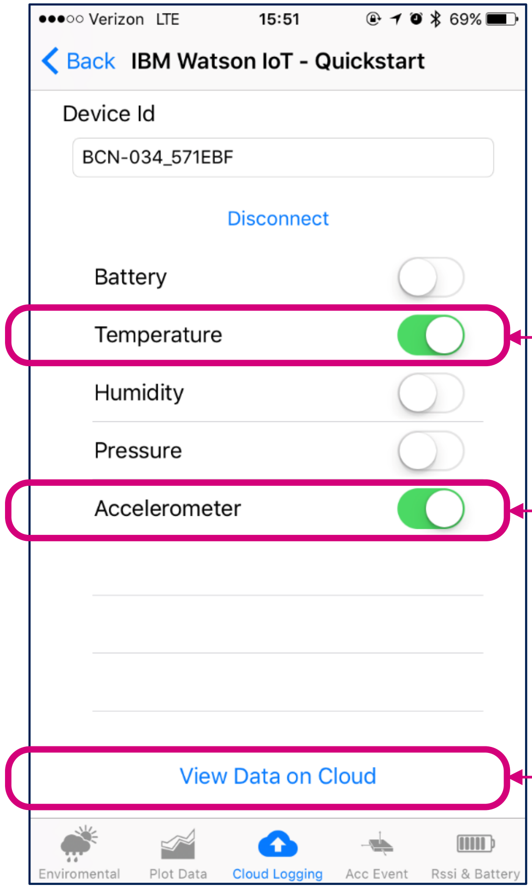


1. select “**Cloud Logging**”

Click “**Connect**”

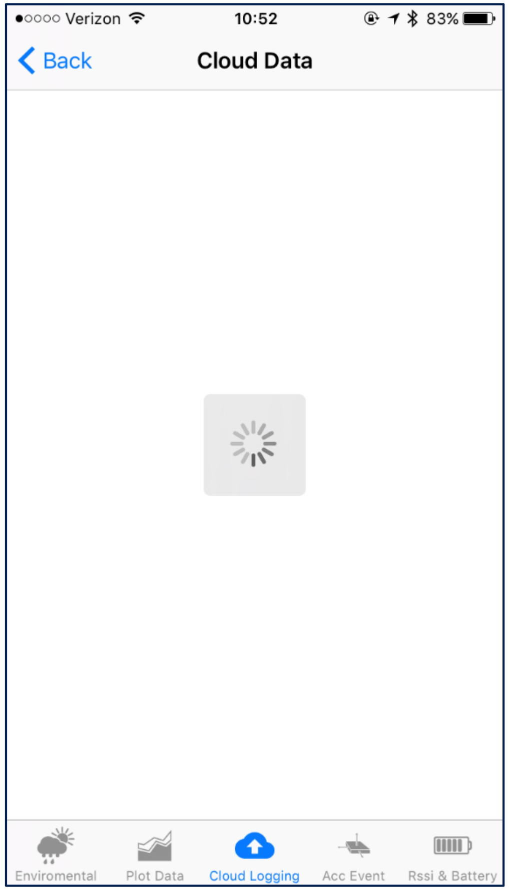


1. **Select** one or multiple features



2. Click “**View Data on Cloud**”

Wait a few seconds



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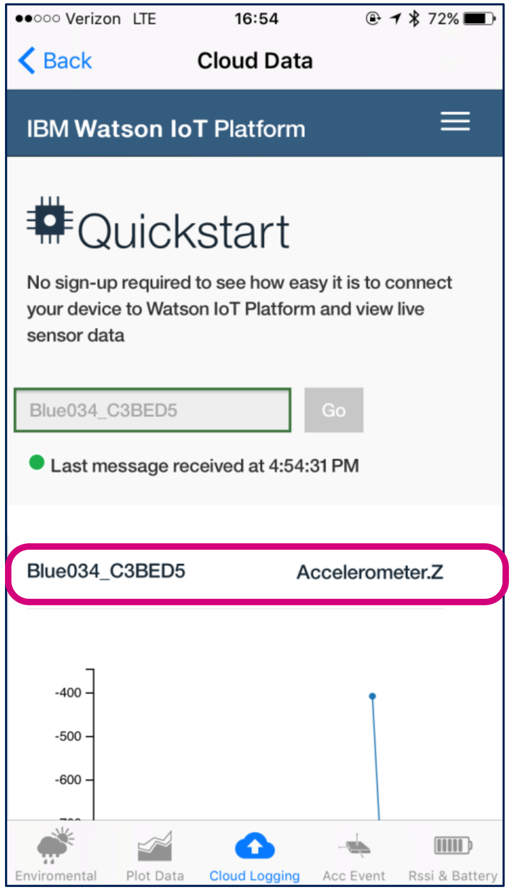
IBM Watson IoT Quickstart

Quickstart will appear



Scroll down to see your selected sensor plot.

You will see the **Plot** of selected feature

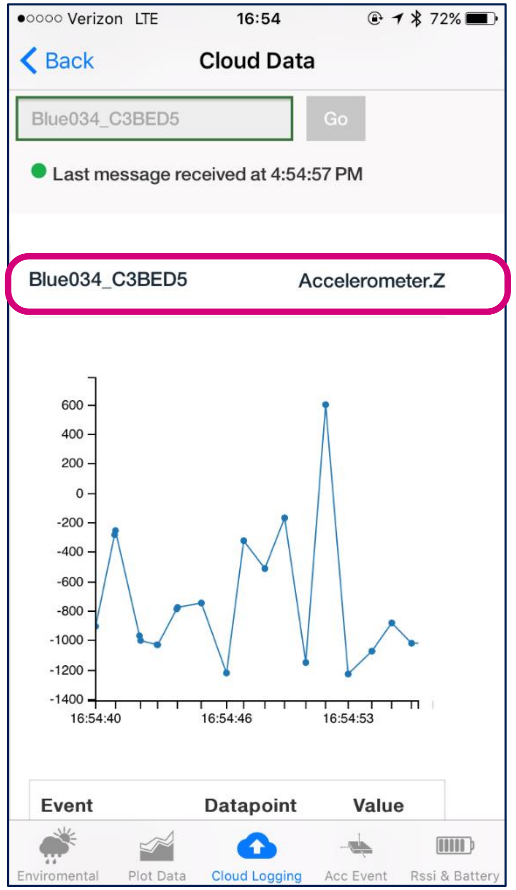
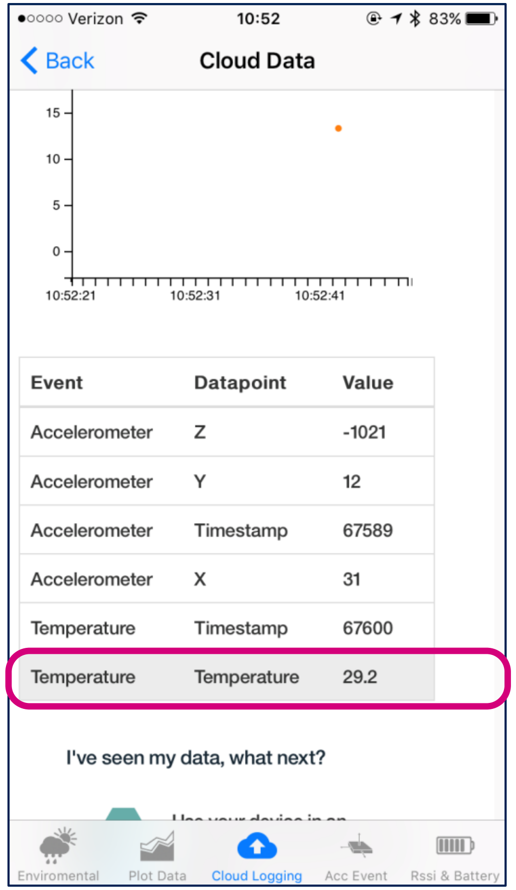
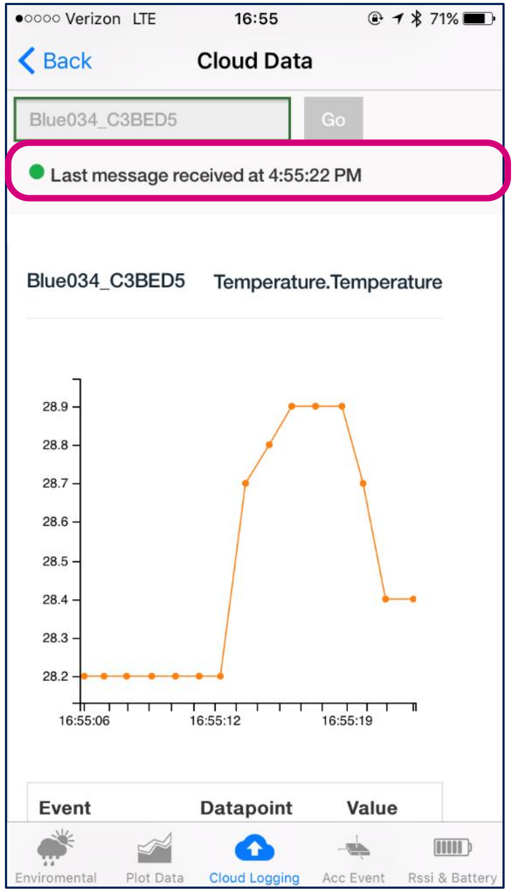


Table of **available features**





Scroll down again to change sensor data or axes

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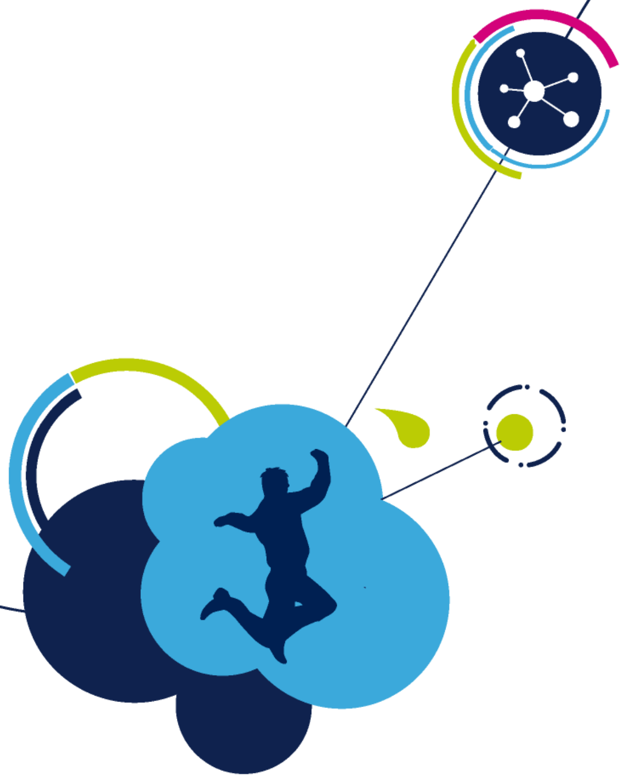

Lab 7

Bonus Lab – Voice over BLE

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Goal

- In this example we are going to demonstrate how to:
  - Enable the BlueVoice library for Voice Over BLE streaming
    - Input: raw data from the MEMS microphone
    - Output: ADPCM data streaming @8kHz
  - Send ADPCM data through BLE notifications packets to the ST BlueMS client

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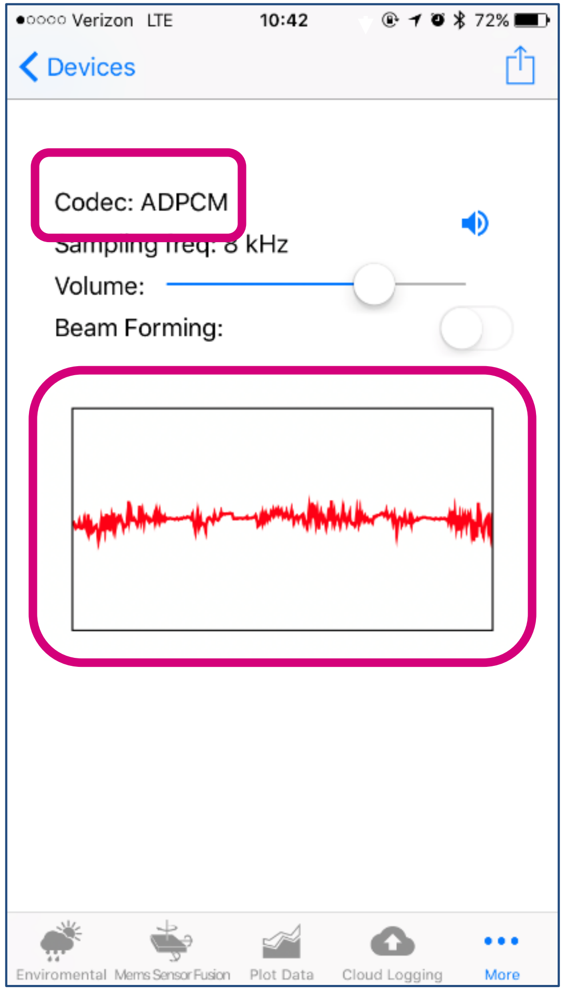
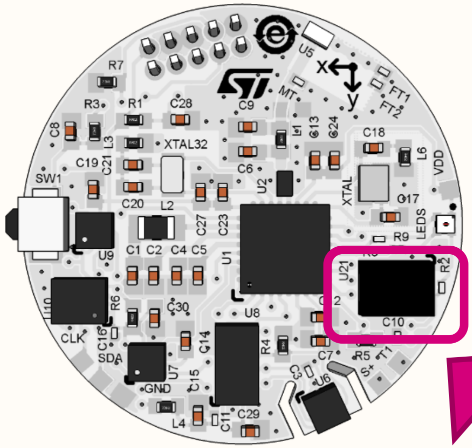
BlueVoice library

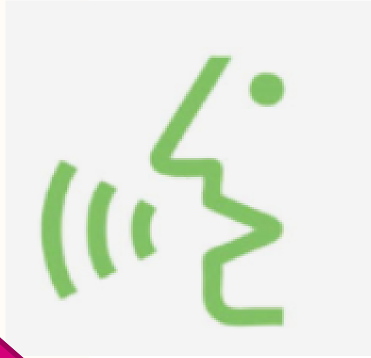


Notification Packet

ADPCM compressed audio



1. Enable BlueVoice library
2. Send voice to the BlueMS client through **BLE notification packet**



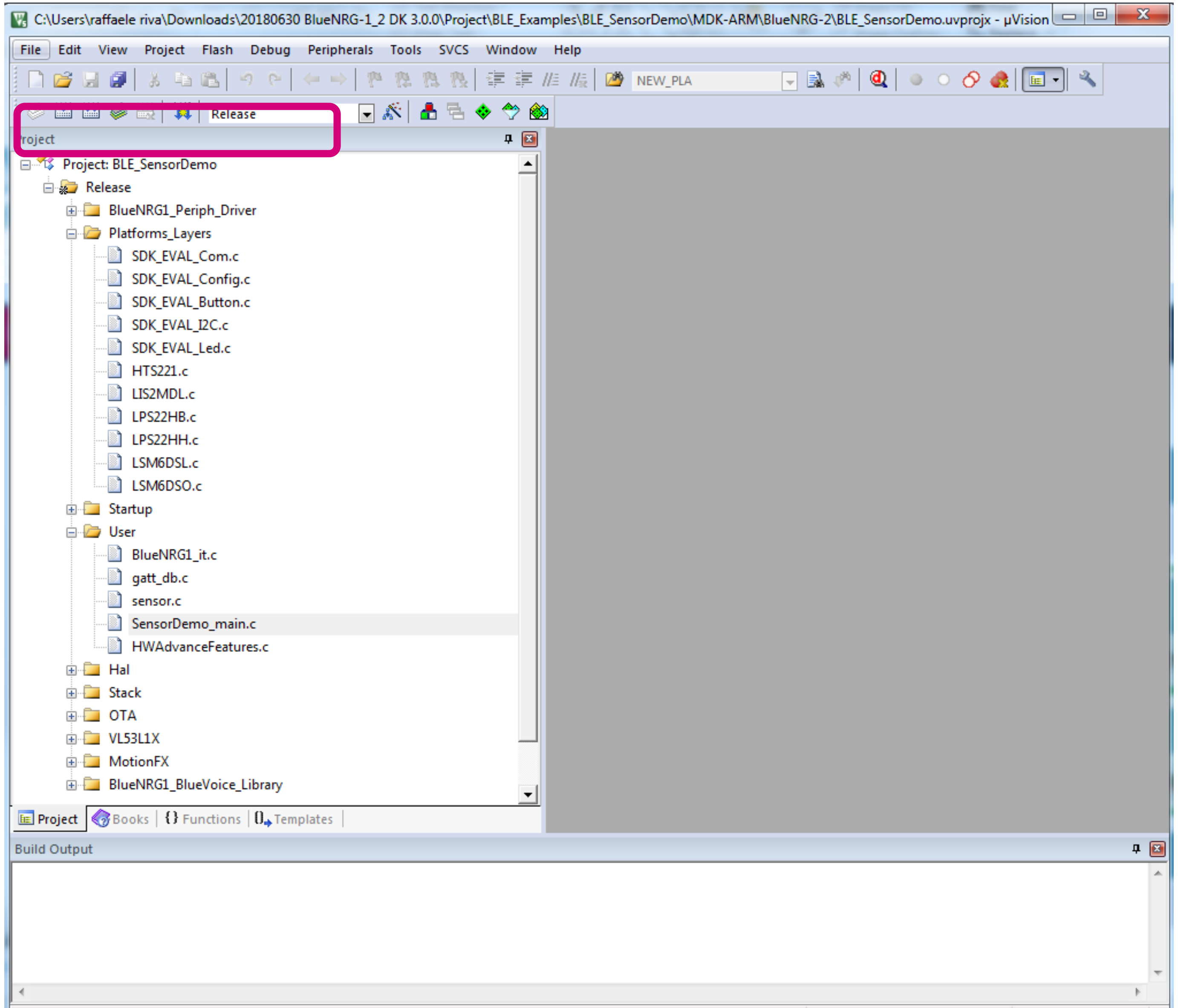
MEMS Microphone

Code modifications

1. Modify advertising packet
2. Enable BlueVoice (voice over BLE) embedded library through preprocessor symbol

Sensor Demo reference application

Now we go **back** again to **Keil uVision**



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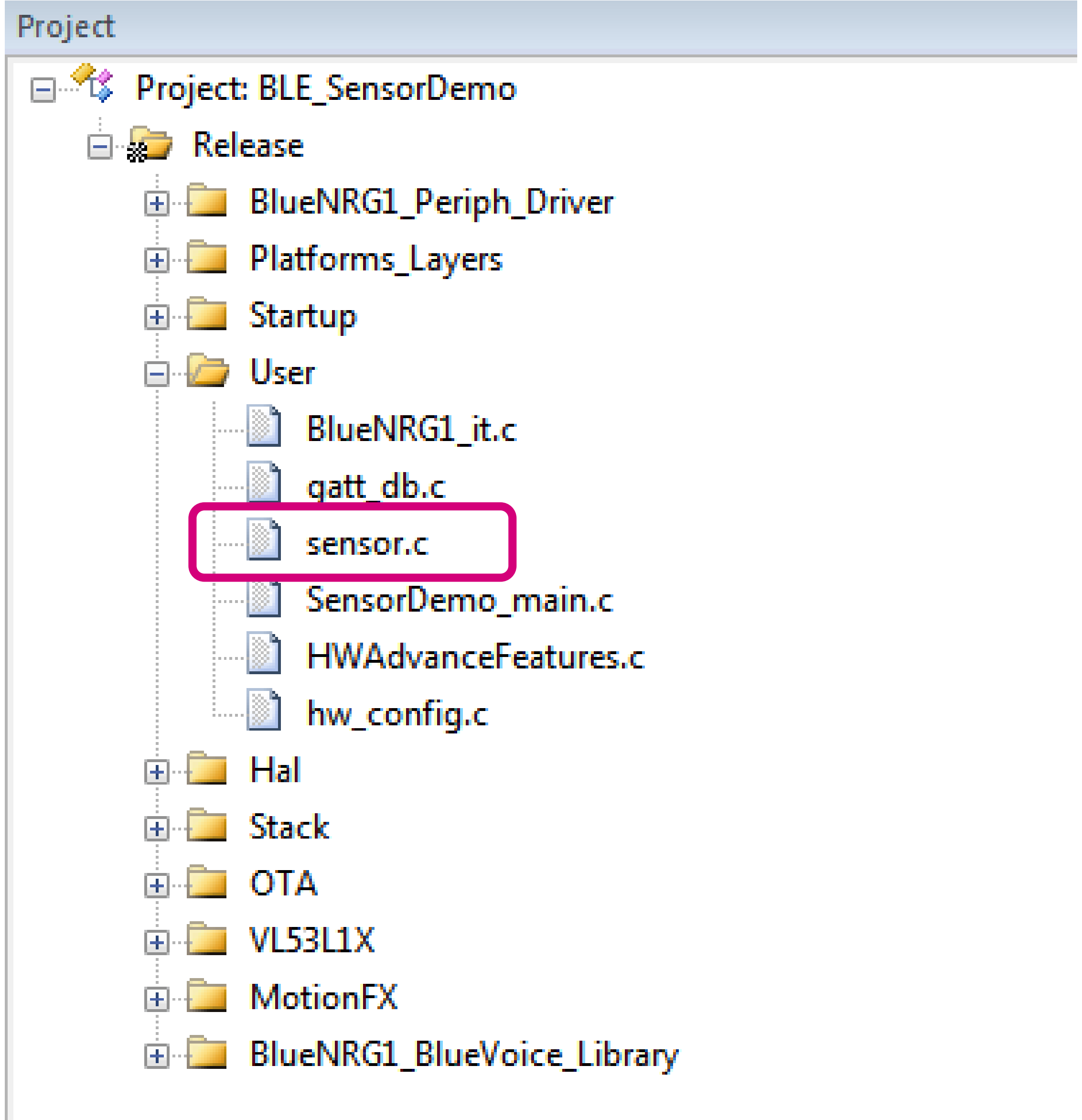
L7 STEP1: Modify advertising packet



BlueMS

ST BlueMS Protocol

4 Bytes

Len	Type	Protocol version	Device ID	Feature Mask	Device MAC	Len	Type	Local Name	Len	Type	Pwr

31	30	29	28	27	26	25	24	
RFU	ADPCM	Switch	DoA	ADPC	MicLevel	Proximity	Lux	0X6A

23	22	21	20	19	18	17	16	
Acc	Gyro	Mag	Pressure	Humidity	Temperat	Battery	2nd Temp	0XFE

15	14	13	12	11	10	9	8	
RFU	RFU	RFU	RFU	Beamform	AccEvent	FreeFall	SensFusC	0X05

7	6	5	4	3	2	1	0	
SensFus	Compass	MotionInt	Activity	Carry Pos	MemsGes	ProxGes	Pedo	0X40

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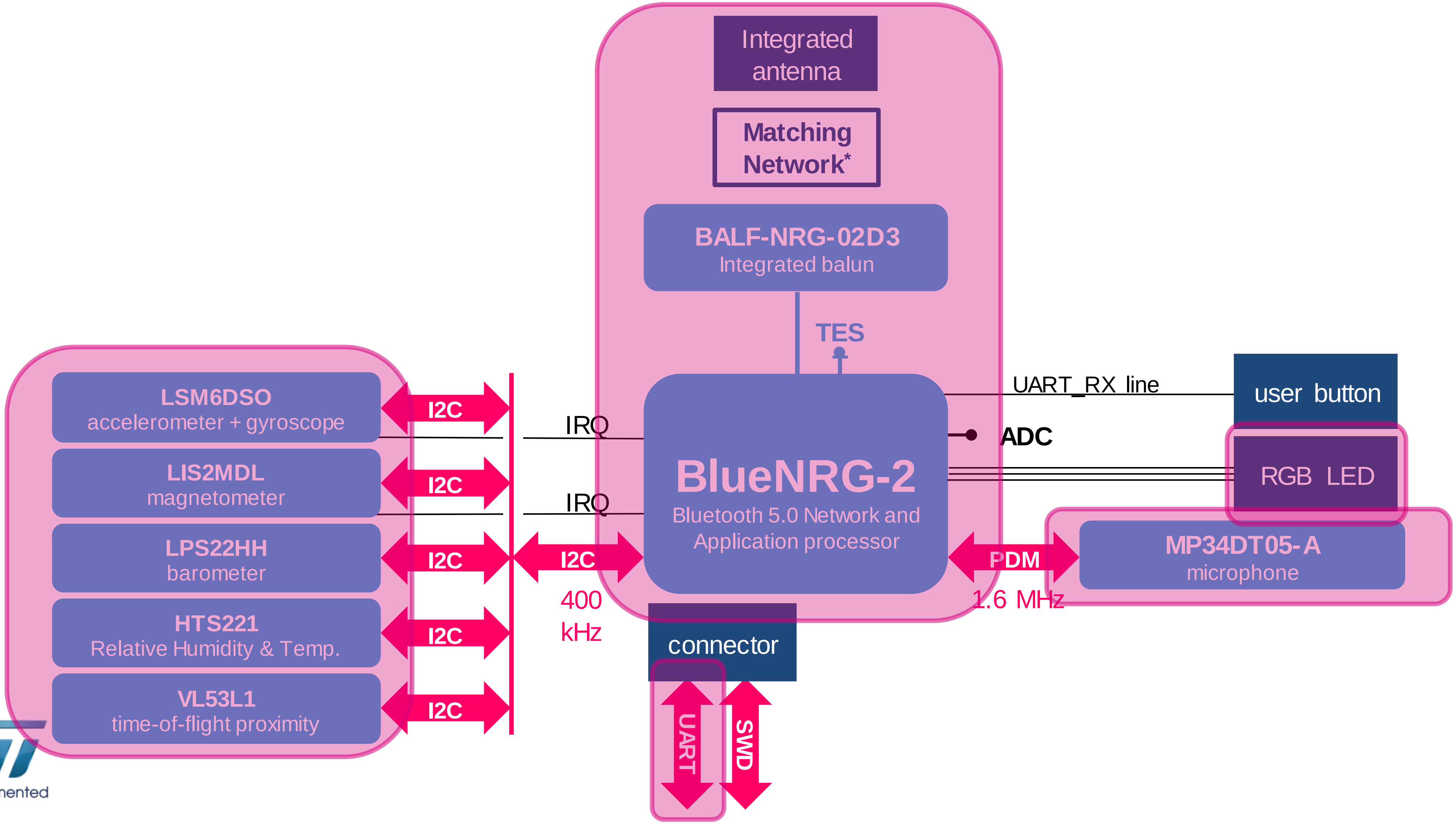
STEVAL-BCN002V1 Block Diagram



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L7 STEP1: Modify advertising packet

Modify the Feature Mask in the advertisement payload

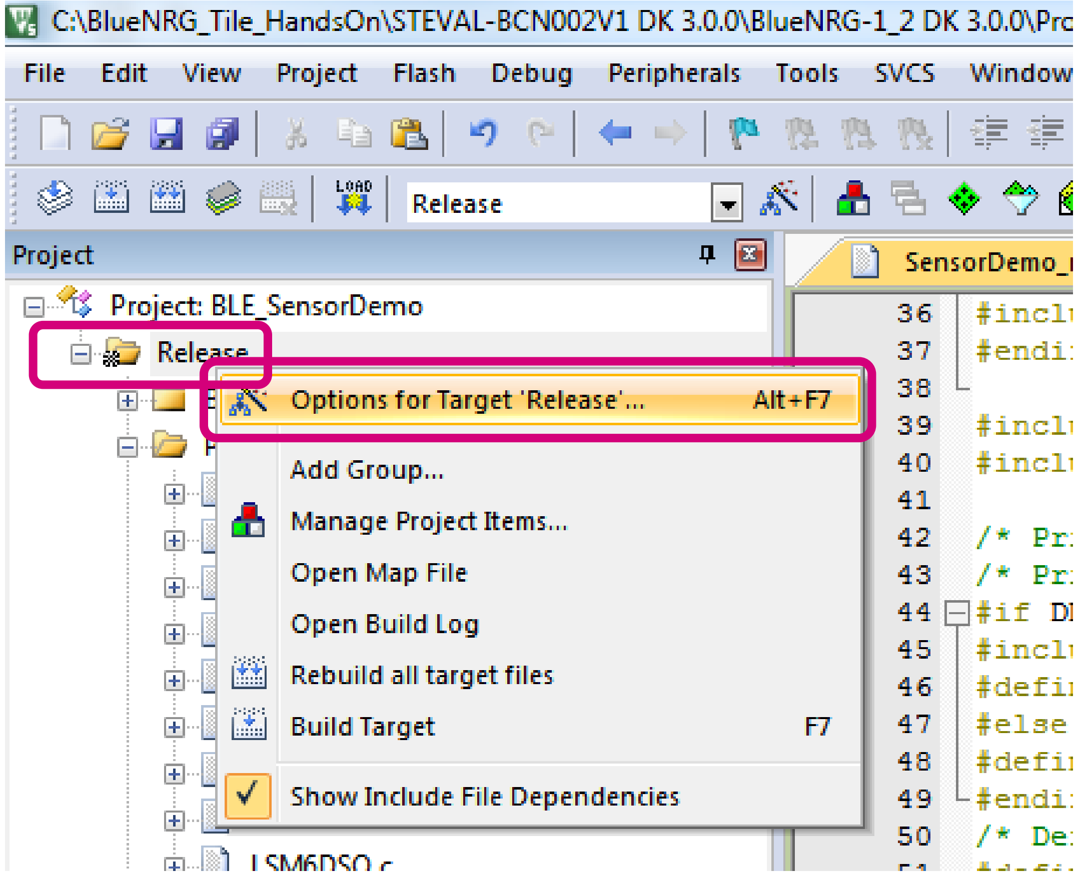
1. In the file **sensor.c** and go to **line 423**
2. Modify **line 423** Feature Mask byte#1 from 0x22 to **0x6A**

sensor.c

```
411 void Set_DeviceConnectable(void) {
412
413     uint8_t manuf_data[26] = {
414     2,                      /* Length of AD type Transmission Power */
415     0x0A, 0x00,             /* Transmission Power = 0 dBm */
416     8,                      /* Length of AD type Complete Local Name */
417     0x09,                   /* AD type Complete Local Name */
418     NAME_ALLMEMS,           /* Local Name */
419     13,                     /* Length of AD type Manufacturer info */
420     0xFF,                   /* AD type Manufacturer info */
421     0x01,                   /* Protocol version */
422     0x05,                   /* Device ID: 0x05 = STEVAL-BCN002V1 Board */
423     0x6A,                   /* Feature Mask byte#1: LAB3 0x20 (LED) / LAB5 (
424     0xFE,                   /* Feature Mask byte#2: LAB4 0x9E (Acc+Press+Hu
425     0x05,                   /* Feature Mask byte#3: LAB4 0x04 (AccEvents) /
426     0x40,                   /* Feature Mask byte#4: LAB5 0x40 (eCompass) */
427     0x00,                   /* BLE MAC start */
```

L7 STEP2: Enable BlueVoice library

- Add the preprocessor defined symbol ENABLE_AUDIO from the project settings
- Right-click on Release
- Select “Options for Target ‘Release’…”



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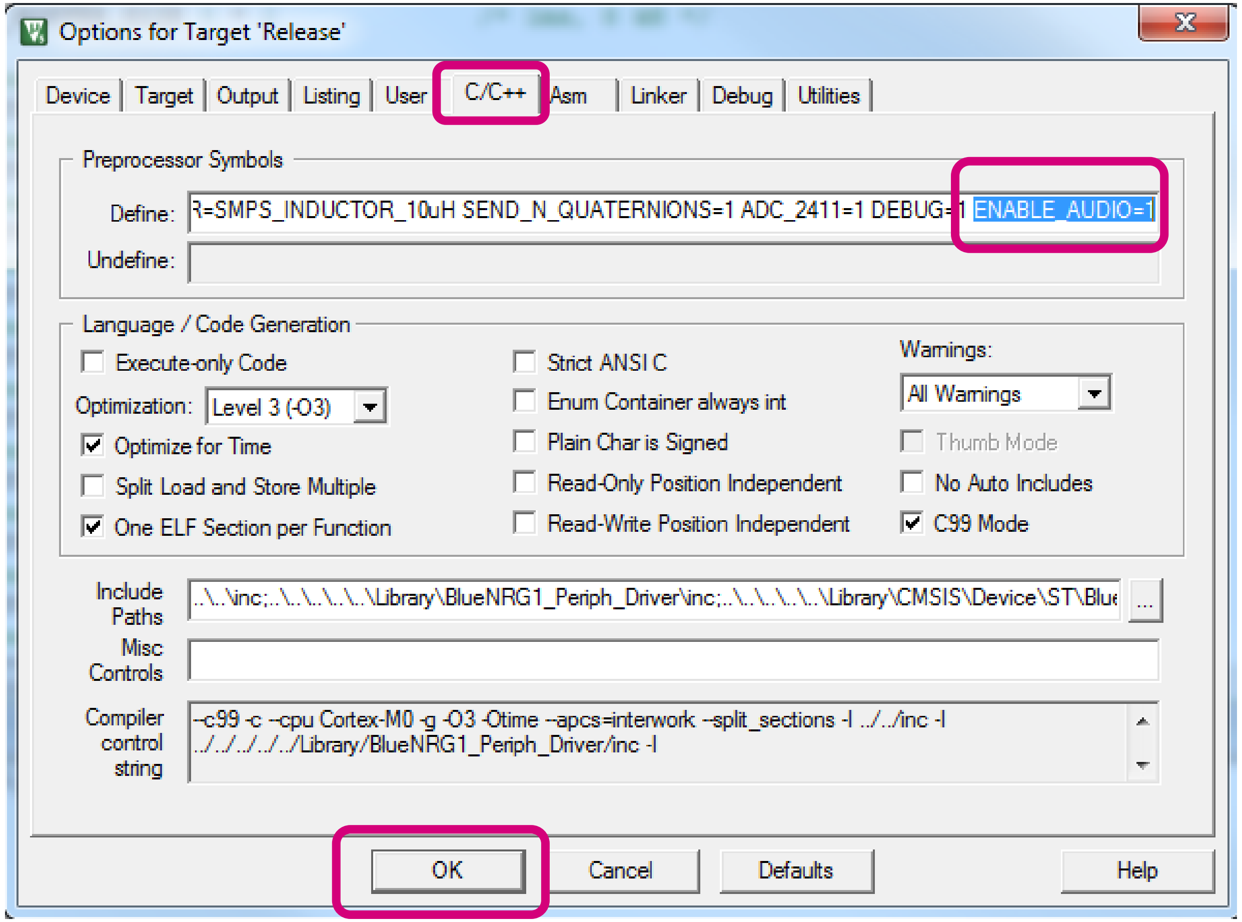
L7 STEP2: Enable BlueVoice library

In the project options

1. Go to the tab **C/C++** and then in the **Preprocessor Symbols**
2. Set the symbol **ENABLE_AUDIO=1** and then click on **OK**



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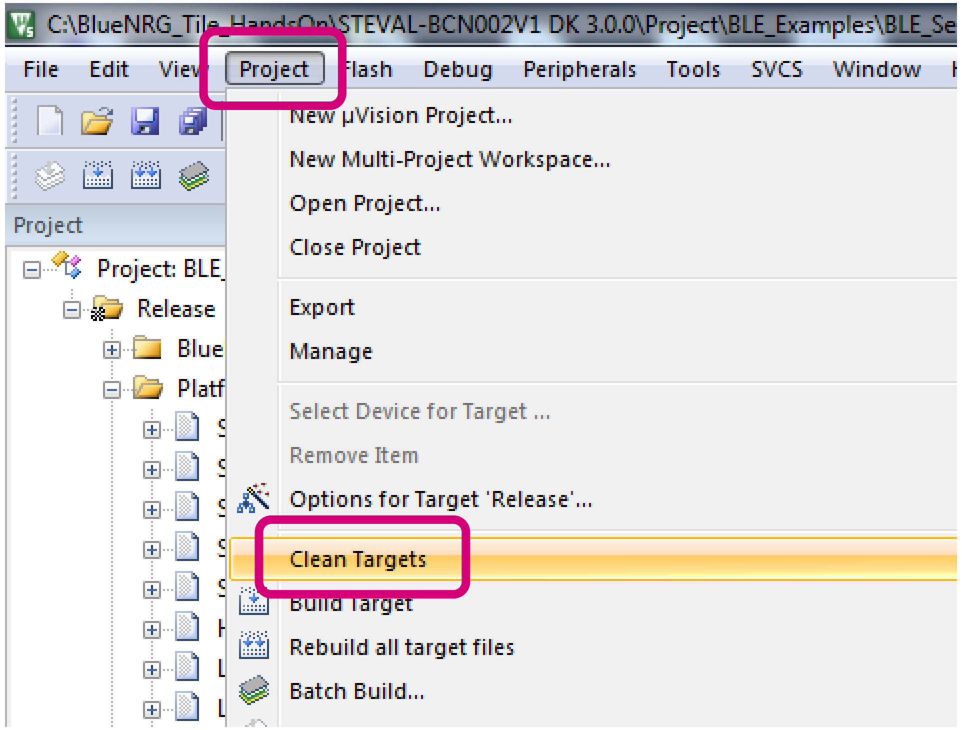
Build the new code

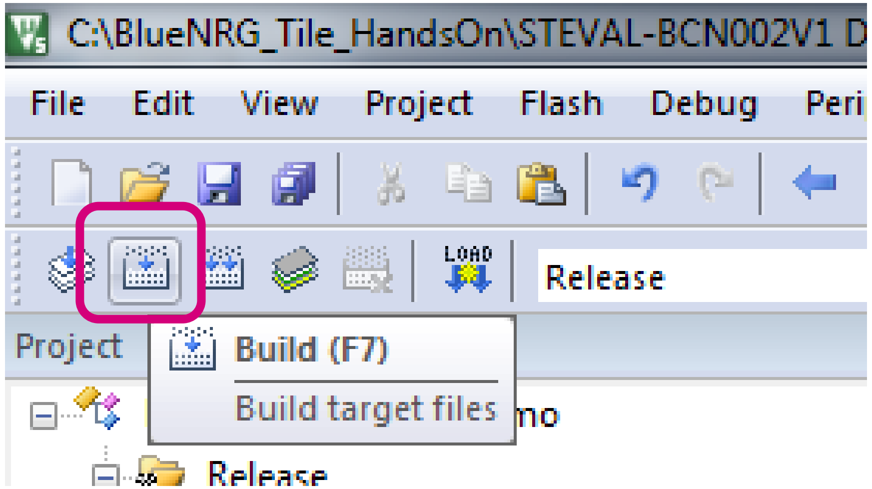
1. Click on **Project**
2. Select **Clean Targets**

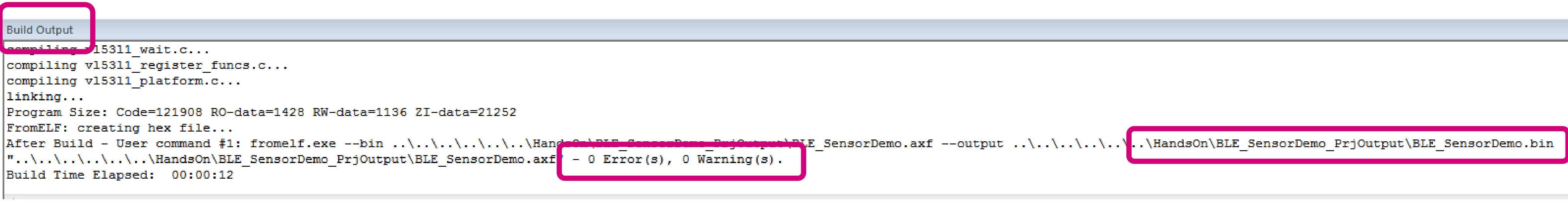
Note: since we have modified the preprocessor options it's recommended to clean all the previously compiled object files



Build the new code

1. Click on the **Build button** (top left corner) or hit **F7** on your keyboard
2. In the **Build Output** window (bottom) wait for the build to be completed.
   - **BLE_SensorDemo.bin** created
   - “**0 Error(s), 0 Warning(s)**” message appear





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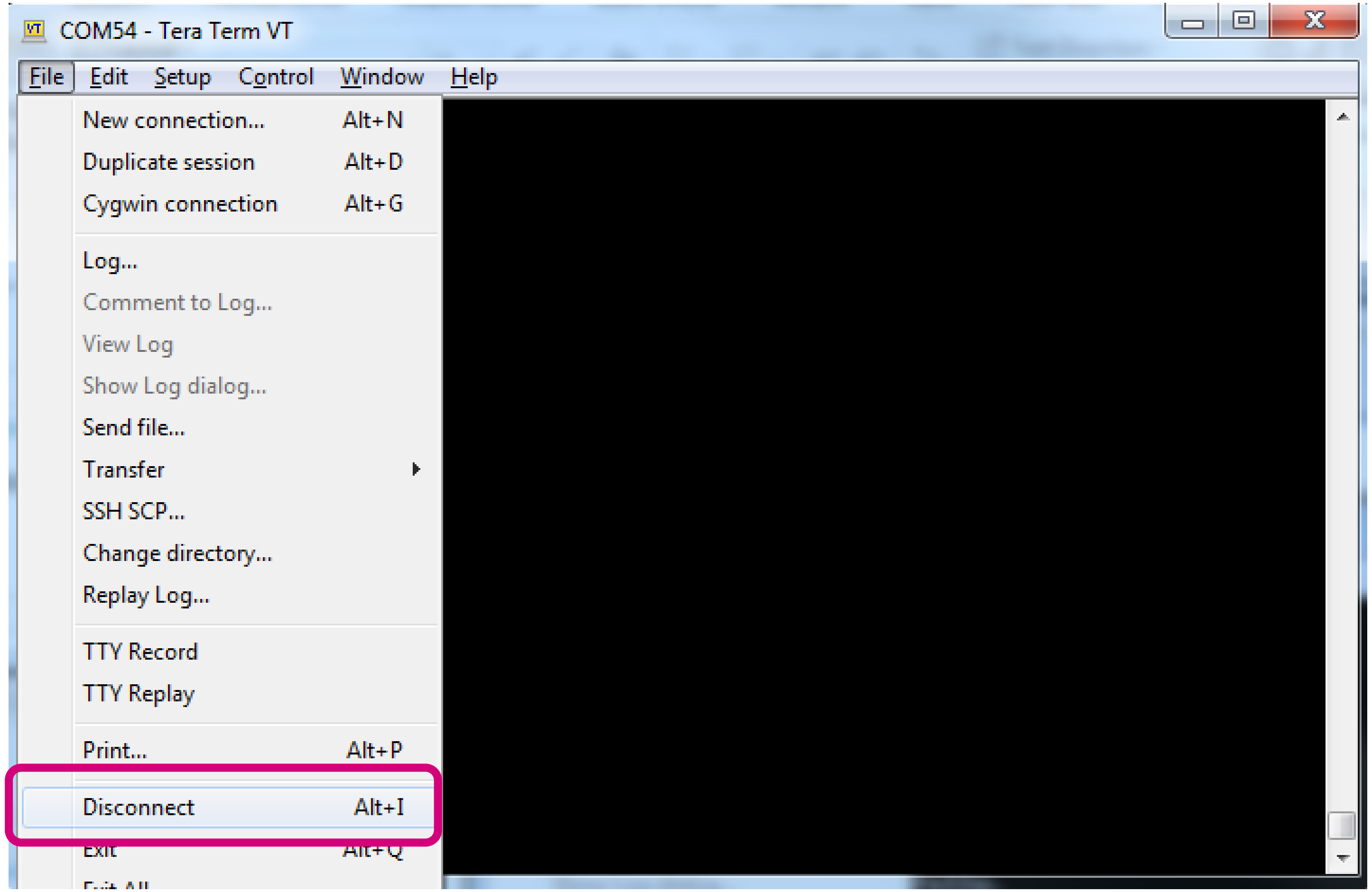
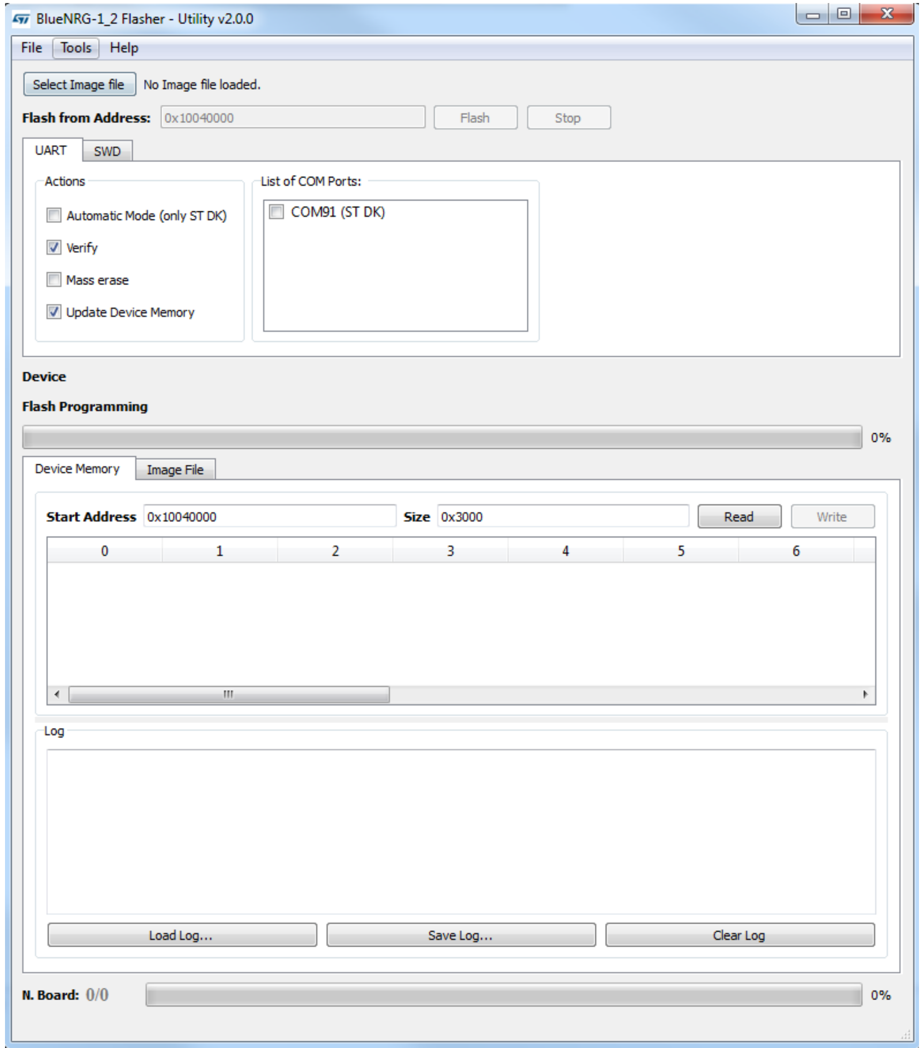
Disconnect the serial terminal

1. Go back to TeraTerm
2. Click on the **File->Disconnect**



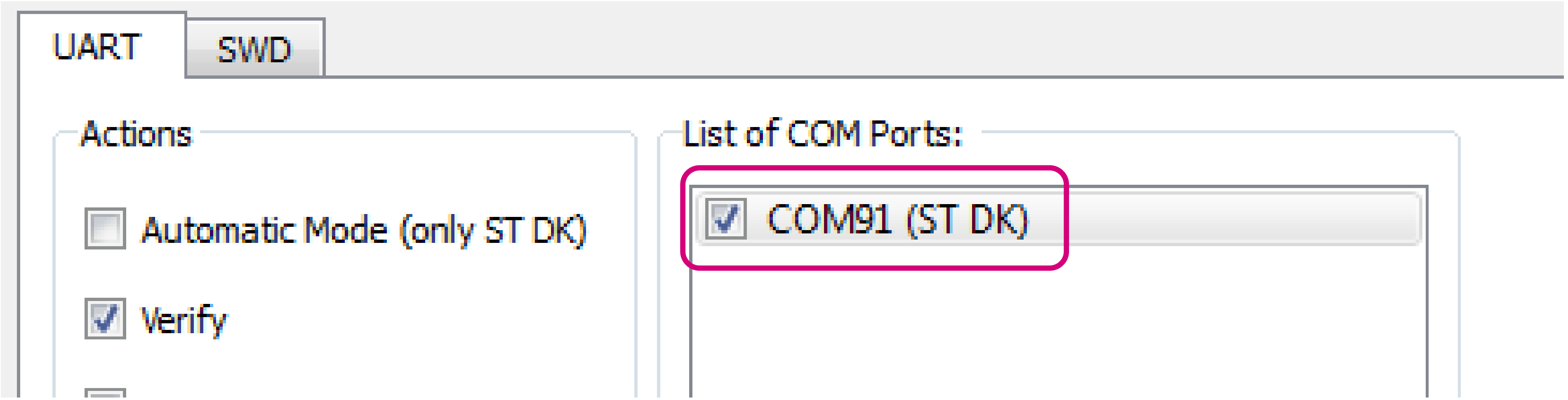
Re-flash the BlueNRG-2

1. Go back to the BlueNRG-2 Flasher Utility



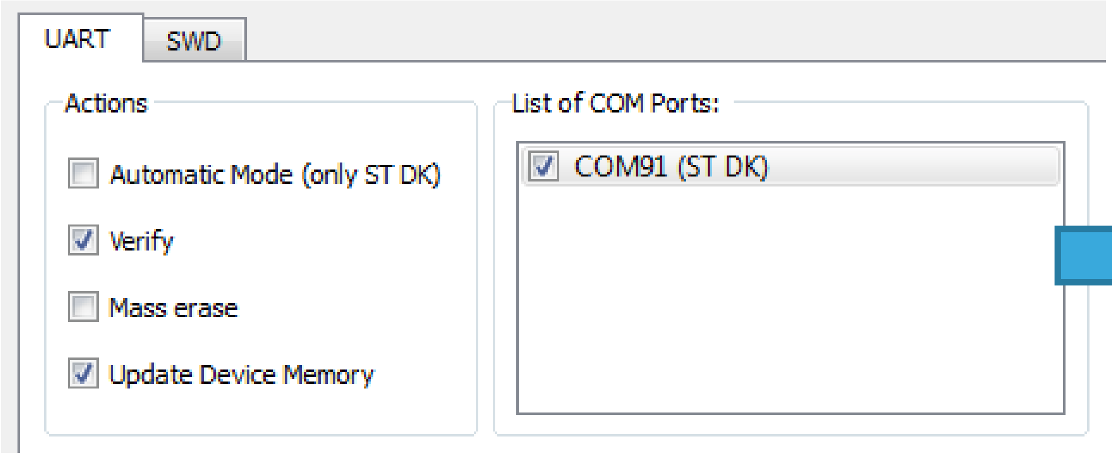
Flash the BlueNRG-2 1/5

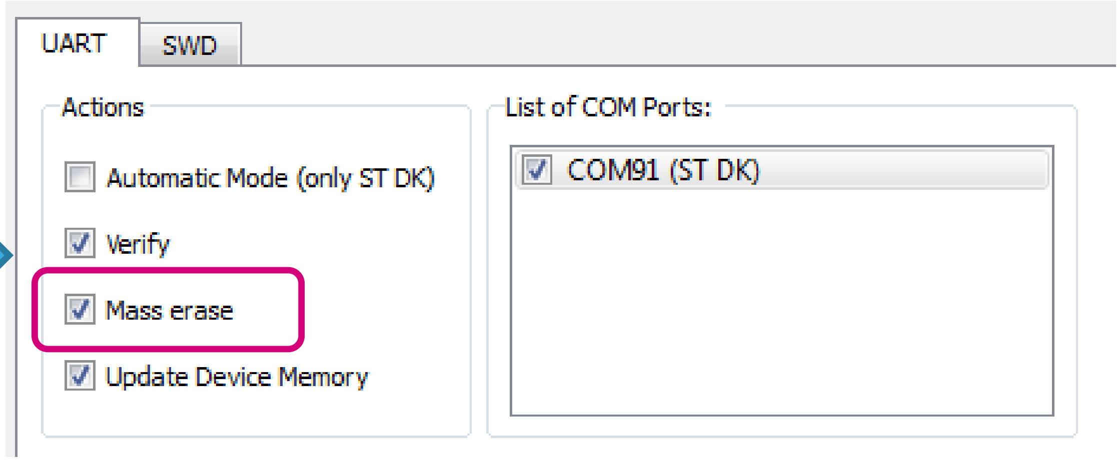
1. Select the COM port labeled **(ST DK)**



Flash the BlueNRG-2 2/5

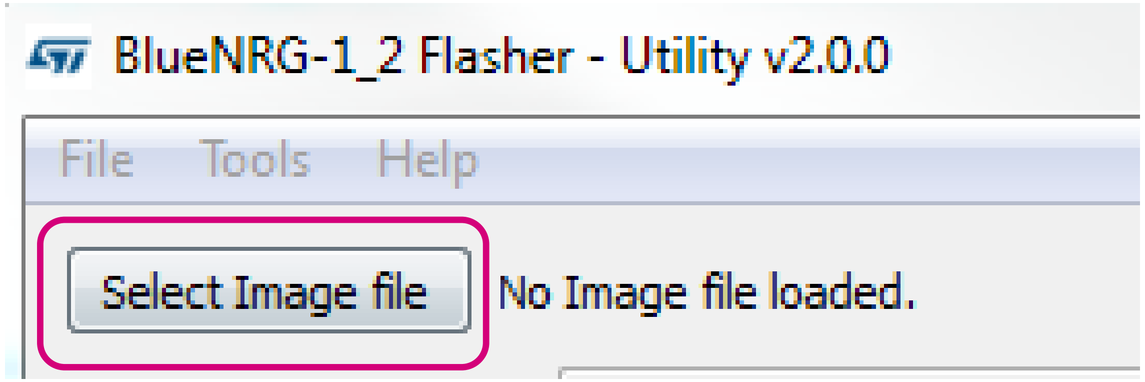
1. Click on **Mass Erase**





Flash the BlueNRG-2 3/5

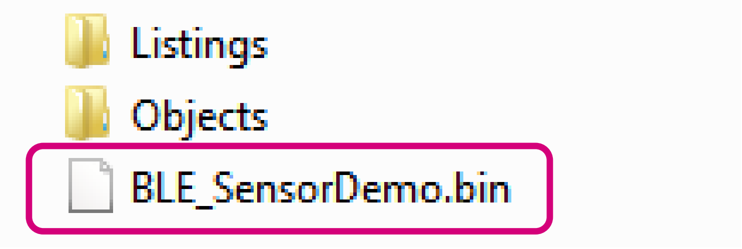
1. Click on **Select Image file** button



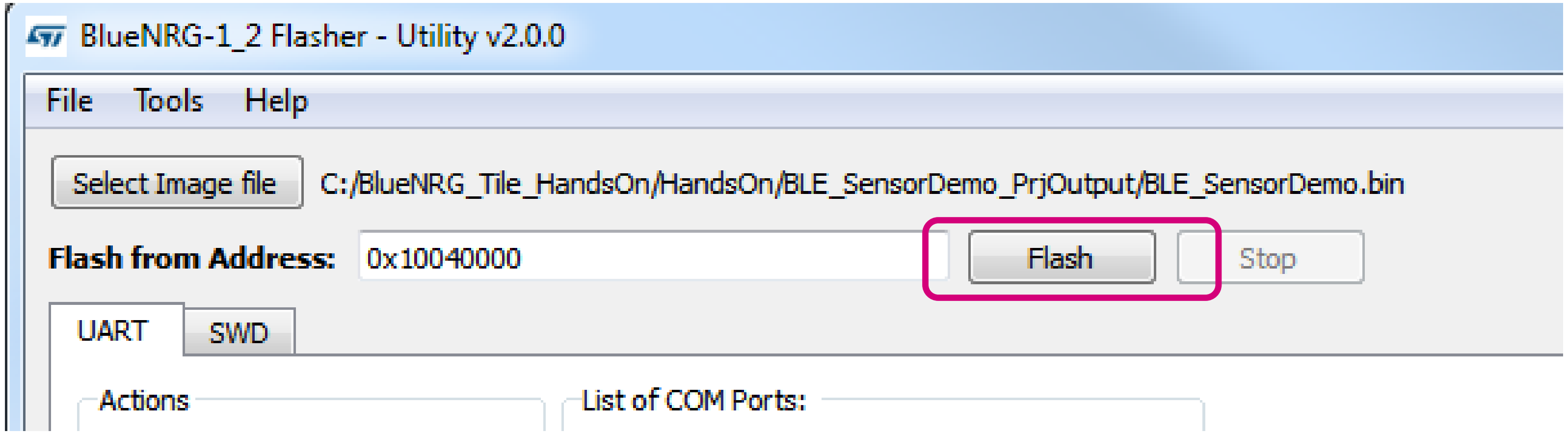
2. And browse the following **path**

Flash the BlueNRG-2 4/5

1. Select **BLE_SensorDemo.bin**



2. Click on the **Flash** button



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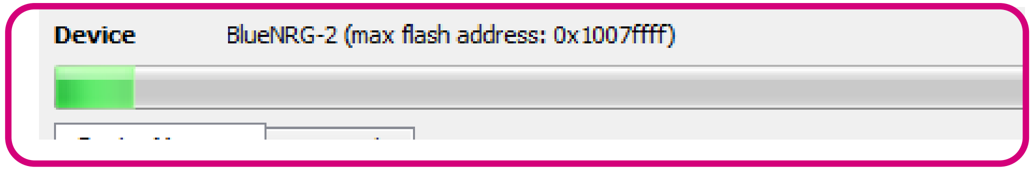
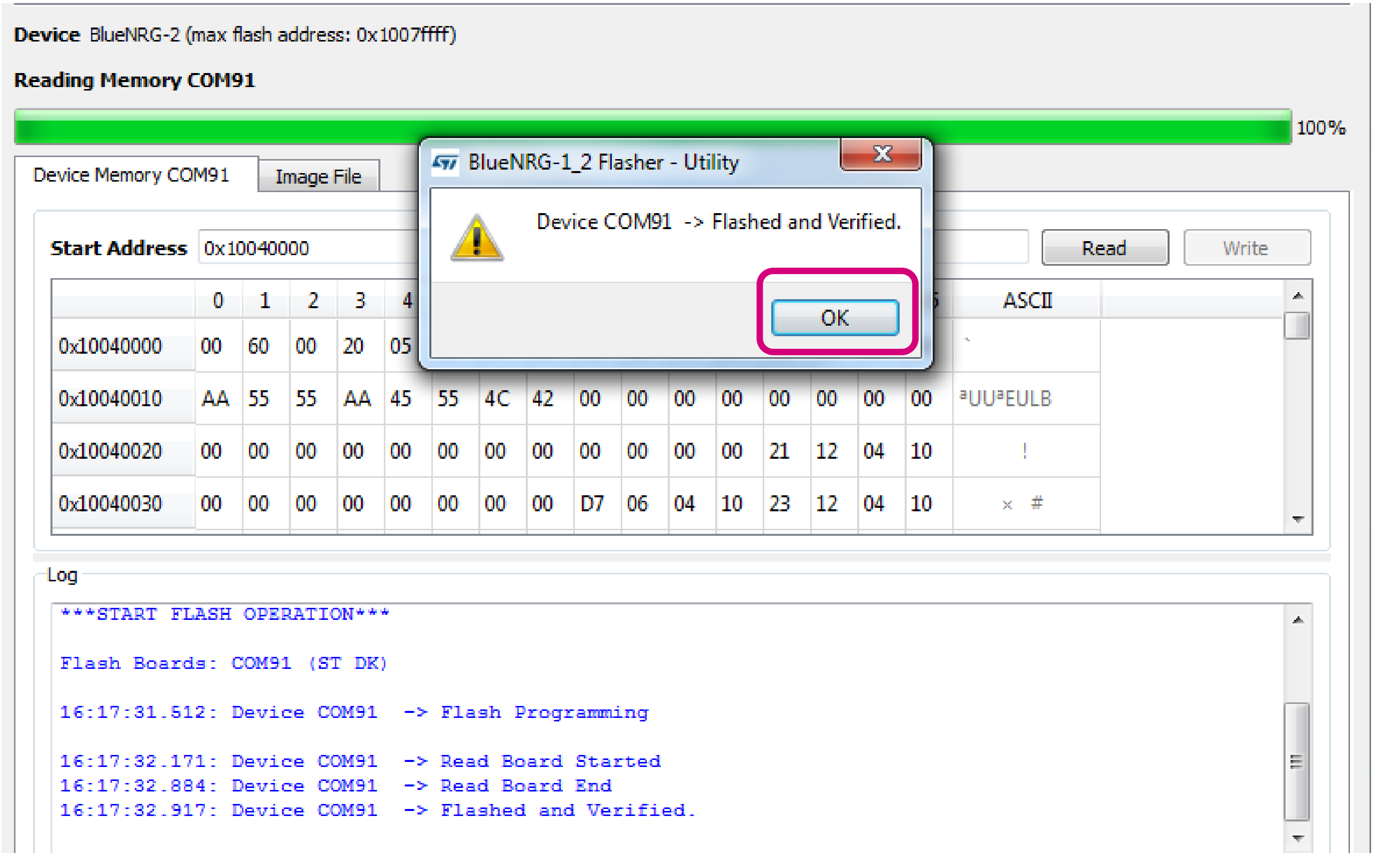
Flash the BlueNRG-2 5/5

1. Flashing starts: **green bar** proceeding



2. Wait for the **pop-up** window and click on **OK**



Do NOT close the Utility!

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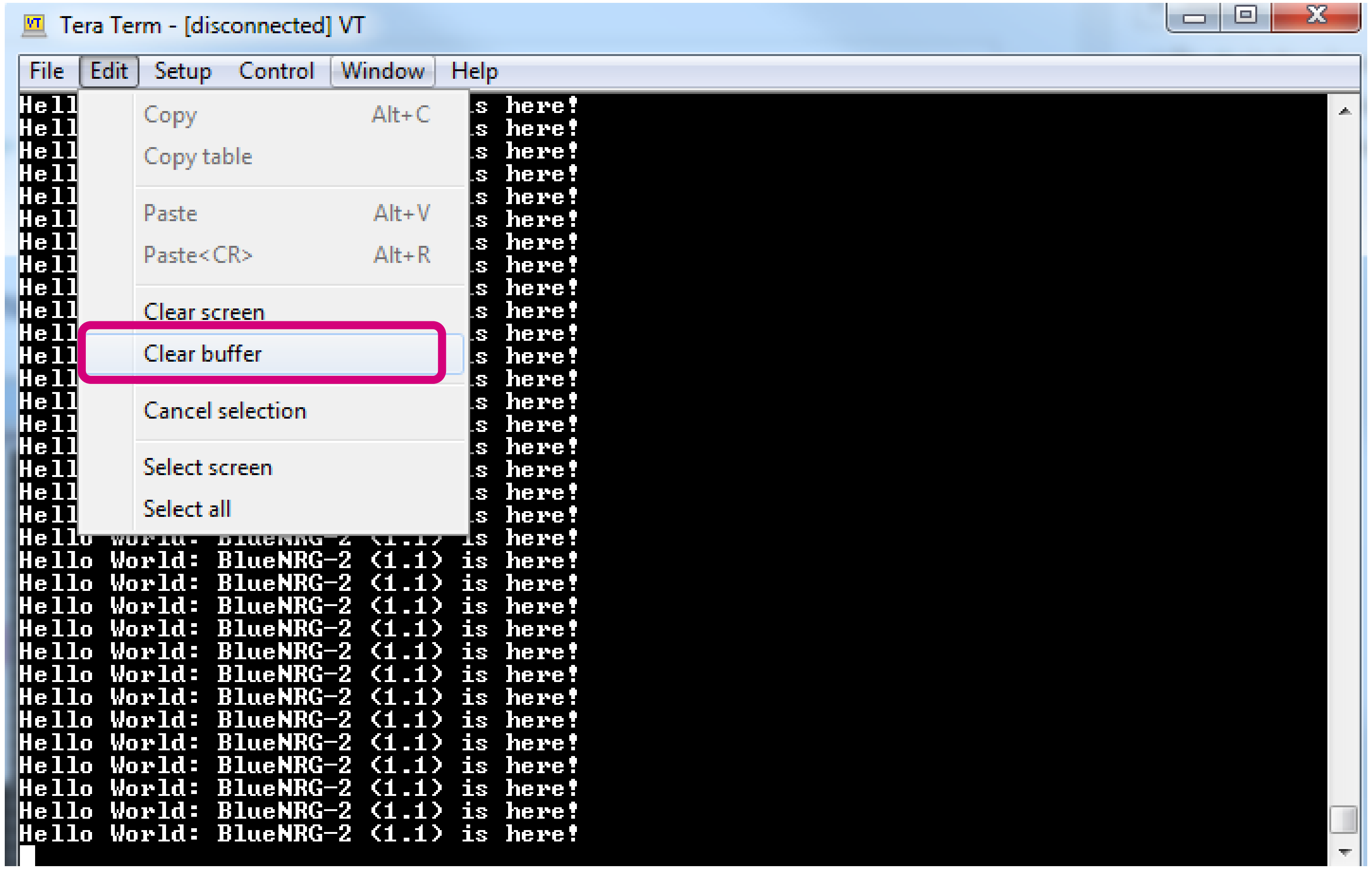
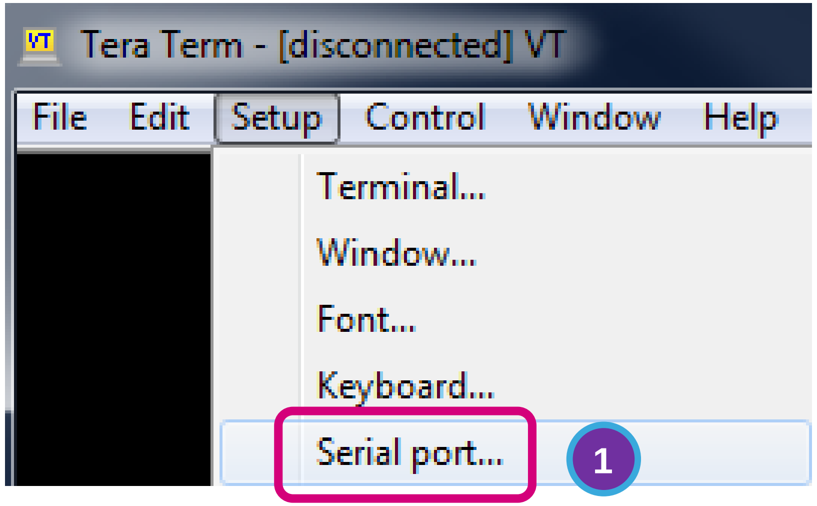
Clean Buffer in the serial terminal

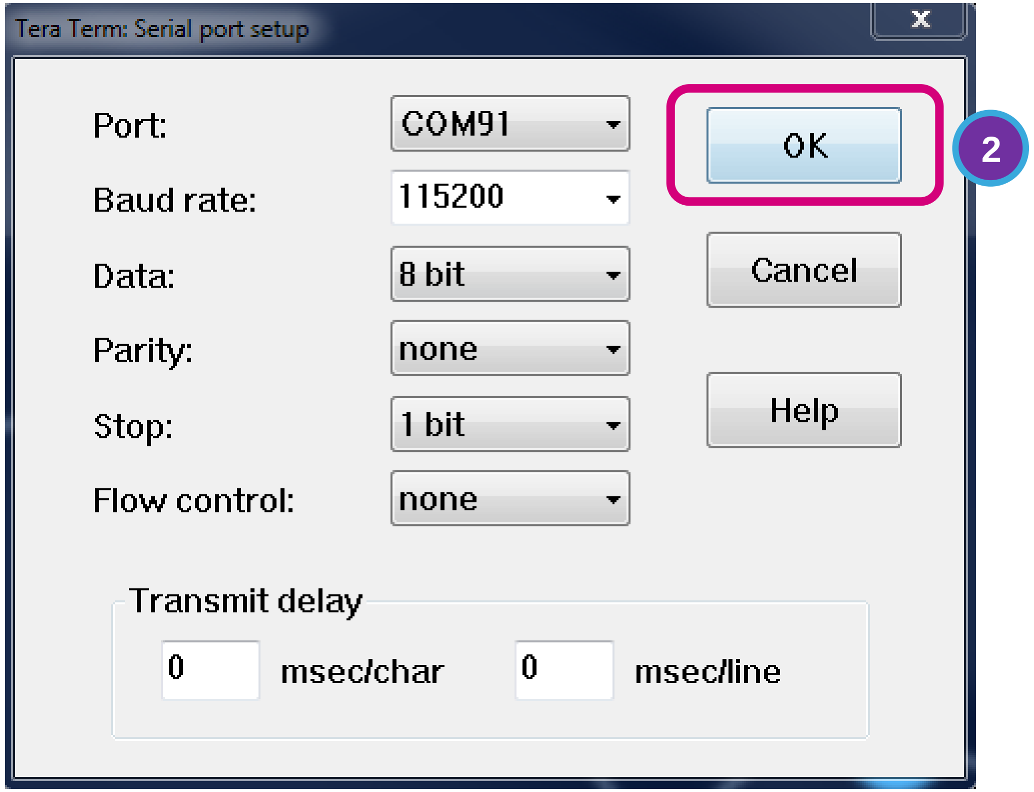
1. In Tera Term in order to have the terminal clean, go to **Edit -> Clear buffer**



Reconnect the serial terminal

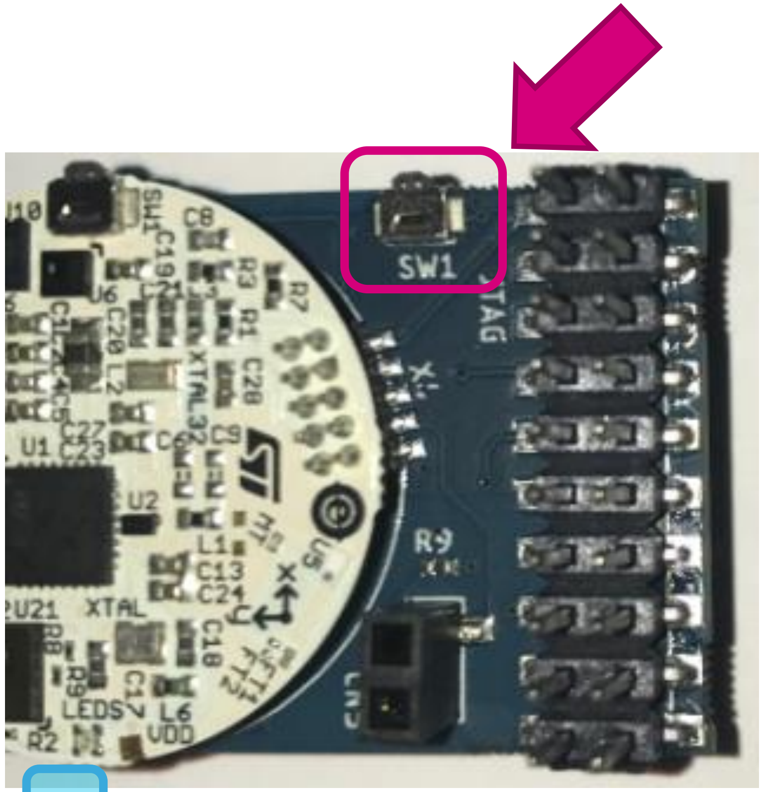
1. Click **Setup** -> **Serial port…**
2. Serial port should already configured. Just need to click on **OK**

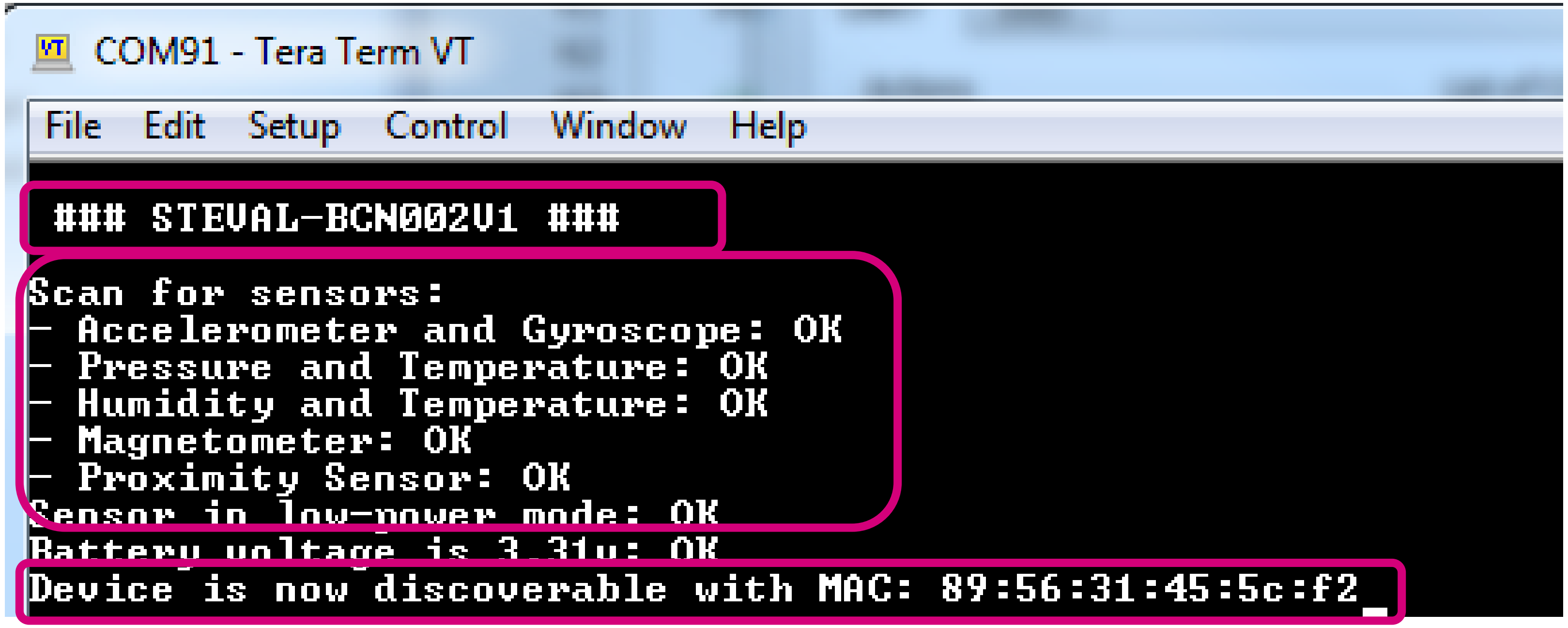




Sanity Check on serial port

Push **SW1 button** on the blue motherboard -> **LED blinking Blue**





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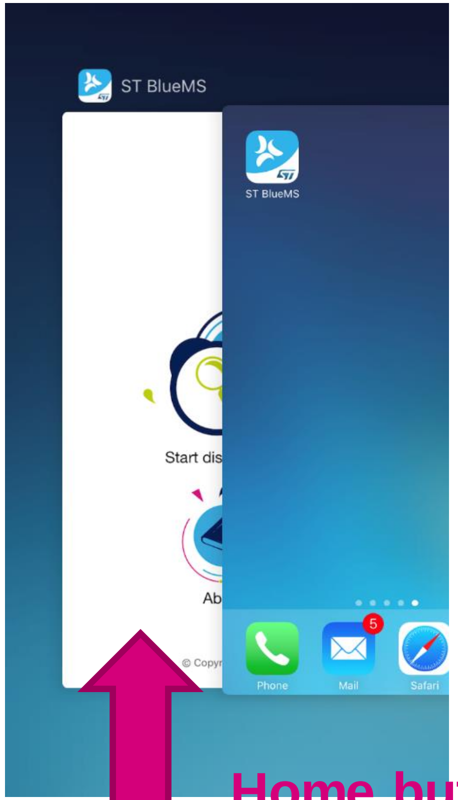
Connect using the BlueMS App

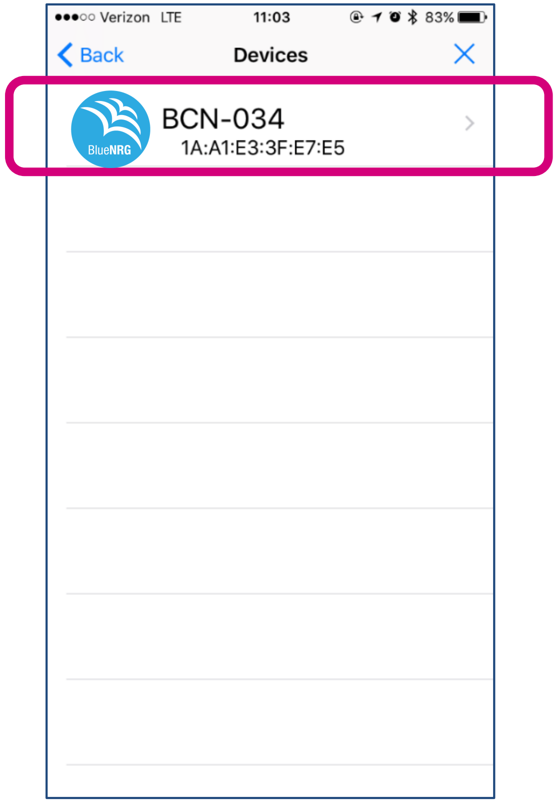
1 **“Kill” the BlueMS app**



Home button and then swipe to top

2 **Touch “Start discovering”**

3 **Select your STEVAL-BCN002V1**



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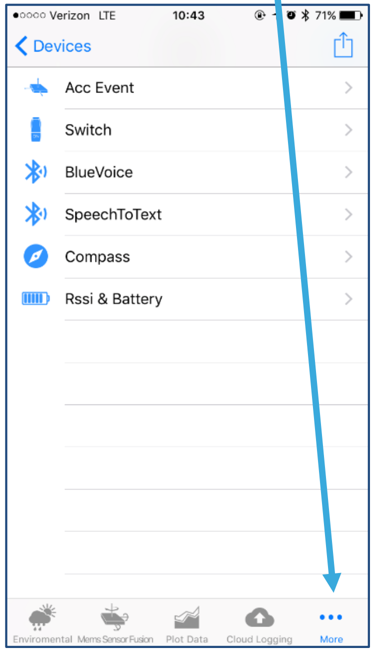
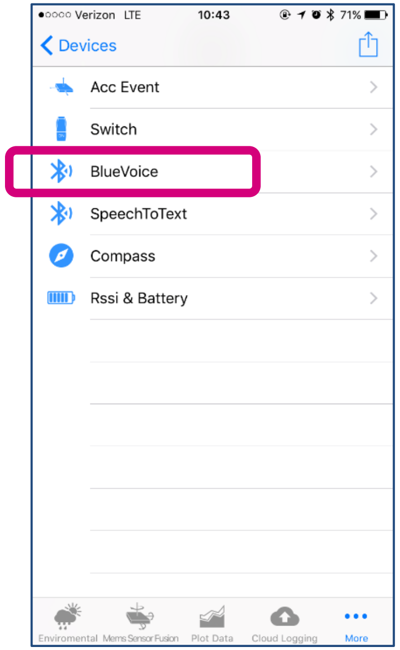
BlueVoice: voice over Bluetooth LE

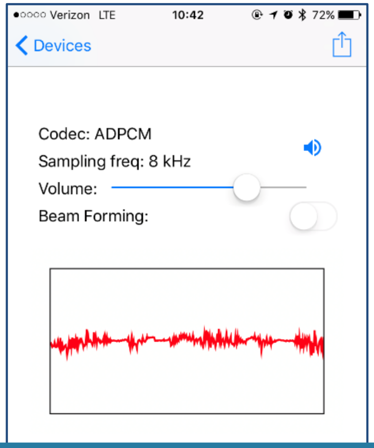
Touch 



Select "**BlueVoice**"

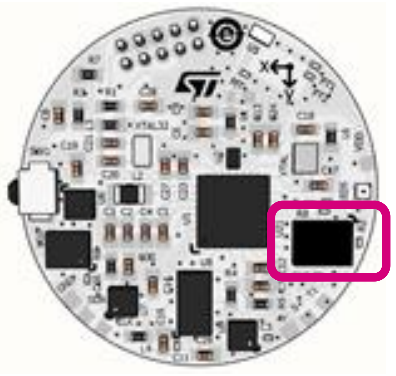


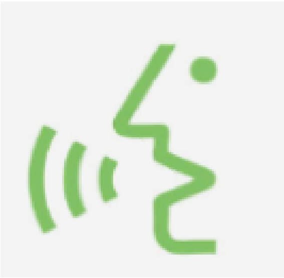
Speak close to the BlueNRG-Tile



Voice will be streamed over BLE
You will hear it from the phone

Do not silence your phone,
must <u>**NOT**</u> be vibration only!





MEMS Microphone

(if the mic captures the audio from the phone speaker, a very high pitch sound can happen!)

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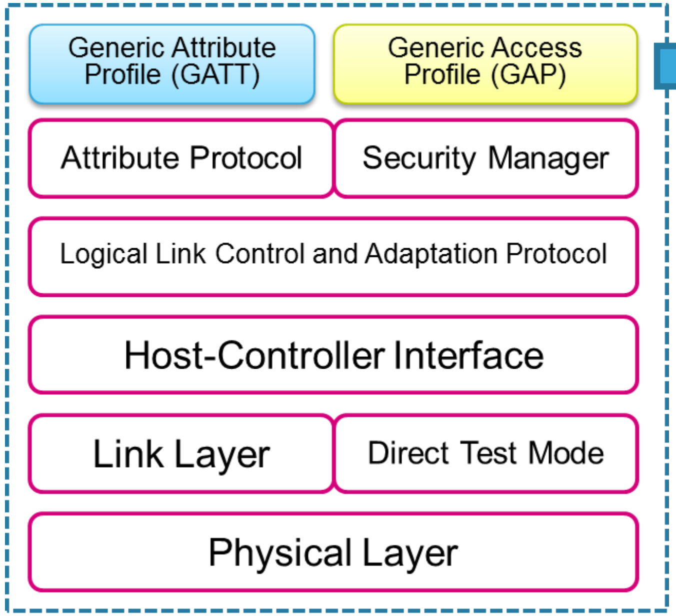
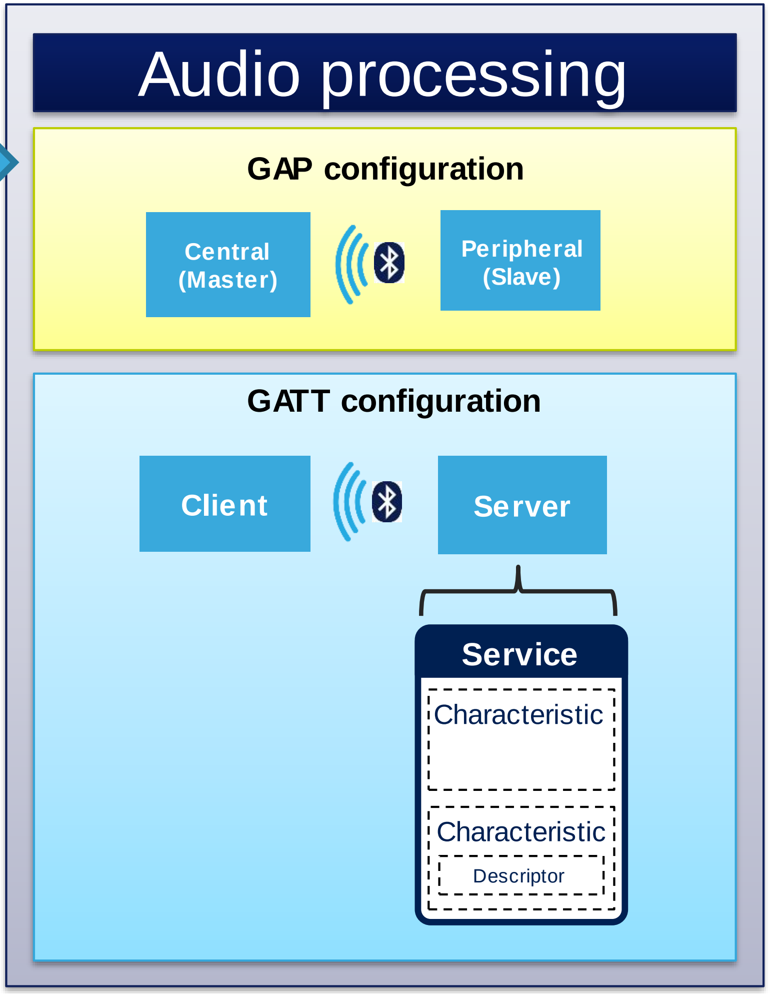
Voice over Bluetooth LE



Bluetooth Low Energy Stack



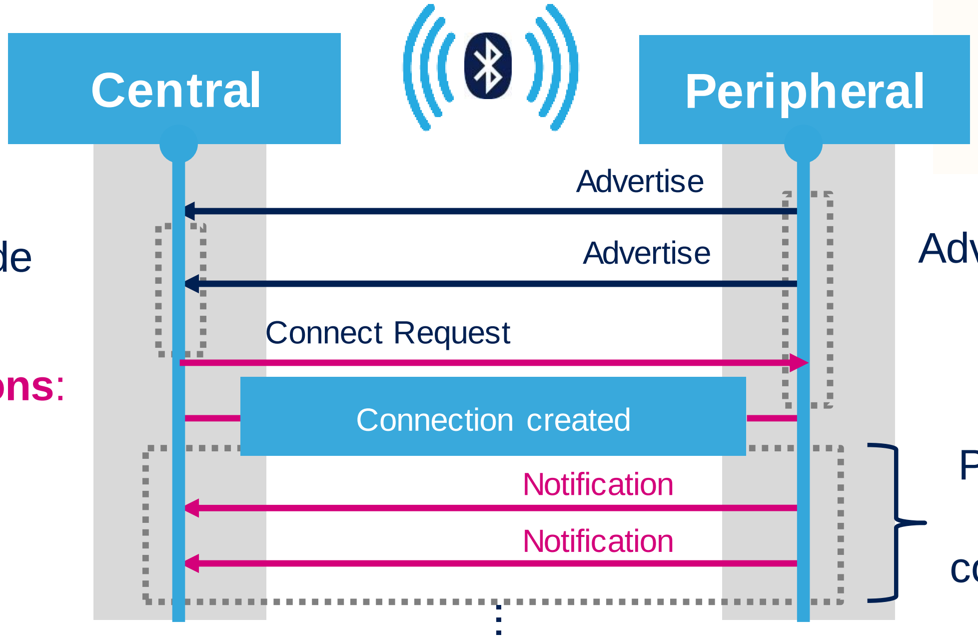
Audio: exported by the Server through 2 dedicated BLE characteristics

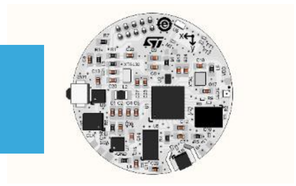
Voice streaming over BLE:
Audio @8kHz
Codec: ADPCM
Bitrate: 32kbps

Receiver can be any STM32 BlueVoice client or an Android/iOS device running ST BlueMS app

BlueVoiceADPCM - Audio 8kHz

Discovery Mode





Advertisement Mode

Peripheral-to-Central communication

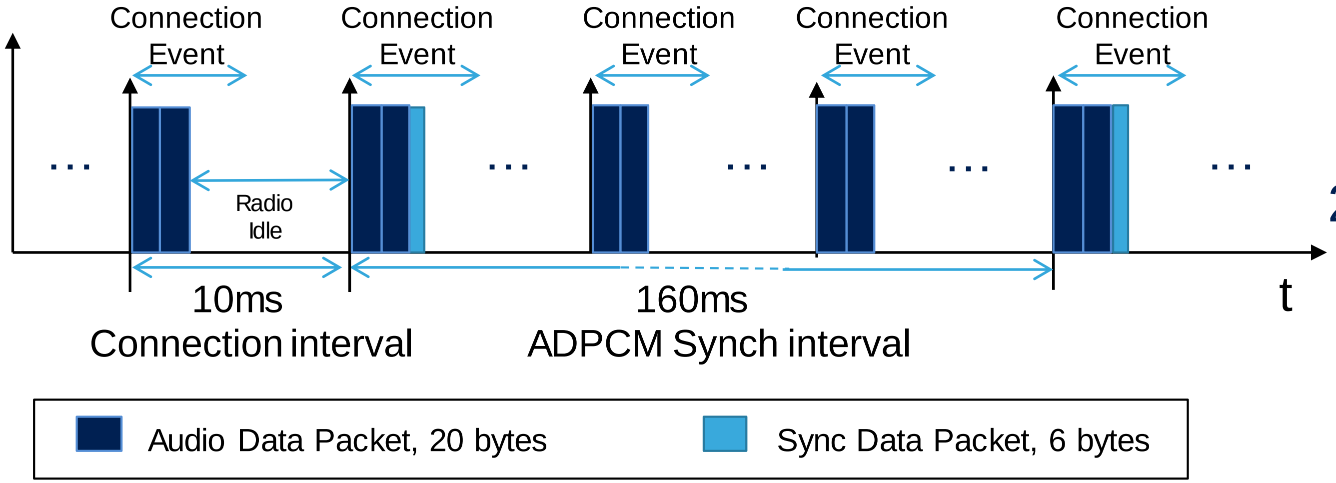
Audio can be half-duplex

No acknowledge required for **Notifications**:

- OK for Audio streaming
- Minimal Latency
- Optimal Bandwidth

Voice Streaming

- Audio Format: PCM 16 bit @ 8 kHz
- ADPCM Compression @ 32 Kbps: Low latency and low complexity
- Side Information at low data rate ehnances error resilience



2 packets/event
20 bytes/packets
100 events/sec
=
32kbps

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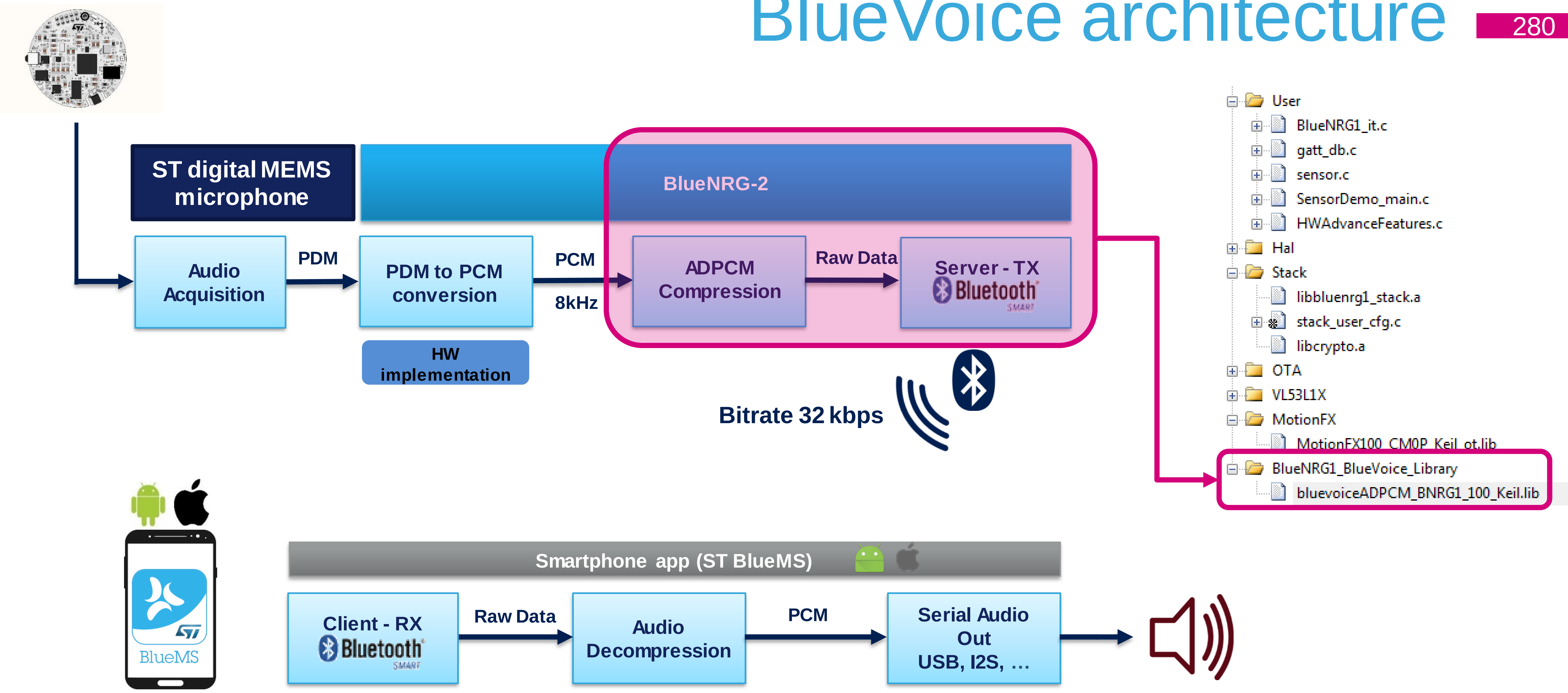
BlueVoice architecture



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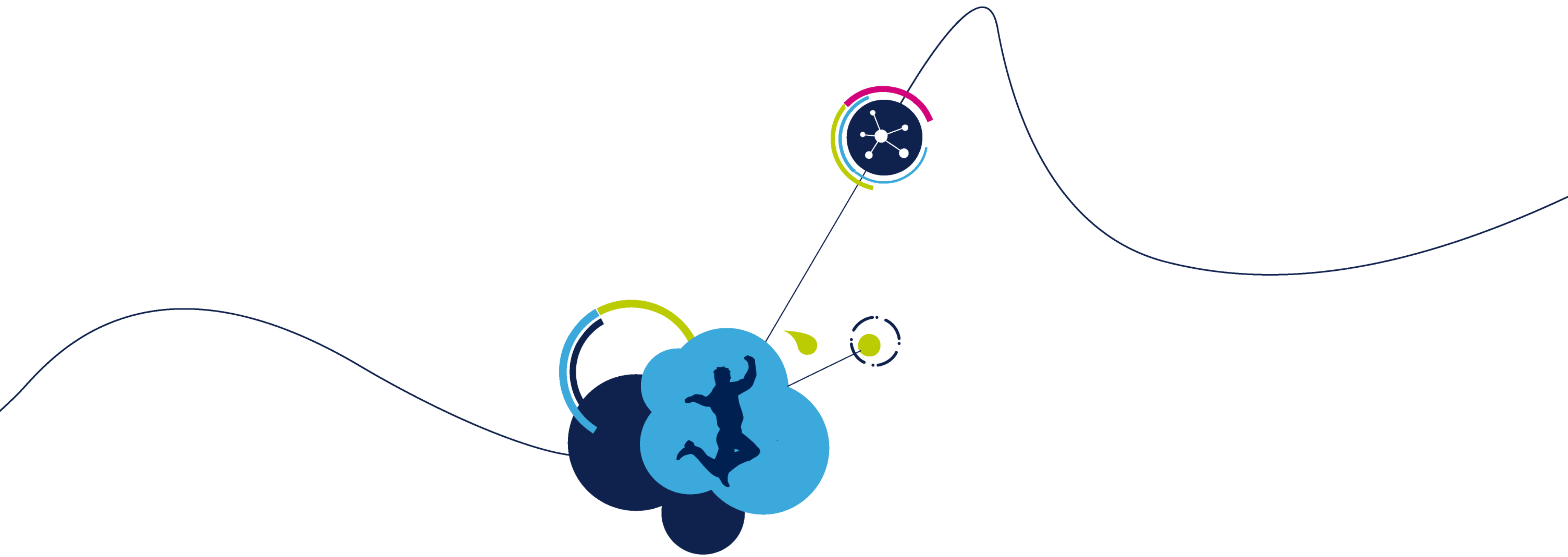

Customizing your design

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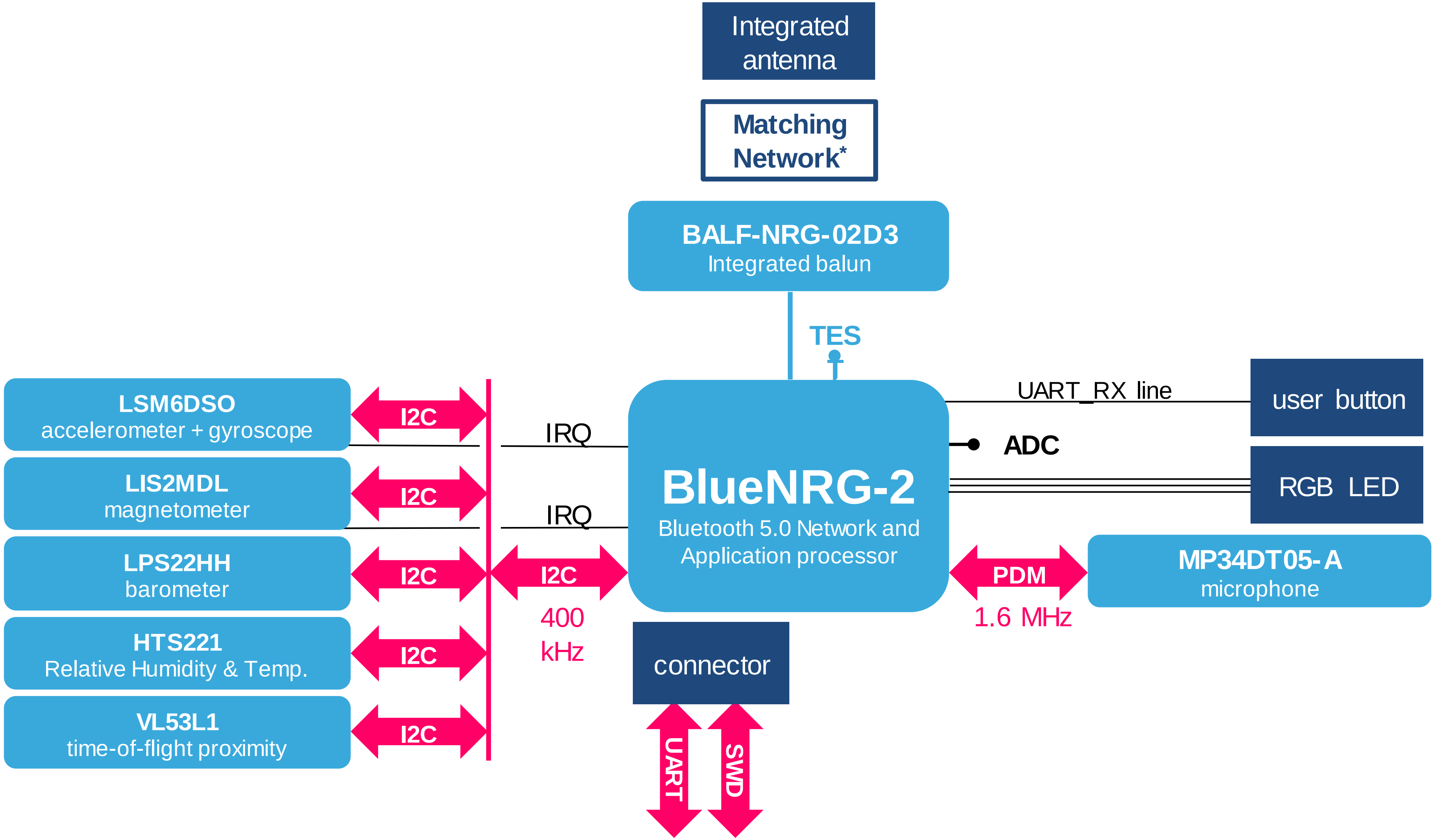
STEVAL-BCN002V1 Block Diagram



Enable/Disable Sensors&Libraries

- Dedicated structure "**FeaturePresence**" for enabling/disabling sensors & libraries individually. File **sensor.h** at line 64

```
64 typedef struct {
65     bool AccelerometerGyroscopePresence;
66     bool MagnetometerPresence;
67     bool HumidityTemperaturePresence;
68     bool PressurePresence;
69     bool ProximityLightPresence;
70     bool iNemoEngine;
71     bool Pedometer;
72 } FeaturePresence;
```

- **SensorScan()** function set each field of the structure to **false** or **true**. File **sensor.c** at line 319

```
318     // Check sensor list
319     SensorsScan();
320
321     // Configure discovered sensors
322     if (xFeaturePresence.PressurePresence)
323       Init_Pressure_Temperature_Sensor();
324     if (xFeaturePresence.HumidityTemperaturePresence)
325       Init_Humidity_Sensor();
326     if (xFeaturePresence.MagnetometerPresence)
327       Init_Magnetometer();
328     if (xFeaturePresence.AccelerometerGyroscopePresence)
329       Init_Accelerometer_Gyroscope();
330     if (xFeaturePresence.ProximityLightPresence)
331       Init_Proximity_Sensor();
332
333     // Configure sensors in low power mode
334     SensorsLowPower();
```

BLE timings

- Advertising intervals:
  - Dedicated API *aci_gap_set_discoverable(Advertising_Type, Advertising_Interval_Min, Advertising_Interval_Max, …)*
  - In file **sensor.c** at line **451**

- Connection intervals:
  - Dictated by the Central device. Peripheral has no full control on this.

- Notifications frequency
  - Dedicated Virtual Timers (mapped on HW physical timers) for different functionalities
  - Timeouts defined in **sensor.h** at line **172-174**

```
172 #define BATTERY_UPDATE_RATE      1000    // Fixed ODR @  1 Hz
173 #define ENV_SENSOR_UPDATE_RATE    100     // Fixed ODR @  10 Hz
174 #define MOTION_SENSOR_UPDATE_RATE   40    // Fixed ODR @ 25 Hz
```

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HW modifications

- In this case redesign is of course necessary

- Schematics and Gerbers files:
  - available on request for the time being
  - will be available soon (November) online at www.st.com/bluetile

- BlueNRG-2 pin mapping
  - Check BlueNRG-2 DS at Table 129

3.12.2 **Functional description**

The table below shows the GPIO configuration table where each IO pin is associated with related functions.

Table 129. **IO functional map**

Pin name[1]	GPIO mode "000"		Serial1 mode '001"		Serial0 mode '100'		Serial2 mode '101'	
	Type	Signal	Type	Signal	Type	Signal	Type	Signal
IO0	I/O	GPIO 0	I	UART_CTS	I/O	SPI_CLK	O	CPUCLK
IO1	I/O	GPIO 1	O	UART_RTS	I/O	SPI_CS1	I	PDM_DATA
IO2	I/O	GPIO 2	O	PWM0	O	SPI_OUT	O	PDM_CLK
IO3	I/O	GPIO 3	O	PWM1	I	SPI_IN	-	-
IO4	I/O	GPIO 4	I	UART_RXD	I/O	I2C2_CLK	O	PWM0
IO5	I/O	GPIO 5	O	UART_TXD	I/O	I2C2_DAT	O	PWM1
IO6	I/O	GPIO 6	O	UART_RTS	I/O	I2C2_CLK	I	PDM_DATA
IO7	I/O	GPIO 7	I	UART_CTS	I/O	I2C2_DAT	O	PDM_CLK
IO8	I/O	GPIO 8	O	UART_TXD	I/O	SPI_CLK	I	PDM_DATA
IO9	I/O	GPIO 9	I	SWCLK	I	SPI_IN	O	XO16/32M
IO10	I/O	GPIO 10	I	SWDIO	O	SPI_OUT	O	CLK_32K
IO11	I/O	GPIO 11	I	UART_RXD	I/O	SPI_CS1	O	CLK_32K
IO12	OD	GPI 12 [2]		-	I/O	I2C1_CLK	-	-
IO13	OD	GPI 13[2]	I	UART_CTS	I/O	I2C1_DAT	-	-
IO14	I/O	GPIO 14	I/O	I2C1_CLK	I/O	SPI_CLK	-	-

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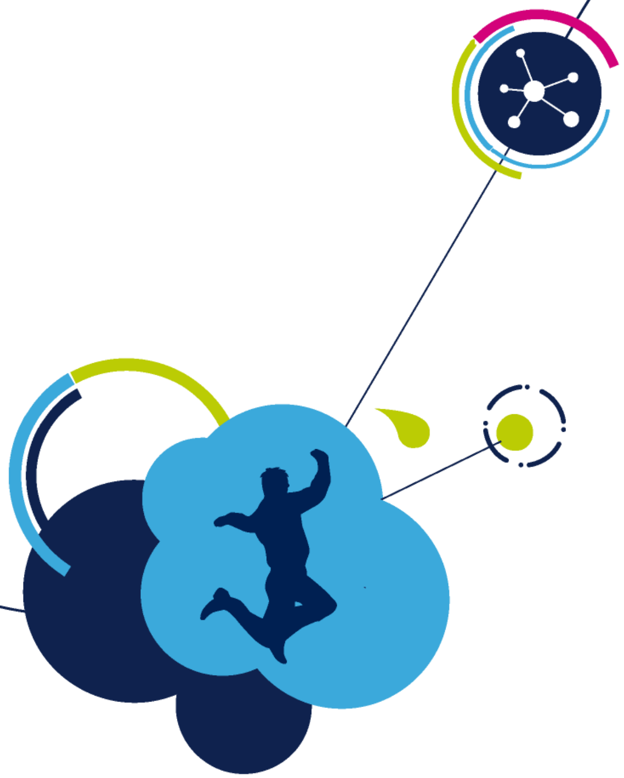

Quick recap

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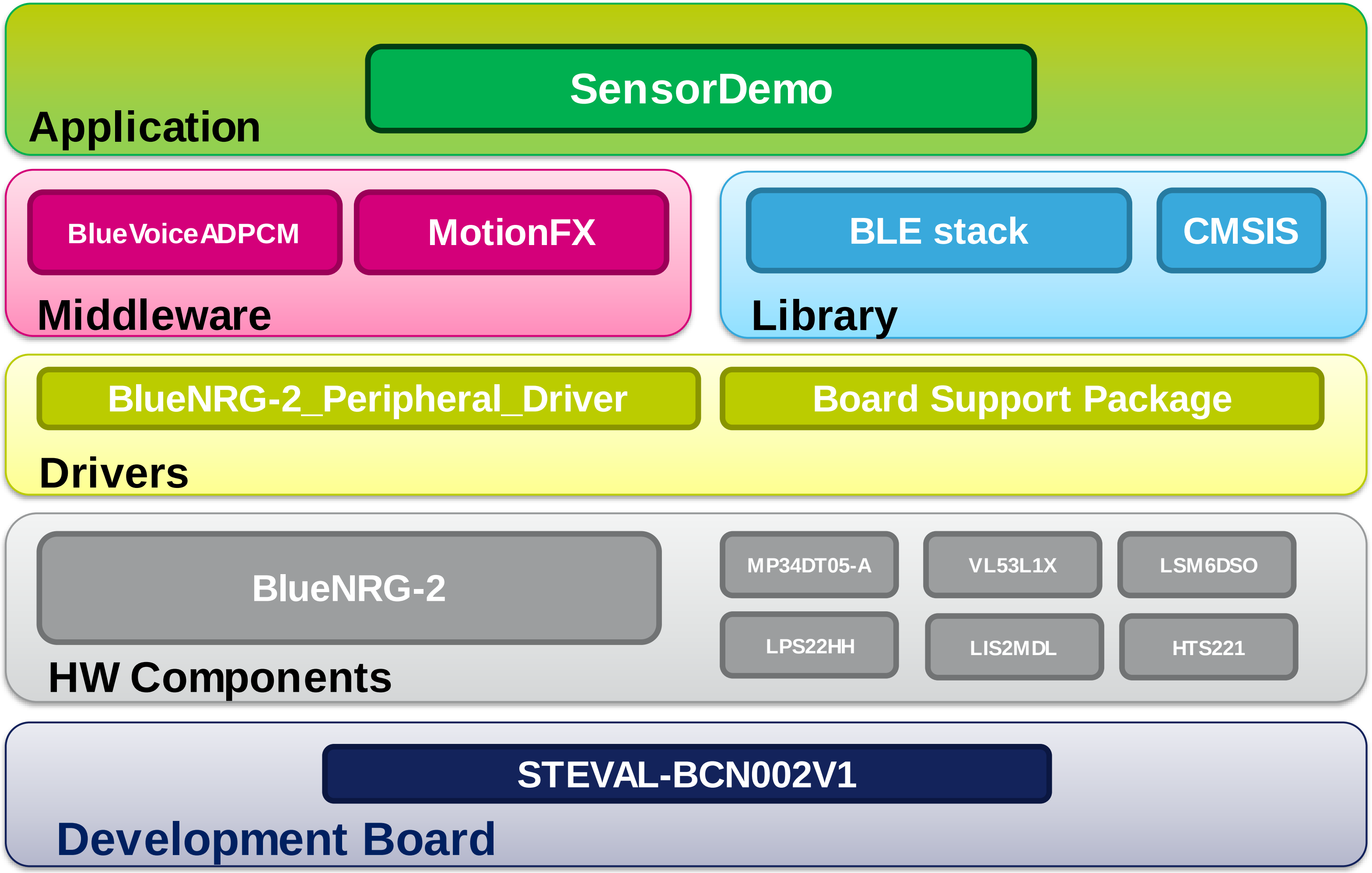
DK 3.0.0 SW architecture



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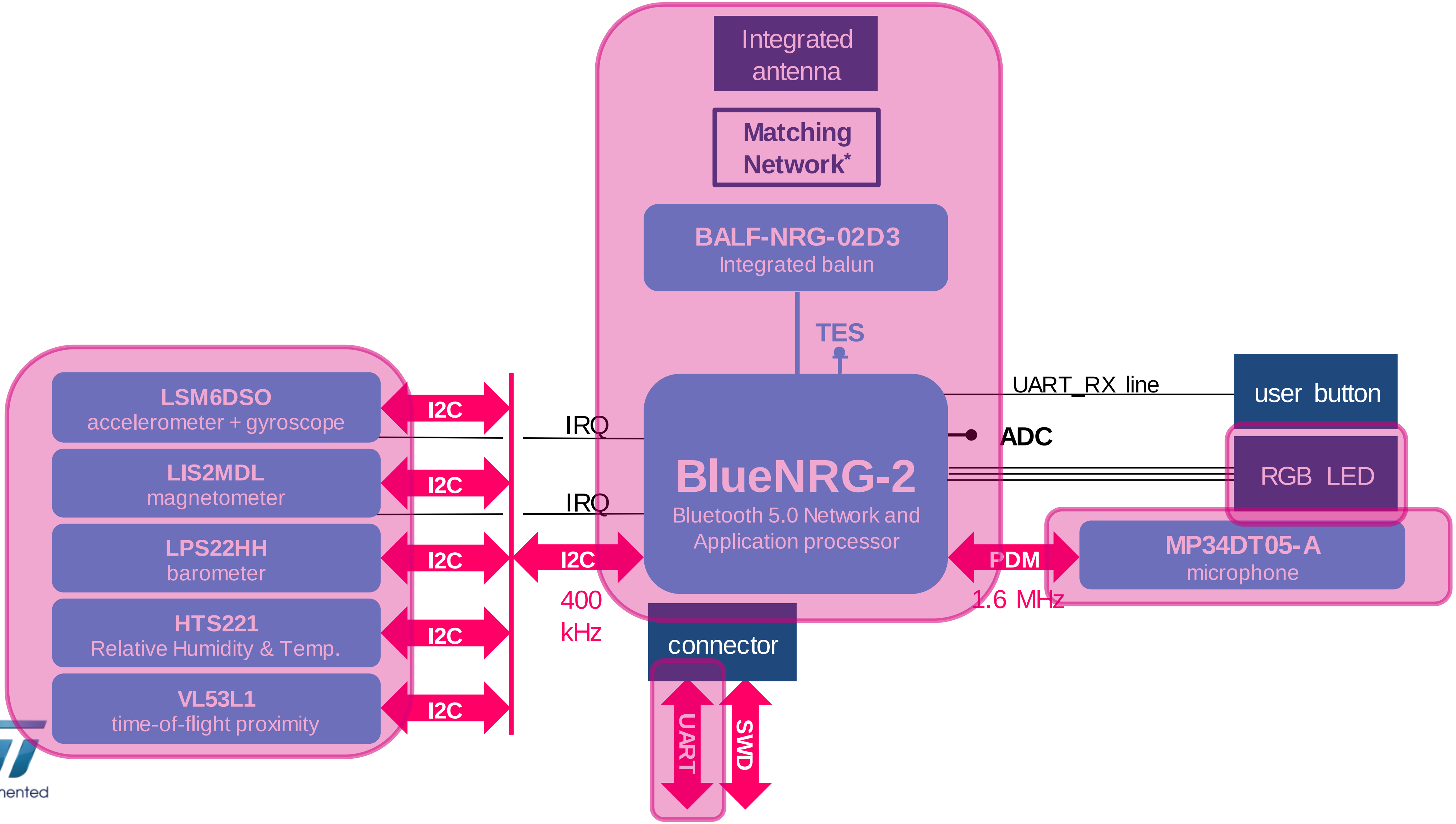
STEVAL-BCN002V1 Block Diagram



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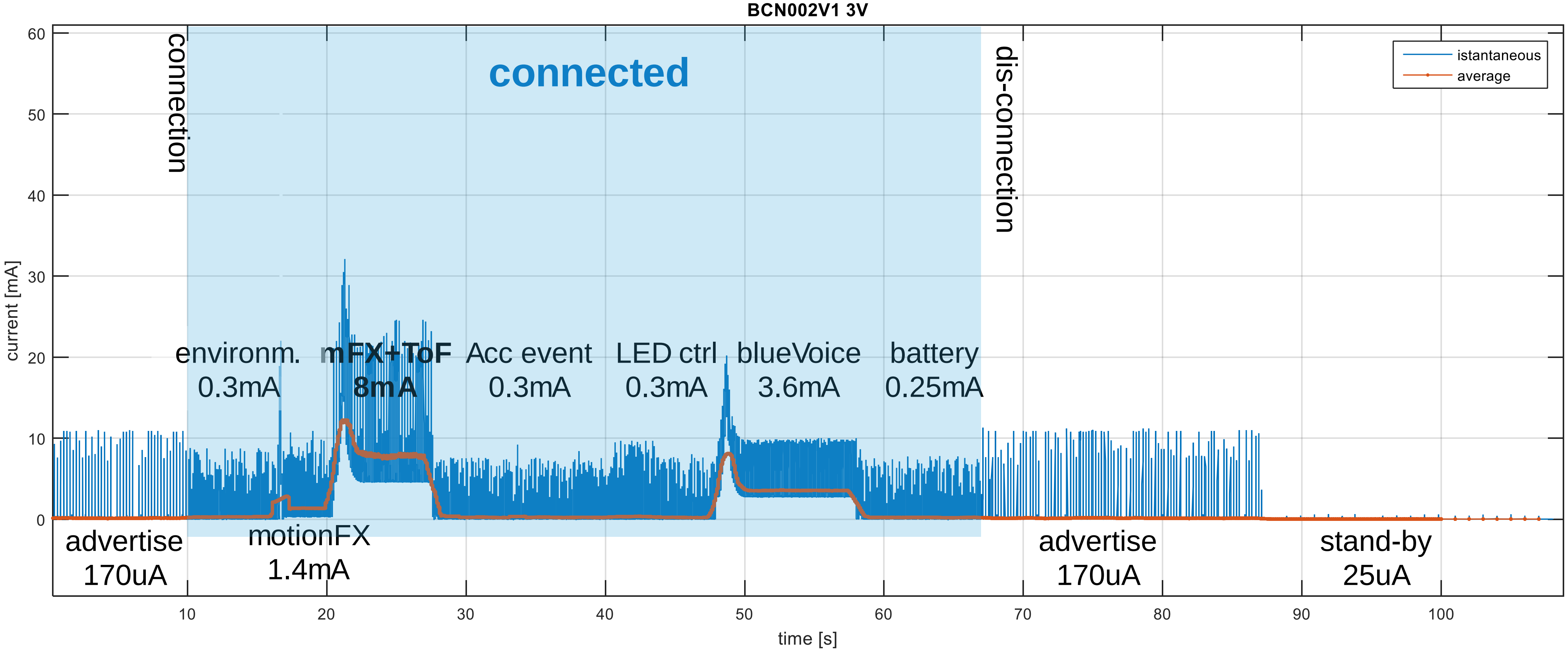
Power consumption

State	Avg power cons
stand-by	25uA
advertise 250ms	170uA
Battery notification	0.25mA
Environmental / AccEvents / LED control	0.3mA
Motion FX (Inertial)	1.4mA
BlueVoice	3.6mA
Motion FX plus Time Of Flight	8mA



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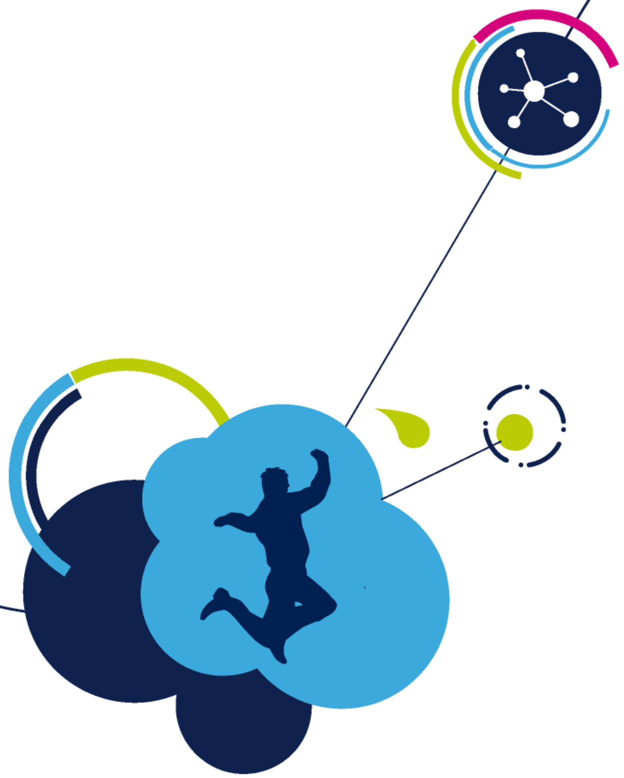
Battery lifetime

State	Avg Power Cons	Battery lifetime
stand-by	25uA	8800 hrs / 367 days
advertise 250ms	170uA	1294 hrs / 54 days
Battery notification	0.25mA	880 hrs / 37 days
Environmental / AccEvents / LED control	0.3mA	733 hrs / 30 days
Motion FX (Inertial)	1.4mA	157 hrs / 6.5 days
BlueVoice	3.6mA	61.1 hrs / 2.5 days
Motion FX plus Time Of Flight	8mA	27.5 hrs

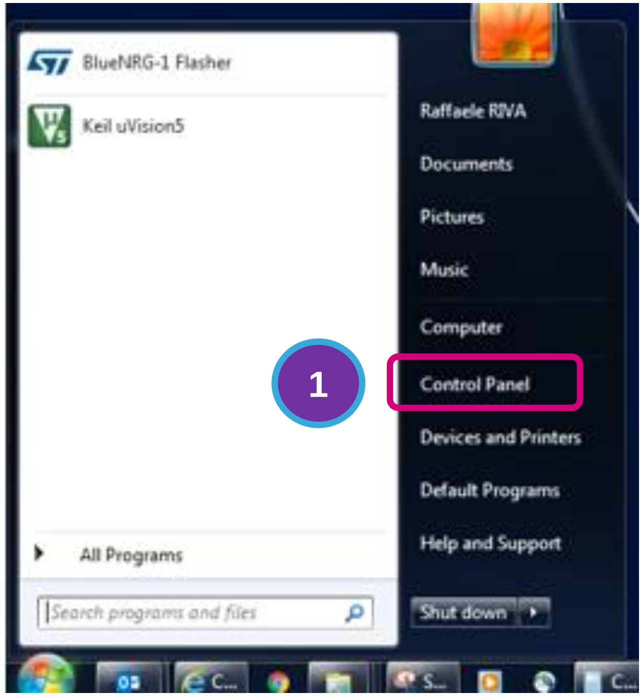


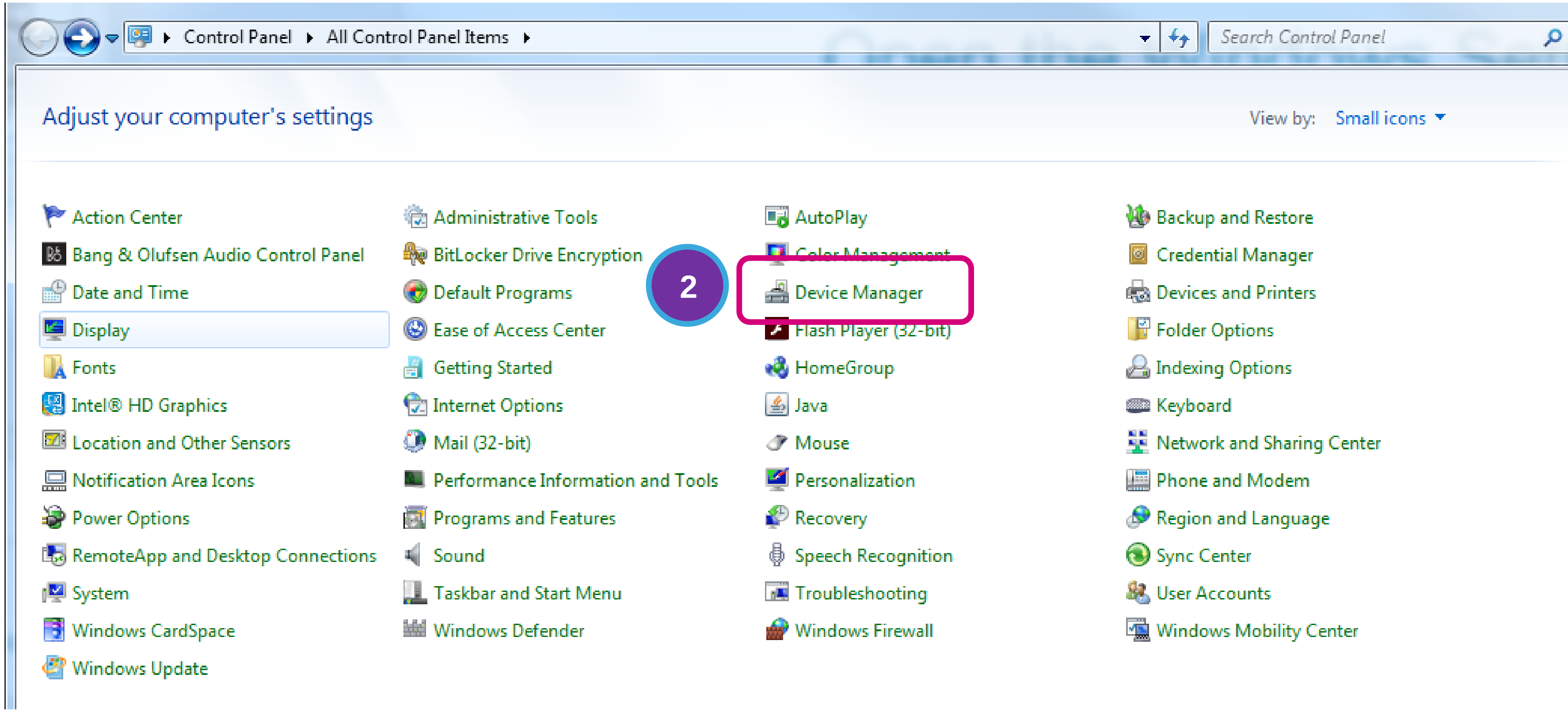
The end: Q&A

Virtual COM driver installation Win7

Open the Windows Control Panel

1. From **Start Menu** select **Control Panel**
2. Select **Device Manager**





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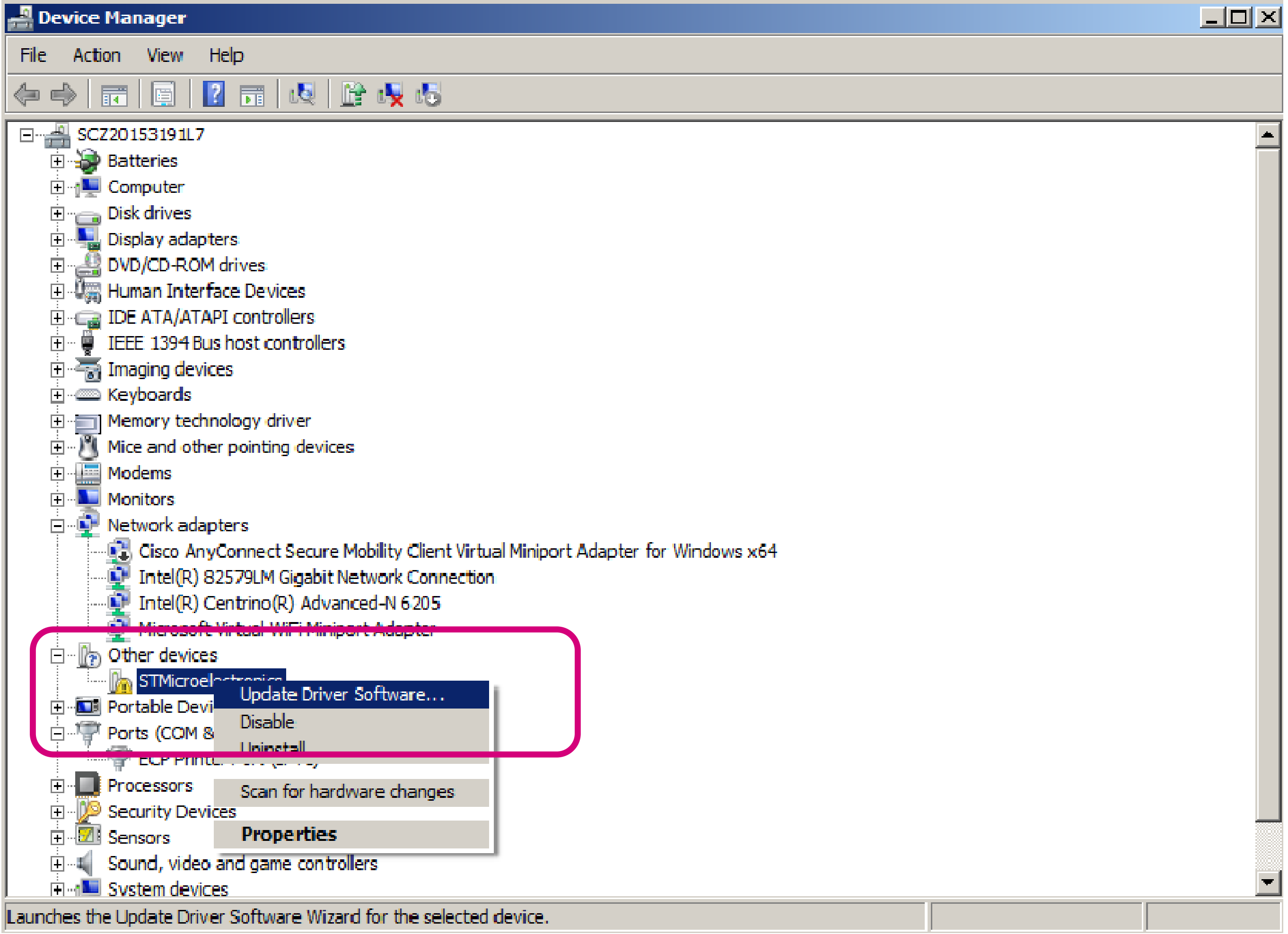
Open the Device Manager

1. Look for **Other devices** and right click and then select **Update Driver Software…**

1



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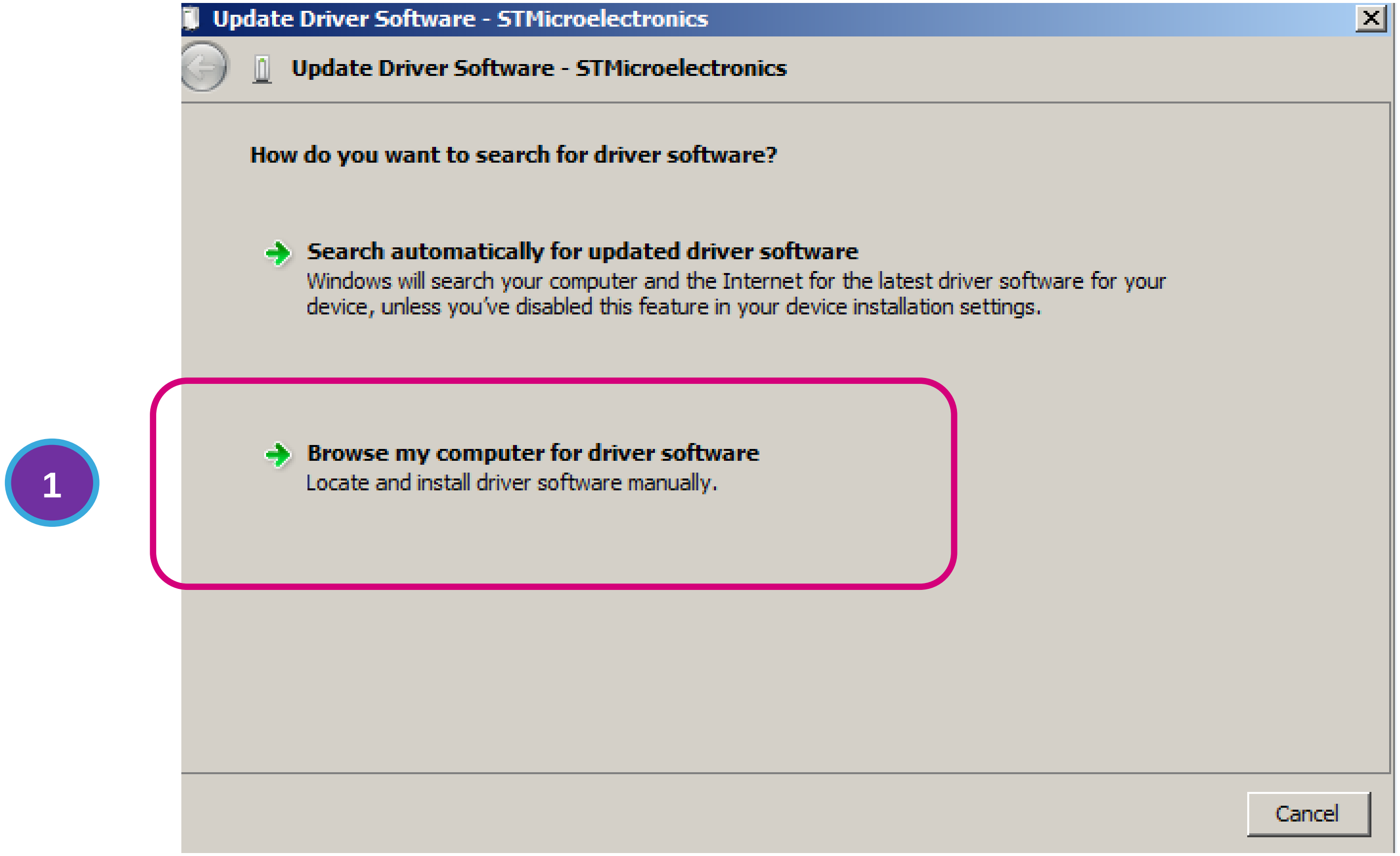
Look for the VCOM Driver

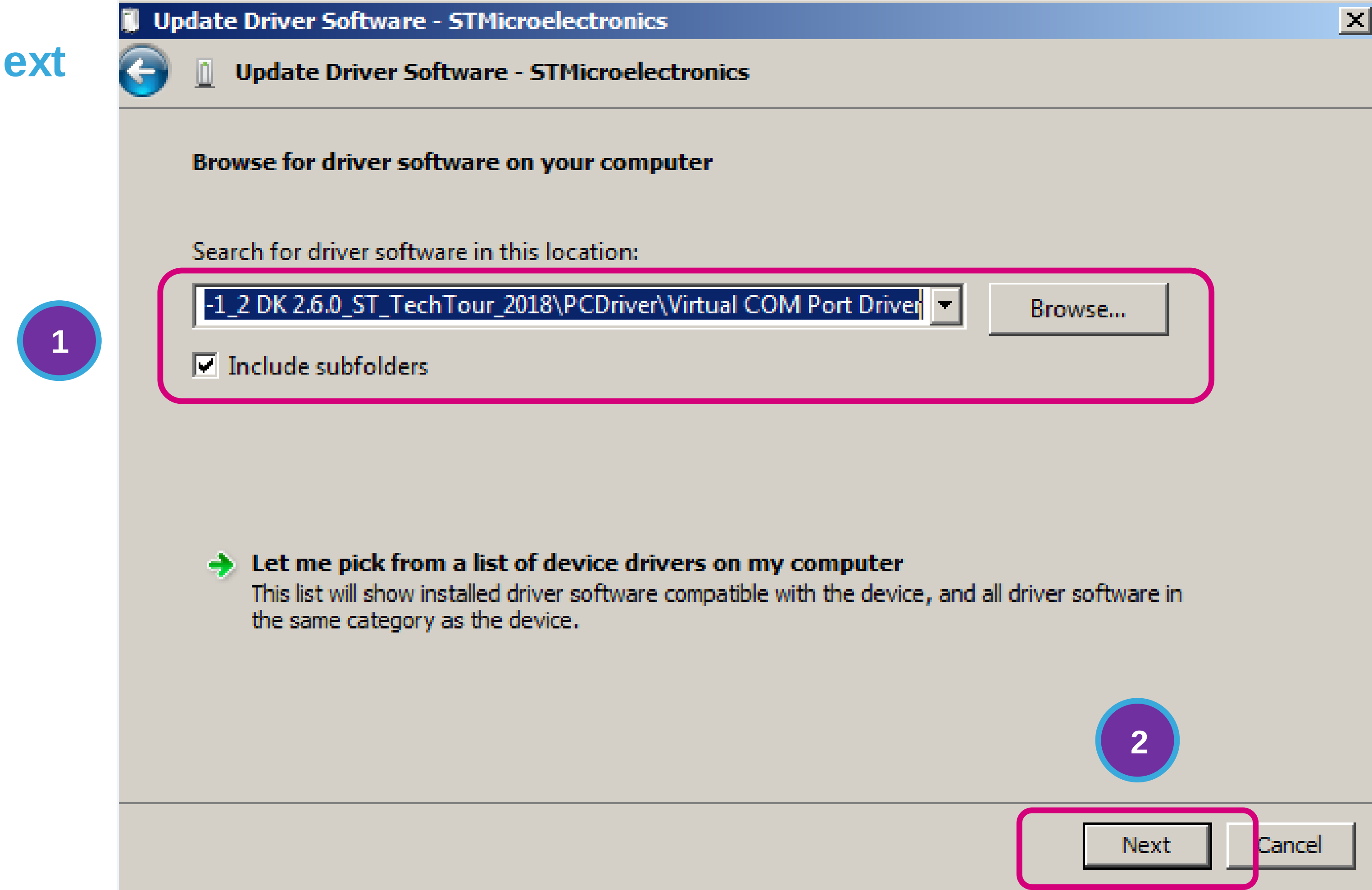
1. Select **Browse my computer for driver software**



Look for the VCOM Driver

1. Click on **Browse** button and go to the folder **“C:\BlueNRG_Tile_HandsOn\STEVAL-BCN002V1 DK 3.0.0\PCDriver\Virtual COM Port Driver”**

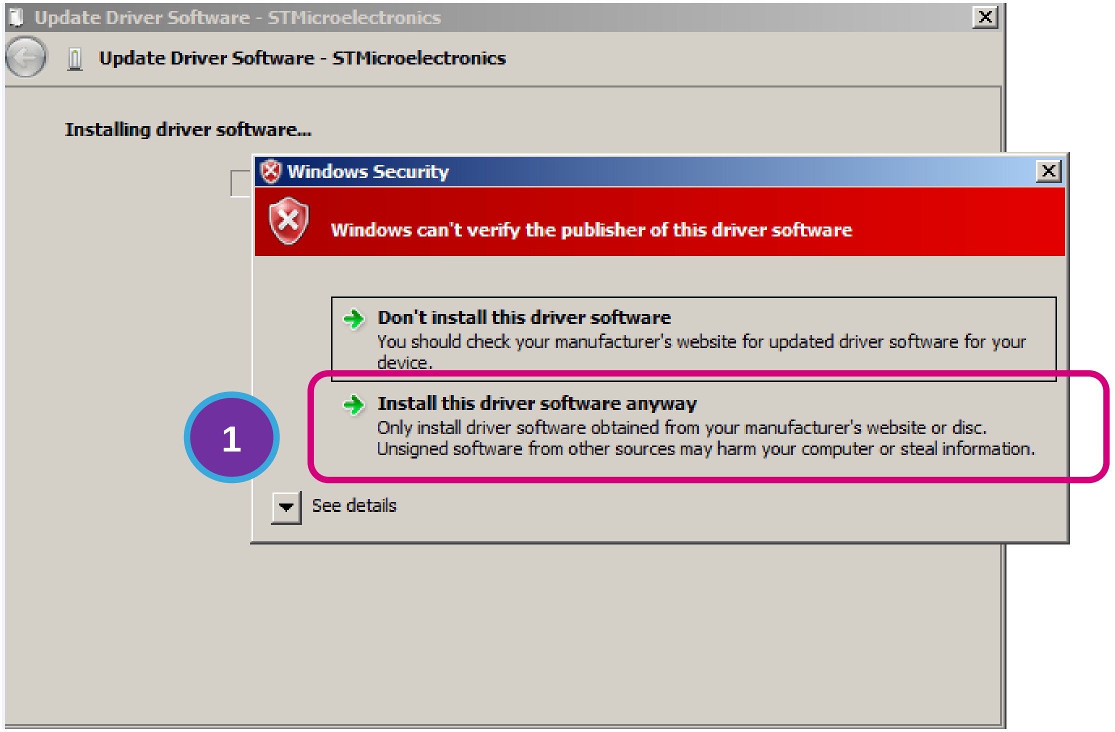
2. Click on **Include subfolder** and then on **Next**

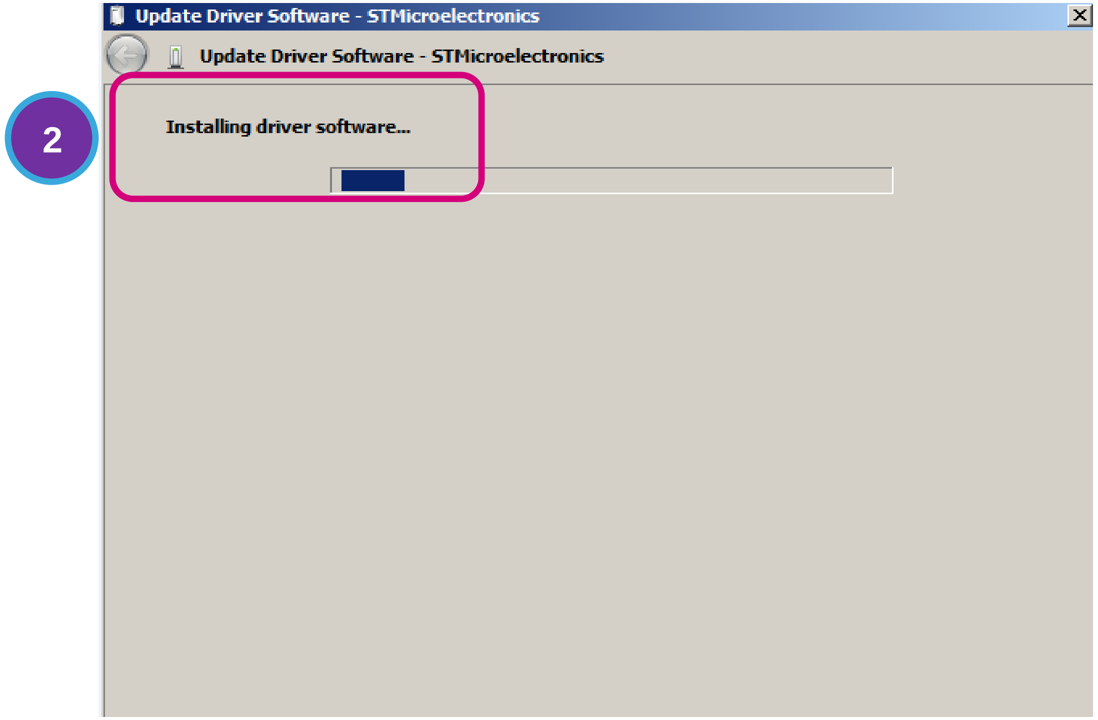


Allow the driver installation

1. Click on **Install driver software anyway**

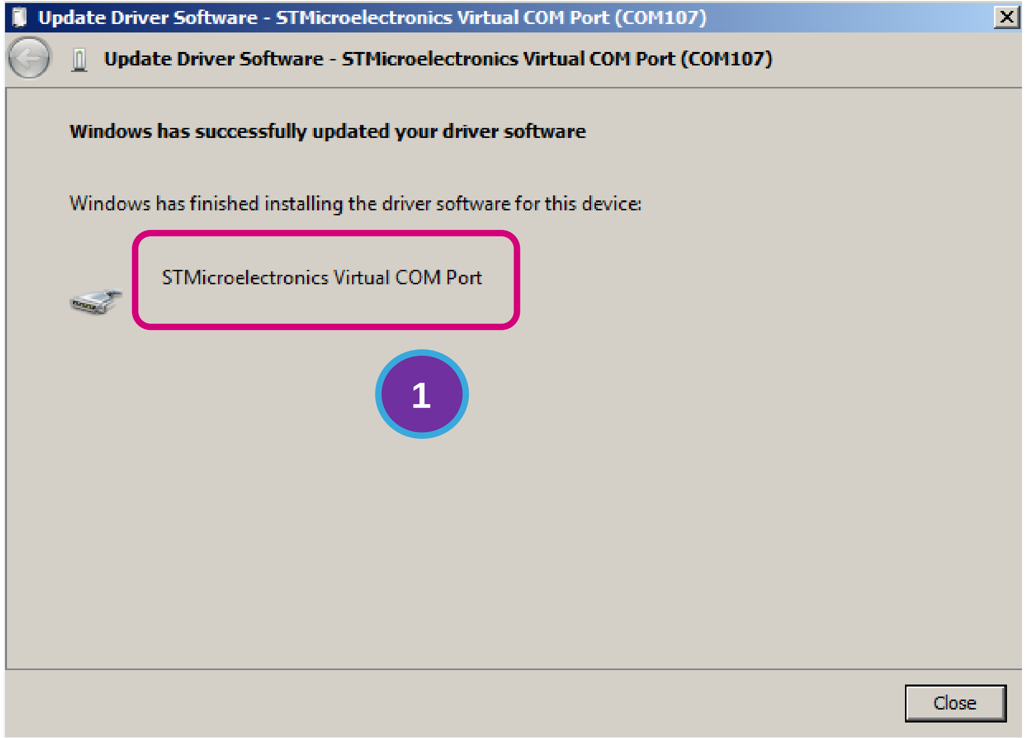
2. Installation starts



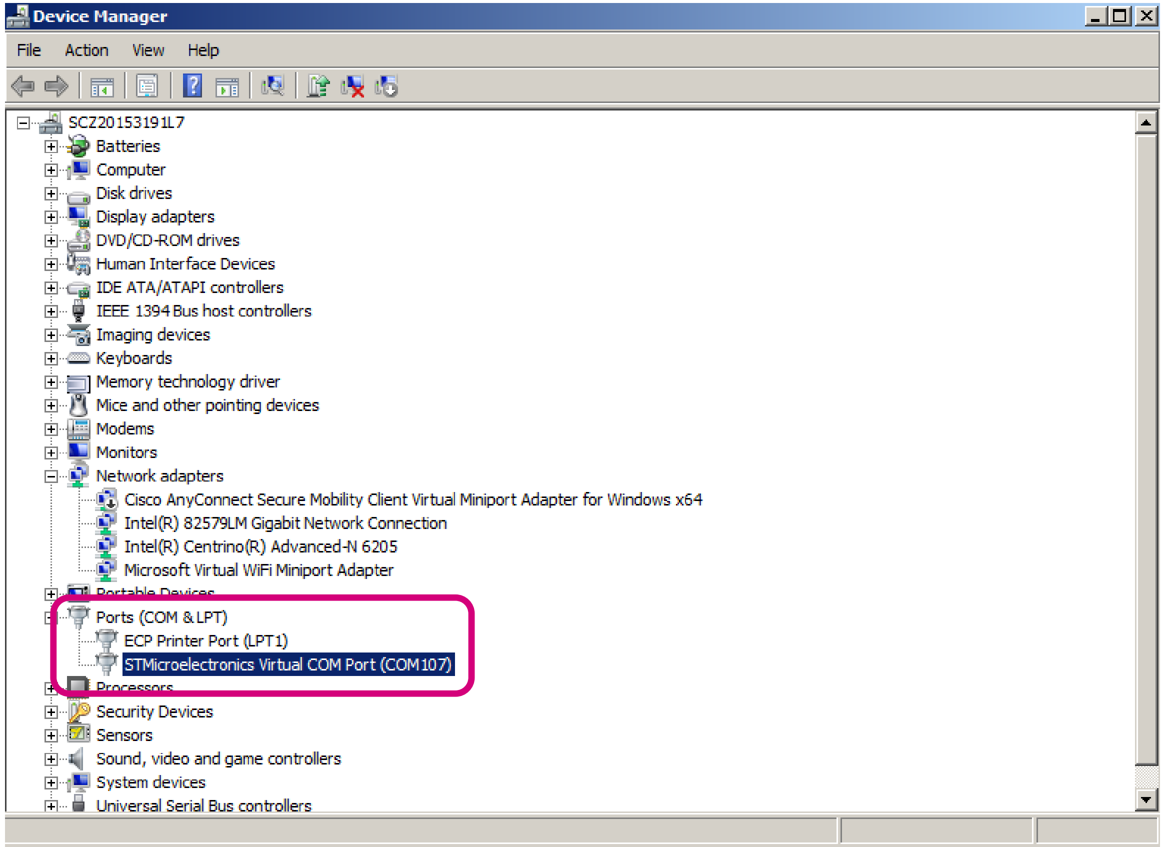


1. Installation completed

2. Device is in the **COM Ports** list



2



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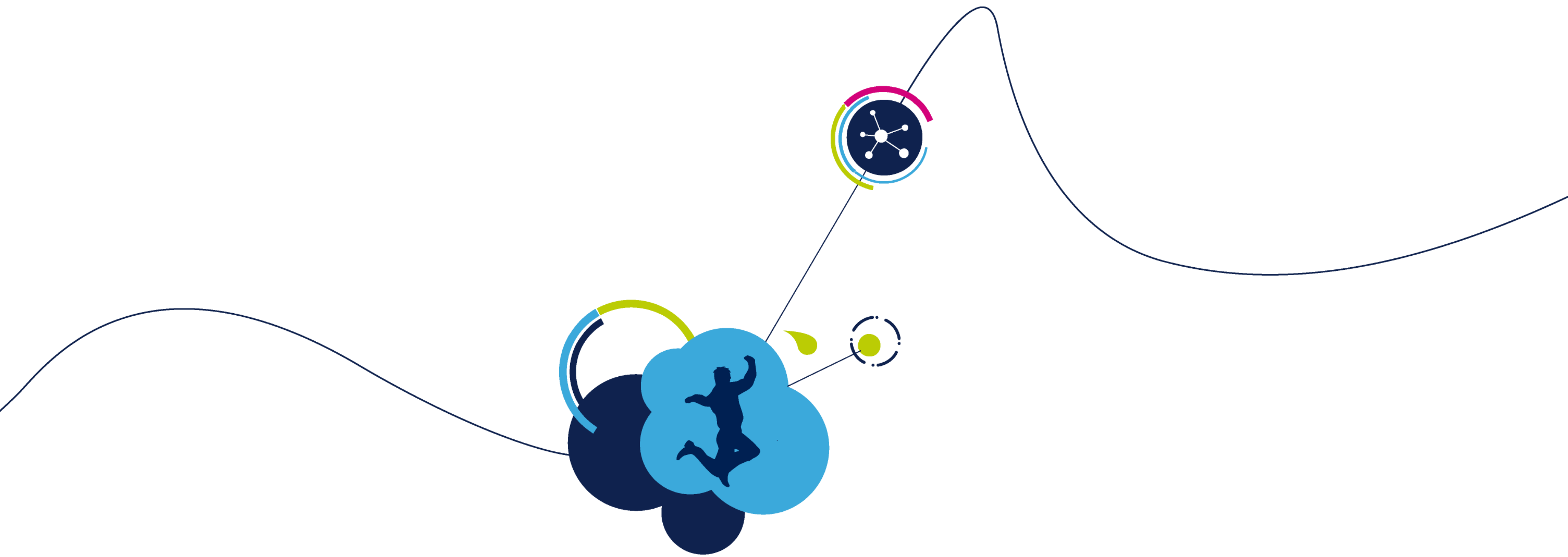
Done! Now please go back from here!



Virtual COM driver installation Win10

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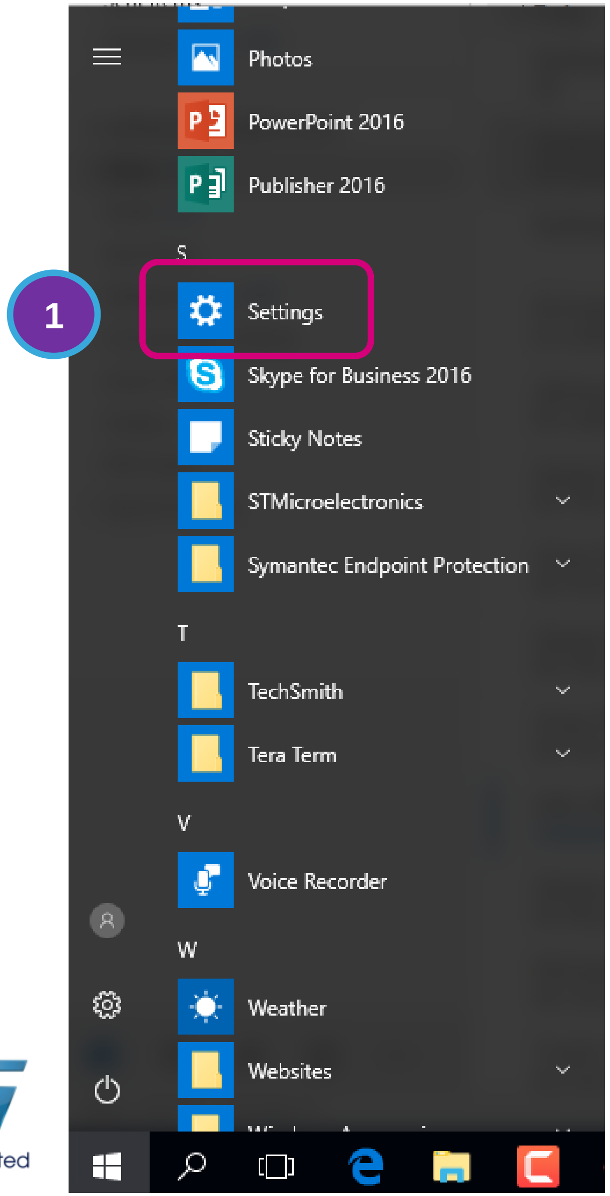
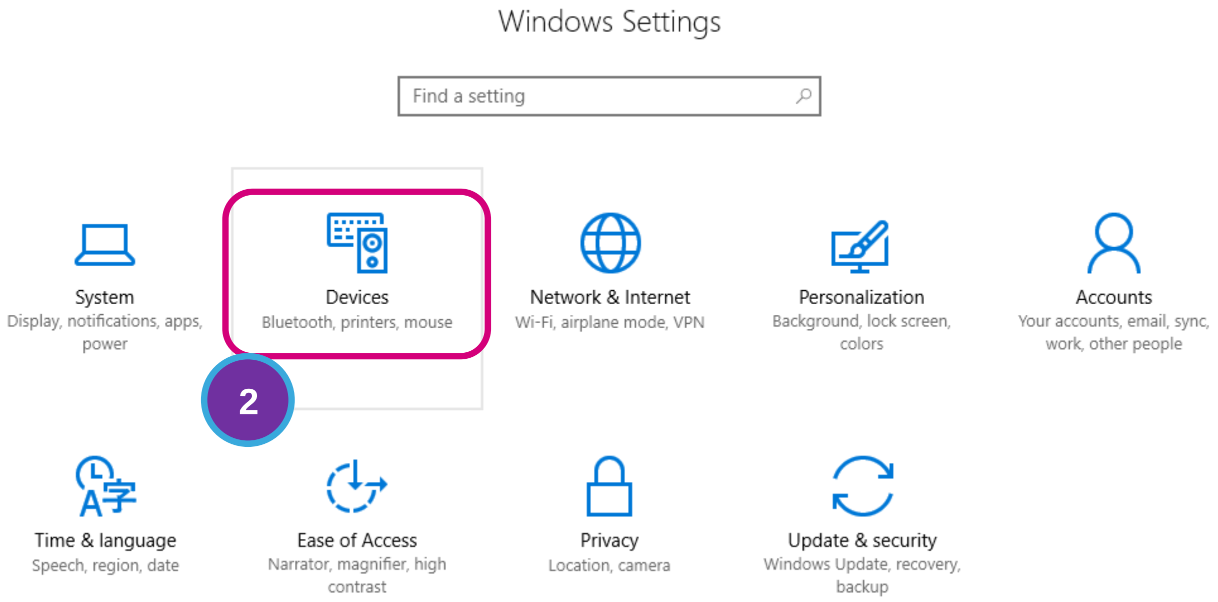
Open the Windows Settings



1. From **Start Menu** select **Settings**
2. Select **Devices**



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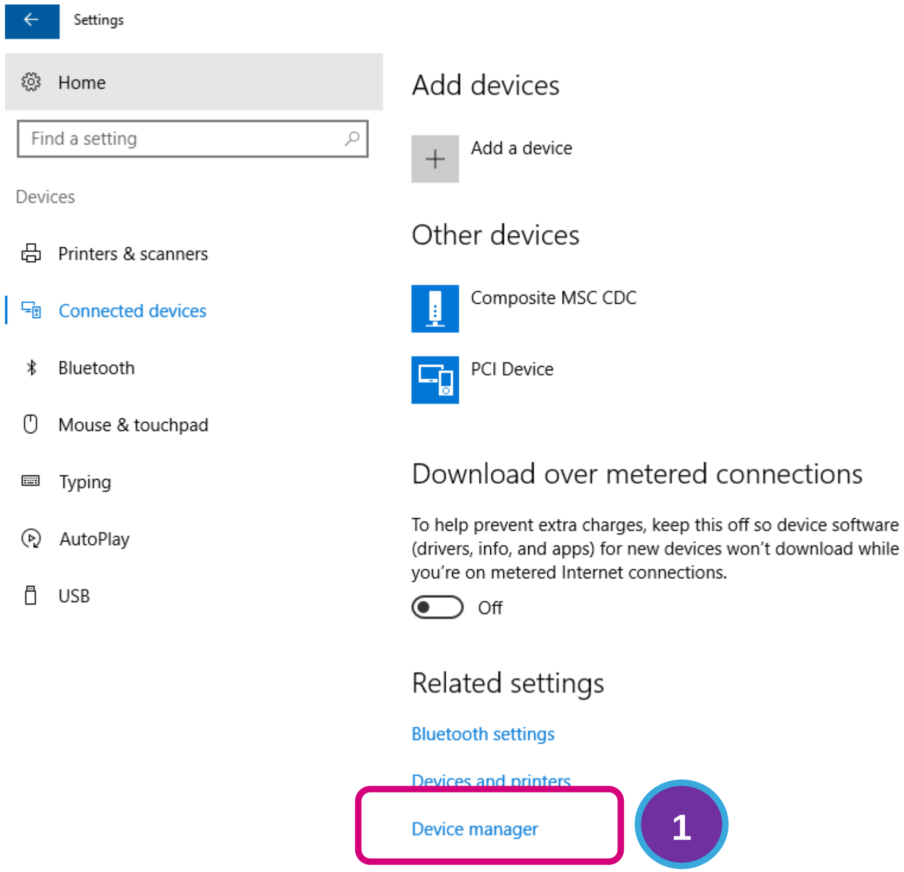
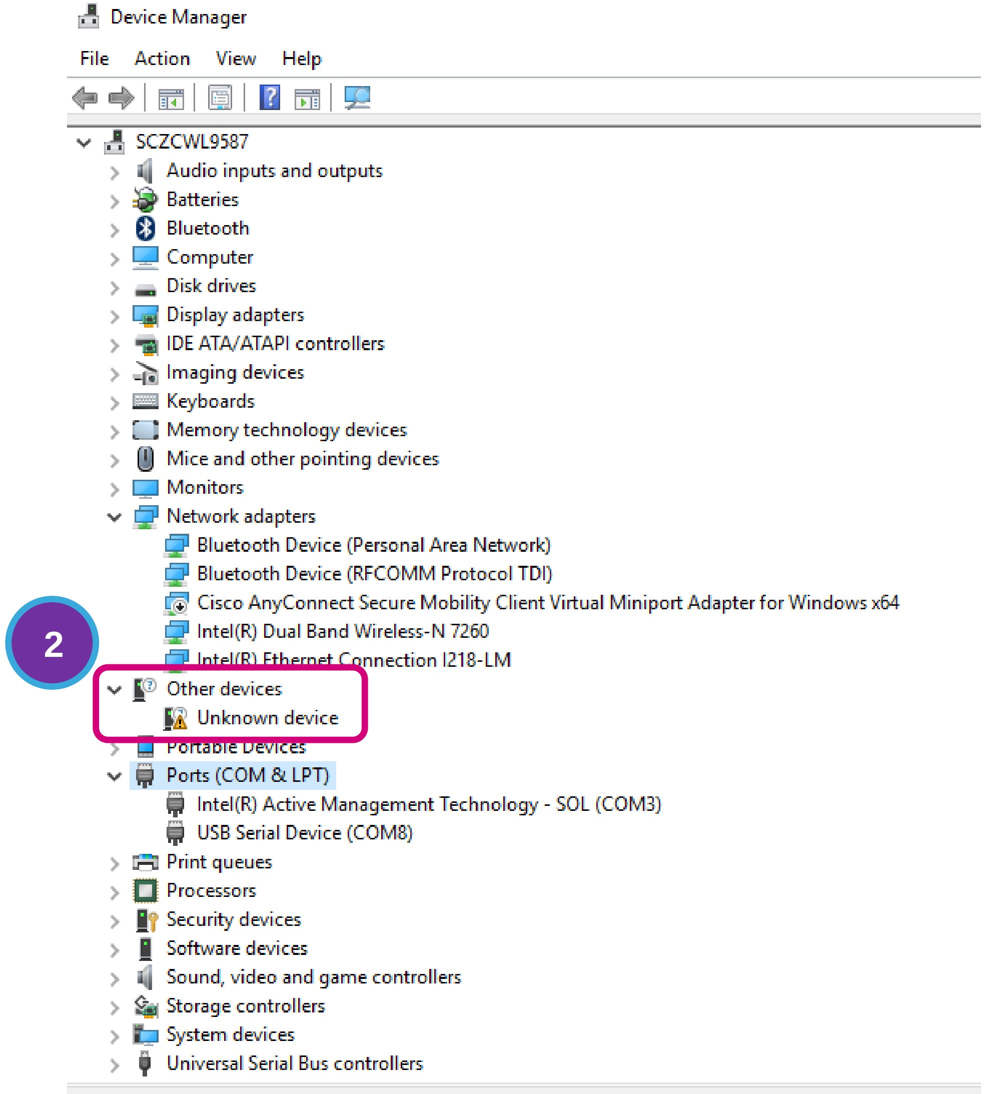
Open the Device Manager

1. Select **Device manager**

2. Select **Other Devices** and **Unknown device**





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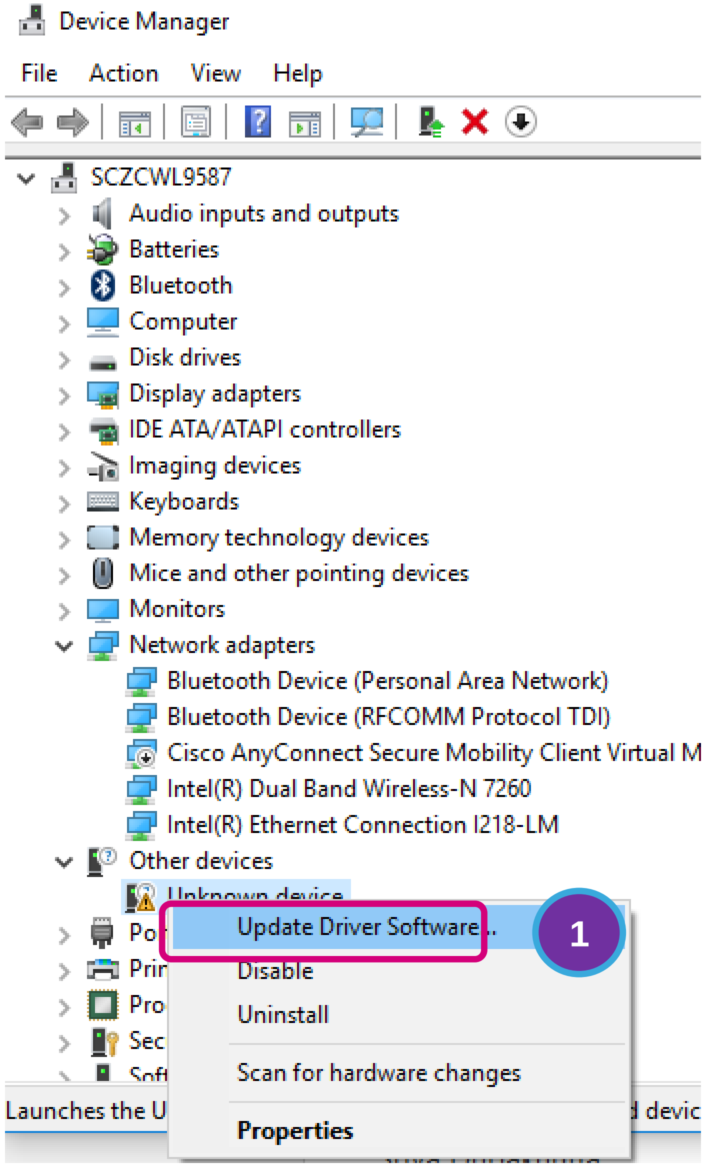
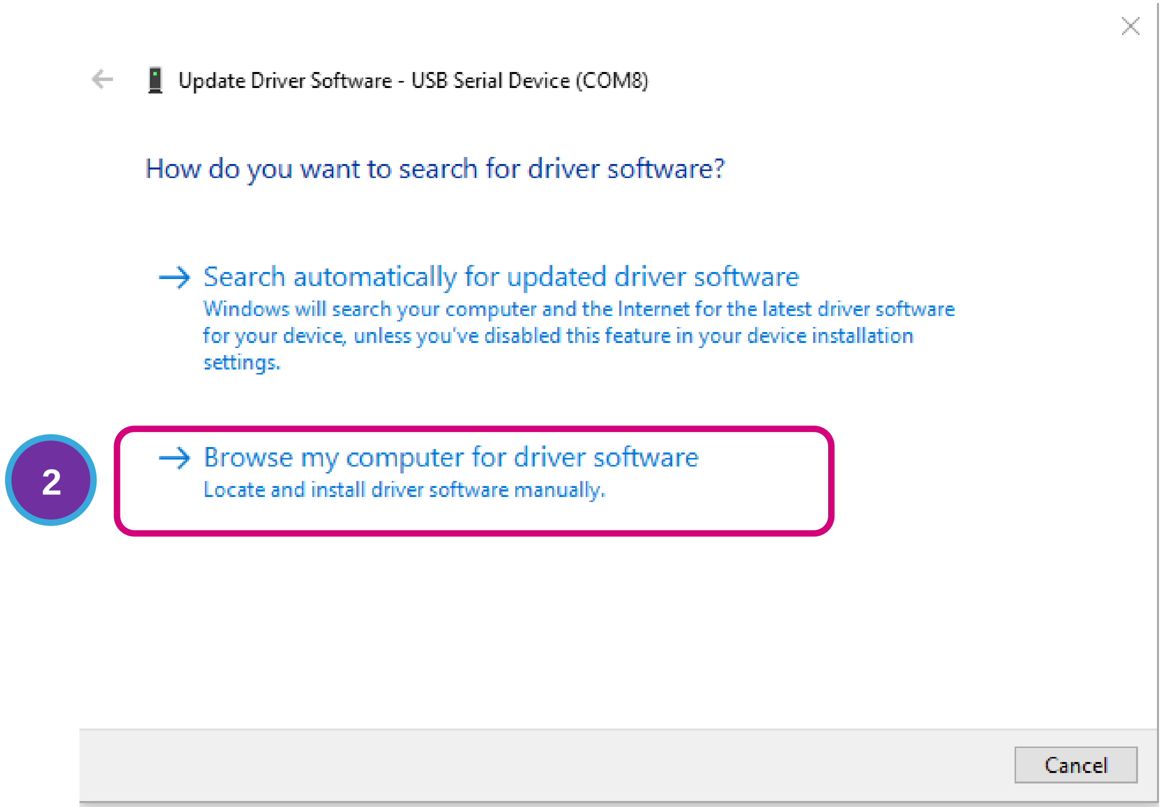
Update Driver Software

1. Right click and then select **Update Driver Software…**
2. Select **Browse my computer for driver software**



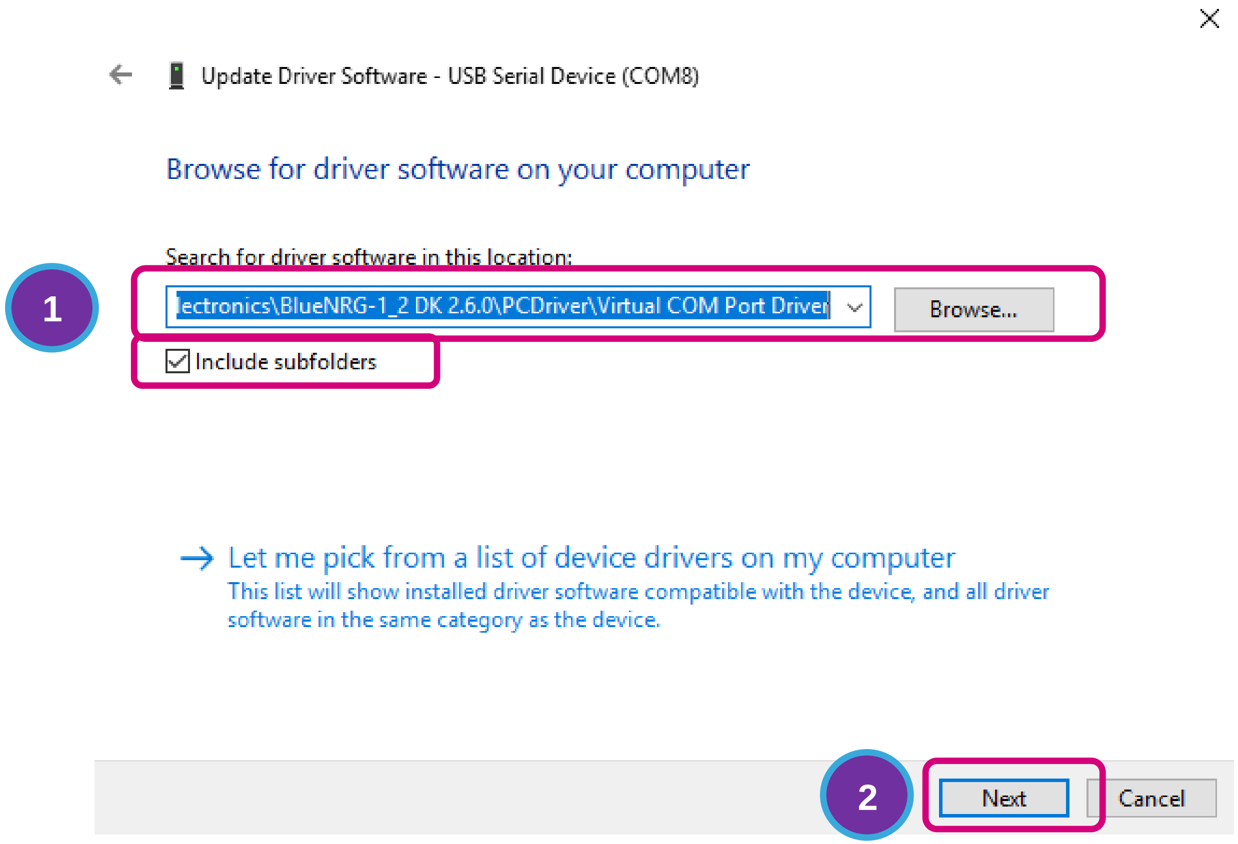


Look for the VCOM Driver

1. Click on **Browse** button and go to the folder

   "C:\BlueNRG_Tile_HandsOn\STEVAL-BCN002V1 DK 3.0.0\PCDriver\Virtual COM Port Driver"

2. Click on **Include subfolder** and then on **Next**



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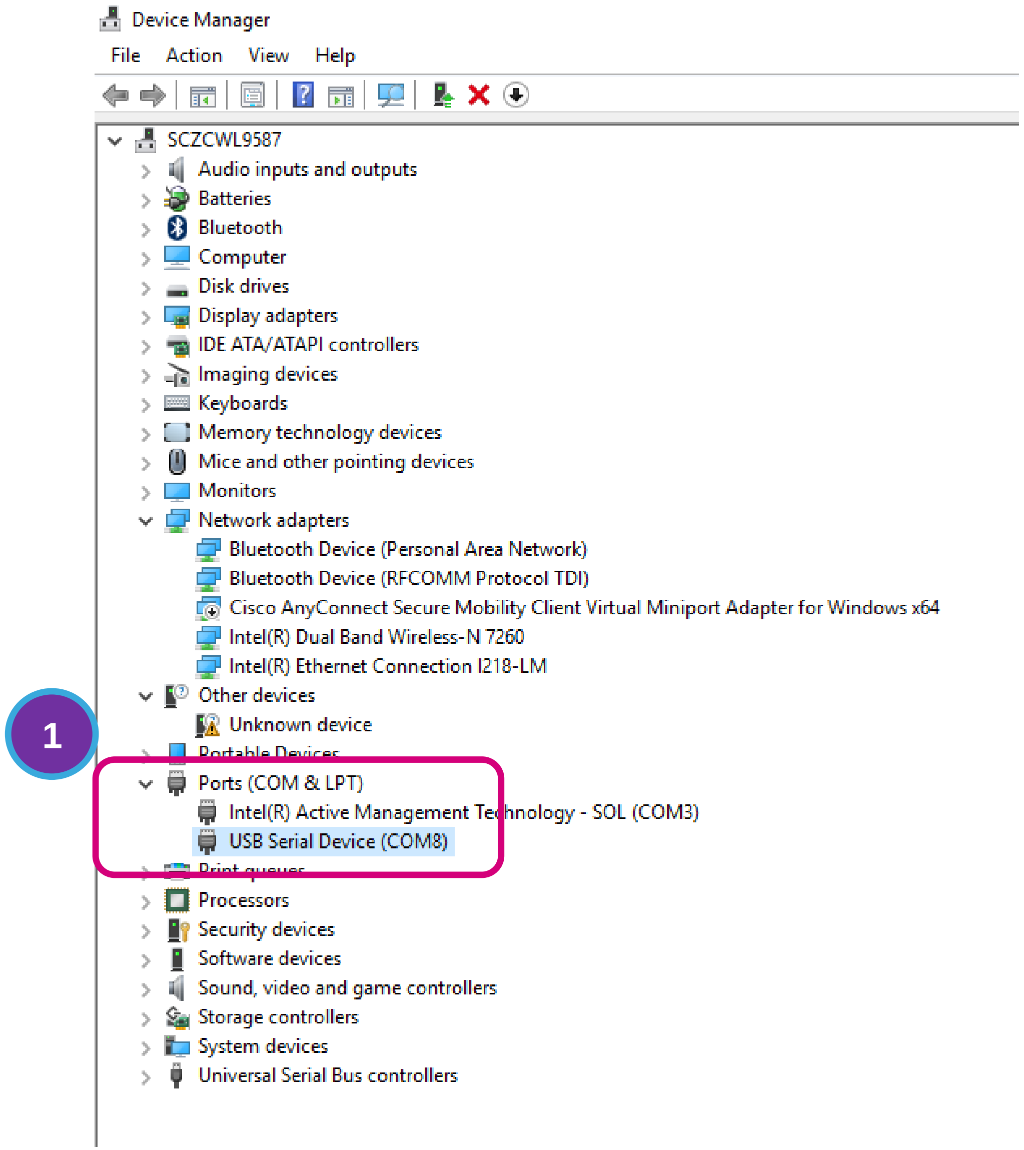
1. Installation completed. Device is in the **COM Ports** list



Done! Now please go back from here!

Keil MDK Free license installation steps

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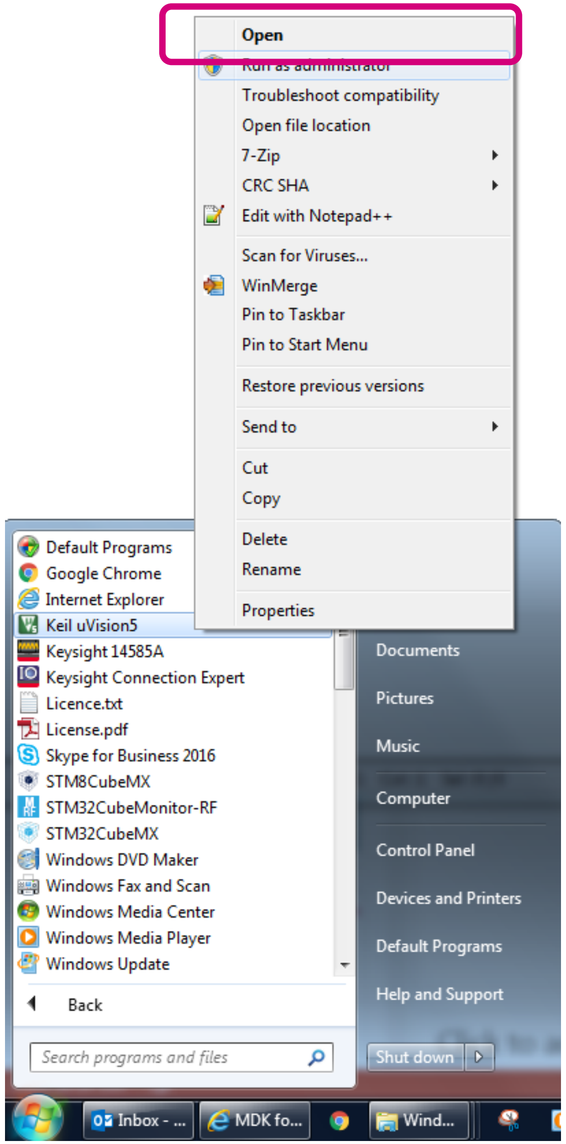
MDK for BlueNRG-2and STM32F0 Installation & Activation

- You can refer to the following webpage:
  - http://www2.keil.com/stmicroelectronics-stm32/mdk

- Note: it is mentioned STM32L0 and STM32F0, but the same procedure applies to BlueNRG-2 device

Arm Keil MDK License Installation 1/6

- Login with an account that has **administration rights**.
- Right-click the µVision icon and select **Run as Administrator...** from the context menu.



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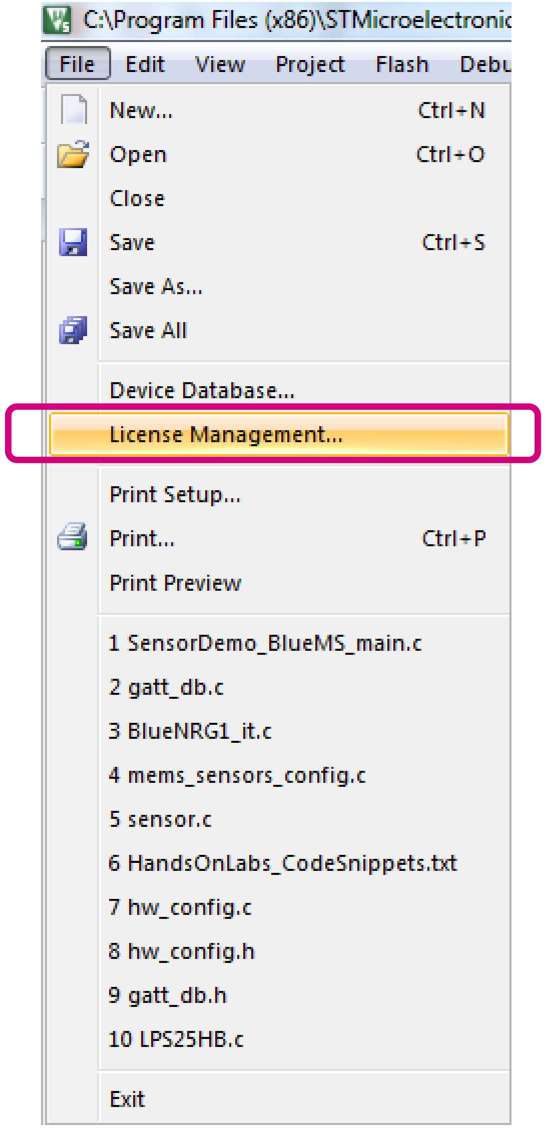
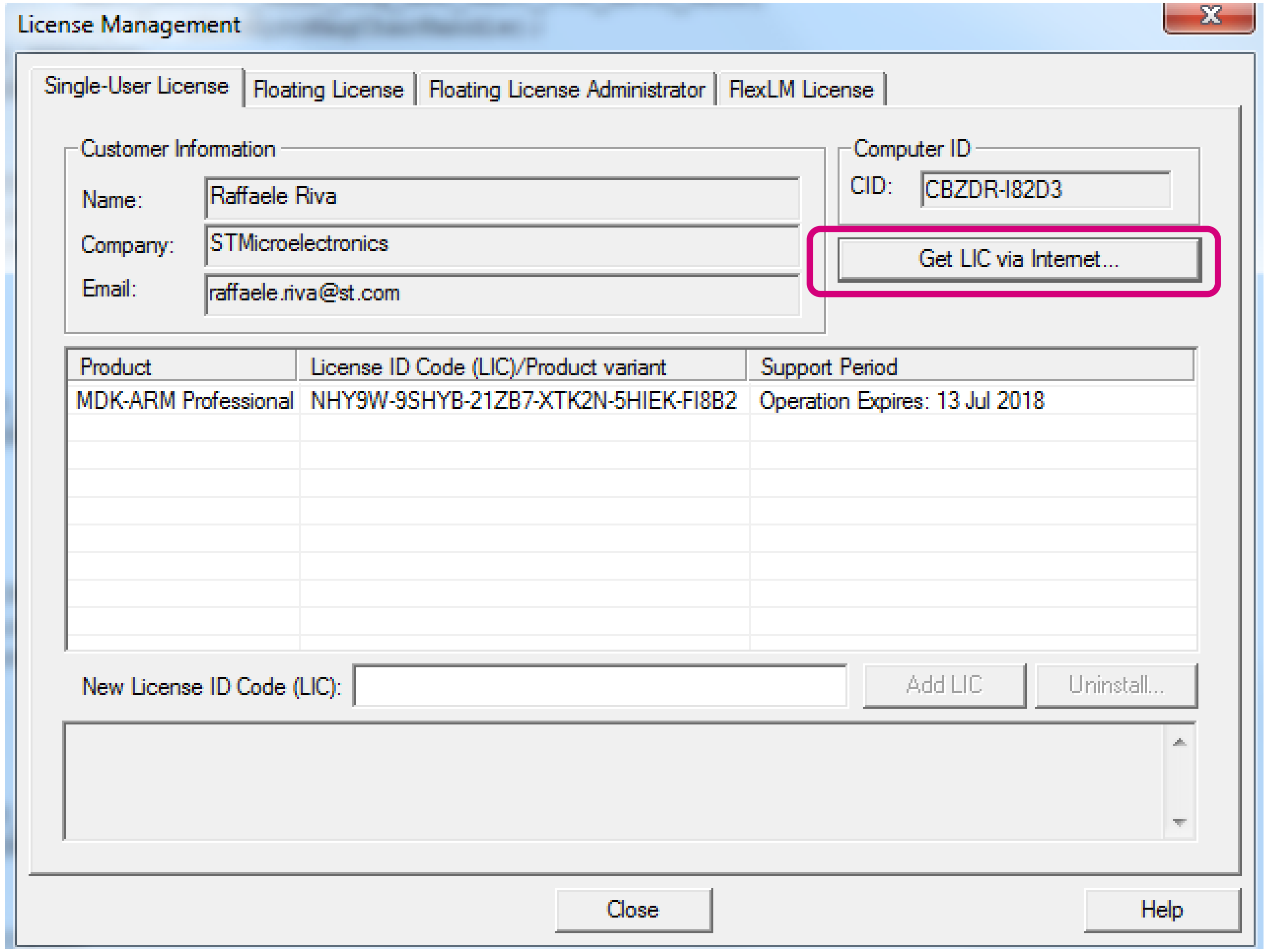
Arm Keil MDK License Installation 2/6

1. Open the dialog **File — License Management...**



Arm Keil MDK License Installation 3/6

Select the **Single-User License** tab and click the button **Get LIC via Internet...**,



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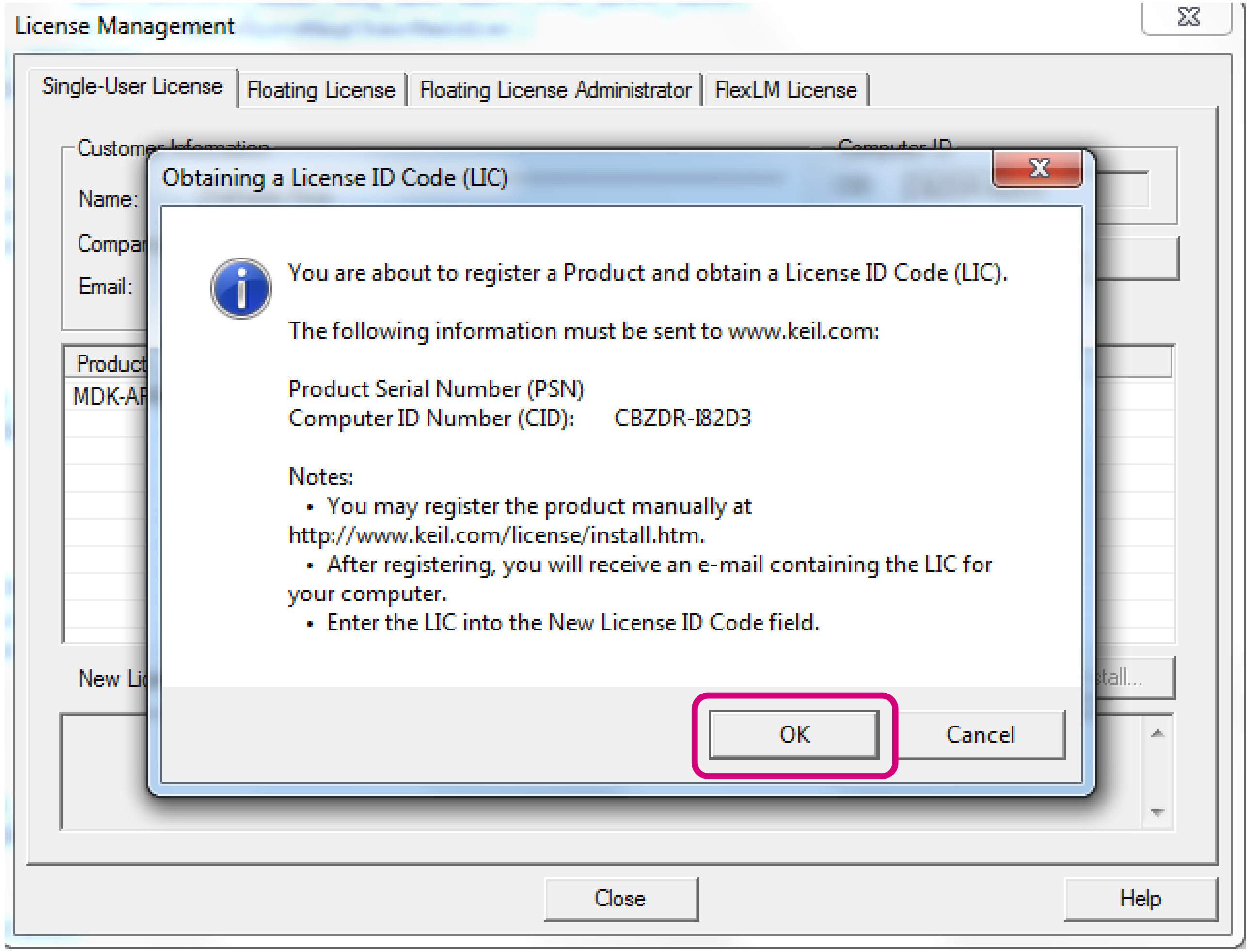
Arm Keil MDK License Installation 4/6

Click the button **OK** to register the product. This action opens the License Management page on the Keil web site.



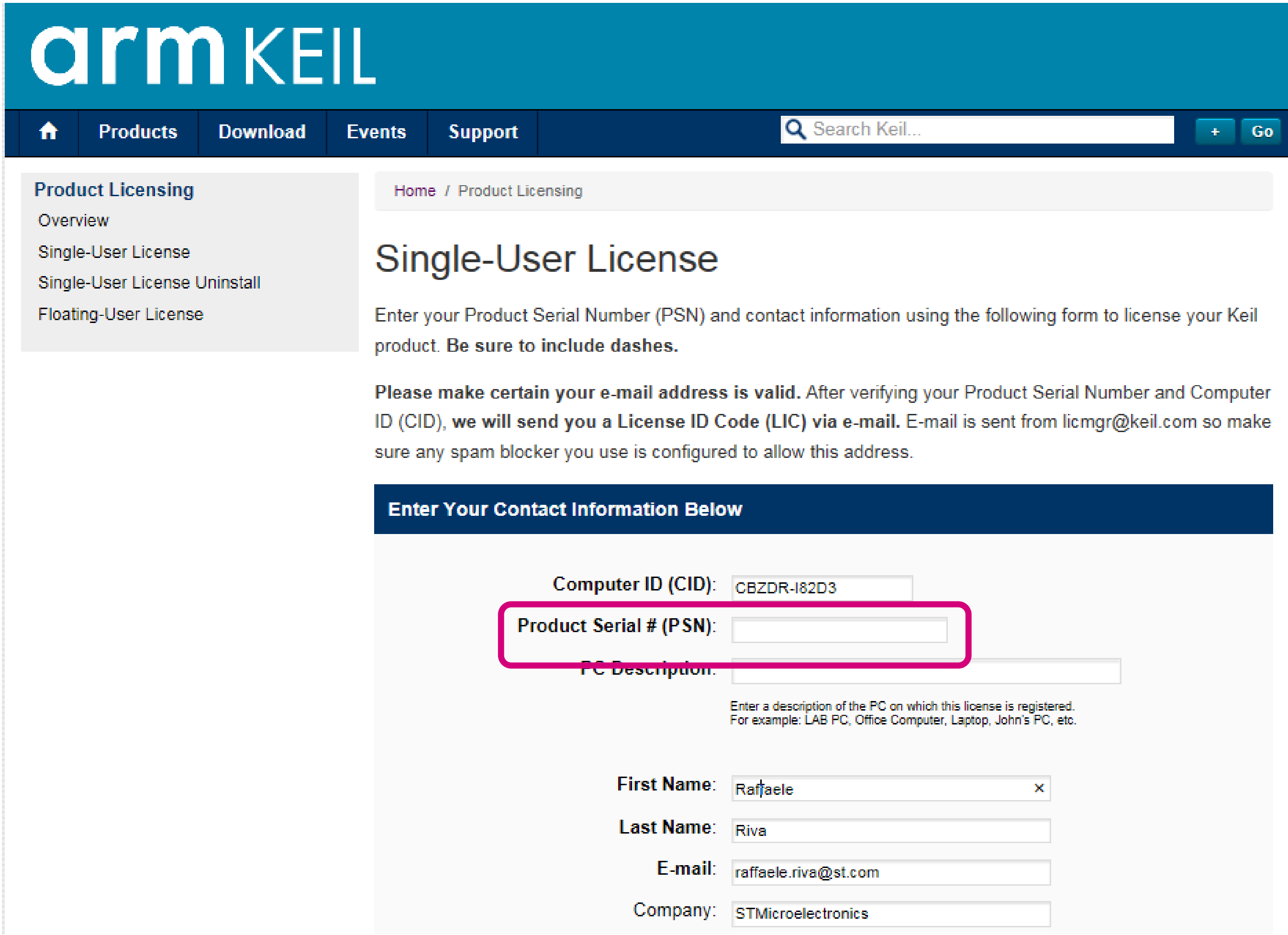
Arm Keil MDK License Installation 5/6

For the latest **Product Serial Number** please check on the Keil website at this URL:

http://www2.keil.com/stmicroelectronics-stm32/mdk

Then enter the PSN in this webpage along with your contact information and click the button **Submit**.

An e-mail is sent back with the **License ID Code (LIC)** within a few minutes.



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Arm Keil MDK License Installation 6/6

To activate the Software Product, enter the **LIC** you received by email in the field **New License ID Code (LIC)** and click **Add LIC**.

Then click on **Close**