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STM32WBA Hands-on #2
Build basic p2pServer application and connect

STM32

Prerequisites Refresh

SW prerequisites

- STM32CubeMX software (v6.9.0 or up)
- STM32CubeWBA MCU package (v1.1.0 or up)
- IDE: STM32CubeIDE
- A serial terminal (e.g. TeraTerm)
- ST BLE ToolBox Smartphone application

HW prerequisites

- NUCLEO-WBA52
- USB A to Micro-B Cable

Hands-on #1 to be first completed

ST BLE Toolbox

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Agenda

1 Hands-on Presentation

2 Step 1 : Profile creation demystification and details

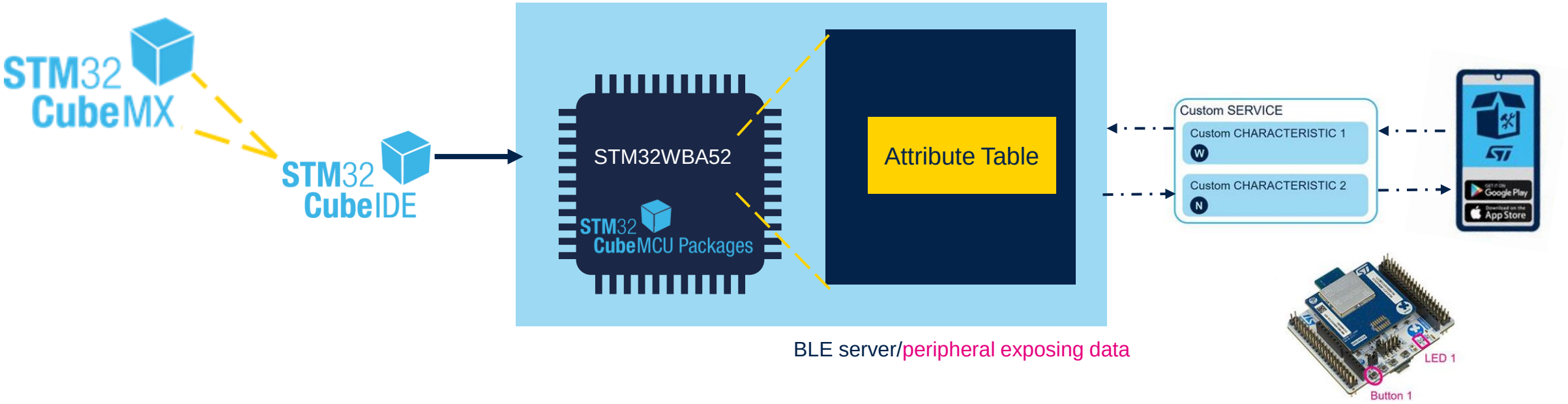
3 Step 2 : Application code

4 Step 3: Low Power

Hands-on presentation

Purpose

- The purpose is to start from WB5A52 chipset level and build a basic server (p2pServer) application using STM32CubeMX and associated STM32CubeIDE
- In this second part, focus is to enhance existing application code (Hands-on #1) to control device and share data



BLE server/peripheral exposing data

Enhance application code to enable a BLE Application Profile (p2pServer)

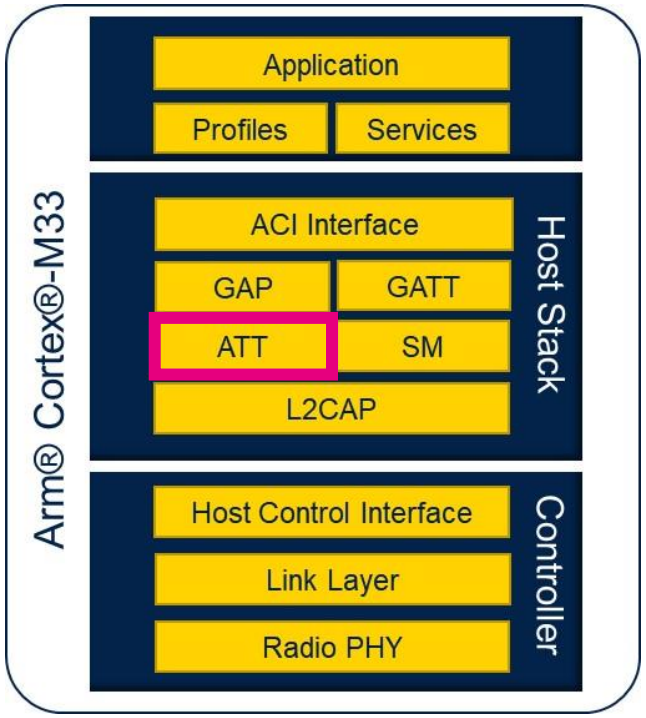
Legenda

- Slides including following symbol are purely theoretical ones 
- Optional steps during development in are marked with a grey bar
- Source code for development is included inside pink boxes

```
HAL_Delay(500);
```

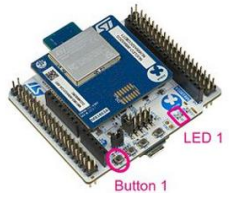
Step1 : GAP/GATT custom application configuration : Profile creation

What is a Bluetooth Low Energy Profile
Attribute Protocol (ATT)



Define Client - Server architecture

« I am looking for data »
Client

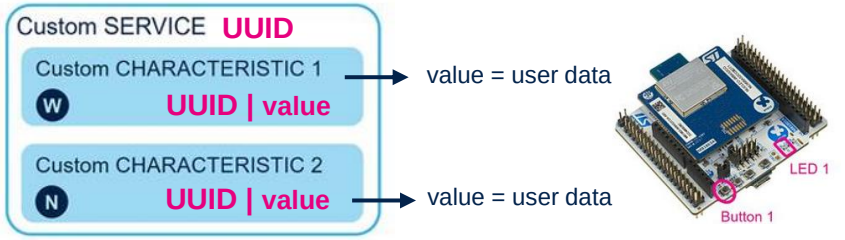


« I have data to share» (sensors, raw data...**what you want** !)
Server

Logical data structure – **« How to access data »** : Attribute table

user data is accessible trough attribute

service → characteristic → data



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What is a Bluetooth Low Energy Profile

A profile is a collection of data (**attributes**) exposes by device trough associated Service and Characteristic

- All attributes have a type which is identified by a UUID (**U**niversally **U**nique **Id**entifier)
- Characteristic can take 3 types of propreties: **R**EAD, **W**RITE, **N**OTIFY
- Profile can be defined by **Bluetooth® SIG**
  - **UUID : 16 bits**
    Service Heart Rate **0x180D**
    Characteristic Heart Rate Measurement **0x2A37**
- Profile can be a **custom** (proprietary) profile
  - **UUID : 128 bits**
    Service P2P **0000FE40**-cc7a-482a-984a-7f2ed5b3e58f
    Characteristic LED **0000FE41**-cc7a-482a-984a-7f2ed5b3e58f

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BLE standard profile vs. proprietary profile

Standard Heart Rate Profile

Heart Rate Service 0x180D

- **Heart Rate Measurement Characteristic** 0x2A37
- **Body sensor Location Characteristic** 0x2A38

Define by the **SIG**, define the role, requirements, behavior and the structure of Attribute Table of each entity (central & peripheral)

Any standard smartphone App will be able to communicate

Proprietary ST P2PServer Profile

P2P Service 0x0000FE40CC7A482A984A7F2ED5B3E58F

- **My_LED_Char** 0x0000FE41CC7A482A984A7F2ED5B3E58F
- **SWITCH_C** 0x0000FE42CC7A482A984A7F2ED5B3E58F

Define your own behavior using your own Attribute Table based in 128 bits UUID

Only your own App will be able to communicate

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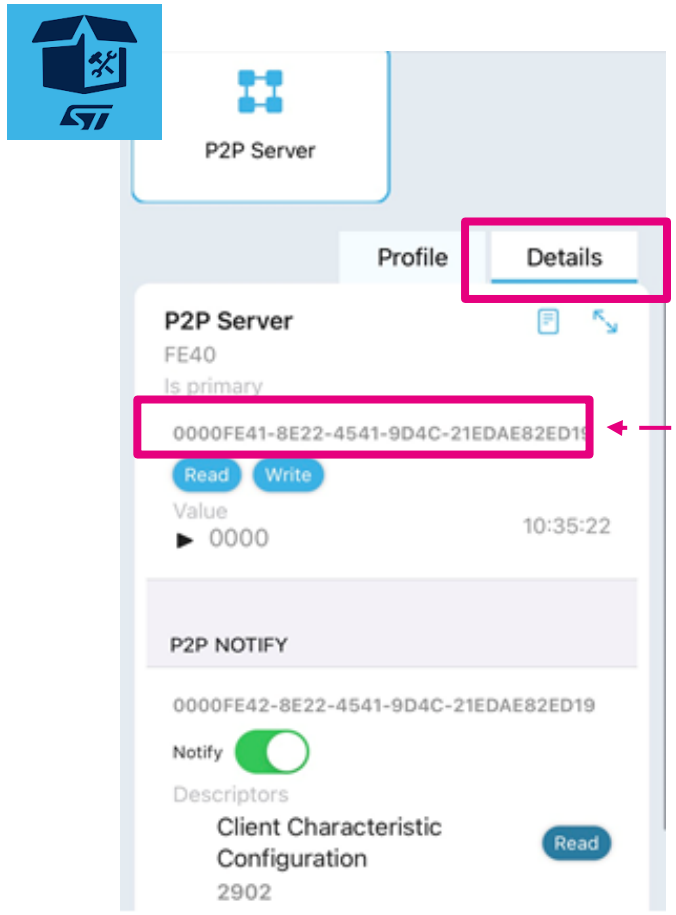
Proprietary profile
ST Toolbox App



ST ToolBox App knows that My_LED_Char proprietary UUID is defined to toggle led .
As consequence App displays nice **toggle button**

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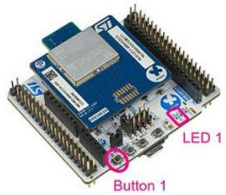
Data exchanges
what is the magic behind

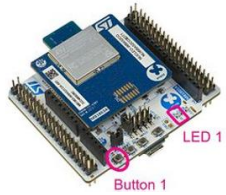


#1 At profile initialization and entry point (**handle @)** will be created in RAM to expose data to client

WBA52 - Attribute Table (RAM)

@ Serv service UUID	**@ Char** W R N char UUID	**@ Char +1** user data

#2 As soon as connected client will discover server attribute table (handle) and will be able to access (**write/read**) data



#3 Application will update data (ie : push button), client will receive **notification** with data updates

@ Serv	**@ Char** W R N	**@ Char +1** update data

BLE write, read, notify procedures using the right attribute handle make data exchange possible

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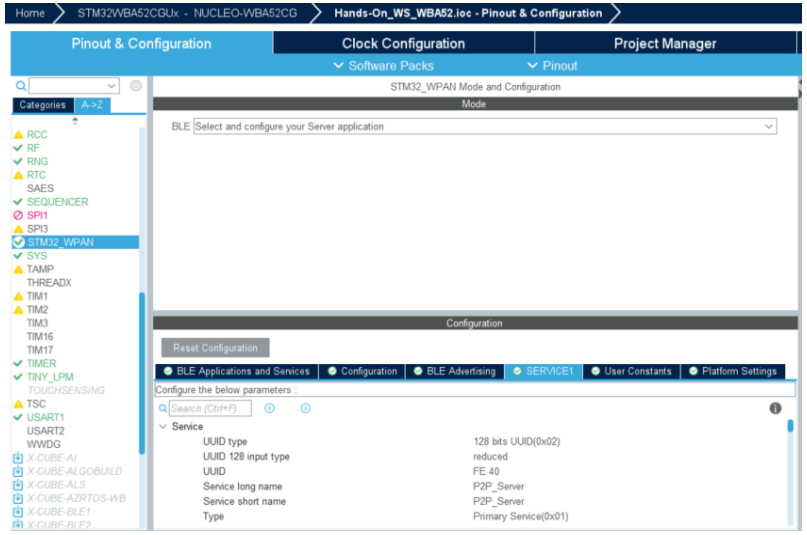
Profile Creation

Hands-on #1

You succeed

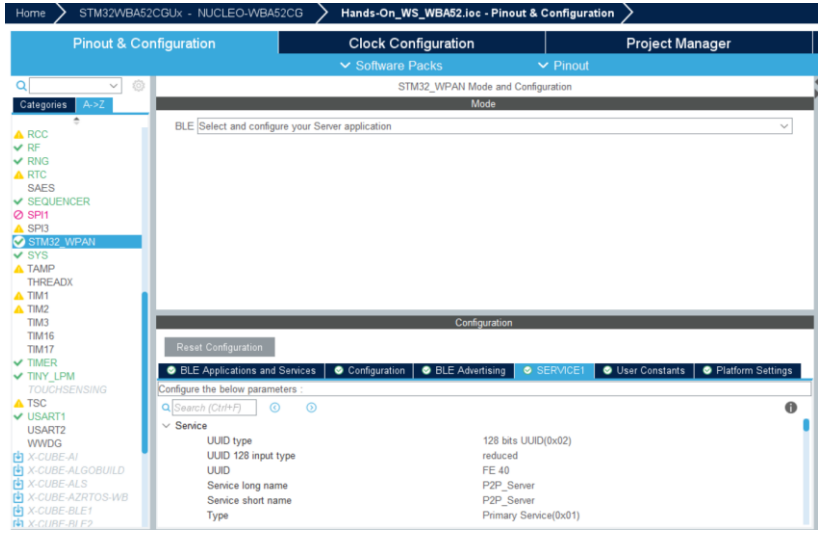
start back from running .ioc



Hands-on #1

More or less…

load Hands-On_WS_WBA52_complete.ioc



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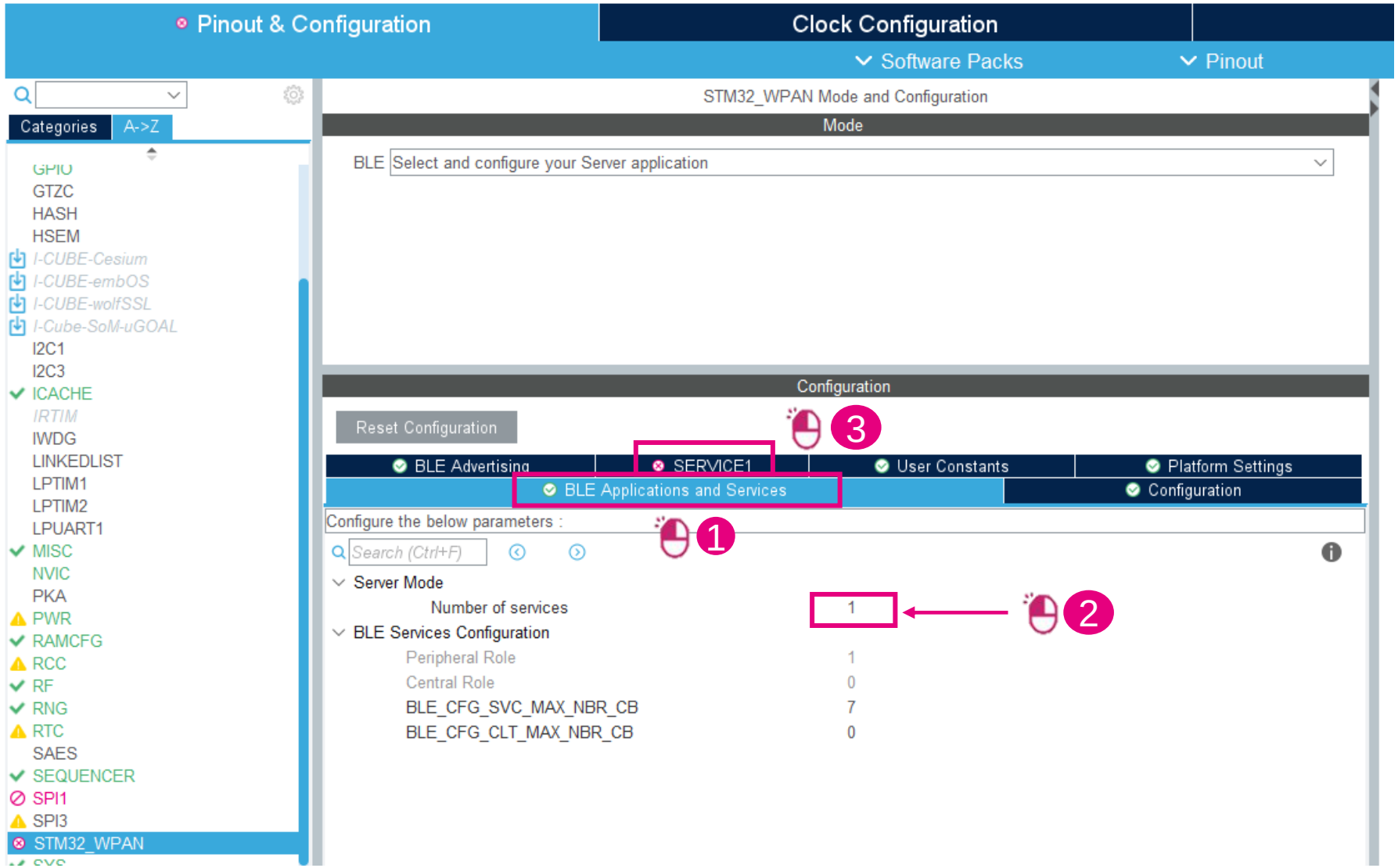
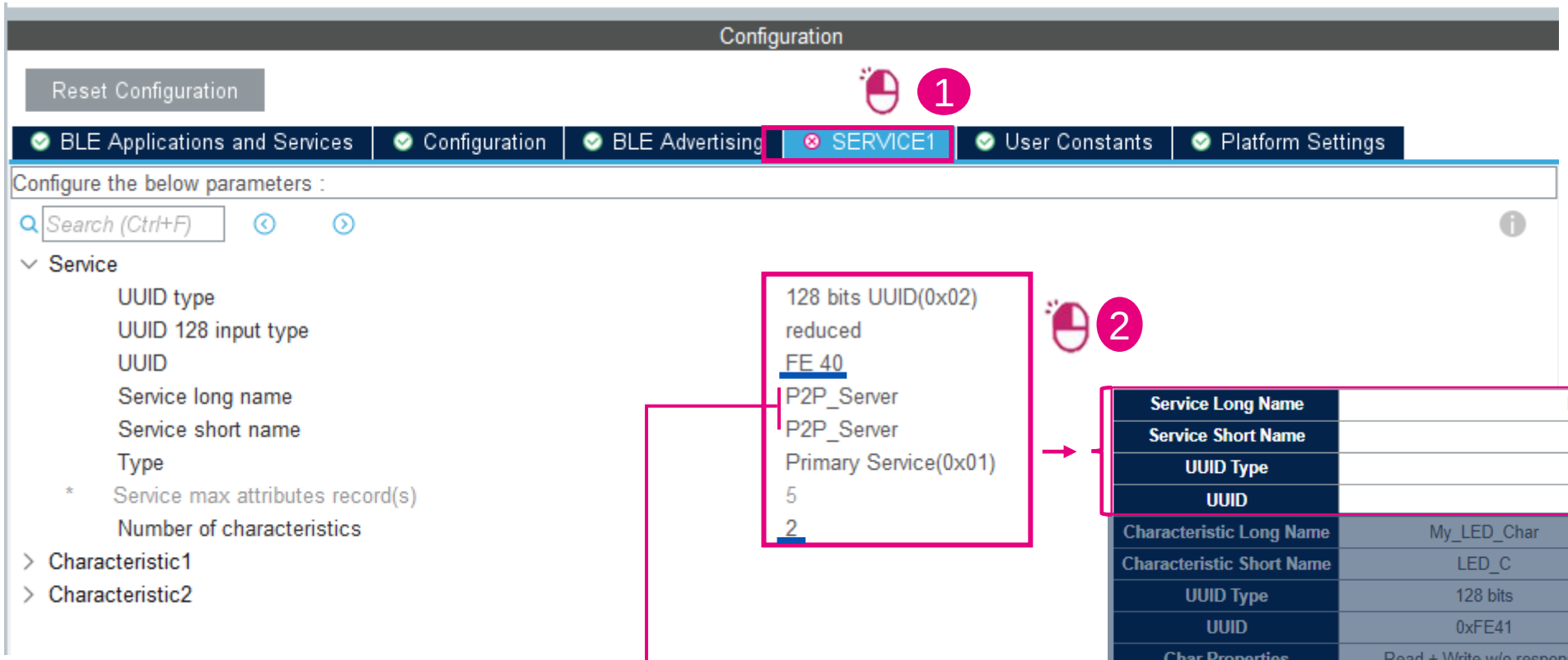
Profile Creation Service



Profile Creation
Configure my P2P Service

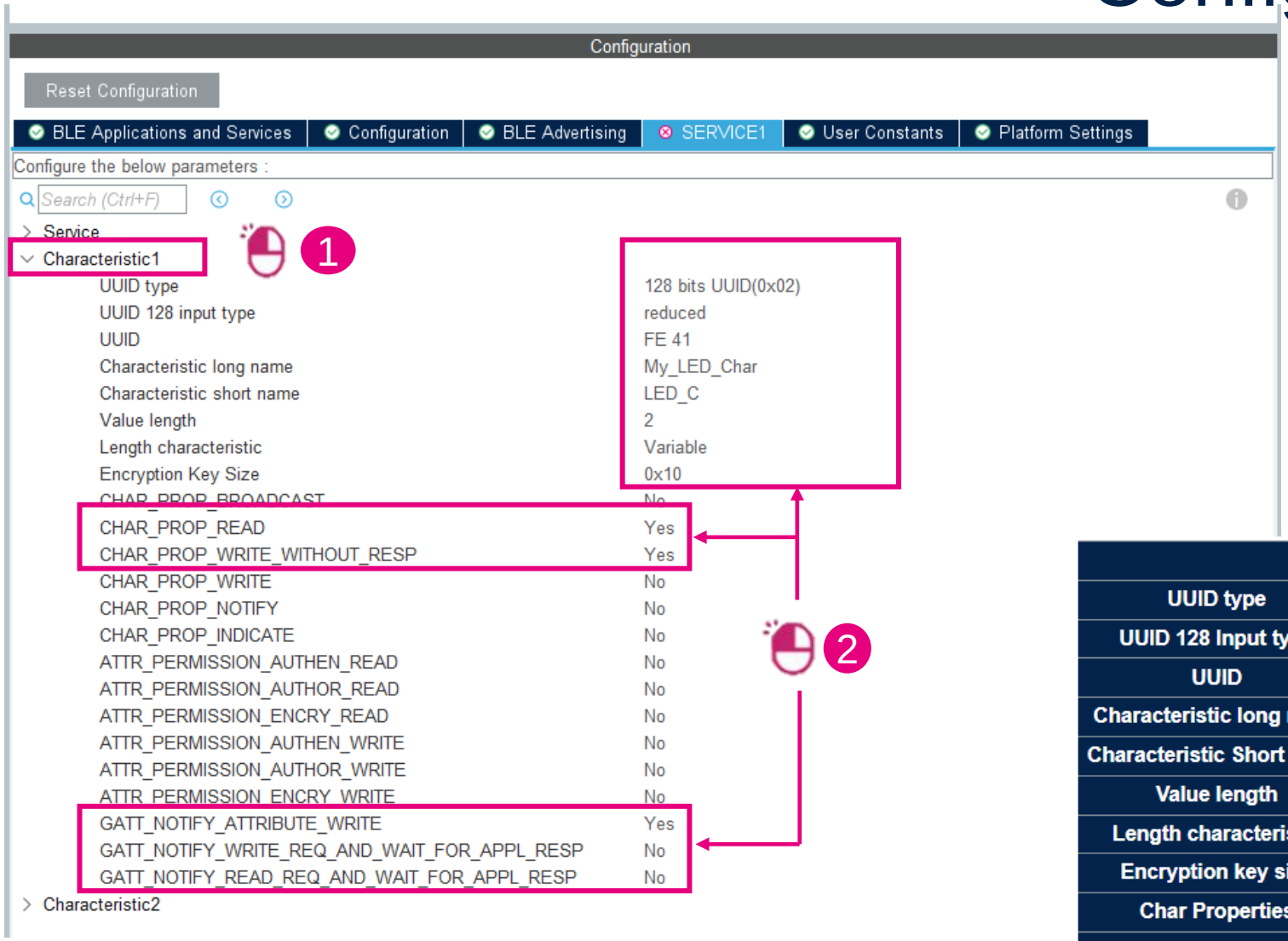


Service Long Name	My_P2P_Server	
Service Short Name	My_P2P	
UUID Type	128 bits	
UUID	0xFE40	
Characteristic Long Name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
UUID Type	128 bits	128 bits
UUID	0xFE41	0xFE42
Char Properties	Read + Write w/o response	Notify
Char Permissions	None	None
Char GATT Events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE

service & characteristic naming used to name function at code generation

UUID : FE 40
The application code will append 112 bits (based on UUID generator) to have a complete **128 bits UUID**

Profile Creation
Configure 1st Characteristic



UUID : FE 41
Application code will complete to have a complete **128 bits UUID**

Properties

Data (**2 bytes**) can be read and write.
The purpose of characteristic 1 is to write data in order to control LED

Permission

Thanks to **notify write**, application is informed that attribute has been modified and can accordingly process expected use case

	Characteristic 1	Characteristic 2
UUID type	128 bits UUID (0x02)	128 bits UUID (0x02)
UUID 128 Input type	Reduced	Reduced
UUID	FE 41	FE 42
Characteristic long name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
Value length	2	2
Length characteristic	Variable	Variable
Encryption key size	0x10	0x10
Char Properties	READ | WRITE_WITHOUT_RESP	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE

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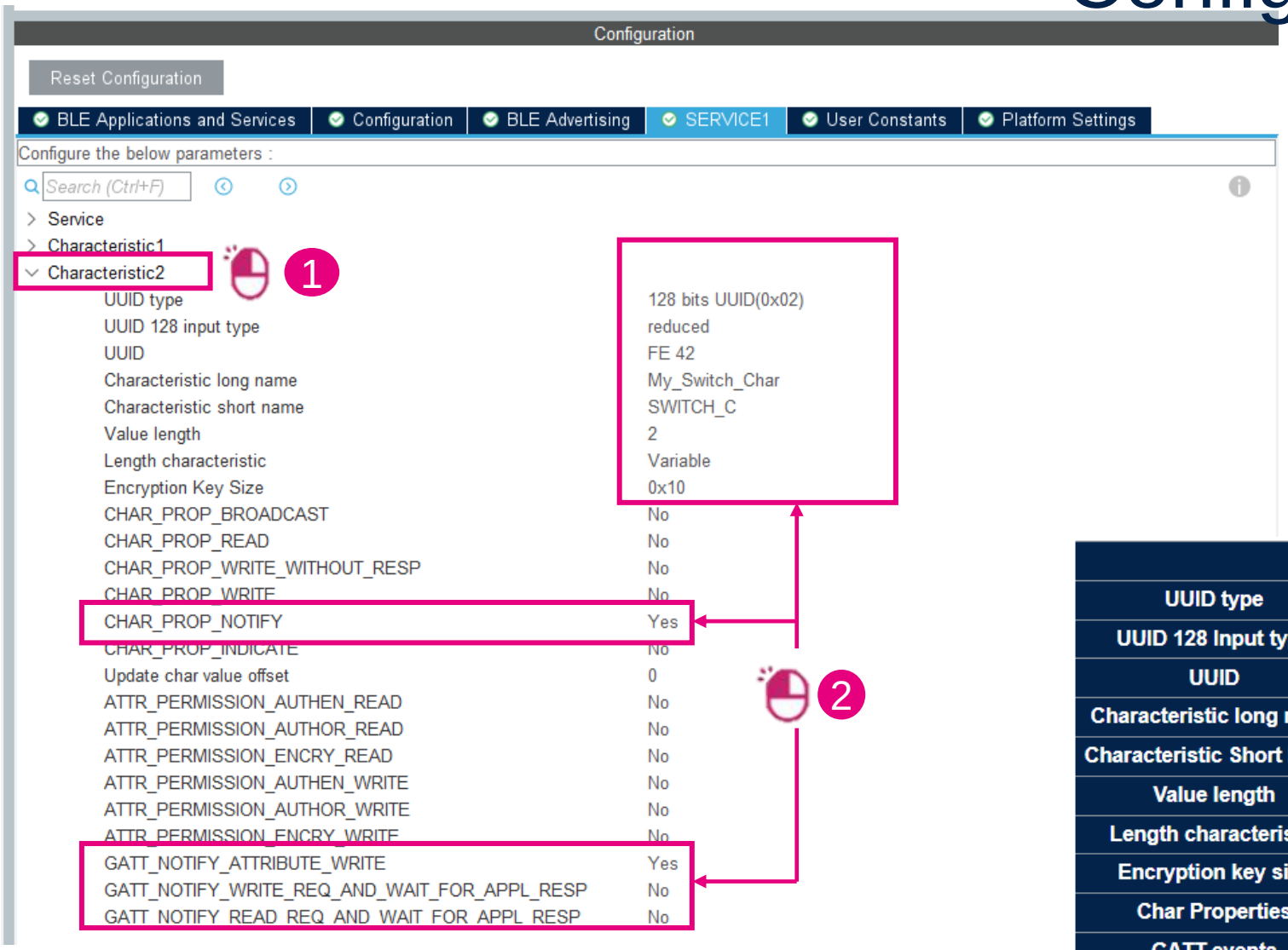
Profile Creation
Configure 2nd Characteristic



UUID : FE 42
Application code will complete to have a complete **128 bits UUID**

Properties

Data (**2 bytes**) as a **notify** characteristic
Each time user press button over NUCLEO, information sent to client

Permission

Here permission has not impact. The server is here sending data to client

	Characteristic 1	Characteristic 2
UUID type	128 bits UUID (0x02)	128 bits UUID (0x02)
UUID 128 Input type	Reduced	Reduced
UUID	FE 41	FE 42
Characteristic long name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
Value length	2	2
Length characteristic	Variable	Variable
Encryption key size	0x10	0x10
Char Properties	READ | WRITE_WITHOUT_RESP	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE

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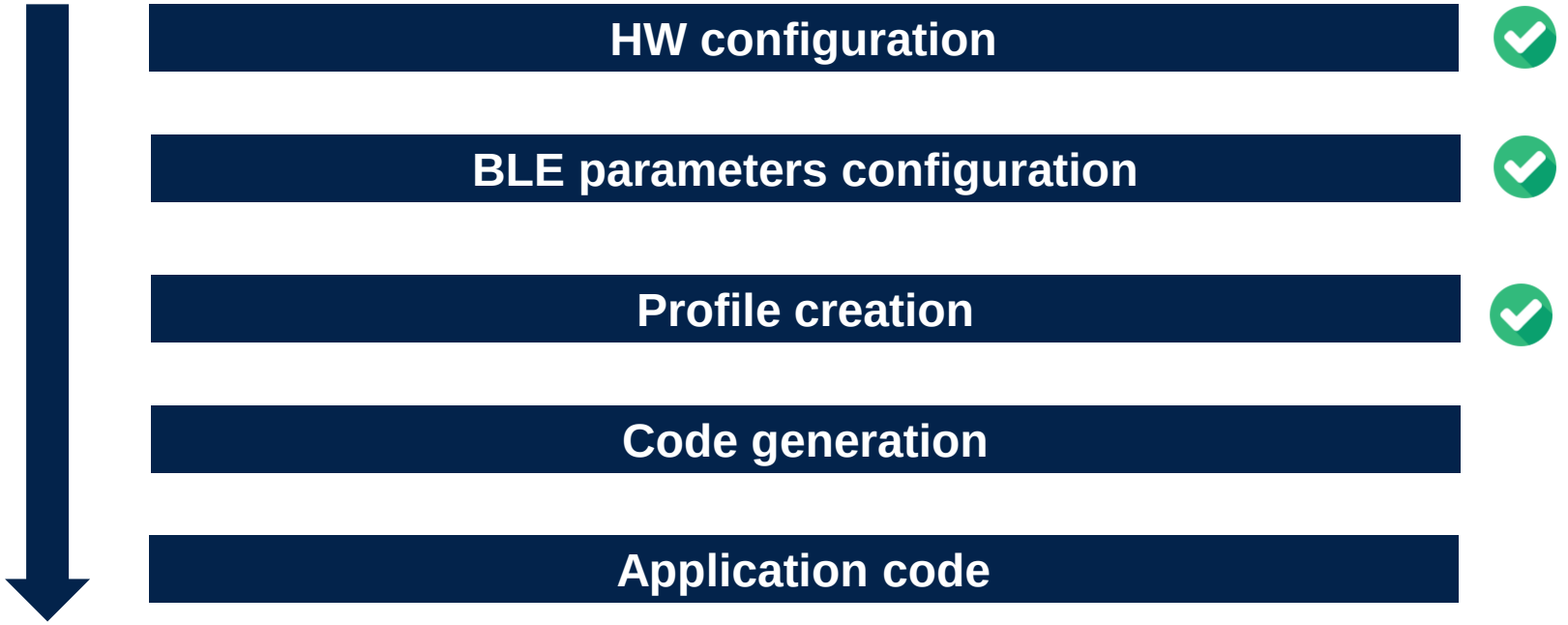
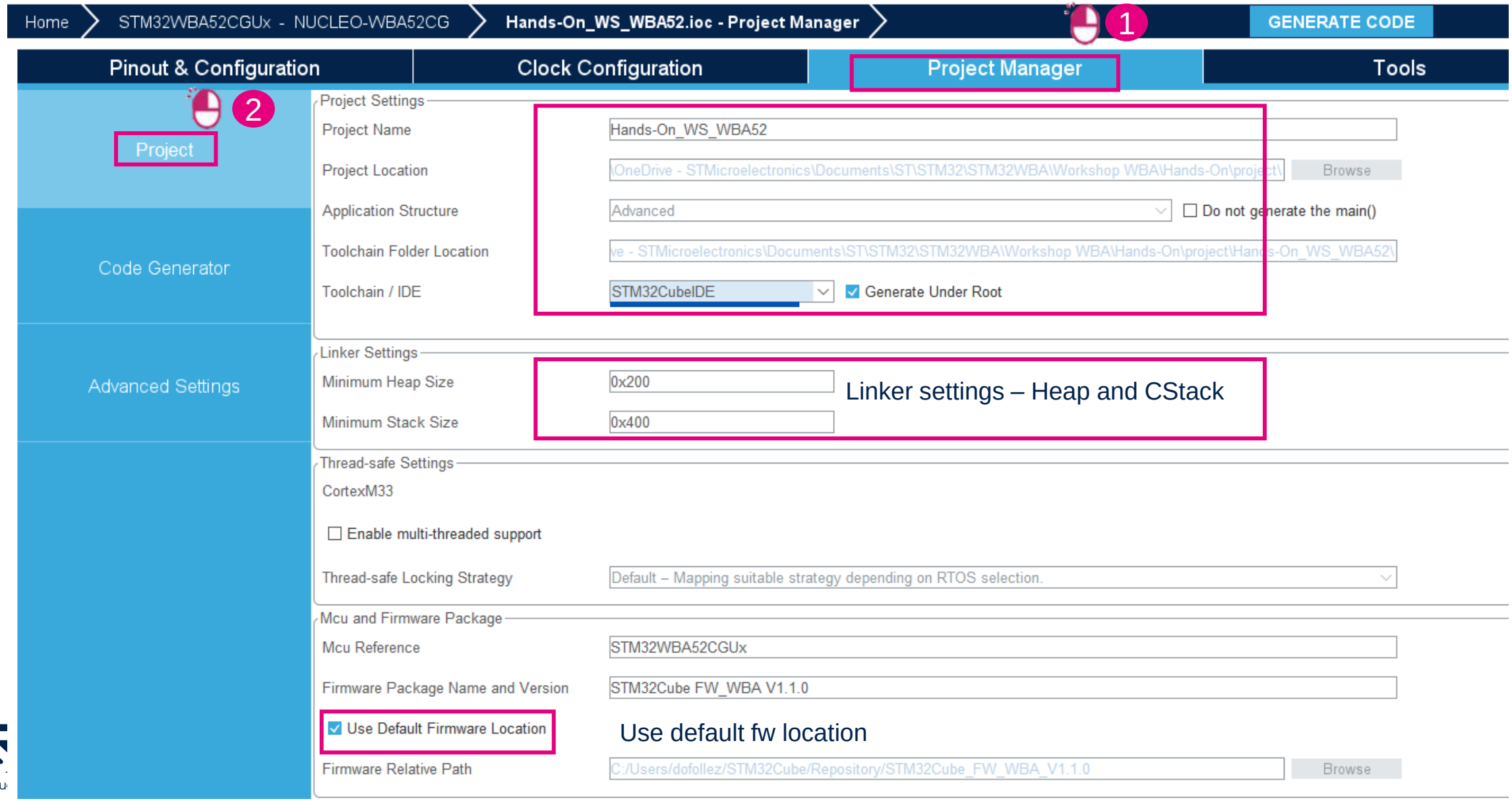
Configuration completed
What's next - Yes code generation

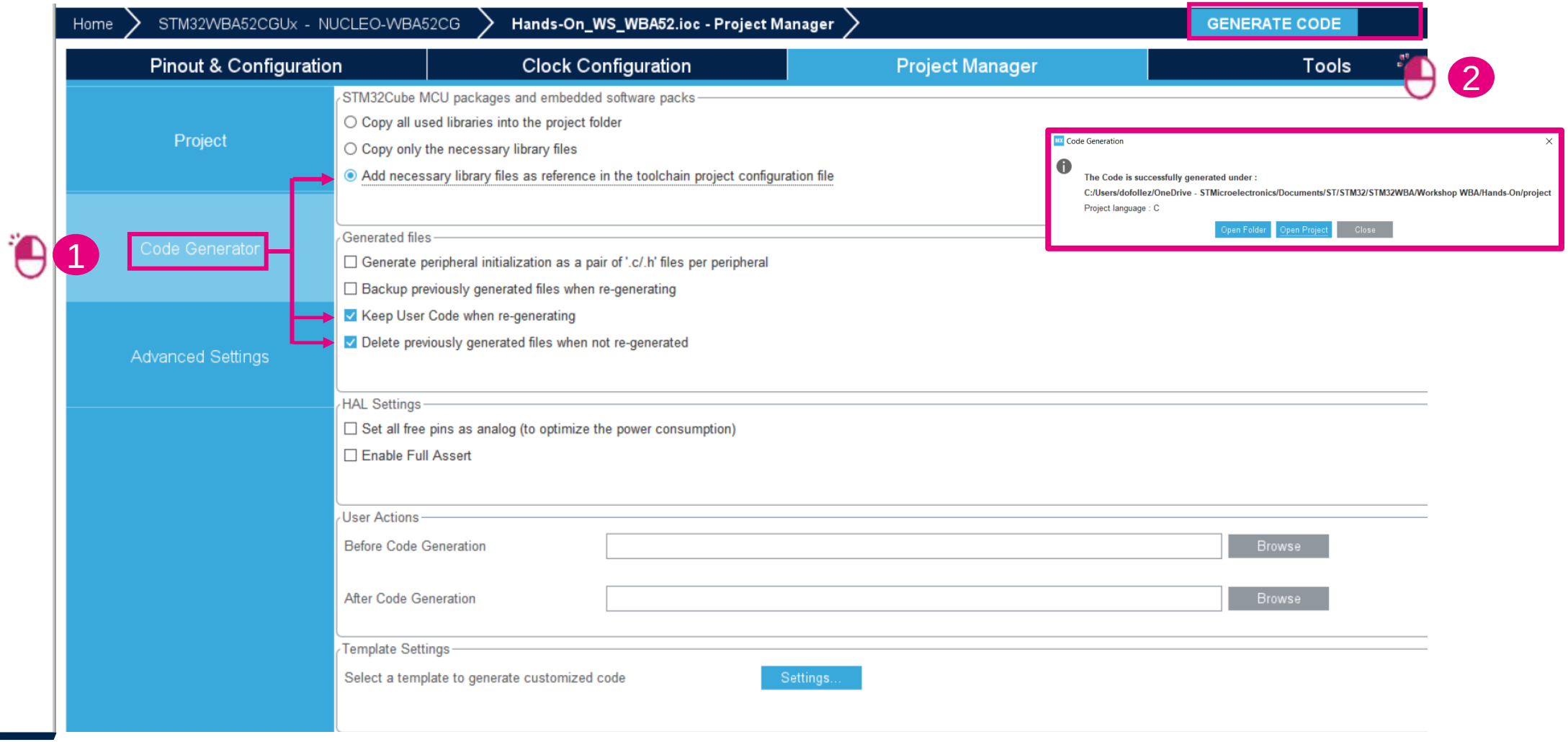


Step 2 : Code generation and user application code

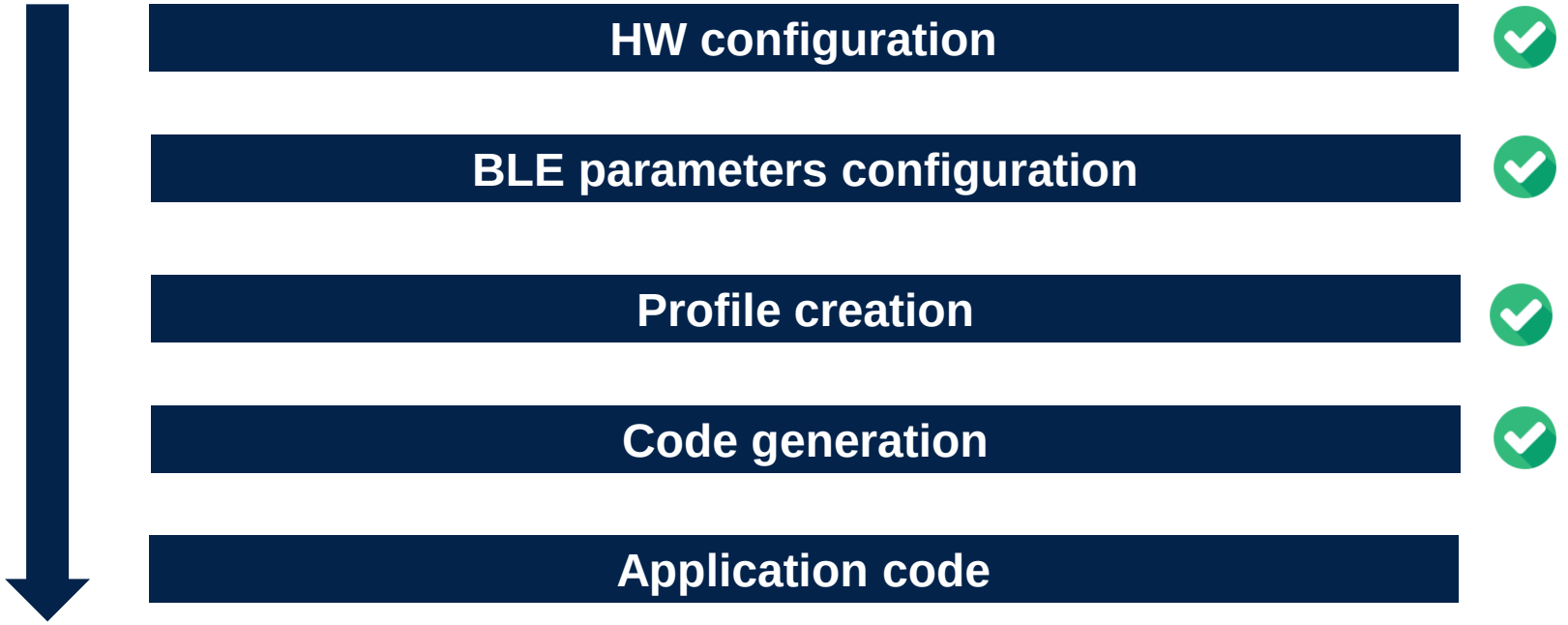
Project configuration



Project configuration

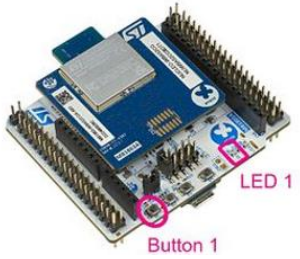


Configuration completed
What's next - Yes code generation

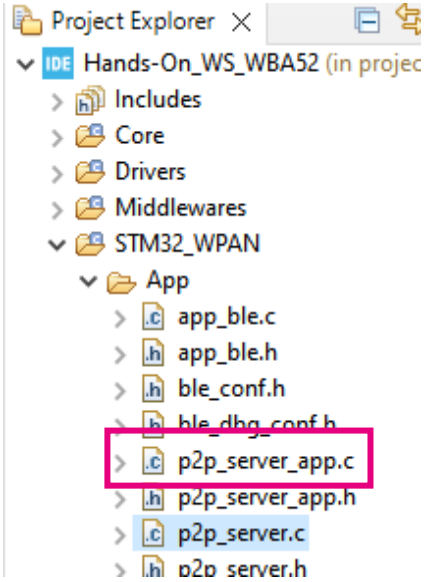


Add application code
Toggle LED from client

write to My_LED_Char (FE 41)



	Characteristic 1	Characteristic 2
UUID type	128 bits UUID (0x02)	128 bits UUID (0x02)
UUID 128 Input type	Reduced	Reduced
UUID	FE 41	FE 42
Characteristic long name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
Value length	2	2
Length characteristic	Variable	Variable
Encryption key size	0x10	0x10
Char Properties	READ | WRITE_WITHOUT_RESP	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE



write client procedure triggers an ACI_GATT_ATTRIBUTE_MODIFIED_VSEVT_CODE at server application level

in p2p_server_app.c / function P2P_SERVER_Notification()

```
/* USER CODE BEGIN Service1Char1_WRITE_NO_RESP_EV*/
HAL_GPIO_TogglePin(GPIOB, LD2_Pin|LD3_Pin|LD1_Pin);
/* USER CODE END Service1Char1_WRITE_NO_RESP_EV */<
```

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How to add a task in sequencer ?

#1 Define a **TaskID** for your « new task » :

In app_conf.h
define a new ID in enum CFG_Task_Id_t
(USER code section)

```
/**
 * These are the lists of task id registered to the sequencer
 * Each task id shall be in the range [0:31]
 */
typedef enum
{
  CFG_TASK_HCI_ASYNCH_EVT_ID,
  CFG_TASK_LINK_LAYER,
  CFG_TASK_LINK_LAYER_TEMP_MEAS,
  CFG_TASK_BLE_HOST,
  CFG_TASK_BPKA,
  CFG_TASK_HW_RNG,
  CFG_TASK_AMM_BCKGND,
  CFG_TASK_FLASH_MANAGER_BCKGND,
  CFG_TASK_BLE_TIMER_BCKGND
  /* USER CODE BEGIN CFG_Task_Id_t */
  TASK_BUTTON_1,
  /* USER CODE END CFG_Task_Id_t */
  CFG_TASK_NBR /* Shall be LAST in the list */
} CFG_Task_Id_t;
```

#2 **UTIL_SEQ_RegTask()** to register your task in the sequencer

```
UTIL_SEQ_RegTask(1U << TASK_BUTTON_1, UTIL_SEQ_RFU, APPE_Button1Action);
```

It associates a callback to your Task.
To be done only Once

#3 **UTIL_SEQ_SetTask()** to notify the sequencer shall execute the registered task

```
UTIL_SEQ_SetTask(1U << TASK_BUTTON_1, CFG_SEQ_PRIO_0);
```

It notify the sequencer that the task must be triggered.
It will generate a call to registered function
(here : APPE_Button1Action())

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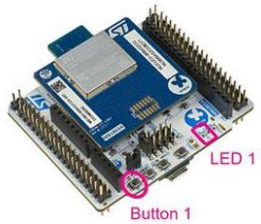
Add application code
Raise an alarm from device to Smartphone(1/3)

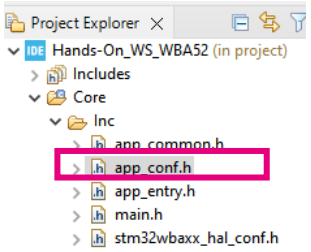


press button

notify peer device trough SWITCH_C (FE 42)

	Characteristic 1	Characteristic 2
UUID type	128 bits UUID (0x02)	128 bits UUID (0x02)
UUID 128 Input type	Reduced	Reduced
UUID	FE 41	FE 42
Characteristic long name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
Value length	2	2
Length characteristic	Variable	Variable
Encryption key size	0x10	0x10
Char Properties	READ | WRITE_WITHOUT_RESP	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE

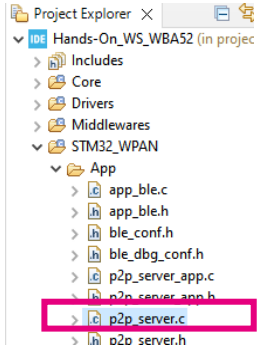
On press button use notify procedure use to push data to client



#1 need to define specific task for button press

In app_conf.h

```
/* USER CODE BEGIN CFG_Task_Id_t */
TASK_BUTTON_1,
/* USER CODE END CFG_Task_Id_t*/
```



#2 register a « button task »

in p2p_server_app.c / function P2P_SERVER_APP_Init

```
/* USER CODE BEGIN Service1_APP_Init */
 UTIL_SEQ_RegTask( 1U << TASK_BUTTON_1, UTIL_SEQ_RFU, P2P_SERVER_Switch_c_SendNotification);
 /* USER CODE END Service1_APP_Init */
```

Function generated by CubeMx as per as Characteristic Short Name

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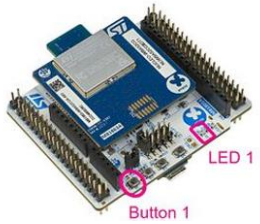
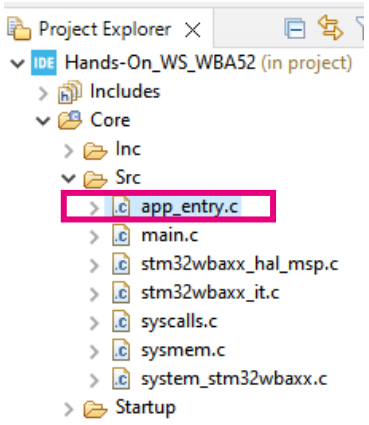
Add application code
Raise a notification from device to Smartphone(2/3)



notify peer device trough SWITCH_C (FE 42)

press button



#3 Manage Button1 interrupt : implement IRQ callback

In app_entry.c / function HAL_GPIO_EXTI_Rising_Callback

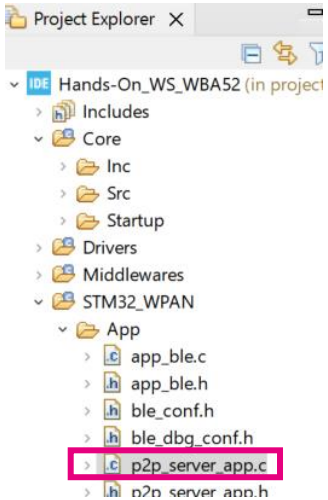
```
  /* USER CODE BEGIN FD_WRAP_FUNCTIONS */
void HAL_GPIO_EXTI_Rising_Callback(uint16_t GPIO_Pin)
{
  if (GPIO_Pin == B1_Pin)
  {
    UTIL_SEQ_SetTask(1U << TASK_BUTTON_1, CFG_SEQ_PRIO_0);
  }

  return;
} /* USER CODE END FD_WRAP_FUNCTIONS */
```

Add application code
Raise a notification from device to Smartphone(3/3)

notify peer device trough SWITCH_C (FE 42)

	Characteristic 1	Characteristic 2
UUID type	128 bits UUID (0x02)	128 bits UUID (0x02)
UUID 128 Input type	Reduced	Reduced
UUID	FE 41	FE 42
Characteristic long name	My_LED_Char	My_Switch_Char
Characteristic Short Name	LED_C	SWITCH_C
Value length	2	2
Length characteristic	Variable	Variable
Encryption key size	0x10	0x10
Char Properties	READ | WRITE_WITHOUT_RESP	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE	GATT_NOTIFY_ATTRIBUTE_WRITE



#4 Manage BLE notification procedure

In p2p_server_app.c/ function P2P_SERVER_Switch_c_SendNotification

```
/* USER CODE BEGIN Service1Char2_NS_1*/

a_P2P_SERVER_UpdateCharData[0] = 0x01; /* Device Led selection */
a_P2P_SERVER_UpdateCharData[1] = 0x00;
/* Update notification data length */
p2p_server_notification_data.Length = (p2p_server_notification_data.Length) + 2;

notification_on_off = Switch_c_NOTIFICATION_ON;

/* USER CODE END Service1Char2_NS_1*/
```

Peer to Peer Service - SWITCH Characteristic		
Byte Index	0	1
Name	Button Selection	Status
Value	0x01: button 1	0x00 or 0x01

STM32WBA Bluetooth® LE – Peer 2 Peer Applications - stm32mcu

P2P_SERVER_UpdateValue

aci_gatt_update_char_value BLE stack API

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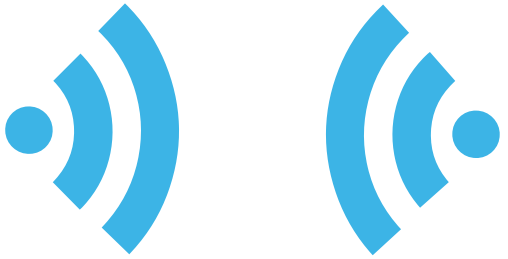
Open your App and Connect



ST BLE Toolbox

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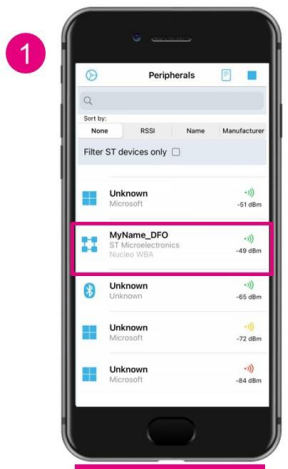
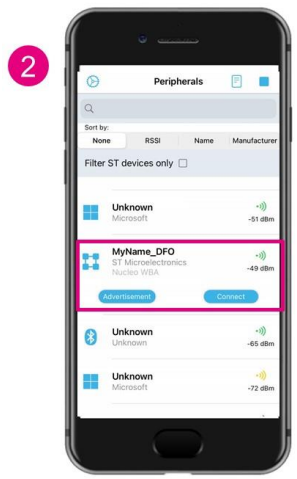
Open your App and Connect (1/2)

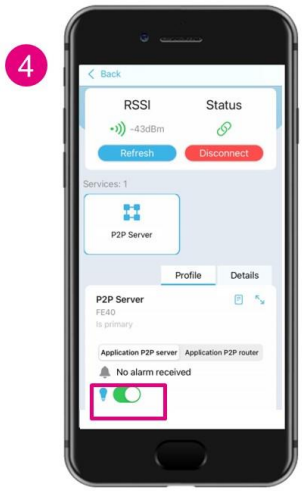


click on device



click on connect

access to profile



control LED status on Nucleo

	Characteristic 1
UUID type	128 bits UUID (0x02)
UUID 128 Input type	Reduced
UUID	FE 41
Characteristic long name	My_LED_Char
Characteristic Short Name	LED_C
Value length	2
Length characteristic	Variable
Encryption key size	0x10
Char Properties	READ | WRITE_WITHOUT_RESP
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE

write client procedure control LED

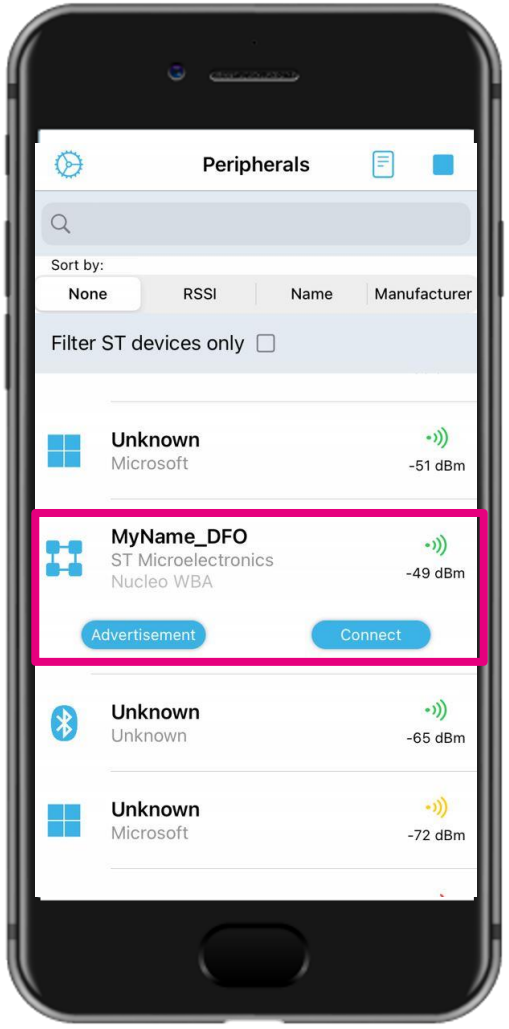
push button 1 and notify device

	Characteristic 2
UUID type	128 bits UUID (0x02)
UUID 128 Input type	Reduced
UUID	FE 42
Characteristic long name	My_Switch_Char
Characteristic Short Name	SWITCH_C
Value length	2
Length characteristic	Variable
Encryption key size	0x10
Char Properties	NOTIFY
GATT events	GATT_NOTIFY_ATTRIBUTE_WRITE

notify procedure use to push data to client

STBLE Toolbox (Connection)

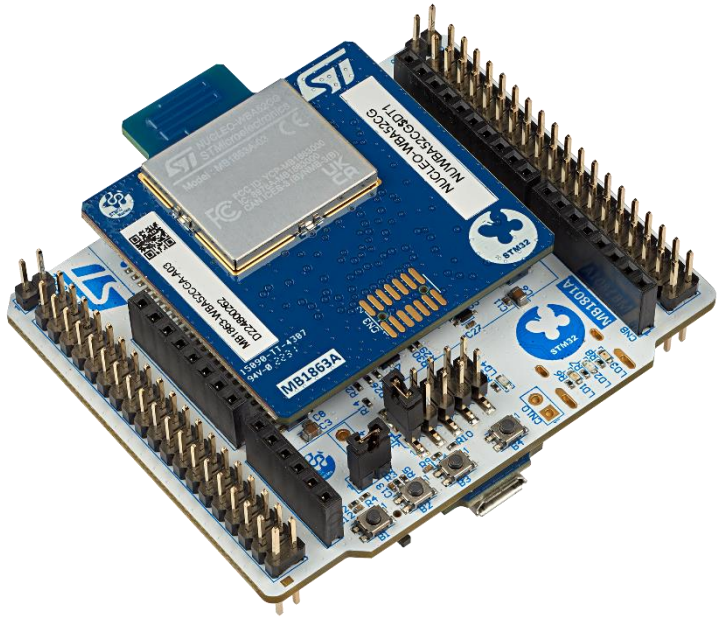
1



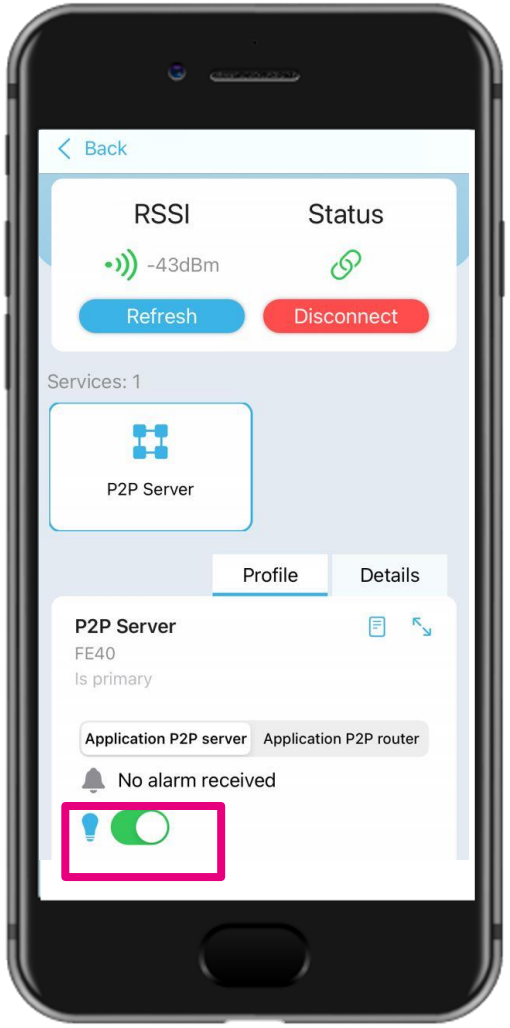
click on connect

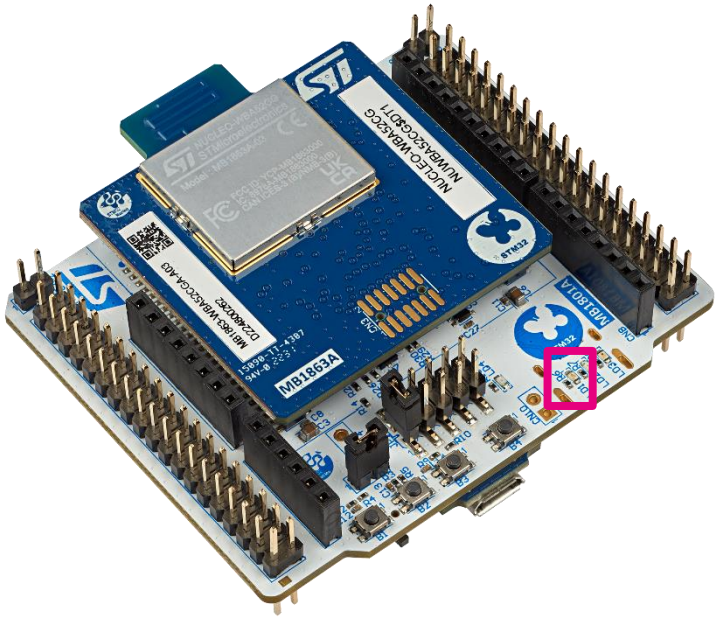
2

access to profile



STBLE Toolbox (LED)

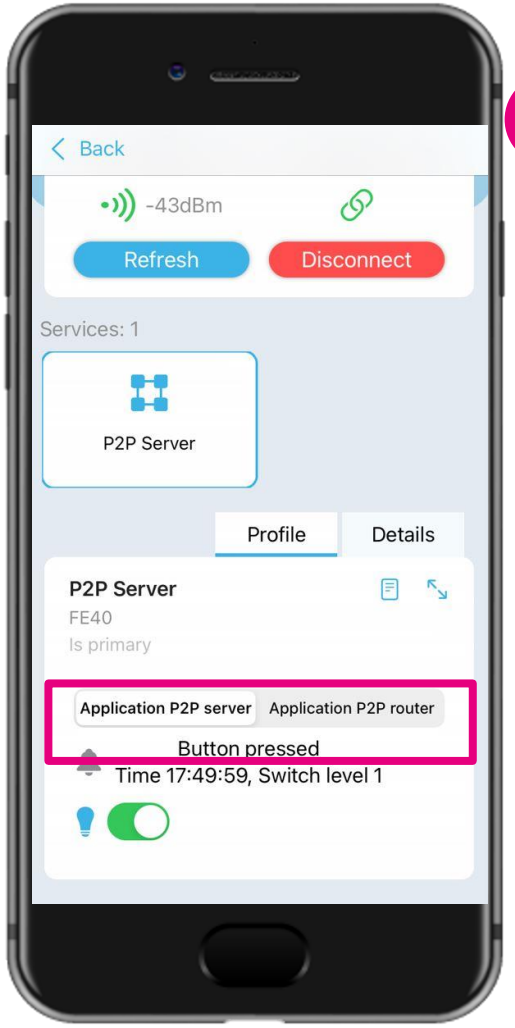




control LED status on Nucleo

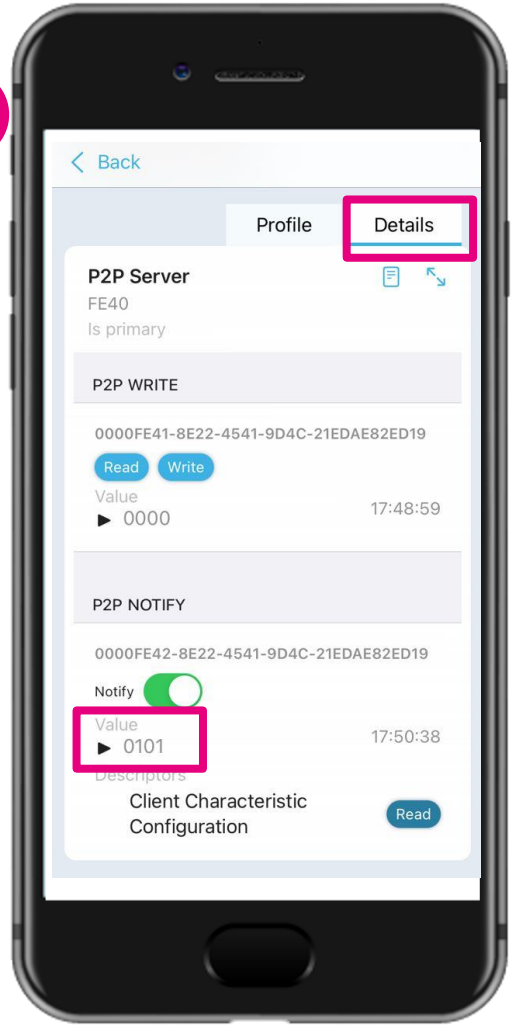
STBLE Toolbox (Push Button)

1



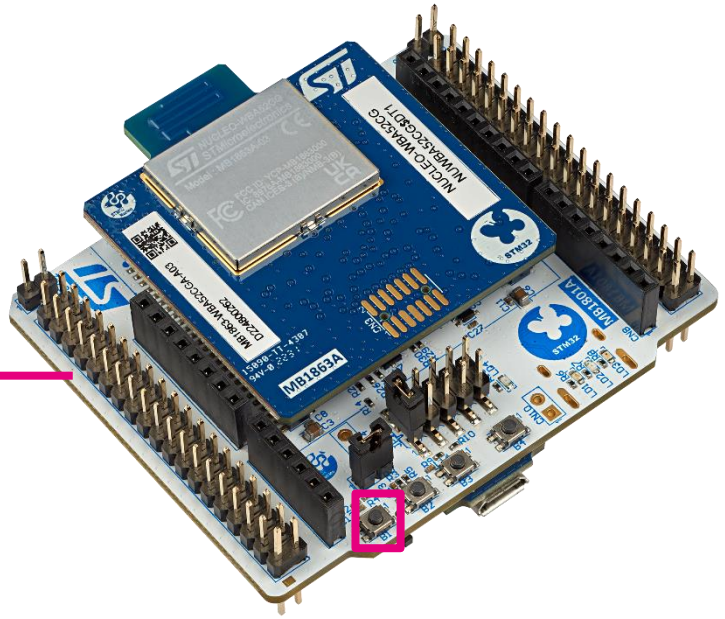
push button 1 and notify device

2



click on details to see bytes sent/received

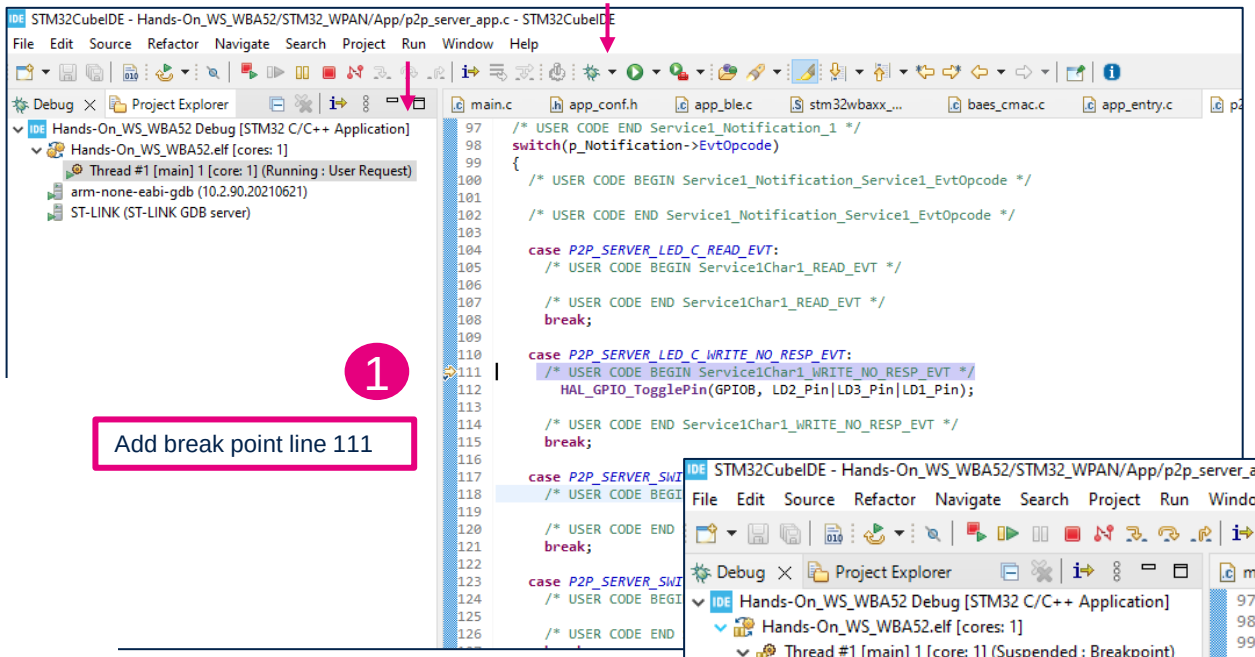
Notification - SWITCH



Open your App and Connect call stack

3

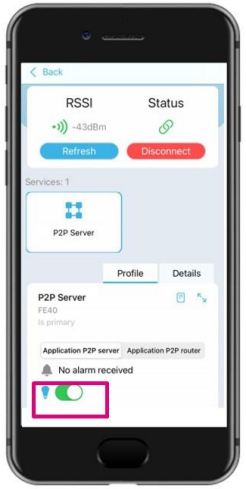
2



1

Add break point line 111

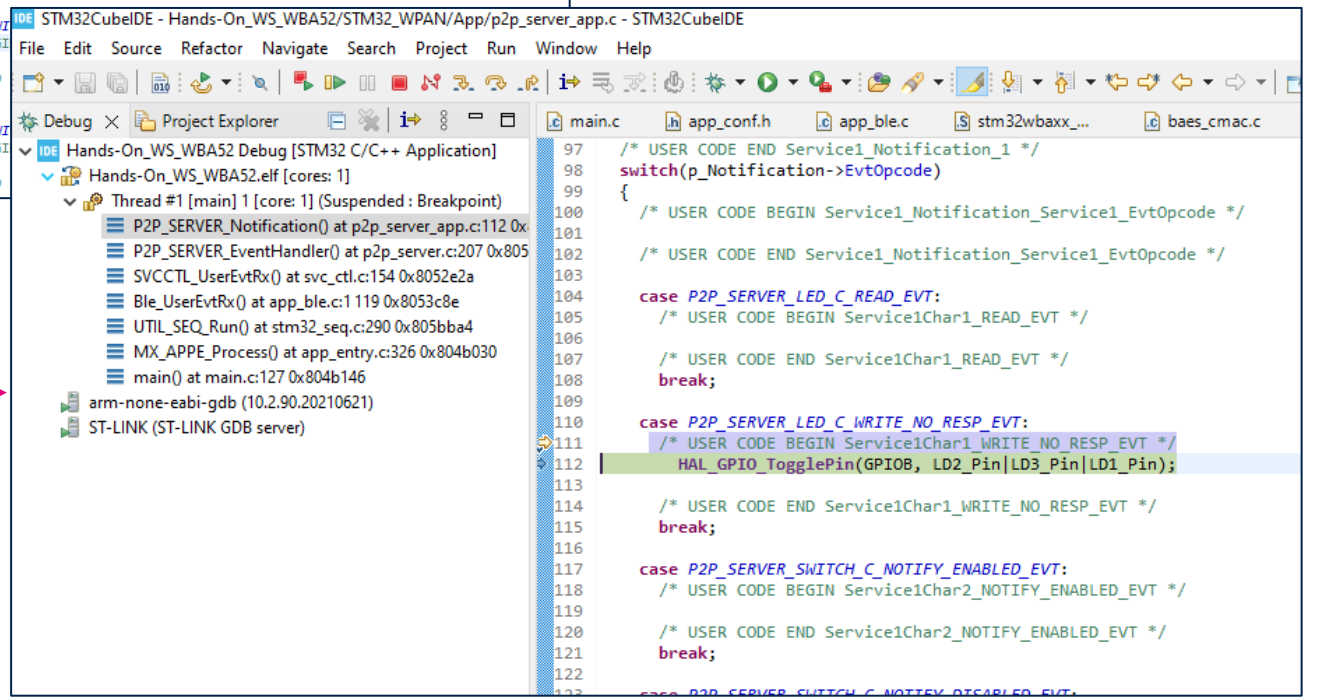
4



control LED status on Nucleo

BLE write procedure initiated by client

ACI_GATT_ATTRIBUTE_MODIFIED event received at application level



HW project development & certification

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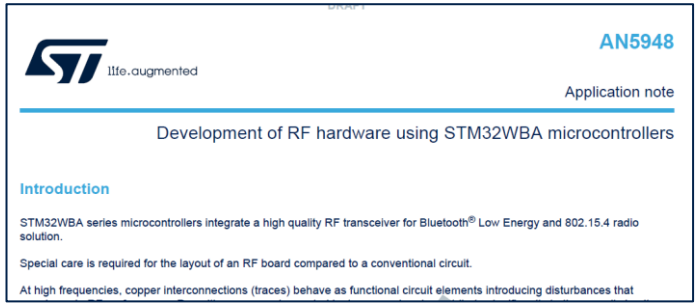
A complete set of documentation

AN5948 : Development of RF Hardware using STM32WBA



COMING SOON on st.com!

- RF basis generalities
- Schematics & components selection guidelines
- STM32WBA5x layout checklist & guidelines

STM32WBA5x CAD resources on st.com

- Download STM32WBA5x symbol
- Download STM32WBA5x footprint

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HW design with STM32WBA5x : key points

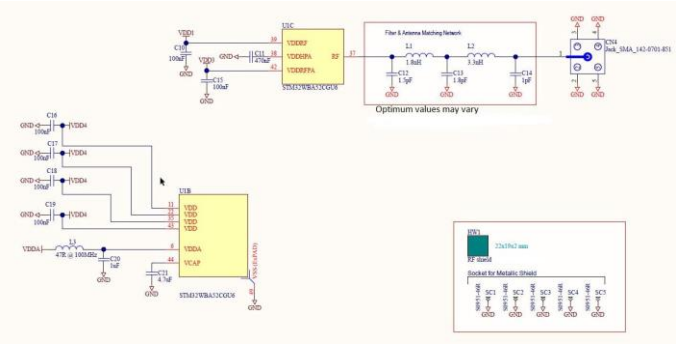
- HW design should be initiated based on documentation shown on previous slides
- Next slides are highlighting the key points you must pay attention when designing schematics and layout:

➢ <u>HSE 32MHz Xtal requirements:</u>

- STM32WBA5x includes internal programmable capacitances to trim the crystal frequency
- Select XTAL with 8pF load capacitors
- Recommended part (or equivalent): NX1612SA-32MHZ-EXS00A-CS09166

➢ <u>LSE or LSI selection. LSE 32kHz Xtal requirements if used:</u>

- LSE mandatory for accurate RTC calendar application.
- BOM optimized (save 32kHz Xtal cost)

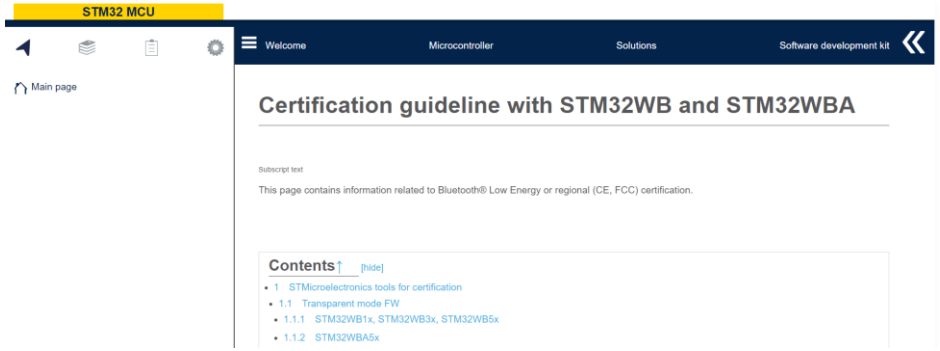


HW design with STM32WBA5x : key points

- RF matching & filtering:
  - Integrated balun so single ended RF matching.
  - Very limited number of discrete components for STM32WBAx matching and filtering.
- Power management. SMPS implementation for STM32WBA55 use case:
  - STM32WBA55 embeds a SMPS that can be used to improve power efficiency.
- Main layout recommendation:
  - Refer our various reference kits layout (Gerbers and Altium files available).
  - 4 layers stack-up recommended but 2 layers is possible.

STM32WBA5x : a certified solution

- STM32WBA5x is compliant in regards of regional (CE, FCC etc.) and Bluetooth requirements.
- We are providing complete set of documentation, FW and tools to certify your product.



Full set of tools and documentation

- Certification guideline on wiki (Certification guideline with STM32WB and STM32WBA - stm32mcu)
- Transparent mode FW available in STM32CubeWBA MCU Package
- STM32CubeMonRF PC tool

Bluetooth certification

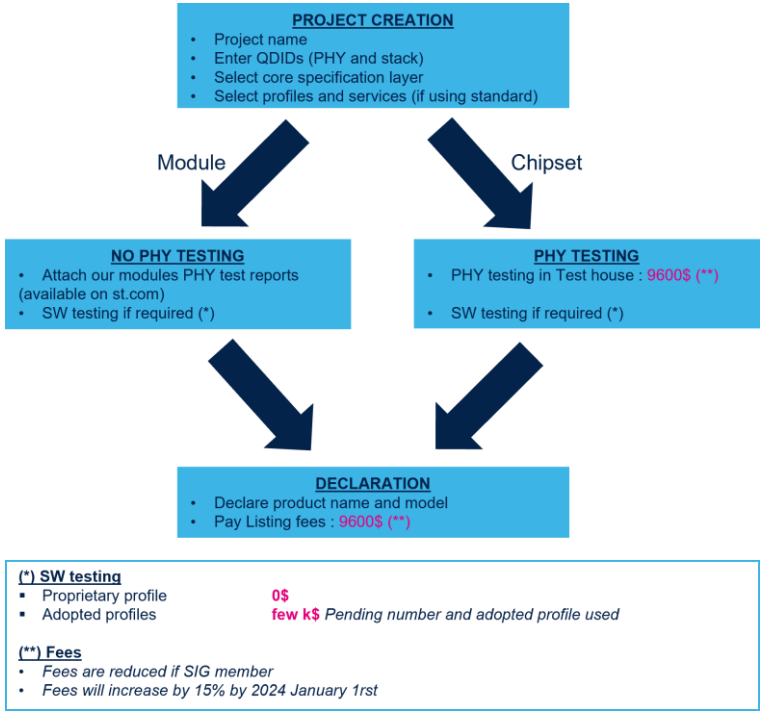
- STM32WBA5x is having reference QDIDs (components and stack) at Bluetooth SIG.
- Customer musty performed PHY testing and declare its product at Bluetooth SIG.

PHY QDID

Package	Part number	Cut version	RF PHY QDID
QFN48	STM32WBA52 (BLE5.4)	1.x	**197135** (TCRL 2022-2)

Stack QDID

Features	Host Stack version	QDID
4.0 HCI Low Energy LL with extended advertising – ATT – GAP – GATT – L2CAP with Enhanced Connected Oriented Channel -SMP BLE 5.3	STM32Cube_WBA_BLE_HCI_STACK STM32Cube_WBA_BLE_FULL_STACK	**198195** (TCRL 2022-1)



Refer wiki Certification guideline on st.com

Thank you

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