UM2295

User manual

Getting started with the ST BlueNRG-Mesh embedded firmware

Introduction

BlueNRG-Mesh connects multiple BLE (Bluetooth Low Energy) devices in Mesh networking for IoT (Internet of Things) solutions. It integrates BlueNRG products with embedded Bluetooth Low Energy communication in a powerful, range-extending Mesh network with true full-duplex communication.

The solution contains the core functionality for secure communication and provides the flexibility you need to build applications. It uses BlueNRG-2, BlueNRG-1, BlueNRG-MS devices with Mesh stack APIs and related event callbacks. The SDK provides the Mesh stack in library form and a sample application in source code to demonstrate how to use the library.

BlueNRG-Mesh can be used in several applications requiring infrequent data transfer in a mesh network over Bluetooth Low Energy, to create distributed control systems such as:

- smart lighting
- home and building automation
- industrial automation

A demo example is available for the device evaluation boards. You can use it to change the application interface and use the library for the required hardware and software functionalities. The demo application is available for the following evaluation boards:

- STEVAL-IDB008V1 and STEVAL-IDB008V2 for BlueNRG-2
- STEVAL-IDB007V1 and STEVAL-IDB007V2 for BlueNRG-1
- X-NUCLEO-IDB05A1 and NUCLEO-L152RE for BlueNRG-MS

The sample application implements Smart Light control scenario, which you may modify according to your requirements.

1 Getting started

The sample application implements a smart lighting control scenario. To modify the application, you need to follow the sequence below.

Step 1. Connect the board to the PC
Step 2. Compile the firmware in IDE
Step 3. Flash the firmware to the board
Step 4. Provision the board in the BlueNRG-Mesh App
Step 5. Toggle LED on board using the app

1.1 Hardware requirements

The following boards can be used for evaluation of the ST BlueNRG-Mesh solution.

Table 1. Hardware requirements

Devices	Evaluation boards	Description
BlueNRG-2	STEVAL-IDB008V1 and STEVAL-IDB008V2	Evaluation platform based on the BlueNRG-2
BlueNRG-1	STEVAL-IDB007V1 and STEVAL-IDB007V2	Evaluation platform based on the BlueNRG-1
BlueNRG-MS	X-NUCLEO-IDB05A1	Bluetooth Low Energy expansion board based on the SPBTLE-RF module for STM32 Nucleo
	NUCLEO-L152RE	STM32 Nucleo-64 development board with the STM32L152RE MCU, supports Arduino™ and ST morpho connectivity

1.2 Board interfaces

The following table explains the details of the evaluation boards for the power requirement, programming and user interface, for example LEDs and buttons.

Table 2. Evaluation board details

Devices	Evaluation boards	Powered by	Programmed by	LEDs	Buttons
BlueNRG-2	STEVAL-IDB008V1 and STEVAL-IDB008V2	Micro-B USB Cable Or AAA x 2 battery	External ST-LINK/V2 or USB port	3x user LEDs +1 power indication	Reset button + 2 x user buttons
BlueNRG-1	STEVAL-IDB007V1 and STEVAL-IDB007V2	Micro-B USB cable or AAA x 2 battery	External ST-LINK/V2 or USB port	3x user LEDs +1 power indication	Reset button +2 x user buttons
BlueNRG-MS	X-NUCLEO-IDB05A1	Mini-USB cable	In-Built STLINK on the STM32 Nucleo board	1 user LED +1 power indication	Reset button + 1 x user buttons
	NUCLEO-L152RE				

1.3 STEVAL-IDB008V1 or STEVAL-IDB008V2 BlueNRG2 board setup

To connect the STEVAL-IDB008V1 or STEVAL-IDB008V2 (BlueNRG-2 evaluation board) and PC, a USB port is required to provide power supply to the board. To connect the ST-Link/V2 debugger, an additional USB port is needed.

Note: *The BlueNRG-2 device on these boards is clocked at 32 MHz XTAL. These settings are performed in project configurations.*

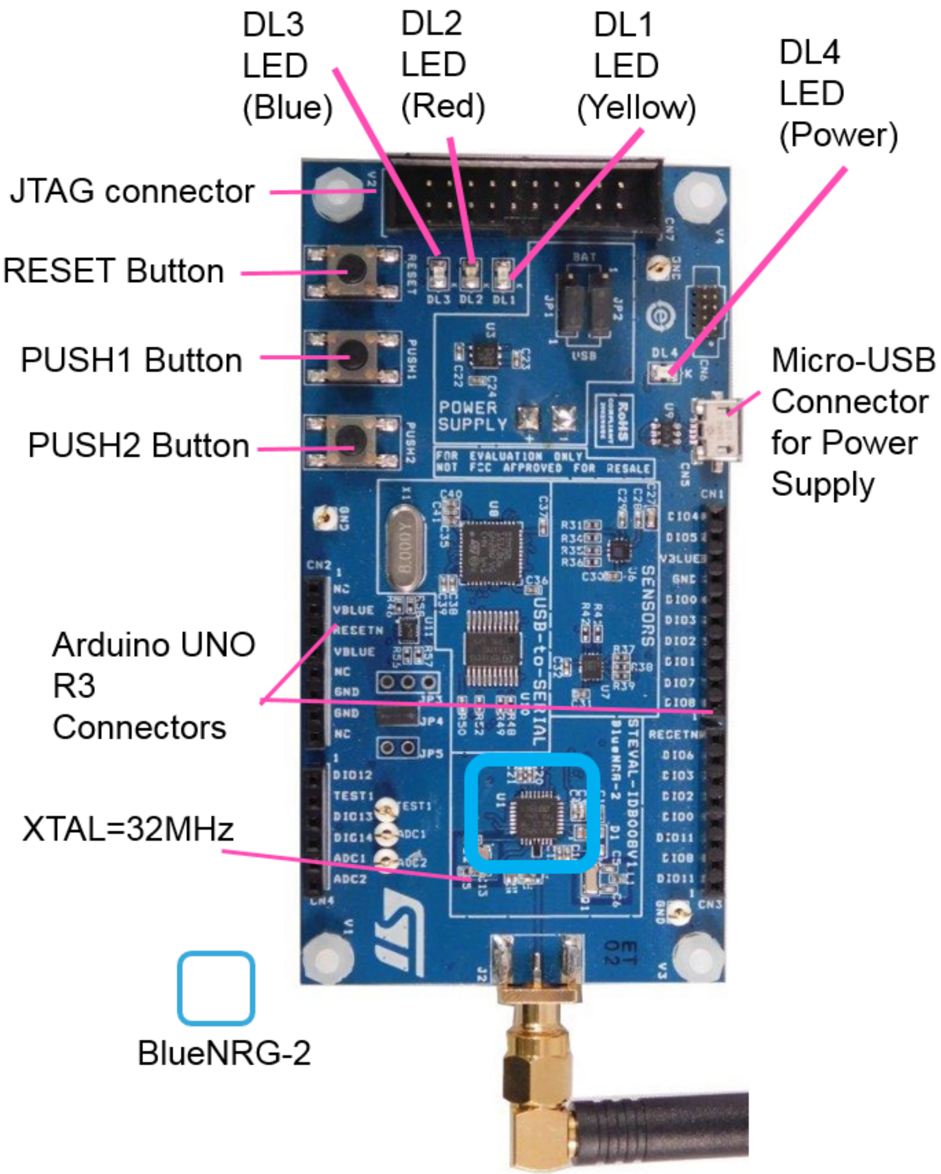


Figure 1. **Connection between the STEVAL-IDB008V1 or STEVAL-IDB008V2 and PC**

RELATED LINKS

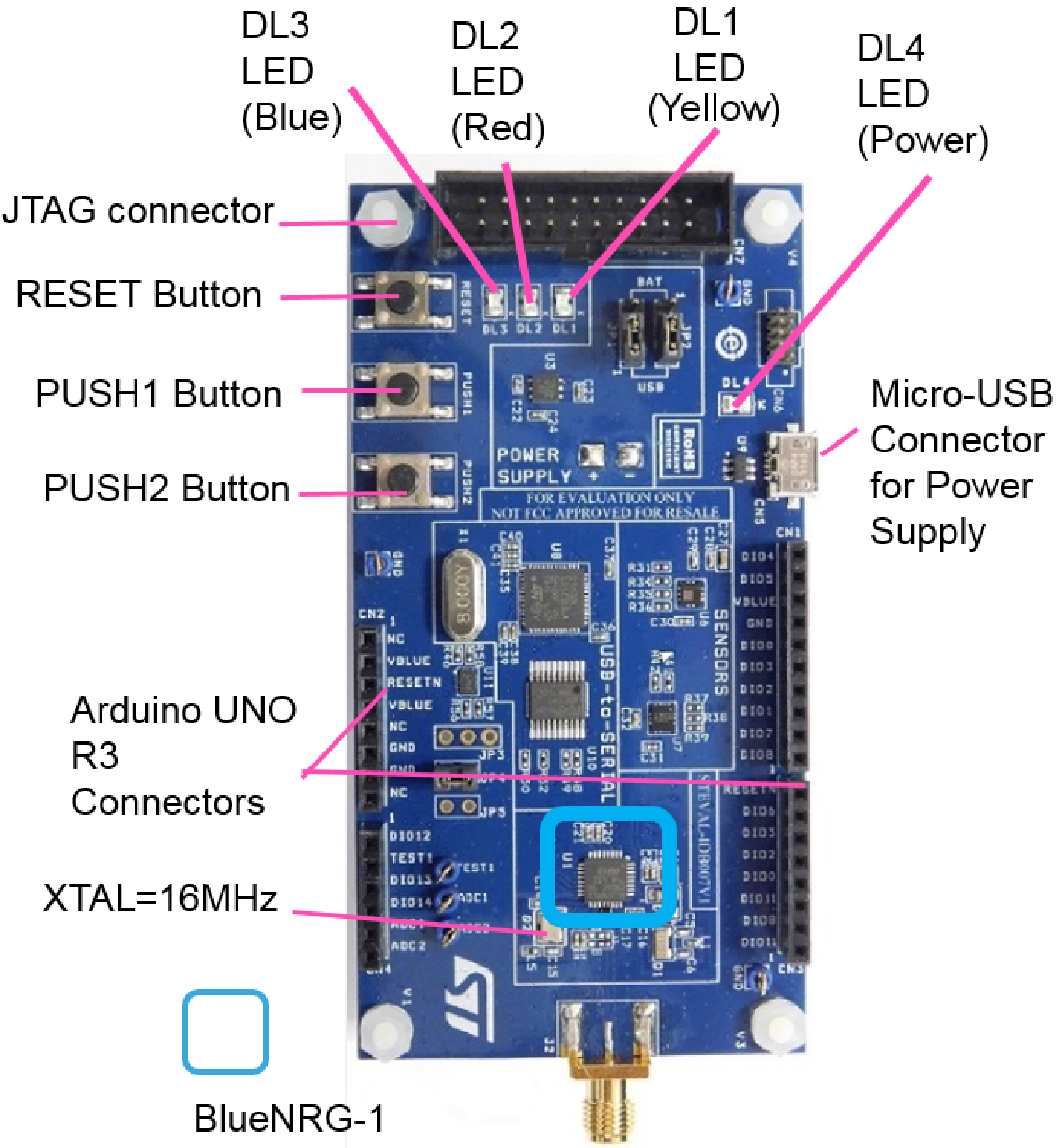
4.1 BlueNRG cold start configuration on page 12

1.4 STEVAL-IDB007V1 or STEVAL-IDB007V2 BlueNRG1 board setup

To connect the STEVAL-IDB007V1 or STEVAL-IDB007V2 (BlueNRG-1 evaluation board) and PC, one USB port is required to provide power supply to the board. To connect the ST-Link/V2 debugger, an additional USB port is needed.

Note: *Please note that the BlueNRG-1 on this evaluation board is clocked by 16 MHz XTAL. These settings are performed in project configurations.*

Figure 2. Connection between the STEVAL-IDB007V1 and PC



RELATED LINKS

4.1 BlueNRG cold start configuration on page 12

1.5 NUCLEO-L152RE plus X-NUCLEO-IDB05A1 board setup

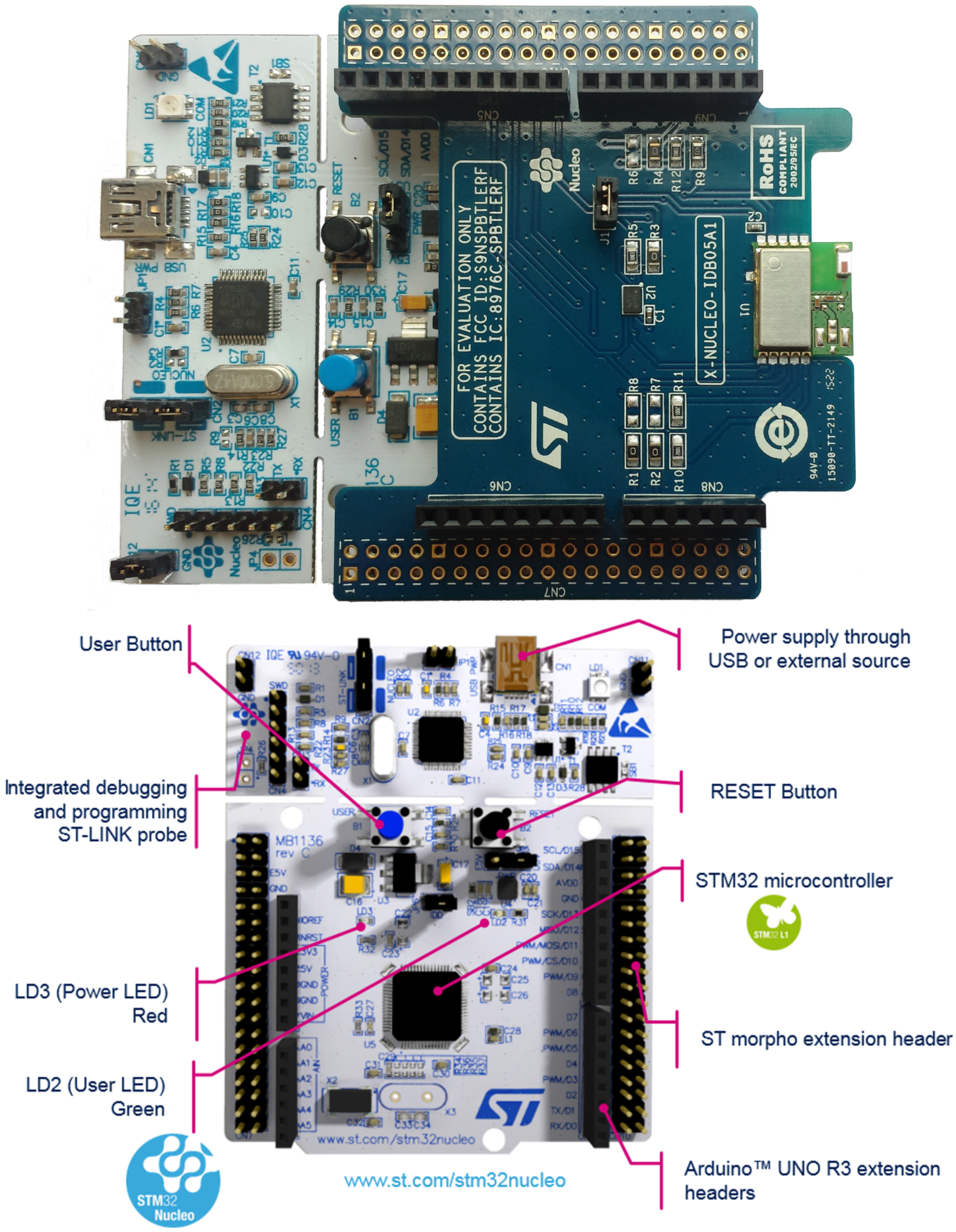
Connect the STM32 NUCLEO-L152RE + X-NUCLEO-IDB05A1 (BlueNRG-MS board) thanks to a USB cable. The USB cable is used for two purposes:

1. Providing power supply to the NUCLEO-L152RE + X-NUCLEO-IDB05A1 board
2. Helping in serial communication of data between the PC and the boards NUCLEO-L152RE + X-NUCLEO-IDB05A1

The STM32 NUCLEO-L152RE board integrates the ST-LINK/V2-1 debugger/ programmer. You can download the relevant version of the STSW-LINK009 ST-LINK/V2-1 USB driver (according to your version of Windows).

Note: *Ensure that BlueNRG-MS is updated with BLE stack version 7.2 c or higher. You can use BlueNRG GUI to manage the update.*

Figure 3. STM32 NUCLEO-L152RE plus X-NUCLEO-IDB05A1 connection with PC


User Button
Power supply through USB or external source
Integrated debugging and programming ST-LINK probe
RESET Button
STM32 microcontroller
LD3 (Power LED) Red
ST morpho extension header
LD2 (User LED) Green
Arduino™ UNO R3 extension headers
www.st.com/stm32nucleo
STM32 Nucleo
X-NUCLEO-IDB05A1
FOR EVALUATION ONLY
CONTAINS FCC ID:S9NSPBTLERF
CONTAINS IC:8976C-SPBTLERF

1.6 System requirements

The minimum requirements to set up the software environment and run the BlueNRG-Mesh smart lighting application are:

- PC with Intel or AMD processor running one of the following Microsoft operating systems: Windows XP or Vista/Windows 7/Windows 10
  - At least 128 MB of RAM
  - 2 x USB ports
  - 40 MB of hard disk space

- Development toolchains and compilers:
  - Keil µVision v5.23
  - IAR Embedded Workbench v7.80.4

Please read the system requirements and setup information provided by the IDE provider.

1.7 Installing STSW-BNRG-Mesh

1. Extract the contents of the package in a temporary directory
2. Launch the installer and follow the on-screen instructions
3. Install in suitable folder in your disk-drive

2 Firmware structure

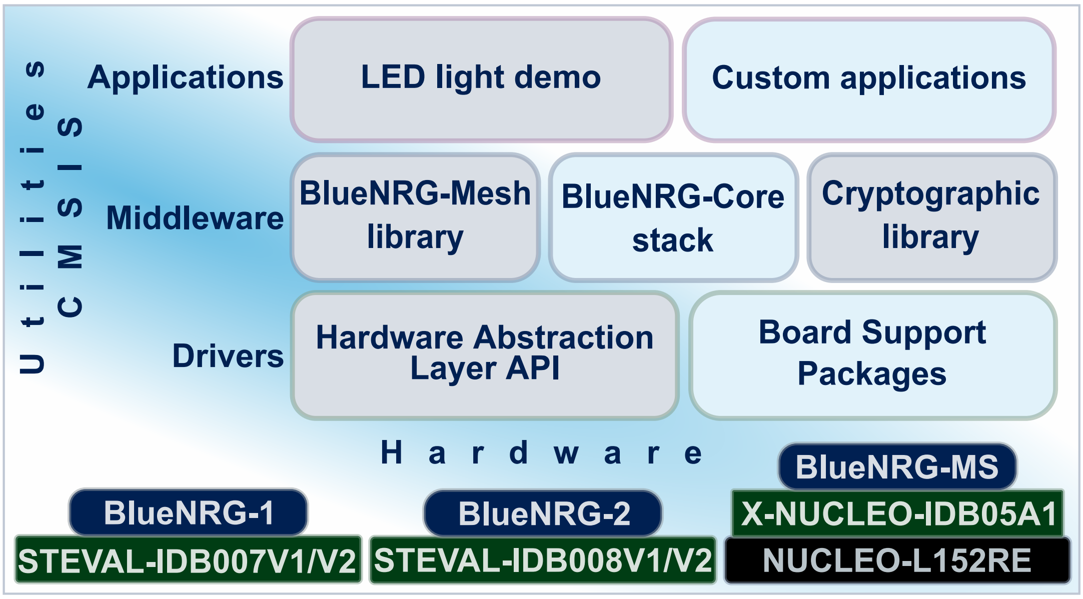


Figure 4. Firmware architecture

The following folders are included in the package firmware folder:

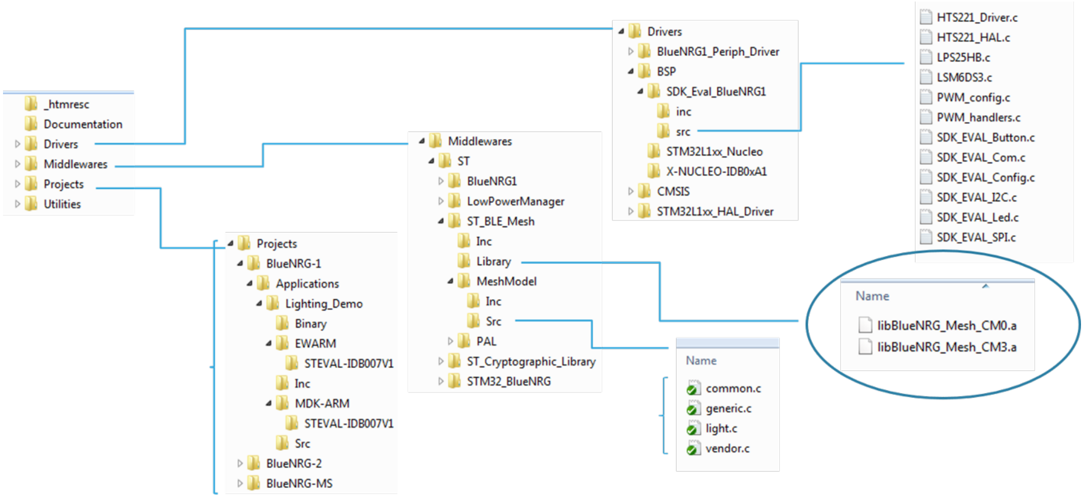
- A Documentation folder with a compiled HTML file generated from the source code and detailed documentation of the software components and APIs.
- A Drivers folder with HAL drivers and specific drivers for supported boards, hardware platforms, and components, and the CMSIS vendor-independent hardware abstraction layer for the Cortex-M processor series.
- A Middleware folder with libraries for Mesh and BLE communication.

  Horizontal interaction between layer components is handled directly by calling the feature APIs, while vertical interaction with the low level drivers is managed through specific callbacks and static macros implemented in the library system call interface.
- A Projects folder contains the workspaces for IAR Embedded Workbench and Keil µVision integrated development environments for the STEVAL-IDB008V1/STEVAL-IDB008V2, STEVAL-IDB007V1/STEVAL-IDB007V2 board and NUCLEO-L152RE plus X-NUCLEO-IDB05A1 board.

  The EWARM folder contains the workspace for IAR Embedded Workbench and MDK-ARM folder contains the workspace for Keil µVision.

  The source files in the folder bind the firmware layers to implement the functions that demonstrate Mesh over BLE functionality.

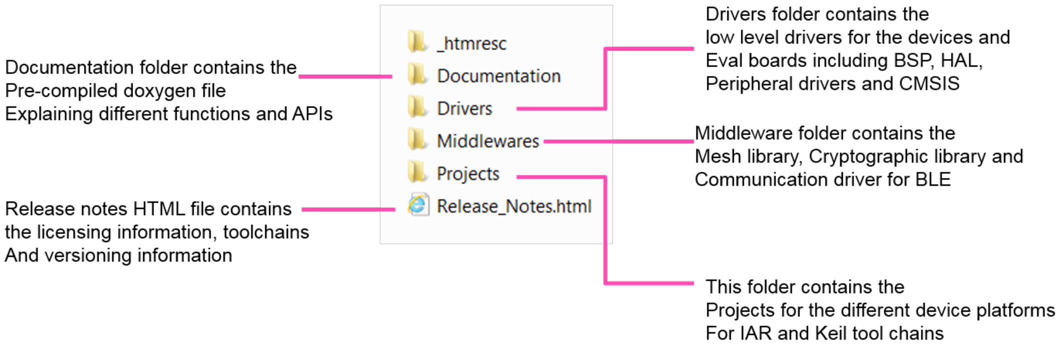
Figure 5. **Folders, sub-folders and contents of the package**



2.1 Root folder

The figure below shows the root folder structure of the firmware package.

Figure 6. **Root folder structure**



Documentation folder contains the
Pre-compiled doxygen file
Explaining different functions and APIs

Release notes HTML file contains
the licensing information, toolchains
And versioning information

Drivers folder contains the
low level drivers for the devices and
Eval boards including BSP, HAL,
Peripheral drivers and CMSIS

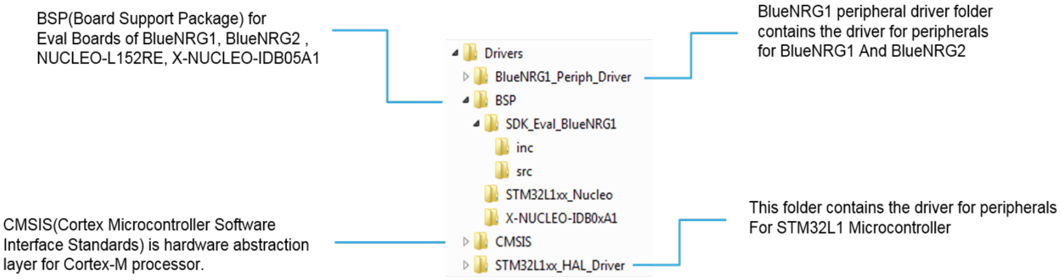
Middleware folder contains the
Mesh library, Cryptographic library and
Communication driver for BLE

This folder contains the
Projects for the different device platforms
For IAR and Keil tool chains

2.2 Driver folder

This folder contains all low level drivers including peripheral drivers and HAL drivers corresponding to the hardware.

Figure 7. **Driver folder**



BSP(Board Support Package) for
Eval Boards of BlueNRG1, BlueNRG2 ,
NUCLEO-L152RE, X-NUCLEO-IDB05A1

CMSIS(Cortex Microcontroller Software
Interface Standards) is hardware abstraction
layer for Cortex-M processor.

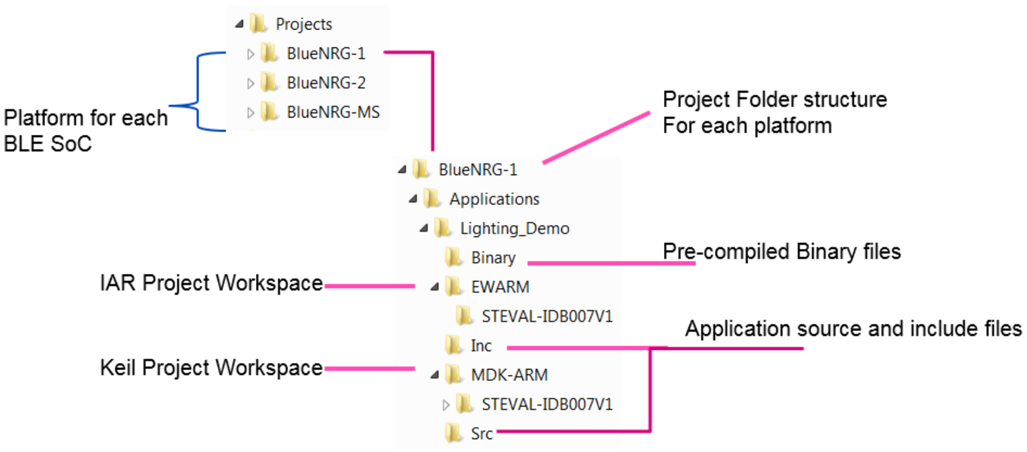
BlueNRG1 peripheral driver folder
contains the driver for peripherals
for BlueNRG1 And BlueNRG2

This folder contains the driver for peripherals
For STM32L1 Microcontroller

2.3 Project folder

This folder contains the projects for IAR and Keil.

Figure 8. Project folder



Platform for each BLE SoC

Project Folder structure For each platform

Pre-compiled Binary files

IAR Project Workspace

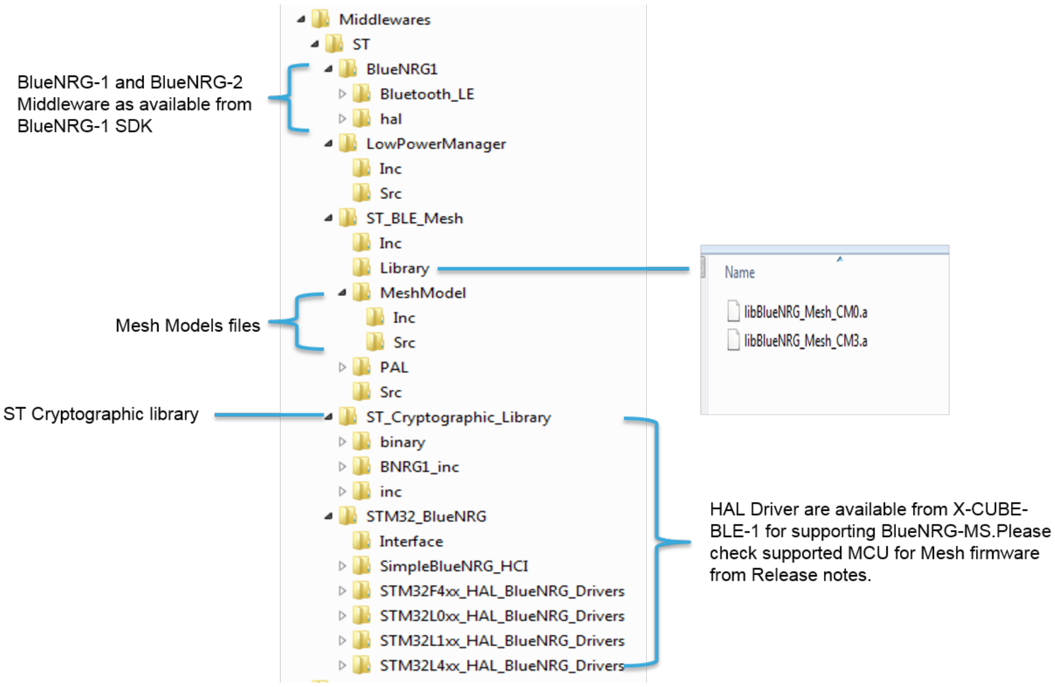
Application source and include files

Keil Project Workspace

2.4 Middleware folder

This folder contains the middleware for the project including pre-compiled Mesh library for the BlueNRG-2, BlueNRG-1 and BlueNRG-MS + STM32L1.

Figure 9. Middleware folder



BlueNRG-1 and BlueNRG-2 Middleware as available from BlueNRG-1 SDK

Mesh Models files

ST Cryptographic library

HAL Driver are available from X-CUBE-BLE-1 for supporting BlueNRG-MS.Please check supported MCU for Mesh firmware from Release notes.

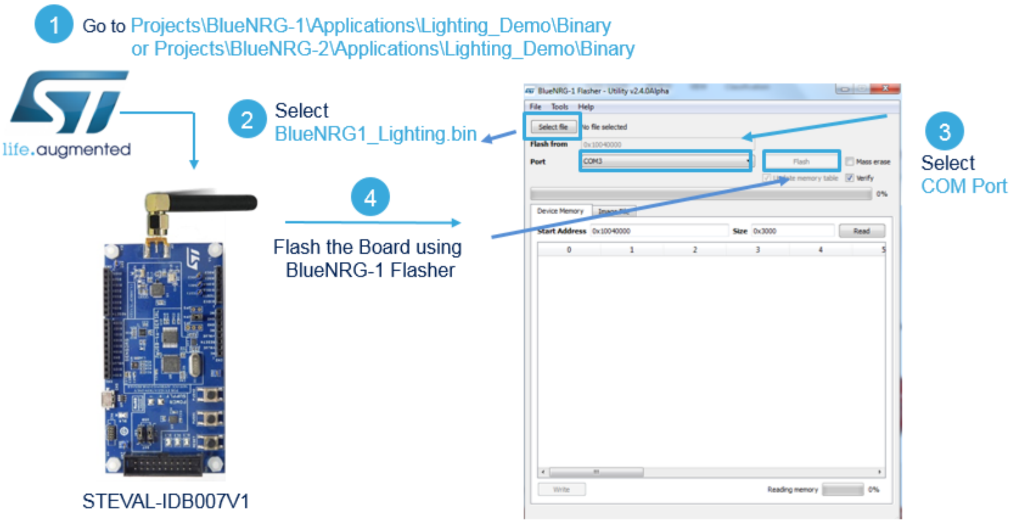
3 Using the BlueNRG-Mesh demo

IAR Embedded Workbench and Keil µVision are used to debug and burn the firmware into the flash memory of the STEVAL-IDB008V1/STEVAL-IDB008V2, STEVAL-IDB007V1/STEVAL-IDB007V2 and NUCLEO-L152RE plus X-NUCLEO-IDB05A1 boards.

3.1 Using binaries for BlueNRG-1 and BlueNRG-2

1. The pre-compiled binaries are available in Project\<Platform>\Application\<Demo>\Binary folder.
   For example for BlueNRG-1, the path is “Projects\BlueNRG-1\Applications\Lighting_Demo\Binary”
2. These can be programmed in the device using different utilities available for the devices, such as the BlueNRG-1 Flasher tool or ST-LINK Utility
3. Use "BlueNRG-1 Flasher" tool to program the (STEVAL-IDB007V1/STEVAL-IDB007V2 or STEVAL-IDB008V1/STEVAL-IDB008V2) boards connected via micro-USB cable
4. Use "STSW-BNRG1STLINK: BlueNRG-1 ST-LINK utility for BlueNRG-1, BlueNRG-2 MCU” utility to program boards via ST-LINK

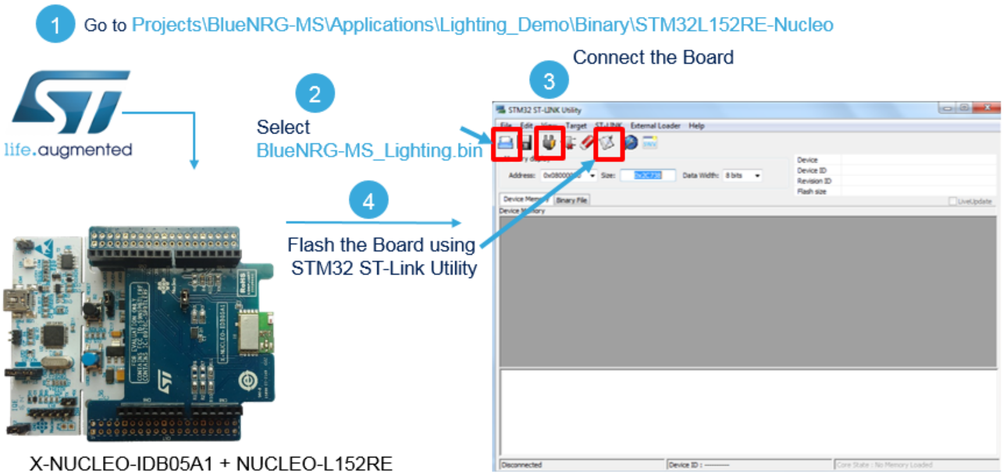
Figure 10. **Binaries for BlueNRG-1 and BlueNRG-2**



3.2 Using binaries for the STM32L152 used with the BlueNRG-MS

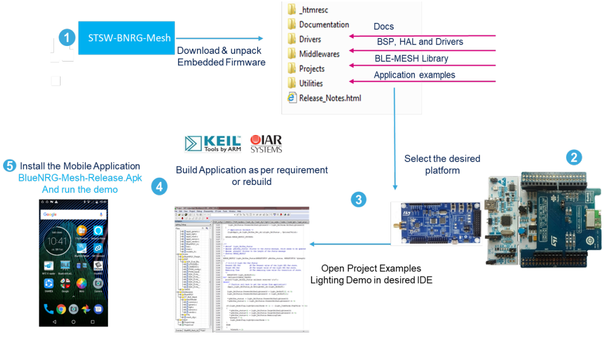
1. The pre-compiled binaries are available in Project\<Platform>\Application\<Demo>\Binary folder
   – For example, for BlueNRG-MS, the path is “Projects\BlueNRG-MS\Applications\Lighting_Demo\Binary \STM32L152RE-Nucleo”
2. These can be programmed in the device using different utilities
3. Use “ST-LINK Utility” tool to program the boards (NUCLEO-L152RE) connected via mini-USB cable
4. Or, simply drag and drop the .bin file in the drive created by ST-LINK on the STM32 Nucleo board. The binary will be programmed in the STM32L152 device on the Nucleo board

Figure 11. Overview of how to program the binary in the STM32L152RE MCU


1 Go to Projects\BlueNRG-MS\Applications\Lighting_Demo\Binary\STM32L152RE-Nucleo
life.augmented
2 Select BlueNRG-MS_Lighting.bin
3 Connect the Board
4 Flash the Board using STM32 ST-Link Utility
STM32 ST-LINK Utility
X-NUCLEO-IDB05A1 + NUCLEO-L152RE

3.3 Using the IAR and Keil projects

Figure 12. Overview


1 STSW-BNRG-Mesh
Download & unpack Embedded Firmware
_htmresc
Documentation
Drivers
Middlewares
Projects
Utilities
Release_Notes.html
Docs
BSP, HAL and Drivers
BLE-MESH Library
Application examples
2 Select the desired platform
3 Open Project Examples Lighting Demo in desired IDE
4 Build Application as per requirement or rebuild
KEIL Tools by ARM
IAR SYSTEMS
5 Install the Mobile Application BlueNRG-Mesh-Release.Apk And run the demo

3.3.1 Using IAR project

1. Choose file→open→workspace. Select the project.eww file from the appropriate location. For example, for the BlueNRG-1, the location is as follows:
   – Embedded\Projects\BlueNRG-1\Applications\Lighting_Demo\EWARM\STEVAL-IDB007V1.
2. A project opens in the workspace. This project contains the information regarding your project files and folders (driver files, application files, middleware, output files, etc.).
3. Build the program with Project→Make Option.
4. Press (download and debug) button to debug the code and flash it to the board.
5. Press go button to run the program.

Similarly, to use the BlueNRG-MS with boards X-NUCLEO-IDB05A1 and NUCLEO-L152RE, select the project.eww from: Embedded\Projects\ BlueNRG-MS\Applications\Lighting_Demo\EWARM\STM32L152RE-Nucleo.

3.3.2 Using Keil project

1. Click on File→Open. Select the project.uvprojx file from: Embedded\Projects\BlueNRG-1\Applications \Lighting_Demo\MDK-ARM\STEVAL-IDB007V1.
2. To build the program, select Project→Build Target or simply click on the Build Target icon.

To debug the program, select Debug→Start/Stop Debug Session or click on the Start/Stop Debug Session icon. To flash the program to the flash memory on the board click on the icon.

4 Firmware initialization and configuration

This section describes the available function APIs for application development based on Mesh network over Bluetooth Low Energy devices.

The Mesh over BLE library manages the following features:

- Creates the Mesh network between nodes
- Handles the unicast, broadcast addressing
- Manages the relay feature: all the packets whose destination address is for another node are re-transmitted
- Communication with devices for advanced features, such as provisioning and proxy service
- Handles the platform specific communication

The user application handles the following

- Initialization of the Mesh stack
- User callbacks required for the application
- Application handling

The following sections describe the requirements for initialization and configuration of the firmware.

4.1 BlueNRG cold start configuration

Concerning the BlueNRG-1 and BlueNRG-2 devices, certain parameters must be defined on BLE device controller registers during the device initialization phase, after the device powers on:

- High speed crystal configuration: 32 or 16 MHz
- Low speed crystal source: external 32 kHz oscillator or internal RO
- SMPS: on or off (if on: 4.7 μH or 10 μH SMPS inductor)

The BlueNRG-1, BlueNRG-2 controllers are configured in the project C/C++ Preprocessor settings.

For example:

- for IAR, go to Project → Options → C/C++ Compiler → Preprocessor → Defined Symbols
- For Keil, go to Project → Options → C/C++ → Preprocessor Symbols → Define

The following symbols are used in the project: USER_DEFINED_PLATFORM=STEVAL_IDB007V1:

- HS_SPEED_XTAL=HS_SPEED_XTAL_16MHZ
- LS_SOURCE=LS_SOURCE_EXTERNAL_32KHZ
- SMPS_INDUCTOR=SMPS_INDUCTOR_10 uH.

These can be changed to suit your hardware design.

RELATED LINKS

1.3 STEVAL-IDB008V1 or STEVAL-IDB008V2 BlueNRG2 board setup on page 2

1.4 STEVAL-IDB007V1 or STEVAL-IDB007V2 BlueNRG1 board setup on page 3

4.2 Setting the transmit power of a node

You can define the transmit power of a node by initializing a callback to the Mesh library. It runs in the following manner:

```
{
  Appli_BleStackInitCb,
  Appli_BleSetTxPowerCb,
  Appli_BleGattConnectionCompleteCb,
  Appli_BleGattDisconnectionCompleteCb,
  Appli_BleUnprovisionedIdentifyCb,
  Appli_BleSetUUIDCb,
  Appli_BleSetNumberOfElementsCb
};
```

The `Appli_BleSetTxPowerCb()` calls the aci function to set the power `aci_hal_set_tx_power_level(uint8_t En_High_Power, uint8_t PA_Level);`

By default, +4 dbm is configured in the nodes for BlueNRG-1 and BlueNRG-2; this can be changed by the user.

For BlueNRG-1 and BlueNRG-2, the following different settings are available in the firmware:

```
/* MACROS for Power Level definitions */
#define POWER_LEVEL_LOW              0
#define TX_POWER_LEVEL_MINUS_18DBM 0 // = -18 dBm,
#define TX_POWER_LEVEL_MINUS_15DBM 1 // = -15 dBm,
#define TX_POWER_LEVEL_MINUS_12DBM 2 // = -12 dBm,
#define TX_POWER_LEVEL_MINUS_9DBM  3 // = -9 dBm,
#define TX_POWER_LEVEL_MINUS_6DBM  4 // = -6 dBm,
#define TX_POWER_LEVEL_MINUS_2DBM  5 // = -2 dBm,
#define TX_POWER_LEVEL_0DBM        6 // =  0 dBm,
#define TX_POWER_LEVEL_PLUS_5DBM   7 // =  5 dBm.
#define POWER_LEVEL_HIGH             1
#define TX_POWER_LEVEL_MINUS_14DBM 0 // = -14 dBm,
#define TX_POWER_LEVEL_MINUS_11DBM 1 // = -11 dBm,
#define TX_POWER_LEVEL_MINUS_8DBM  2 // = -8 dBm,
#define TX_POWER_LEVEL_MINUS_5DBM  3 // = -5 dBm,
#define TX_POWER_LEVEL_PLUS_2DBM   5 // =  2 dBm,
#define TX_POWER_LEVEL_PLUS_4DBM   6 // =  4 dBm,
#define TX_POWER_LEVEL_PLUS_8DBM   7 // =  8 dBm
```

4.3 UART interface on the firmware

The boards can be connected to a PC via USB connection. Any terminal software (HyperTerminal, Hercules, Putty, etc.) can be used to open the serial communication port on the PC to check the messages from the board.

The UART of the controller on the board is connected to the PC via a VCOM (virtual communication) port. The settings to open the communication port are:

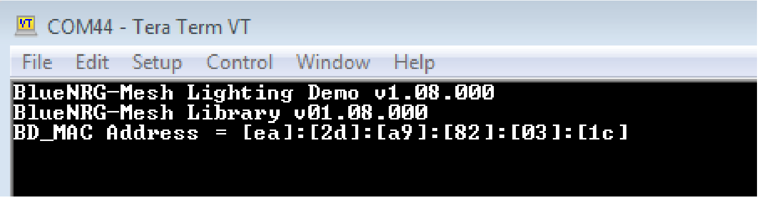
- Baud: 115200
- data size: 8
- parity: none
- stop bits: 1
- no hardware control

From the firmware main.c file, you can see certain messages are printed to the VCOM by the following code:

```
#if !defined(DISABLE_TRACES)
  /* Prints the MAC Address of the board */
  printf("BlueNRG-Mesh Lighting Demo v%s\n\r", BLUENRG_MESH_APPLICATION_VERSION);
  printf("BlueNRG-Mesh Library v%s\n\r", BluenrgMesh_GetLibraryVersion());
  printf("BD_MAC Address = [%02x]:[%02x]:[%02x]:[%02x]:[%02x]:[%02x] \n\r",
  bdaddr[5],bdaddr[4],bdaddr[3],bdaddr[2],bdaddr[1],bdaddr[0] );
#endif
```

After the board is connected and the terminal window is opened, press the reset button. If the firmware starts successfully, the following messages are printed to the virtual com window

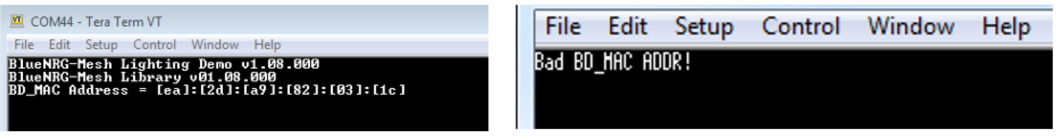
Figure 13. VCOM window



```
BlueNRG-Mesh Lighting Demo v1.08.000
BlueNRG-Mesh Library v01.08.000
BD_MAC Address = [ea]:[2d]:[a9]:[82]:[03]:[1c]
```

In some evaluation boards, an error can be received. In this case, MAC address management section of the document helps to meet this issue. Examples of bad MAC address are provided below

Figure 14. **Bad MAC address**


COM44 - Tera Term VT
File Edit Setup Control Window Help
File Edit Setup Control Window Help

```
BlueNRG-Mesh Lighting Demo v1.08.000
BlueNRG-Mesh Library v01.08.000
BD_MAC Address = [ea]:[2d]:[a9]:[82]:[03]:[1c]
```

```
Bad BD_MAC ADDR!
```

4.4 MAC address management

MAC address is required to be unique in each node for the Mesh network. The following options are available to configure the MAC addresses of the node

Table 3. **MAC address management**

Number	MAC address management	Comments
1	Using external MAC address	User can program the nodes with desired unique MAC address. This is stored at specific location in the flash. It is user’s responsibility to make sure that the MAC address programmed in the device is compliant to the requirements of the Bluetooth communication. To configure this, define the following macro in the project pre-processor. EXTERNAL_MAC_ADDR_MGMT
2	Using unique serial number of the device	It is possible to configure the MAC address of the device using the unique serial number available in each device. This is the default setting.
3	Using static random MAC address	It is possible to configure the MAC address of device using the static random MAC address

4.5 Button usage

Features	BlueNRG-1 and BlueNRG-2 (STEVAL-IDB007V1 and STEVAL-IDB008V1)		BlueNRG-MS (X-NUCLEO-IDB05A1 + NUCLEO-L152RE)	
	Buttons	LEDs	Buttons	LEDs
Mesh Lib error		DL3 Blinks continuously		LD2 Blinks continuously
Mesh Lib library successful start		2 Blinks on DL3		NO Blinks
Provisioning		DL3 Blinks for few times		DL3 Blinks for few times
Un-Provisioning	1. RESET + PUSH1 button pressed 2. Release RESET button 3. Long press of PUSH1 button causes un-provisioning 4. Reset the board	1. DL3 blinks and then keeps glowing during un-provisioning	1. RESET + USER button pressed 2. Release RESET button 3. Long press USER button causes un-provisioning 4. Reset the board	LD2 Blinks and then keeps glowing during un-provisioning

Features	BlueNRG-1 and BlueNRG-2 (STEVAL-IDB007V1 and STEVAL-IDB008V1)		BlueNRG-MS (X-NUCLEO-IDB05A1 + NUCLEO-L152RE)	
	Buttons	LEDs	Buttons	LEDs
Running the demo from board	1. Press PUSH1 button on any board 2. It will send the command on Publication Address	1. DL3 on the board toggles (If Subscribed for the Published Address) 2. DL3 on other boards (if subscribed for the Published address) will also toggle	1. Press USER button on any board 2. It will send the command on Publication Address	1. LD2 on the board toggles (If Subscribed for the Published Address) 2. LD2 on other boards (if subscribed for the Published address) will also toggle
OTA	(1) 1. Long Press PUSH2 2. RESET the Board			

1. ONLY on BlueNRG-2

4.6 Initialization of application callbacks

The configuration of the application starts by initializing the callbacks required for the different events and functionalities. These callbacks are used in the BlueNRG-Mesh library to call the functions based on specific events or the library state machine.

```
{
  Vendor_WriteLocalDataCb,
  Vendor_ReadLocalDataCb,
  Vendor_OnResponseDataCb
};
```

/* Callbacks used by BlueNRG-Mesh library */

```
BluenrgMesh_SetVendorCbMap(&vendor_cb);
```

The structure MOBLE_VENDOR_CB_MAP is used to initialize the vendor model for the application implementation. The function `BluenrgMesh_SetVendorCbMap(&vendor_cb);` is used to initialize the vendor callbacks in the library.

4.7 Initialization and main application loop

This procedure develops an application for Mesh over BLE on the BlueNRG platforms.

The following steps are for the BlueNRG-2 and BlueNRG-1 platforms. The procedure is similar for the BlueNRG-MS platform, but with a few minor differences.

Step 1. Call the `InitDevice()` API.

This in turn calls the `SystemInit()` API to initialize the BlueNRG-1 device vector table, interrupt priorities and clock. The initialization is run similarly for the BlueNRG-MS platform. Even PWM is intialized for BlueNRG-1, BlueNRG-2.

Step 2. Call the `Appli_CheckBdMacAddr()` API to check the validity of the MAC address.

If the MAC address is not valid, then the firmware is stuck in while(1) loop with LED blinking continuously.

Step 3. Initialize the hardware callback functions for the BLE hardware.

You do this by updating `MOBLE_USER_BLE_CB_MAP user_ble_cb =`

```
{
  Appli_BleStackInitCb,
  Appli_BleSetTxPowerCb,
  Appli_BleGattConnectionCompleteCb,
  Appli_BleGattDisconnectionCompleteCb,
  Appli_BleUnprovisionedIdentifyCb,
  Appli_BleSetUUIDCb,
  Appli_BleSetNumberOfElementsCb
};
```

Step 4. These APIs are useful to have an application interface for BLE radio initialization and TxPower configuration.

– Initialize GATT connection and disconnection callbacks for the application interface.

– `BluenrgMesh_BleHardwareInitCallBack(&user_ble_cb)` can be called to complete the initialization of hardware callbacks.

Step 5. Initialize the BlueNRG-Mesh library by calling `BluenrgMesh_Init(&BLEMeshlib_Init_params) )`.

You do this by updating the structure containing Mesh library Initialisation info data .

```
const Mesh_Initialization_t BLEMeshlib_Init_params = {
bdaddr,
&FnParams,
&LpnParams,
MESH_FEATURES,
&DynBufferParam
};
```

In the event of an error, the demo firmware prints a message on the terminal window opened for the VCOM port created by the USB connection available on the boards, and the `Appli_LedBlink()` API causes the LED to blink continuously.

Step 6. Check whether the device has been provisioned or not. A provisioned device has network keys and other parameters configured in the internal flash memory.

Checks can be performed with `BluenrgMesh_IsUnprovisioned()` API.

If the Node is unprovisioned, BluenrgMesh_InitUnprovisionedNode() API initializes it.

If the device is already provisioned , then `BluenrgMesh_InitprovisionedNode()` API helps to initialize the device.

Step 7. Print the messages to the terminal window for the nodes that are being initialised.

The message also prints the MAC address assigned to the node.

Step 8. Check the button state. To initialize the node to the unprovisioned state, hold down the user button.

When the unprovisioning button sequence is detected, the `BluenrgMesh_Unprovision()` API erases all the network parameters configured in the internal memory of the device.

Once unprovisioning is complete, you need to reset the board.

Step 9. Initialize all the 3 models (vendor, generic and lighting model) triggered by the events.

```
BluenrgMesh_ModelsInit();
```

Step 10. Process MoBLE and HCI events in while(1) loop.

The application must call `BluenrgMesh_Process(); ,BluenrgMesh_ModelsProcess(); , Appli_Process();`

in while(1) loop as frequently as possible.

This function calls `MobleStackProcess();` internally to process BLE communication.

Any application implementation shall be performed in the state-machine by non-blocking functions with frequent calls to `BluenrgMesh_Process()`.

Step 11. Check for user-inputs or buttons regularly for any action to take.

5 Mesh networking information

5.1 Local and remote concept

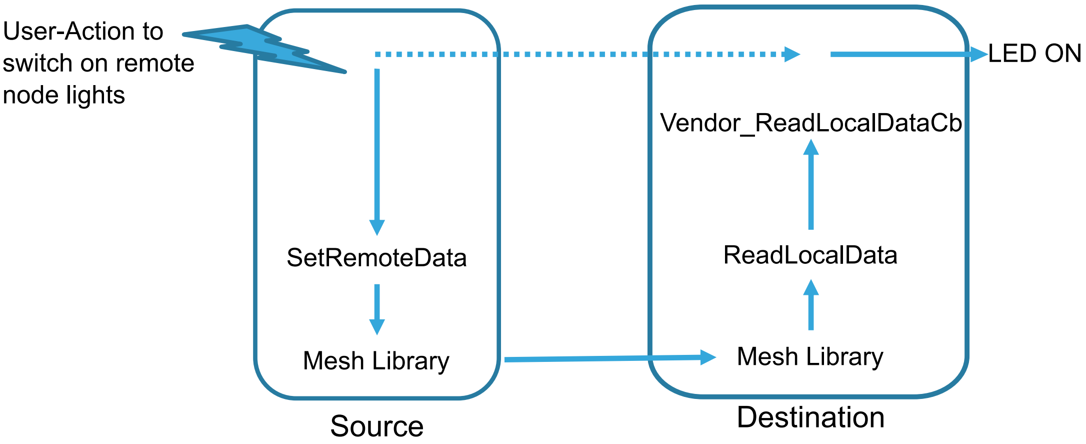
Remote actions or operations refer to other nodes in the network, while local actions refer to the resources on the same node in the network.

For example, if you want to control the LEDs of nodes on the BlueNRG-Mesh app, click the icon button to invoke the `_SetRemoteData` action from the app. This causes a `Vendor_WriteLocalDataCb`action on the node.

This is also the case when you wants to control the LEDs of the nodes of a group from the board. The LEDs on the nodes subscribed to the Publish address will toggle when the button on the board is pressed.

The same message received on the node which needs to turn on the LEDs requires a `WriteLocal` action on that node. This is shown in the figure below for the `SetRemote`/`WriteLocal` actions on different nodes in the network.

Figure 15. SetRemote/WriteLocal actions



5.2 Acknowledged and unacknowledged messages

By default, all messages in the Mesh network are configured as unacknowledged. The difference between acknowledged and unacknowledged messages is the response to the message. For example, a write message to a node may have a response in acknowledged communication. Whereas, in unacknowledged communication, the response may not be there.

You should use unacknowledged messages in the mesh network to avoid the exchange of multiple messages in the network, which may take time to the process.

5.3 Provisioning process

The process of configuring a devices in a network is called provisioning. The process is started by a “Provisioner”, which is a BlueNRG-Mesh app running on the smartphone.

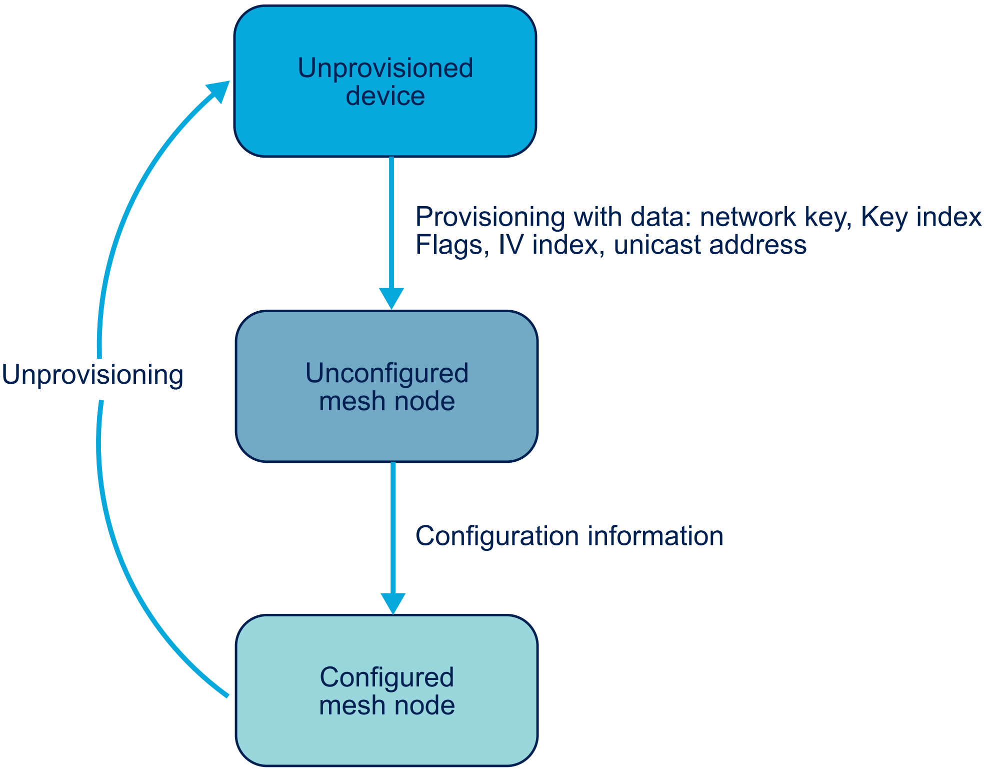
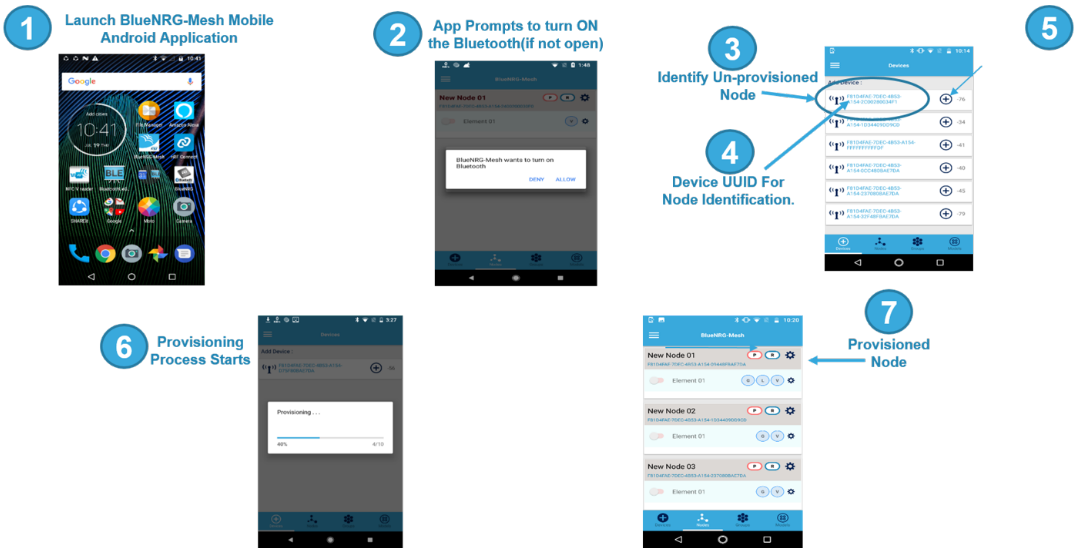

Unprovisioned device
Provisioning with data: network key, Key index Flags, IV index, unicast address
Unconfigured mesh node
Configuration information
Configured mesh node
Unprovisioning

Figure 16. **Provisioning process**

The BlueNRG-Mesh app can be installed on the smartphone with BLE 4.0 or higher. During installation, the app asks for some user permissions, refer to the appropriate BlueNRG-Mesh user manual for your device type (Android or iOS) on www.st.com . The steps required for the provisioning are shown in the figure below.

Figure 17. **Provisioning steps**


1 Launch BlueNRG-Mesh Mobile Android Application
2 App Prompts to turn ON the Bluetooth(if not open)
3 Identify Un-provisioned Node
4 Device UUID For Node Identification.
5
6 Provisioning Process Starts
7 Provisioned Node

The provisioning is executed by GATT connection between the smartphone and the unprovisioned device.

RELATED LINKS

5.4 GATT connection/disconnection node on page 19

5.4 GATT connection/disconnection node

Each node in the network has the capability to make connection with the smartphone through GATT interface. When this connection is established, the node becomes a “proxy”. The proxy has the responsibility to bridge the commands and response between the Mesh network and the smartphone. The detection of connection and disconnection with smartphone is managed by the following callbacks

```
Appli_BleGattConnectionCompleteCb;
Appli_BleGattDisconnectionCompleteCb;
```

These are initialized during the main loop. It can be interesting sometimes to know which node is connected to the smartphone when there are many nodes nearby.

During provisioning, the GATT connection is established with the node which needs to be provisioned. It may be noted that if the smartphone moves out of the range of the proxy node, it establishes a new connection with the node which is available. For example: in the example project, for BlueNRG-1 and BlueNRG-2, a LED indication (LED2) is used to show the proxy connection.

RELATED LINKS

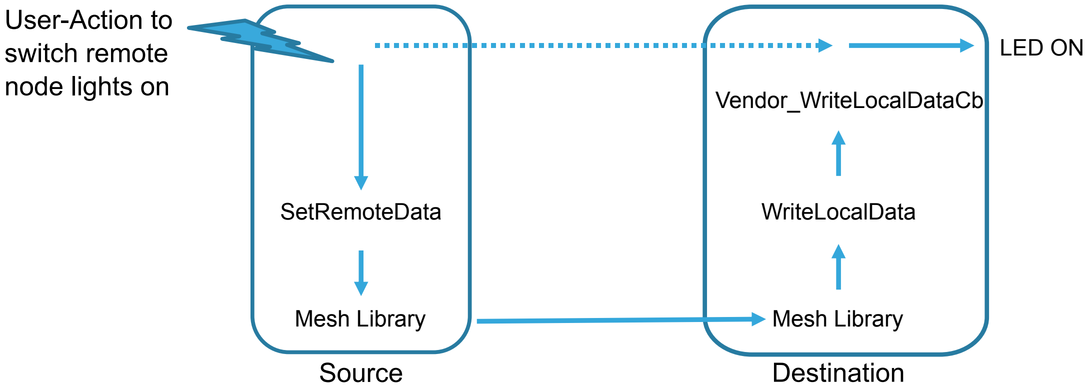
5.3 Provisioning process on page 17

5.5 Write command from remote node

A command from a remote node or from a smartphone to an addressed node invokes a `WriteLocalData` callback.

This callback can be used to process the commands or data received inside the network. In the application demo, the `Vendor_WriteLocalDataCb` function is the callback where data or commands will be processed. The command/data flow can be visualised in the picture below.

Figure 18. Write command data flow

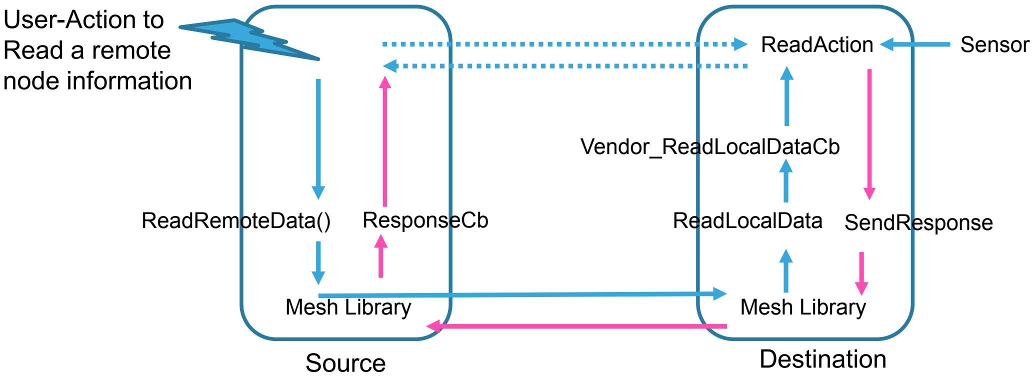


The response data from the node is sent through `SendResponse` function.

5.6 Read command from a remote node

A Read command from a remote node or from a smartphone to an addressed node to get some information, invokes the `Vendor_ReadLocalDataCb` callback. This callback can be used to read some information that a remote node asks and provides the data back to the remote node. In the application demo, the `Vendor_ReadLocalDataCb` function is the callback where the read commands is processed. The command/ data flow can be seen in the picture below.

Figure 19. **Read command from a remote node**



The response data from the node is sent via the `BluenrgMesh_SendResponse` function.

5.7 Application functions and callbacks

The following section explains the different APIs available for the user application.

5.7.1 User interface and indications

Table 4. **Appli_LedCtrl**

Function	Description
Prototype	void Appli_LedCtrl(void)
Behaviour description	It blinks the on-board LED. This function is used at power-on and at the error conditions due to user's attention
Input parameter	None
Output parameter	Void

Table 5. **SetLed**

Function	Description
Prototype	void SetLed(int state)
Behaviour description	Sets the state of the LEDs or Lighting interface connected
Input parameter	int state: sets the state of LEDs
Output parameter	Void

5.7.2 User and button interface

Table 6. **Appli_ShortButtonPress**

Function API parameters	Description
Prototype	Static void Appli_ShortButtonPress(void)
Behaviour description	Function calls when a button is pressed for short duration
Input parameter	Void
Output parameter	Void

Table 7. **Appli_LongButtonPress**

Function	Description
Prototype	Static void Appli_LongButtonPress(void)
Behaviour description	Function calls when a button is pressed for long duration
Input parameter	Void
Output parameter	Void

Table 8. **Appli_UpdateButtonState**

Function	Description
Prototype	Void Appli_UpdateButtonState(int isPressed)
Behaviour description	Updates the button status
Input parameter	int isPressed
Output parameter	Void

5.7.3 Device BLE configuration type interface

This section explains the functions available to the application developer to configure the device to be used in the network.

Table 9. **Appli_BleStackInitCb**

Function	Description
Prototype	MOBLE_RESULT Appli_BleStackInitCb()
Behaviour description	This function helps with hardware configuration; mainly the initialization of the BLE Stack based on the structured parameters defined in BlueNRG_Stack_Init_params. The user can modify the Low level hardware configuration data for the device defined in CONFIG_TABLE like LOW_SPEED_SOURCE and HS_STARTUP_TIME, which may depend on the user hardware design. The Parameters initializes BlueNRG Stack
Input parameter	None
Output parameter	MOBLE_RESULT status of result

Table 10. **Appli_BleSetTxPowerCb**

Function	Description
Prototype	MOBLE_RESULT Appli_BleSetTxPowerCb()
Behaviour description	This callback sets the transmission power of BLE radio. IN turns this function call aci_hal_set_tx_power_level. By default, the power level is set to +4 dbm
Input parameter	None
Output parameter	MOBLE_RESULT status of result

Table 11. Appli_BleGattConnectionCompleteCb

Function	Description
Prototype	void Appli_BleGattConnectionCompleteCb(void)
Behaviour description	This function is called when GATT Connection is detected by the node. The application can use this callback to indicate to the user that node is connected to the smartphone
Input parameter	Void
Output parameter	Void

Table 12. Appli_BleGattDisconnectionCompleteCb

Function	Description
Prototype	void Appli_BleGattDisconnectionCompleteCb(void)
Behaviour description	This function is called when GATTDisconnection is detected by the node. The application can use this callback to indicate to the user that node is no longer connected to the smartphone
Input parameter	None
Output parameter	None

5.7.4 Vendor model network data communication functions

The functions explained below help the developer to manage the network data communication and take the associated actions.

Table 13. Vendor_WriteLocalDataCb

Function	Description
Prototype	MOBLE_RESULT Vendor_WriteLocalDataCb(MOBLE_ADDRESS peer_addr, MOBLE_ADDRESS dst_peer, MOBLEUINT8 command, MOBLEUINT8 const *data, MOBLEUINT32 length, MOBLEBOOL response)
Behaviour description	Call back function called when action is required on node itself
Input parameters	MOBLE_ADDRESS peer_addr: address of the peer MOBLE_ADDRESS dst_peer: destination address of the command. This address can be the address of Group to which the node is subscribed or the unicast address of element MOBLEUINT16 command: command received for the action MOBLEUINT8 const *data pointer to the data MOBLEUINT32 length: length of the data MOBLEBOOL response: If this is MOBLE_TRUE, the sender expects an acknowledgement
Output parameter	MOBLE_RESULT status of result

Table 14. **Vendor_ReadLocalDataCb**

Function	Description
Prototype	MOBLE_RESULT Vendor_ReadLocalDataCb(MOBLE_ADDRESS peer_addr, MOBLE_ADDRESS dst_peer, MOBLEUINT8 command, MOBLEUINT8 const *data, MOBLEUINT32 length, MOBLEBOOL response)
Behaviour description	Callback function invoked when some data are required from node
Input parameter	MOBLE_ADDRESS peer_addr: address of the peer MOBLE_ADDRESS dst_peer: destination address of the command. This address can be the address of Group to which the node is subscribed or the unicast address of element MOBLEUINT16 command : command received for processing MOBLEUINT8 const *data pointer to the data MOBLEUINT32 length: length of the data MOBLEBOOL response: If this is MOBLE_TRUE, the sender expects an acknowledgement
Output parameter	MOBLE_RESULT status of result

5.7.5 MAC address configuration

Table 15. **Appli_CheckBdMacAddr**

Function	Description
Prototype	int Appli_CheckBdMacAddr(void)
Behaviour description	Checks MAC address validity
Input parameter	Void
Output parameter	MOBLEUINT8 sum return the sum calculated MAC

Table 16. **Appli_GetMACfromUniqueNumber**

Function	Description
Prototype	#ifdef INTERNAL_UNIQUE_NUMBER_MAC static void Appli_GetMACfromUniqueNumber(void)
Behaviour description	Reads the unique serial number of the device and generates the MAC address from it
Input parameter	Void
Output parameter	Void

5.7.6 BlueNRG-Mesh node configuration

The following tables list the available functions to configure the node to be used in the network.

Table 17. BluenrgMesh_InitUnprovisionedNode

Function	Description
Prototype	MOBLE_Result BluenrgMesh_InitUnprovisionedNode(void);
Behaviour Description	Initializes Unprovision Node
Input Parameter	void
Output Parameter	MOBLE RESULT status of Result

Table 18. BluenrgMesh_InitProvisionedNode

Function	Description
Prototype	MOBLE_Result BluenrgMesh_InitProvisionedNode(void);
Behaviour Description	Initializes Provision Node
Input Parameter	void
Output Parameter	MOBLE RESULT status of Result

Table 19. BluenrgMesh_GetUnprovisionState

Function	Description
Prototype	MOBLEUINT8 BluenrgMesh_GetUnprovisionState (void);
Behaviour Description	Get Provisioning process state
Input Parameter	void
Output Parameter	MOBLEUINT8

Table 20. BluenrgMesh_GetAddress

Function	Description
Prototype	MOBLE_ADDRESS BluenrgMesh_GetAddress (void);
Behaviour Description	Get mesh address of a node
Input Parameter	void
Output Parameter	Mesh address of a node

Table 21. BluenrgMesh_GetPublishAddress

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetTTL (MOBLEUINT8 ttl);
Behaviour Description	Get Publish address of a node
Input Parameter	void
Output Parameter	Mesh address of a node

Table 22. BluenrgMesh_GetSubscriptionAddress

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_GetSubscriptionAddress (MOBLE_ADDRESS *addressList, , MOBLEUINT8 *sizeOfList, MOBLEUINT8 elementNumber);
Behaviour Description	Get Subscription address of a node
Input Parameter	SubscriptionList, SizeofList, elementNumber
Output Parameter	MOBLE RESULT status of Result

Table 23. BluenrgMesh_SetTTL

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetTTL (MOBLEUINT8 ttl);
Behaviour Description	Set default TTL value
Input Parameter	MOBLEUINT8 ttl value
Output Parameter	MOBLE RESULT status of Result

Table 24. BluenrgMesh_GetTTL

Function	Description
Prototype	MOBLEUINT8 BluenrgMesh_GetTTL (void);
Behaviour Description	Get default TTL value
Input Parameter	void
Output Parameter	MOBLEUINT8 Default TTL value

Table 25. BluenrgMesh_GetTTL

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetNetworkTransmitCount (MOBLEUINT8 count);
Behaviour Description	Set Network Transmit Count value
Input Parameter	MOBLEUINT8 count, network transmit value. Supported values are 1-8
Output Parameter	MOBLE RESULT status of Result

Table 26. BluenrgMesh_GetNetworkTransmitCount

Function	Description
Prototype	MOBLEUINT8 BluenrgMesh_GetNetworkTransmitCount (void);
Behaviour Description	Get Network Transmit Count value
Input Parameter	void
Output Parameter	MOBLE RESULT status of Result

Table 27. BluenrgMesh_SetRelayRetransmitCount

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetRelayRetransmitCount (MOBLEUINT8 count);
Behaviour Description	Set Relay Retransmit Count value
Input Parameter	MOBLEUINT8 count Relay Retransmit value. Supported values are 1-8
Output Parameter	MOBLE RESULT status of Result

Table 28. BluenrgMesh_GetRelayRetransmitCount

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_GetRelayRetransmitCount (void);
Behaviour Description	Get Relay Retransmit Count value
Input Parameter	void
Output Parameter	MOBLE_RESULT Default Relay retransmit Count value

Table 29. BluenrgMesh_SetHeartbeatCallback

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetHeartbeatCallback (MOBLE_HEARTBEAT_CB cb);
Behaviour Description	Set callback for handling heartbeat messages
Input Parameter	MOBLE_HEARTBEAT_CB cb Callback
Output Parameter	MOBLE RESULT status of Result

Table 30. BluenrgMesh_SetAttentionTimerCallback

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetAttentionTimerCallback (MOBLE_ATTENTION_TIMER_CB cb);
Behaviour Description	Set callback for attention timer. To be used for attention during provisioning and for health model
Input Parameter	MOBLE_ATTENTION_TIMER_CB cb Callback
Output Parameter	MOBLE RESULT status of Result

5.7.7 BlueNRG-Mesh Library configuration

The following tables list the available functions to configure and initialize the ST BlueNRG-Mesh Library.

Table 31. BluenrgMesh_Init

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_Init (const Mesh_Initialization_t* pInit_params);

Function	Description
Behaviour Description	To initialize ST BlueNRG-Mesh Library
Input Parameter	Bdaddr, Features to be supported by library,Low power node,Friendship & Dynamic Buffer parameters
Output Parameter	MOBLE RESULT status of Result

Table 32. BluenrgMesh_GetLibraryVersion

Function	Description
Prototype	Char* BluenrgMesh_GetLibraryVersion (void);
Behaviour Description	To get the latest library version
Input Parameter	void
Output Parameter	string

Table 33. BluenrgMesh_GetLibrarySubVersion

Function	Description
Prototype	Char* BluenrgMesh_GetLibrarySubVersion (void);
Behaviour Description	To get the latest library sub version
Input Parameter	void
Output Parameter	string

Table 34. BluenrgMesh_Process

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_Process (void);
Behaviour Description	Mesh task processing function
Input Parameter	void
Output Parameter	MOBLE RESULT status of Result

Table 35. BluenrgMesh_SetRemoteData

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SetRemoteData (MOBLE_ADDRESS peer, MOBLEUINT8 command, MOBLEUINT8 const * data, MOBLEUINT32 length, MOBLEUINT8 response);
Behaviour Description	Set remote data on the given peer
Input Parameter	peer Destination address, vendor model commands, Data buffer, Length of data in bytes, response (If not '0', used to get the response. If '0', no response)
Output Parameter	MOBLE RESULT status of Result

Table 36. **BluenrgMesh_ReadRemoteData**

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_ReadRemoteData (MOBLE_ADDRESS peer, MOBLEUINT16 command);
Behaviour Description	Read remote data on the given peer
Input Parameter	peer Destination address, vendor model commands
Output Parameter	MOBLE RESULT status of Result

Table 37. **BluenrgMesh_SendResponse**

Function	Description
Prototype	MOBLE_RESULT BluenrgMesh_SendResponse (MOBLE_ADDRESS peer, MOBLEUINT8 status, MOBLEUINT8 const * data, MOBLEUINT32 length);
Behaviour Description	Send response on received packet
Input Parameter	peer Destination address, Status of response, Data buffer, Length of data in bytes
Output Parameter	MOBLE RESULT status of Result

A References

Table 38. References

Name	Title/description
Bluetooth specifications	Specification of the Bluetooth system (v4.0, v4.1, v4.2, v5.0)
Bluetooth specifications	Mesh profile specifications v1.0

B Licensing and other information

Developer-friendly license terms

The initial BlueNRG-Mesh is built over Motorola's Mesh Over Bluetooth Low Energy (MoBLE) technology.

The present solution involving both the Mesh library and applications is developed and maintained solely by STMicroelectronics.

Revision history

Table 39. Document revision history

Date	Revision	Changes
09-Feb-2018	1	Initial release
27-Sep-18	2	Updated Figure 5. Folders, sub-folders and contents of the package , Figure 9. Middleware folder, Figure 12. Overview, Section 4.2 Setting the transmit power of a node, Section 4.3 UART interface on the firmware, Table 3. MAC address management, Section 4.6 Initialization of application callbacks, Section 4.7 Initialization and main application loop, Section 5.1 Local and remote concept, Figure 17. Provisioning steps, Section 5.5 Write command from remote node, Section 5.6 Read command from a remote node, Section 5.7.1 User interface and indications, Table 10. Appli_BleSetTxPowerCb, Table 13. Vendor_WriteLocalDataCb, Table 14. Vendor_ReadLocalDataCb and Table 16. Appli_GetMACfromUniqueNumber. Added Section 5.7.6 BlueNRG-Mesh node configuration and Section 5.7.7 BlueNRG-Mesh Library configuration

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- **Acronyms and abbreviations**

Table 40. **Acronyms and abbreviations**

Acronym	Description
API	Application programming interface
BLE	Bluetooth Low Energy
BSP	Board support package
DFU	Device firmware upgrade
GUI	Graphical user interface
HAL	Hardware abstraction layer
HW	Hardware
IDE	Integrated development environment
LED	Light emitting diode
MCU	Microcontroller unit
MoBLE	Mesh over Bluetooth Low Energy
SoC	System-on-chip
USB	Universal serial bus

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