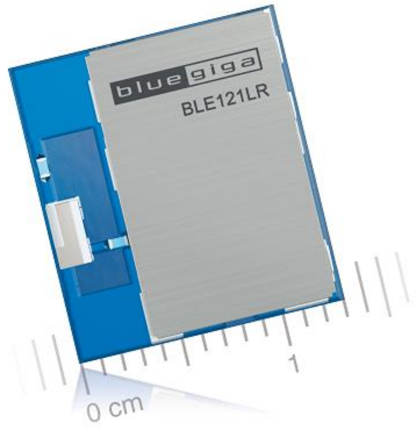
Developing Long Range *Bluetooth*® Smart Devices

Topics

- Bluegiga BLE121LR *Bluetooth* Smart Long Range Module
- Bluegiga *Bluetooth* Smart Software
- Hardware Design with BLE121LR
- Developing a long range iBeacon with Bluegiga *Bluetooth* Smart Software
- iOS and Android Device Consideratons
- More Information
- Questions and Answers

BLE121LR Key Features



- ***Bluetooth* v.4.0, single mode compliant**
  - Supports master and slave modes
  - Up to 8 connections
- **Integrated *Bluetooth* Smart stack**
  - GAP, GATT, L2CAP and SMP
  - *Bluetooth* Smart profiles
- **Radio Performance**

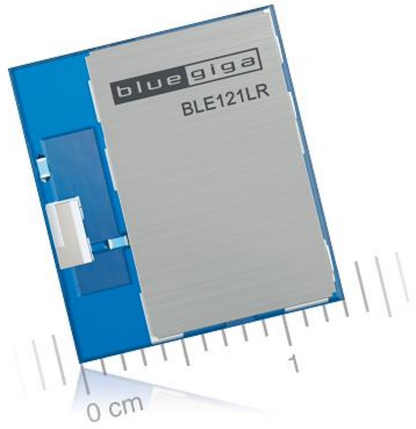
Transmit power :	+8 dBm
Receiver sensitivity:	-98 dBm

- **Low Current Consumption**

Transmit:	36 mA
Transmit:	25 mA (with DC/DC)
Sleep mode 3:	0.5 uA

- **Flexible Peripheral Interfaces**
  - UART, SPI and I2C serial interfaces
  - PWM, GPIO
  - 12-bit ADC
- **Host Interfaces**
  - UART
- **Host Interfaces**
  - 14.7 x 13.0 x 1.8 mm
- **Programmable 8051 processor for stand-alone operation**
- ***Bluetooth*, CE, FCC, IC, South-Korea and Japan qualified**

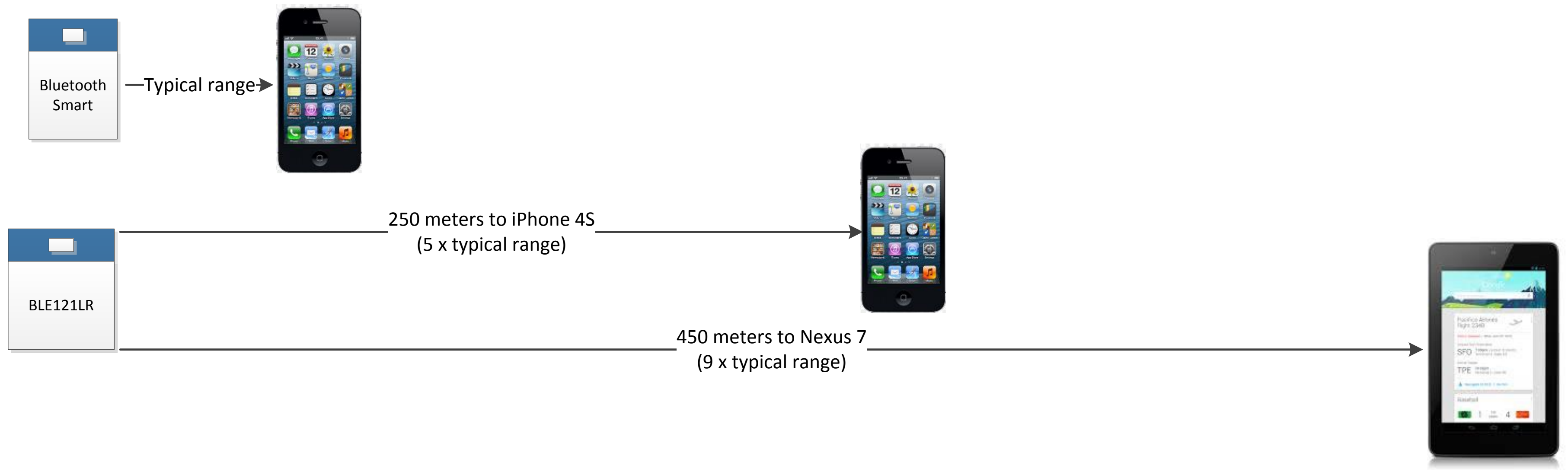
BLE121LR Benefits



- **World Leading Radio Performance**
  - +8dBm TX power and -98 dBm sensitivity
  - 5-10 x range compared to conventional *Bluetooth* Smart solutions
- **Application Hosting Capability**
  - Application code can be executed on the BLE121LR
  - No need for a separate micro controller
  - Programmable with Bluegiga BGScript™ or C
- **Flash Based**
  - On-the-Field firmware updates over UART or OTA
  - Application data can be stored on the flash
- ***Bluetooth*, CE, FCC, IC, Japan and Korea Qualifications**
  - Minimal qualification costs
  - Proven interoperability

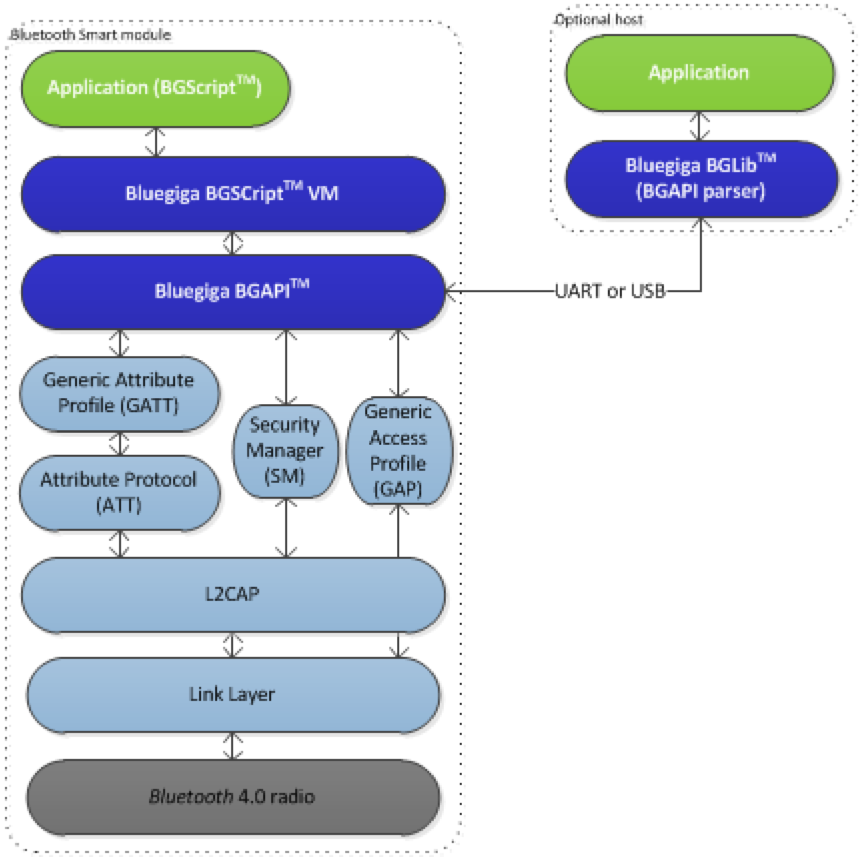
Range

- **World Leading Radio Performance**
  - 5-10 x range compared to conventional *Bluetooth* Smart solutions



Bluetooth Smart Software

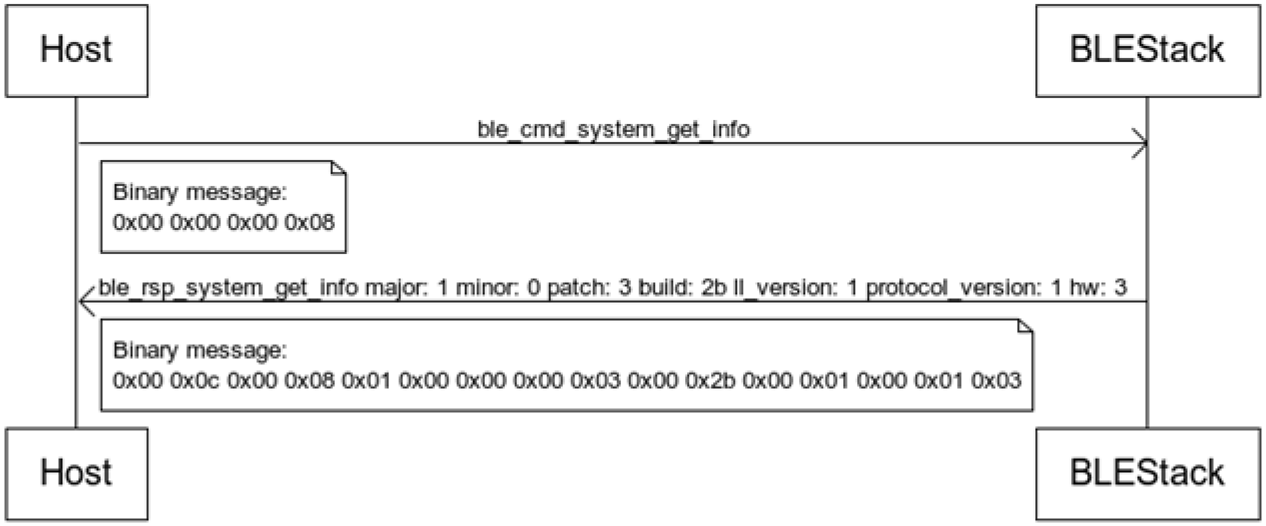
- ***Bluetooth* v.4.0, Single Mode Compliant**
  - Supports master and slave modes
  - Up to 8 simultaneous connections
- **Implements all *Bluetooth* Smart Functionality**
  - GAP, L2CAP, ATT, GATT
  - Security manager: bonding, encryption
  - *Bluetooth* Smart profiles
- **Simple API for External Host Processors**
  - BGAPI™ : A simple protocol over UART or USB interfaces
  - BGLib™ : A C library for host processors implementing BGAPI
- **Supports Integrated Applications**
  - BGScript™ : A simple scripting language for writing applications
  - Native C application development with IAR Embedded Workbench
  - No separate host needed
- **DFU and OTA Firmware Upgrade Support**
- **Blutoooth Smart Profile Toolkit™**
  - XML based development tool for Bluetooth Smat profiles
  - Fast and simple profile development
- **Small Memory Requirements**
  - ~4-6 kB RAM
  - ~60-90 kB flash (depending of used features/profiles)
- ***Bluetooth* Qualified**



Bluegiga *Bluetooth*® Smart Software

Bluetooth Smart Software

- **BGAPI™ protocol** : A simple binary command, response and event protocol between the host and the stack
  - Used when a separate host (MCU) is used to control BLE121LR over UART
  - Very small memory requirements size requirement and low implementation overhead

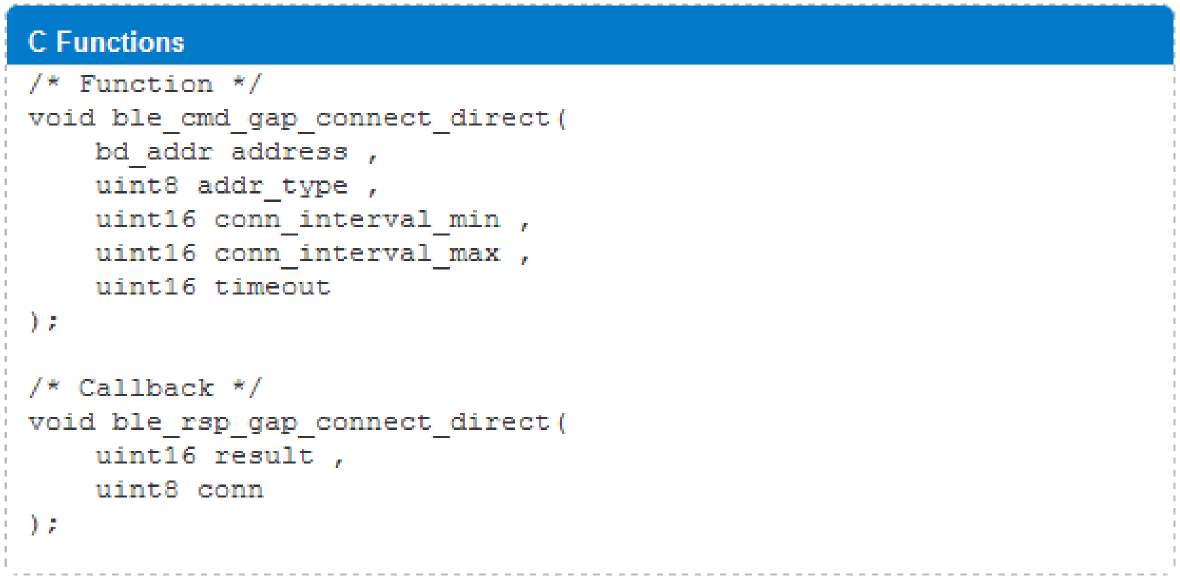

Host
BLEStack
ble_cmd_system_get_info
ble_rsp_system_get_info major: 1 minor: 0 patch: 3 build: 2b ll_version: 1 protocol_version: 1 hw: 3
Host
BLEStack

Binary message:
0x00 0x00 0x00 0x08

Binary message:
0x00 0x0c 0x00 0x08 0x01 0x00 0x00 0x00 0x03 0x00 0x2b 0x00 0x01 0x00 0x01 0x03

Bluetooth Smart Software

- **BGLib™ library** : A portable ANSI C library, which implements the BGAPI protocol
  - Easy to port to various architectures such as : ARM Cortex, PIC16/32 etc.
  - Ported to multiple programming languages : ANSI C, Java, Python and C#
  - Uses fuction–call back architecture

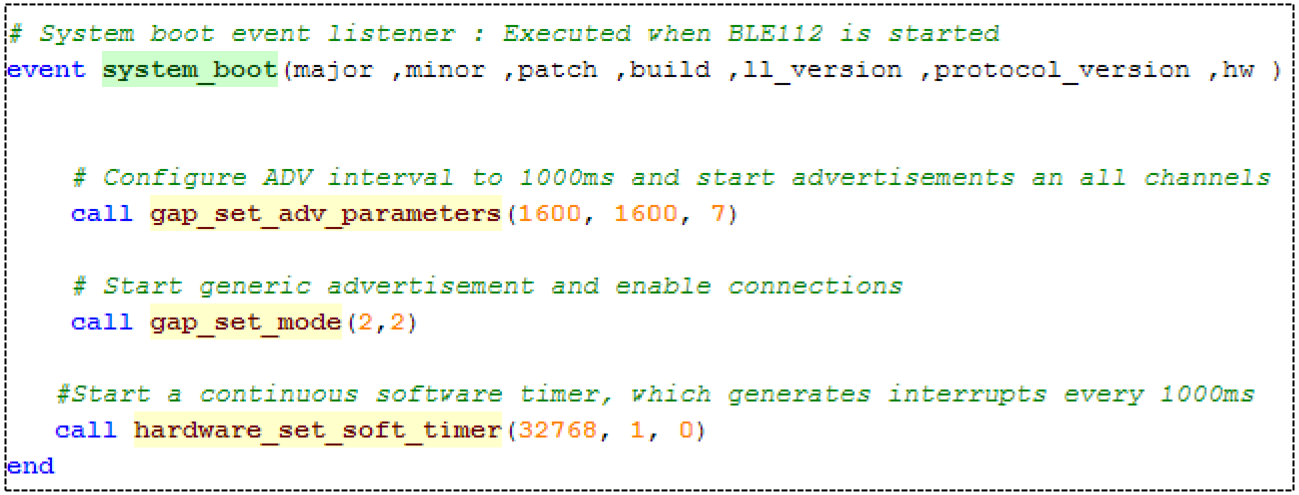


C Functions

```
/* Function */
void ble_cmd_gap_connect_direct(
    bd_addr address ,
    uint8 addr_type ,
    uint16 conn_interval_min ,
    uint16 conn_interval_max ,
    uint16 timeout
);

/* Callback */
void ble_rsp_gap_connect_direct(
    uint16 result ,
    uint8 conn
);
```

Bluetooth Smart Software

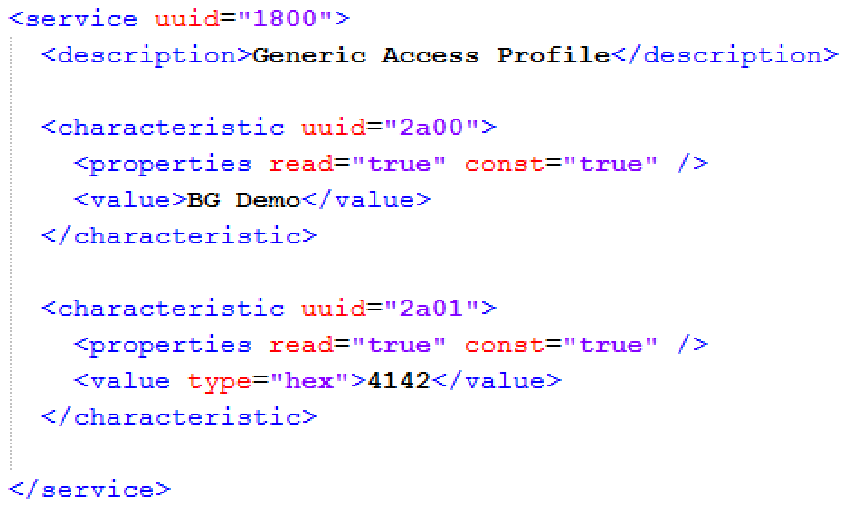
- **BGScript^{TM} scripting language** : A very simple BASIC-like application scripting language
  - Used when applications are implemented on the BLE121LR's 8051 controller
  - Enables very fast application development and allows programs to be executed directly on the BLE121LR without the need of an external MCU



```
# System boot event listener : Executed when BLE112 is started
event system_boot(major ,minor ,patch ,build ,ll_version ,protocol_version ,hw )


    # Configure ADV interval to 1000ms and start advertisements an all channels
    call gap_set_adv_parameters(1600, 1600, 7)

    # Start generic advertisement and enable connections
    call gap_set_mode(2,2)

   #Start a continuous software timer, which generates interrupts every 1000ms
   call hardware_set_soft_timer(32768, 1, 0)
end
```

Bluetooth Smart Software

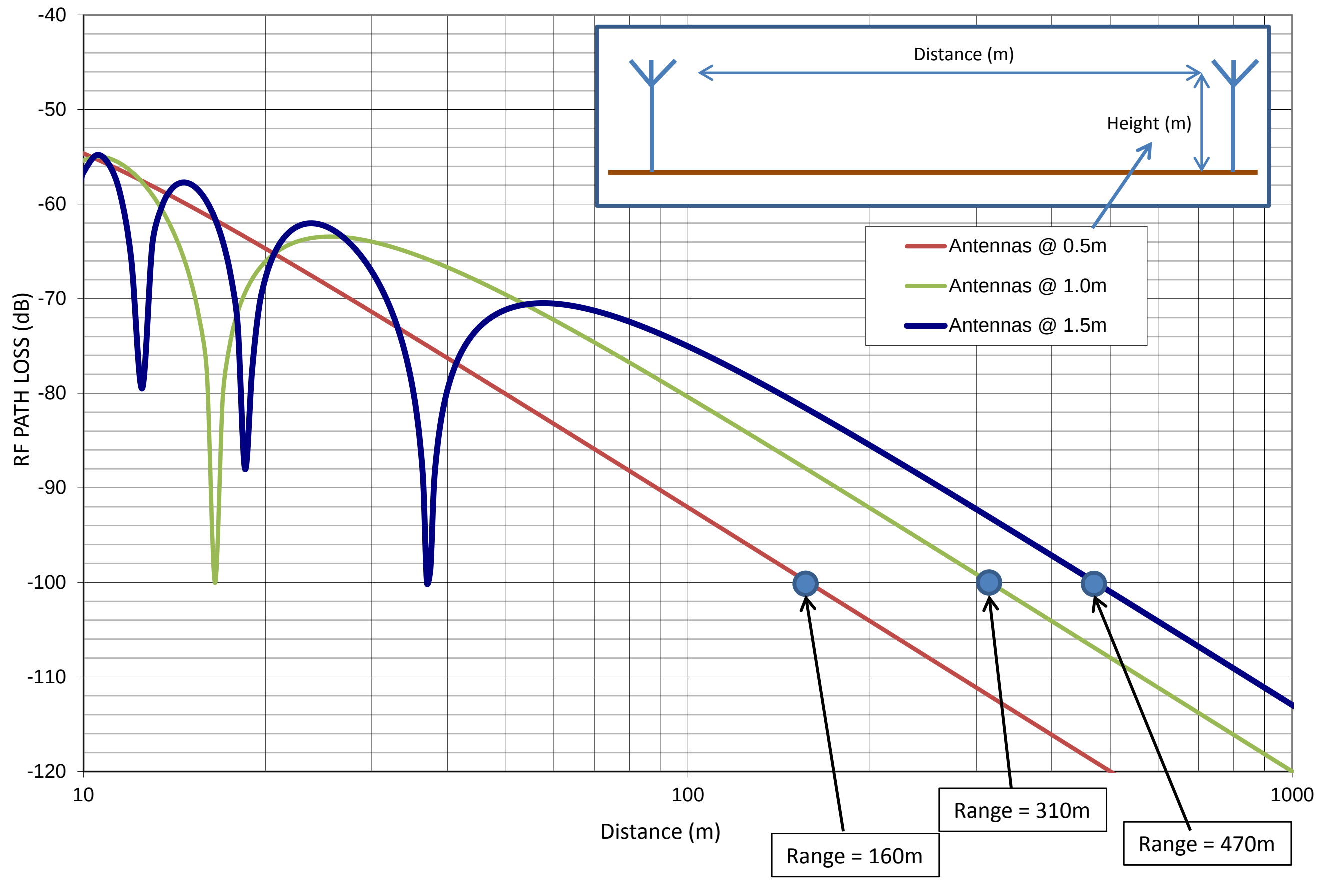
- ***Bluetooth* Smart Profile Toolkit™**: A tool for creating *Bluetooth* Smart profiles
  - *Bluetooth* Smart profiles are very simple
  - Can be describes with a single file of XML
  - Profile toolkit is a Simple XML description template for *Bluetooth* Smart Profiles
- **Several example profiles and services available**
  - Heart Rate transmitter
  - Proximity reporter
  - Blood glucose sensor
  - iBeacon
  - etc.



```xml
<service uuid="1800">
  <description>Generic Access Profile</description>

  <characteristic uuid="2a00">
    <properties read="true" const="true" />
    <value>BG Demo</value>
  </characteristic>

  <characteristic uuid="2a01">
    <properties read="true" const="true" />
    <value type="hex">4142</value>
  </characteristic>

</service>
```

RF Signal Propagation

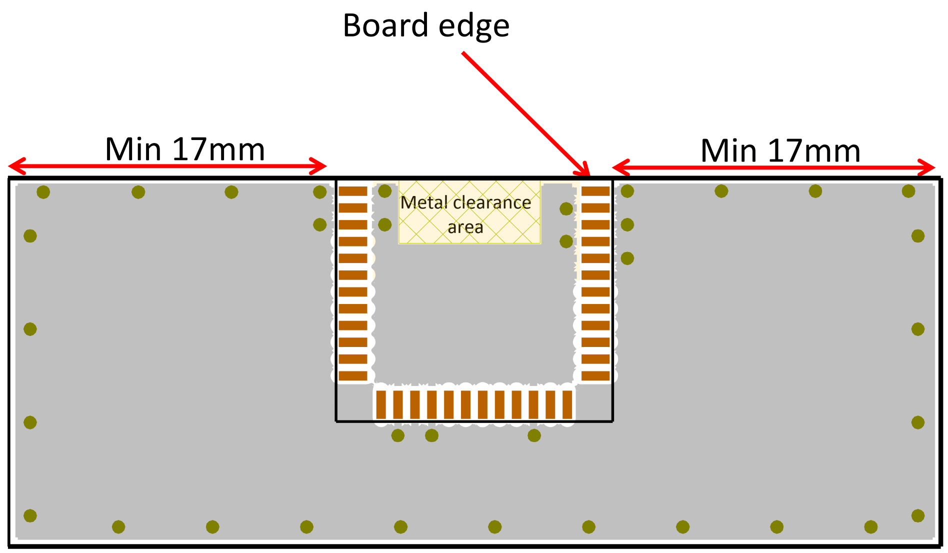
- RF signal will attenuate as the distance increases
- The distance of the (transmitter or receiver) from the ground significantly affects the range as can be seen from the chart below



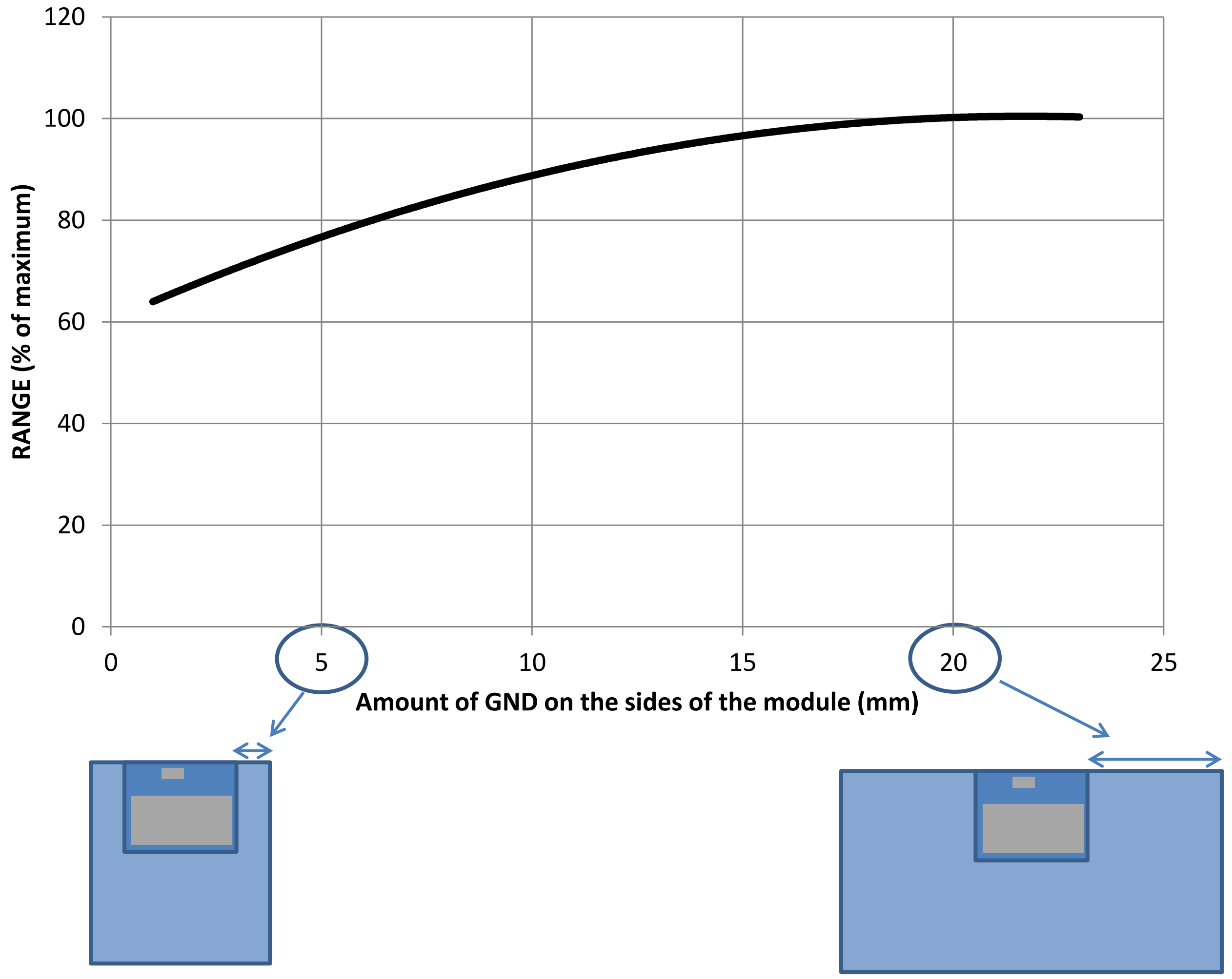
PCB Design Tips

BLE121LR-A Layout Guide

- For optimal performance of the antenna place the module at the edge of the PCB.
- Do not place any metal (traces, components, battery etc.) within the clearance area of the antenna.
- Connect all the GND pins directly to a solid GND plane.
- Place the GND vias as close to the GND pins as possible.
- Do not place plastic or any other dielectric material in touch with the antenna.



Ground vs. Antenna Performance



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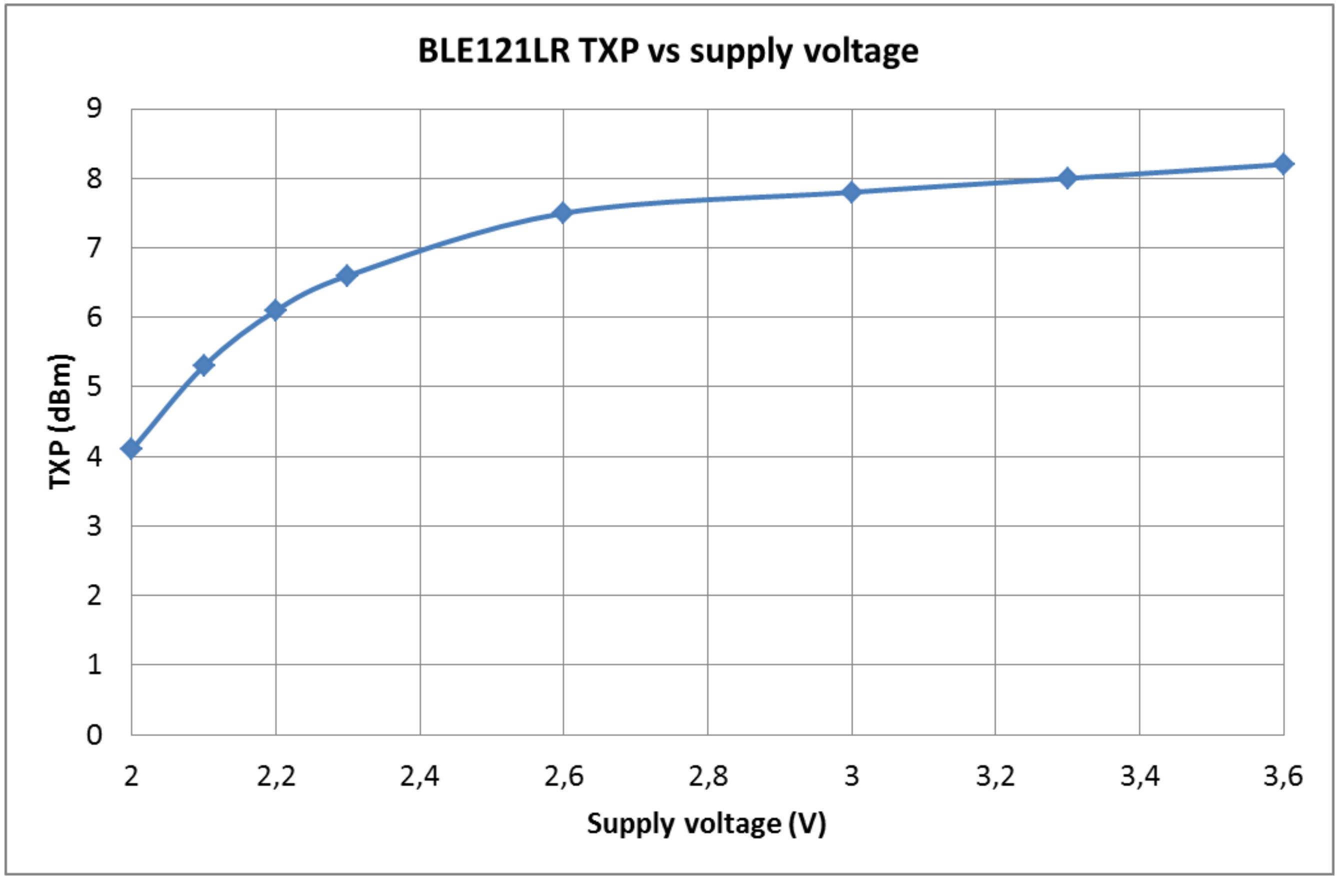
Supply Voltage



What are Beacons?

iBeacon is Apple's implementation of Bluetooth Smart technology to create a way of providing location-based information and services to iPhones and other iOS devices.

The beacons are small Bluetooth Smart transmitters. Apps installed the phone can listen out for the signal transmitted by the beacons and respond accordingly when in range.

Beacons can be used to provide users with location for example is a shopping mall or present notifications for example about items in sale.

Region monitoring

- Enables iOS devie to detect if it enters or exits a specific region. iOS will notify the app if such an event occurs even if the app is in the background or locked.
- A notification can be presented as well even if the app is closed

Ranging

- When the App is active ranging can be used to detect and show all discovered iBeacons
- A distance estimation can also be made

Implementing iBeacon with Bluegiga *Bluetooth* Smart Software

iBeacons are so simple devices that they are trivial to implement with BGScript scripting language and therefore it is used in this example.

This example implements an iBeacon with the following functionality:

- iBeacon functionality as defined by the Apple's specification
- OTA firmware update

Project steps:

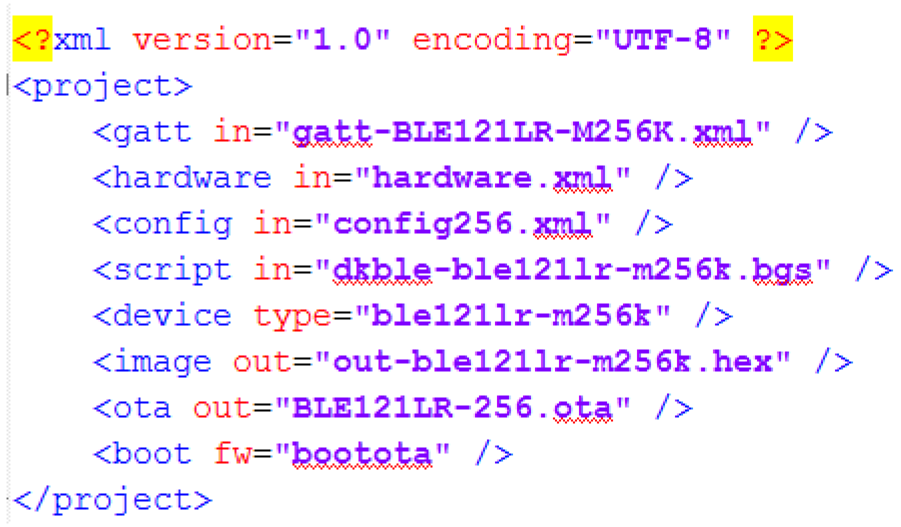
1. **Project configuration –** defines the project resources

2. **Hardware and application configuration** – defines the hardware and application properties

3. **GATT database** – defines the services and data exposed by the iBeacon

4. **BGScript code** – implementes the application functionality

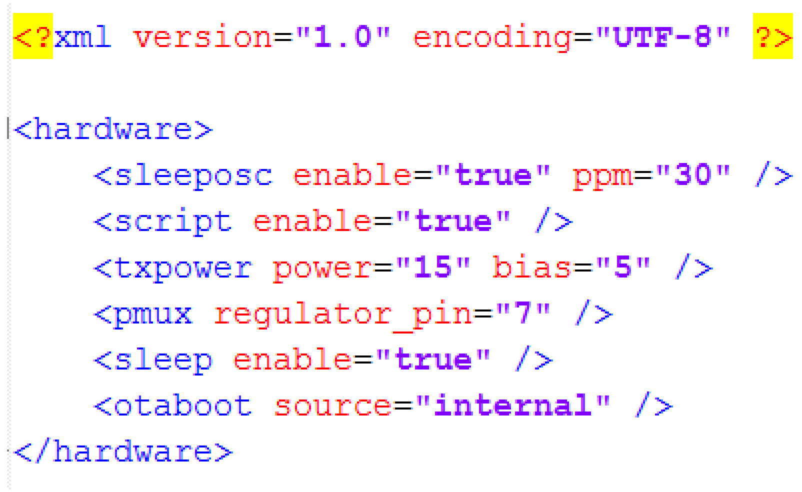
Project settings



```xml
<?xml version="1.0" encoding="UTF-8" ?>
<project>
    <gatt in="gatt-BLE121LR-M256K.xml" />
    <hardware in="hardware.xml" />
    <config in="config256.xml" />
    <script in="dkble-ble121lr-m256k.bgs" />
    <device type="ble121lr-m256k" />
    <image out="out-ble121lr-m256k.hex" />
    <ota out="BLE121LR-256.ota" />
    <boot fw="bootota" />
</project>
```

GATT:	The GATT database file
Hardware:	The hardware configuration file
Config:	The Application configuration file
Script:	The BGScript code
Device:	Bluegiga Bluetooth Module Type
Image:	Firmware output file
Ota	OTA firmware output image
Boot:	Firmware update (DFU) interface

Hardware settings



```
<?xml version="1.0" encoding="UTF-8" ?>

<hardware>
    <sleeposc enable="true" ppm="30" />
    <script enable="true" />
    <txpower power="15" bias="5" />
    <pmux regulator_pin="7" />
    <sleep enable="true" />
    <otaboot source="internal" />
</hardware>
```

– Sleeposc:	Sleep clock is enabled
– Script:	BGScripting is enabled
– TX power:	TX power set to maximum value
– pmux:	External DC/DC converter enalbed
– sleep:	Power saving modes are enabled
– otaboot:	Internal flash used for OTA firmware update
– Boot:	Firmware update (DFU) interface

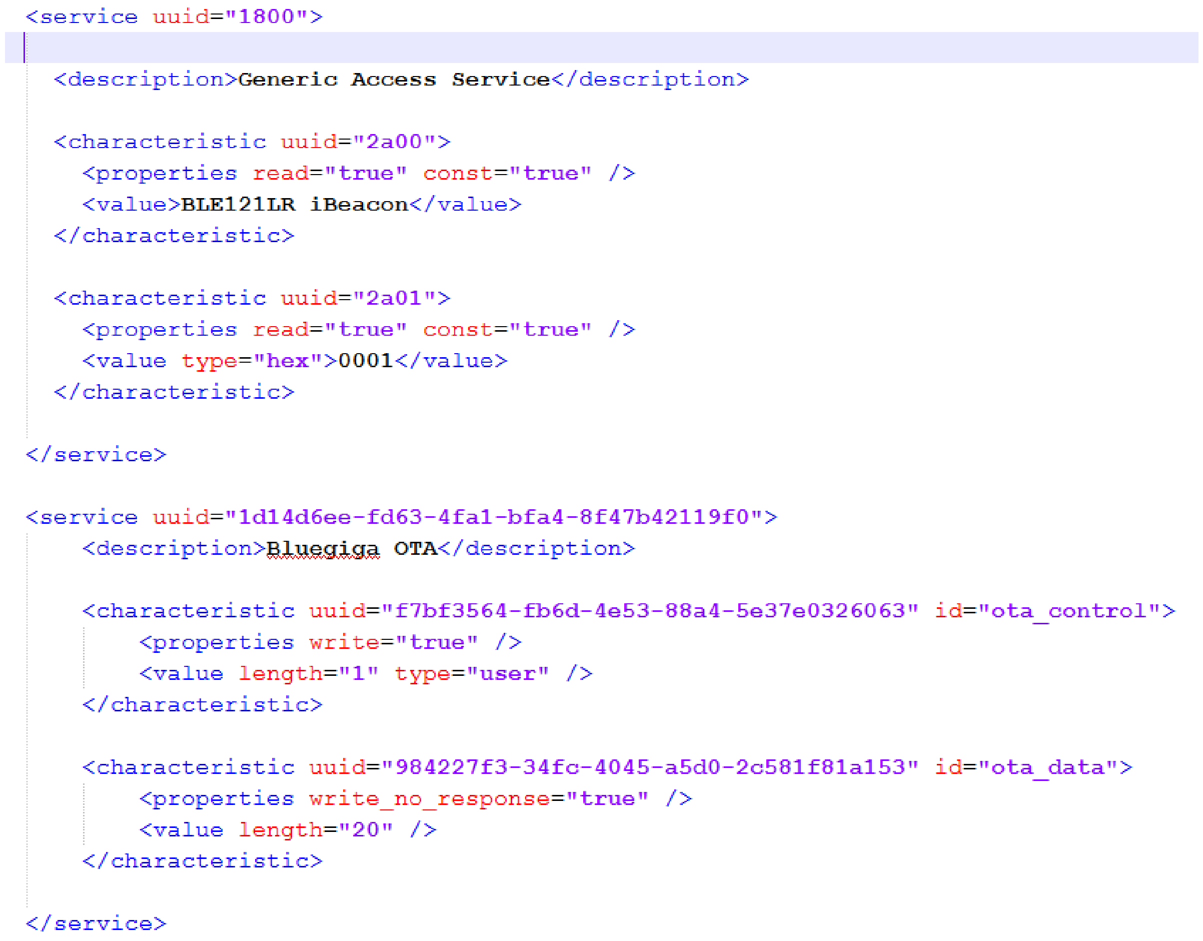
The GATT database

The GAP service:

- UUID: 0x1800
- Device name characteristic
  - UUID: 0x2a00
  - Read property
- Device Type characteristic
  - UUID: 0x2a01
  - Read property

The OTA service:

- UUID: 128-bit UUID
- OTA control characteristic
  - UUID: 128-bit UUID
  - Write property
  - 1 byte
- OTA data characteristic
  - UUID: 128-bit UUID
  - Write property
  - 20 bytes

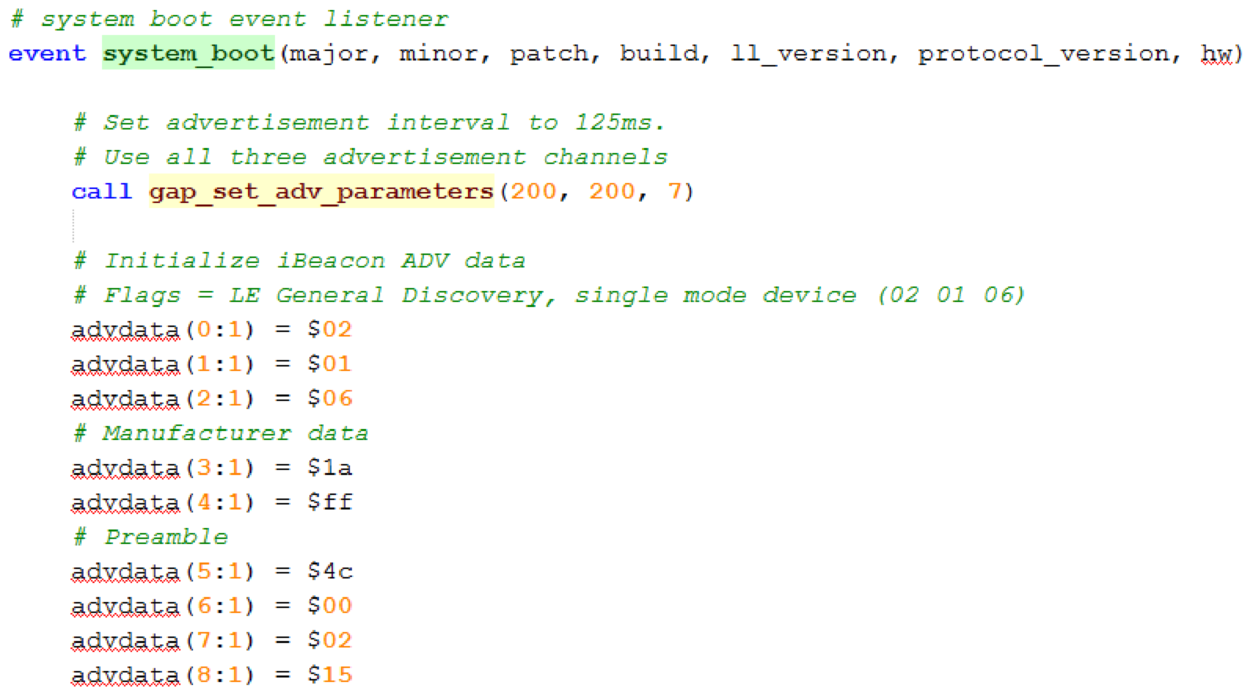


```
<service uuid="1800">

  <description>Generic Access Service</description>

  <characteristic uuid="2a00">
    <properties read="true" const="true" />
    <value>BLE121LR iBeacon</value>
  </characteristic>

  <characteristic uuid="2a01">
    <properties read="true" const="true" />
    <value type="hex">0001</value>
  </characteristic>

</service>

<service uuid="1d14d6ee-fd63-4fa1-bfa4-8f47b42119f0">
    <description>Bluegiga OTA</description>

    <characteristic uuid="f7bf3564-fb6d-4e53-88a4-5e37e0326063" id="ota_control">
        <properties write="true" />
        <value length="1" type="user" />
    </characteristic>

    <characteristic uuid="984227f3-34fc-4045-a5d0-2c581f81a153" id="ota_data">
        <properties write_no_response="true" />
        <value length="20" />
    </characteristic>

</service>
```

The BGScript Code

System Boot event is executed on start-up

- Sets advertisement parameters
- Initializes iBeacon advertisement data
- Starts advertisement



```
# system boot event listener
event system_boot(major, minor, patch, build, ll_version, protocol_version, hw)

    # Set advertisement interval to 125ms.
    # Use all three advertisement channels
    call gap_set_adv_parameters(200, 200, 7)

    # Initialize iBeacon ADV data
    # Flags = LE General Discovery, single mode device (02 01 06)
    advdata(0:1) = $02
    advdata(1:1) = $01
    advdata(2:1) = $06
    # Manufacturer data
    advdata(3:1) = $1a
    advdata(4:1) = $ff
    # Preamble
    advdata(5:1) = $4c
    advdata(6:1) = $00
    advdata(7:1) = $02
    advdata(8:1) = $15
```

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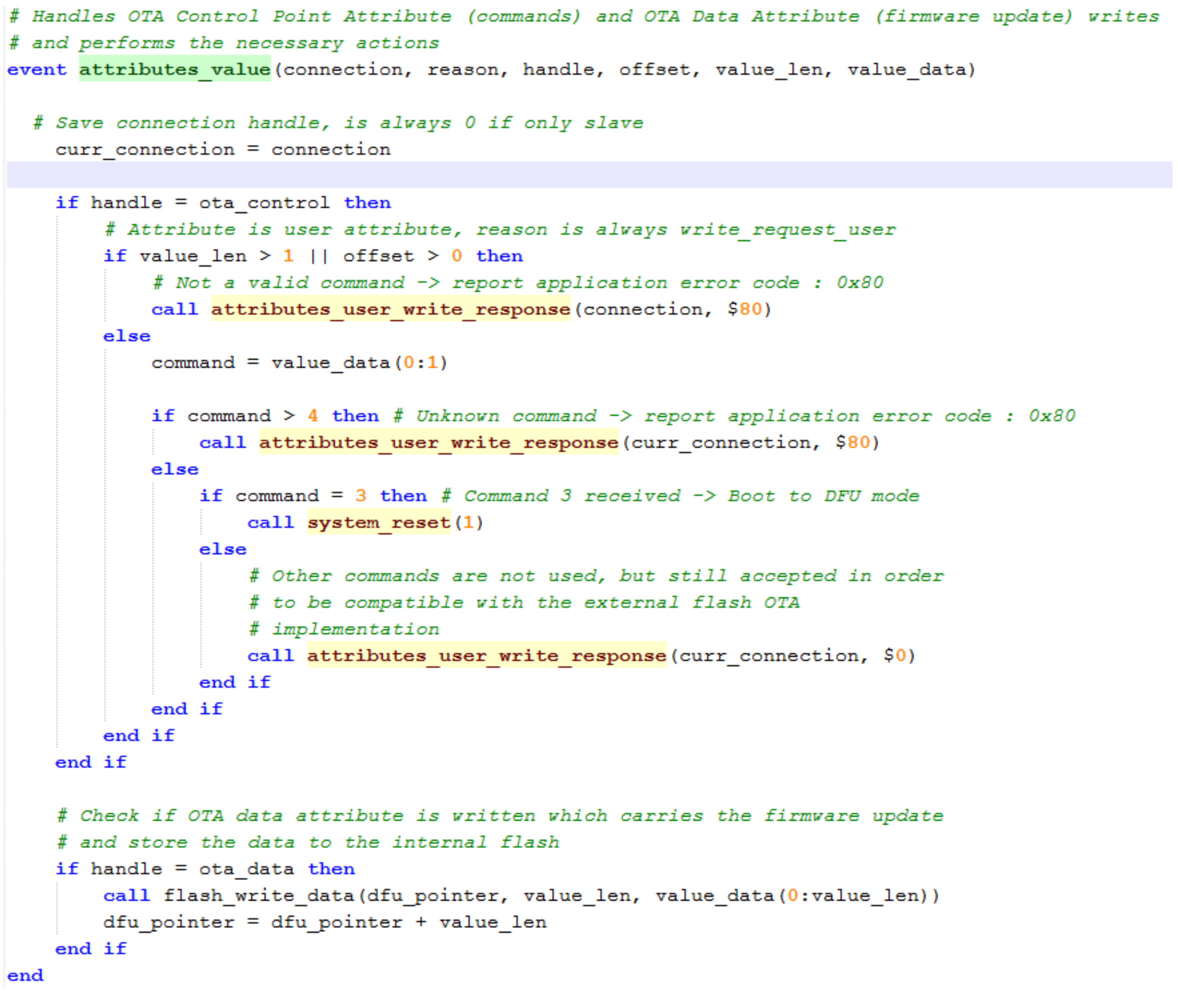
The BGScript Code

OTA update -

- If ***OTA control*** or ***OTA Data*** attributes are written by the remote device
- ***OTA control*** characteristic is used to control the OTA process
- ***OTA data*** characteristic carries the firmware update
  - When data is received, it's stored to the internal flash and DFU pointer increased



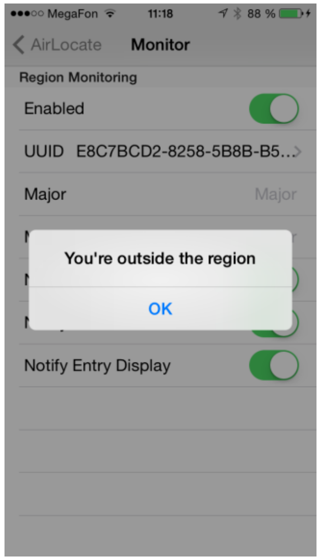
```
# Handles OTA Control Point Attribute (commands) and OTA Data Attribute (firmware update) writes
# and performs the necessary actions
event attributes_value(connection, reason, handle, offset, value_len, value_data)

  # Save connection handle, is always 0 if only slave
    curr_connection = connection

    if handle = ota_control then
        # Attribute is user attribute, reason is always write_request_user
        if value_len > 1 || offset > 0 then
            # Not a valid command -> report application error code : 0x80
            call attributes_user_write_response(connection, $80)
        else
            command = value_data(0:1)

            if command > 4 then # Unknown command -> report application error code : 0x80
                call attributes_user_write_response(curr_connection, $80)
            else
                if command = 3 then # Command 3 received -> Boot to DFU mode
                    call system_reset(1)
                else
                    # Other commands are not used, but still accepted in order
                    # to be compatible with the external flash OTA
                    # implementation
                    call attributes_user_write_response(curr_connection, $0)
                end if
            end if
        end if
    end if

    # Check if OTA data attribute is written which carries the firmware update
    # and store the data to the internal flash
    if handle = ota_data then
        call flash_write_data(dfu_pointer, value_len, value_data(0:value_len))
        dfu_pointer = dfu_pointer + value_len
    end if
end
```

Testing the Application

The application can be tested for example on the DKBLE *Bluetooth* Smart Development kit

Apple App Store has multiple applications for testing iBeacon functionality and ***Beacon Region*** and ***Beacon Ranging*** functionality:

- BLExplr
- Locate Beacon



Region Monitoring

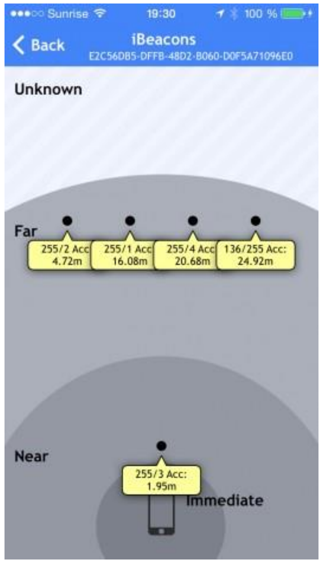
Enabled

UUID E8C7BCD2-8258-5B8B-B5...

Major Major

You're outside the region

Notify Entry Display

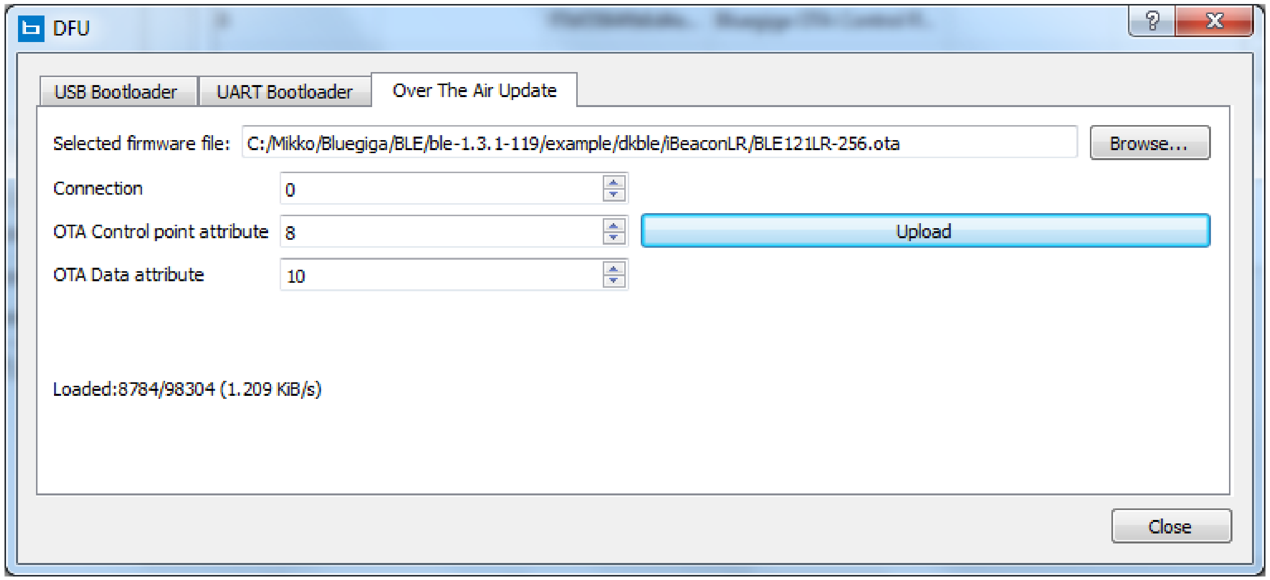


Testing the Application

OTA Update can for example be tested with the BLEGUI Windows application included in the Bluegiga Bluetooth Smart Software.

The development kits include a BLED112 USB dongle that can be used as the hardware

BLExplr application also includes OTA update functionality



Selected firmware file: C:/Mikko/Bluegiga/BLE/ble-1.3.1-119/example/dkble/iBeaconLR/BLE121LR-256.ota

Connection 0

OTA Control point attribute 8

OTA Data attribute 10

```
Loaded:8784/98304 (1.209 KiB/s)
```

iOS Device Considerations

- iOS can operate as central and peripheral
- Advertise the service UUIDs in advertisement packet
  - The iOS App can filter devices based on UUIDs
- Minimum connection interval ~20ms
  - When App is put to background the connection interval might be increased
- iOS devices cache services
  - Implement the generic GATT service and iOS will refresh services on every connection

iOS Device Considerations

- Need xCode developer license and OSX developer tools
  - Available at the Apple's developer site
- MFI
  - You do not need to be part of MFI in order to develop *Bluetooth* Smart Apps for iOS
- Bluegiga example iOS App available
  - Download from www.bluegiga.com
  - Available in source code

Android Device Considerations

- *Bluetooth* Smart APIs available since 4.3
  - In API level 18
- Currentle supported devices: Nexus 4, 6, 7 and 9. Multiple devices from other vendors as well
- Android only supports central mode (master)
- Backgroud applications supported
- Android supports secure connections and insecure connections
- Note: Bluetooth Smart implementation is not very robust in 4.3 – multiple improvements in 4.4 and Android 5.

Android Device Considerations

- You need Android Development Kit (ADK)
  - Available on Android developer web site
  - Free-of-Charge
- You need the latest API level 18 access
- Bluegiga example Android App available
  - Download from www.bluegiga.com
  - Available in source code and as APK

More Information

- Bluegiga BLE Software and SDK, Example Applications, Documents and Smart Phone examples
  - Documentation and Downloads

- *Bluetooth* Smart SDK v.1.2 Introduction
  - Presentation

- Over-the-Air Firmware Update
  - Application Note

- iBeacons example and discussion
  - Example: Bluegiga Forums
  - Discussion: Bluegiga Forums

More Information

- Bluegiga
  - www.bluegiga.com
  - www.bluegiga.com/support

- *Bluetooth* SIG
  - www.bluetooth.org
  - www.bluetooth.com
  - http://developer.bluetooth.org

- iOS Development
  - iOS Dev Center

- Android Development
  - Android Developers

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  - www.bluetooth.com
  - http://developer.bluetooth.org
- iOS Development
  - iOS Dev Center
- Android Development
  - Android Developers

Thank You