BLUETOOTH SMART

GETTING STARTED

Saturday, 8 June 2013

Version 1.5

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1 Introduction

This document is meant to provide a short introduction to *Bluetooth* Smart technology and to Bluegiga's *Bluetooth* Smart products. The purpose of this document is not to give a deep technology or product overview, but should act more as an introduction to both of them and give the necessary information to continue studying.

The document is organized into two sections. Firstly a quick introduction to *Bluetooth* Smart technology is given and then the Bluegiga's *Bluetooth* Smart product family is discussed.

2 What is Bluetooth Smart

Bluetooth low energy (*Bluetooth* 4.0) is a new, open standard developed by the *Bluetooth* SIG. It's targeted to address the needs of new modern wireless applications such as ultra-low power consumption, fast connection times, reliability and security. *Bluetooth* low energy consumes 10-20 times less power and is able to transmit data 50 times quicker than classical *Bluetooth* solutions.

Link: How Bluetooth low energy technology works?

Bluetooth low energy is designed for new emerging applications and markets, but it still embraces the very same benefits we already know from the classical, well established *Bluetooth* technology:

- **Robustness and reliability** - The adaptive frequency hopping technology used by *Bluetooth* low energy allows the device to quickly hop within a wide frequency band, not just to reduce interference but also to identify crowded frequencies and avoid them. On addition to broadcasting *Bluetooth* low energy also provides a reliable, connection oriented way of transmitting data.

- **Security** - Data privacy and integrity is always a concern is wireless, mission critical applications. Therefore *Bluetooth* low energy technology is designed to incorporate high level of security including authentication, authorization, encryption and man-in-the-middle protection.

- **Interoperability** - *Bluetooth* low energy technology is an open standard maintained and developed by the *Bluetooth* SIG. Strong qualification and interoperability testing processes are included in the development of technology so that wireless device manufacturers can enjoy the benefit of many solution providers and consumers can feel confident that equipment will communicate with other devices regardless of manufacturer.

- **Global availability** - Based on the open, license free 2.4GHz frequency band, *Bluetooth* low energy technology can be used in world wide applications.

There are two types of *Bluetooth* low energy devices:

- ***Bluetooth* Smart** devices that only support *Bluetooth* low energy and are optimized for low-power, low-cost and small size solutions.

- ***Bluetooth* Smart Ready devices** that support *Bluetooth* low energy and classical *Bluetooth* technologies and are interoperable with all the previously *Bluetooth* specification versions.

Key features of *Bluetooth* low energy wireless technology include:

- Ultra-low peak, average and idle mode power consumption
- Ability to run for years on standard, coin-cell batteries
- Low cost
- Multi-vendor interoperability
- Enhanced range

Bluetooth low energy is also meant for markets and applications, such as:

- Automotive
- Consumer electronics
- Smart energy
- Entertainment
- Home automation
- Security & proximity
- Sports & fitness

2.1 Classic Bluetooth vs. Bluetooth low energy

The table below shows a high level comparison between classic *Bluetooth (also known as Bluetooth* BR/EDR) and *Bluetooth* low energy technologies.

Technical specification	Classic *Bluetooth* technology	*Bluetooth* low energy technology
Radio frequency	2.4GHz	2.4GHz
Distance/Range	~10-100 meters	~10-100 meters
Symbol rate	1-3Mbps	1Mbps
Application throughput	0.9 – 2.1Mbps	0 - 250 kbps
Nodes/Active slaves	7	Theoretically unlimited
Security	56 to 128 bit	128-bit AES
Robustness	FHSS	FHSS
Latency (from not connected state to send data)	100+ ms	as low as 6ms
Government regulation	Worldwide	Worldwide
Certification body	Bluetooth SIG	Bluetooth SIG
Voice capable	Yes	No
Network topology	Point-to-point, scatternet	Point-to-point, star
Power consumption	1 (reference value)	0.01 to 0.5 (use case dependent)
Service discover	Yes	Yes
Profile concept	Yes	Yes
Primary use cases	Mobile phones, headsets, stereo audio, automotive, PCs etc.	Mobile phones, gaming, PCs, sport & fitness, medical, automotive, industrial, automation, home electronics etc.
Profiles	Serial Port, Hands-Free, OBEX, A2DP etc.	Proximity profile, Battery status, Weight scale, Heart rate monitor, Humidity etc.

2.2 Backwards compatibility

Bluetooth 4.0 single mode (*Bluetooth* Smart) devices are not inter-operable with classic *Bluetooth* devices such as *Bluetooth* 2.1 + EDR devices. Single mode devices are only compliant with other *Bluetooth* 4.0 devices.

The *Bluetooth 4.0 dual mode (Bluetooth* Smart Ready) devices on the other hand are backwards compatible and can be connected to all other *Bluetooth* devices, even those supporting the very old 1.0 standard. The dual mode devices typically are mobile phones and PCs which are not as power constrained as the single mode devices and need to support uses cases like hands-free or stereo headset connectivity.

If specification versions are used, then all *Bluetooth* v.4.0 are inter-operable with each other, but NOT all *Bluetooth* v.4.0 devices are inter-operable with older specification versions.

2.3 Bluetooth Smart branding

Bluetooth Smart Ready devices are the most effective way to connect to billions of *Bluetooth* devices in the market today, and the over 5 million *Bluetooth* enabled devices commercialized every single day. Examples include phones, tablets, PCs, TVs, even set-top boxes and game consoles that sit at the center of the consumers' connected world. These devices efficiently receive data sent from Classic *Bluetooth* devices and *Bluetooth*Smart devices and feed it into applications that turn data into useful information. These are the hub devices of the *Bluetooth* ecosystem. [Source : Bluetooth SIG]

To bear *Bluetooth* Smart Ready mark, a device must meet three criteria:

- Be built to *Bluetooth* v4.0 specifications with GATT-based architecture
- Feature a dual-mode low energy radio
- Allow consumers to update the device software

Bluetooth Smart devices are designed to gather a specific type of information – are all the windows on my house locked, what is my blood glucose level, how much do I weigh today? – and send it to a *Bluetooth* Smart Ready device. Examples include heart-rate monitors, blood-glucose meters, smart watches, window and door security sensors, car key fobs, and blood-pressure cuffs – the opportunities are endless. [Source : Bluetooth SIG]

To bear the *Bluetooth* Smart mark, the device must meet these three criteria:

- Be built to *Bluetooth* v4.0 specifications with GATT-based architecture
- Feature a single-mode low energy radio
- Use the GATT-based architecture to enable particular functionality of the device

Compatibility

If your product bears this logo...	It's compatible with products bearing any of these logos...		
Bluetooth® SMART READY	**Bluetooth®** SMART READY	**Bluetooth®**	**Bluetooth®** SMART
Bluetooth®	**Bluetooth®** SMART READY	**Bluetooth®**	
Bluetooth® SMART	**Bluetooth®** SMART READY		

More information:

- https://www.bluetooth.org/apps/content/default.aspx?doc_id=242825

2.4 More information

Want to learn more about *Bluetooth* low energy technology? Please have a look at the following material and links:

How it works (video):

- http://www.youtube.com/watch?v=r6Re7-kIdhs

***Bluetooth* specifications:**

- https://www.bluetooth.org/Technical/Specifications/adopted.htm

***Bluetooth* developer web site**

- http://developer.bluetooth.org/

***Bluetooth SIG's Bluetooth* low energy web sites:**

- https://www.bluetooth.org/Events/Training/LowEnergyTraining.htm
- http://bluetooth.com/Pages/Low-Energy.aspx

***Bluetooth* low energy at Wikipedia:**

- http://en.wikipedia.org/wiki/Bluetooth_low_energy

3 Bluegiga's Bluetooth 4.0 products

3.1 BLE112 - Bluetooth Smart Module

BLE112 is a *Bluetooth* Smart module targeted for low power sensors and accessories. It integrates all features required for a *Bluetooth* Smart application: *Bluetooth* radio, software stack and GATT based profiles. BLE112 *Bluetooth* Smart module can also host end user applications, which means no external micro controller is required in size or price constrained devices. BLE112 *Bluetooth* Smart module also has flexible hardware interfaces to connect to different peripherals and sensors. BLE112 *Bluetooth* smart module can be powered directly from a standard 3V coin cell battery or pair of AAA batteries. In lowest power sleep mode it consumes only 500 nA and will wake up in few hundred microseconds.

Key features

- *Bluetooth* v.4.0, single mode compliant
  - Supports master and slave modes
  - Supports up to eight connections

- Integrated *Bluetooth* Smart stack
  - GAP, GATT, L2CAP and SMP
  - *Bluetooth* Smart profiles

- Radio performance
  - Transmit power : +3 dBm to -23 dBm
  - Receiver sensitivity: -93 dBm

- Ultra low current consumption
  - Transmit: 27 mA (0 dBm)
  - Sleep mode 3: 0.5 uA

- Flexible peripheral interfaces
  - UART or SPI
  - Software I2C
  - PWM, GPIO
  - 12-bit ADC

- Host interfaces
  - UART
  - USB

- Programmable 8051 processor for stand-alone operation
  - Simple Bluegiga BGScript^{TM} scripting language for quick application development
  - Bluegiga Profile Toolkit^{TM} allowing the quick development of GATT based profiles
  - Free Software Development Kit

- *Bluetooth*, CE, FCC, IC and South-Korea and Japan qualified

Benefits

- Fully integrated *Bluetooth S*mart solution
  - Integrated *Bluetooth* Radio, micro controller and software stack
  - Fast time to market
  - Low development risks

- Application hosting capabilities
  - All application code can be executed on the BLE112
  - No need for external micro controller
  - Lower cost and smaller physical size

- Flash based
  - Firmware is field upgradable

- Application data can be stored on the flash
- Settings can be stored on the flash

- Good radio performance
  - Long range and robust connections
  - Software programmable TX power

- *Bluetooth*, CE,FCC, IC, Japan and South Korea qualified
  - Proven interoperability
  - Minimal qualification costs

PHYSICAL OUTLOOK

3.2 BLED112 - Bluetooth 4.0 single mode USB dongle

BLED112 *Bluetooth* Smart Dongle integrates all *Bluetooth* Smart features. The USB dongle can a virtual COM port that enables simple host application development using a simple application programming interface. The BLED112 can be used for *Bluetooth* Smart development. With two BLED112 dongles you can quickly prototype new *Bluetooth* Smart application profiles by utilizing Bluegiga Profile Toolkit^{TM} and also automate inmodule software functions with Bluegiga BGScript^{TM} .

Key features

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    - Supports master and slave modes
    - Supports up to eight connections

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    - GAP, GATT, L2CAP and SMP
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PHYSICAL OUTLOOK

3.3 BLE113 - Bluetooth Smart Module

BLE113 is a *Bluetooth* Smart module targeted for small and low power sensors and accessories. It integrates all features required for a *Bluetooth* Smart application: *Bluetooth* radio, software stack and GATT based profiles. BLE113 *Bluetooth* Smart module can also host end user applications, which means no external micro controller is required in size or price constrained devices. BLE113 *Bluetooth* Smart module also has flexible hardware interfaces to connect to different peripherals and sensors. BLE113 *Bluetooth* Smart module can be powered directly from a standard 3V coin cell battery or pair of AAA batteries. In lowest power sleep mode it consumes only 500 nA and will wake up in few hundred microseconds.

BLE113 is about 30% lower power and smaller than the BLE112 Bluetooth Smart Module

Key features

- *Bluetooth* v. 4.0, single mode compliant
    - Supports master and slave modes
    - Up to eight connections
- Integrated *Bluetooth* Smart stack
    - GAP, GATT, L2CAP and SMP
    - *Bluetooth* Smart profiles
- Radio performance
    - Transmit power : 0 dBm to -23 dBm
    - Receiver sensitivity: -93 dBm
- Ultra low current consumption
    - Transmit: 18.2 mA (0 dBm)
    - Transmit: 14.3 mA (0 dBm and DC/DC)
    - Receive: 14.3 mA
    - Sleep mode 3: 0.4 uA
- Flexible peripheral interfaces
    - UART and SPI
    - I2C, PWM and GPIO
    - 12-bit ADC
- Host interfaces:
    - UART
- Programmable 8051 processor for stand-alone operation
- Dimensions: 9.15 x 15.75 x 1.9 mm
- *Bluetooth*, CE, FCC, IC, South Korea and Japan qualified

Benefits

- BLE113 has thirty percent lower power and smaller size than the BLE112 *Bluetooth* Smart Module
- Fully integrated *Bluetooth* Smart solution
- Integrated *Bluetooth* radio, micro controller and software stack
- Fast time-to-market
- Low development risks

PHYSICAL OUTLOOK
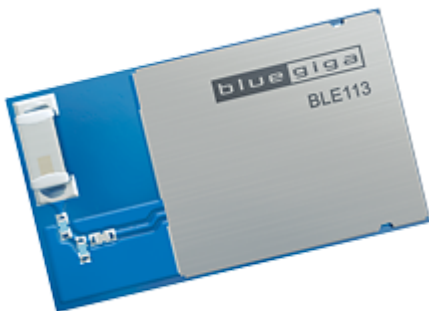
3.4 DKBLE112 - BLE112 Development Kit

BLE112 development kit provides a quick environment for prototyping Bluetooth 4.0 Smart applications. It provides both a hardware and a software development environment for evaluating BLE112 Bluetooth 4.0 single mode product.

Package contains:

- 1 BLE112 evaluation board
    - BLE112 module
    - Display
    - Accelerometer
    - Potentimeter
    - UART, USB and I/O interfaces
    - Current measurement points
    - CR2032 battery holder
    - Programming interface
- 2 BLE112 Bluetooth 4.0 single mode modules
- 1 BLED112 Bluetooth 4.0 single mode USB dongle
- 1 CC debugger firmware programming cable
- 1 USB cable
- 1 CR2032 coin cell battery
- Bluetooth low energy software development kit

Example applications:

- Health Thermometer
- Heart Rate Transmitter
- FindMe target
- Proximity Profile
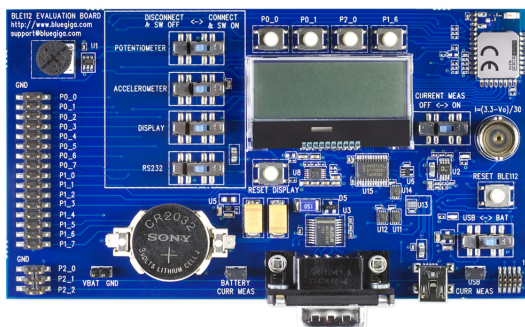
3.5 Bluetooth Smart software

Bluegiga's *Bluetooth* Smart stack suite provides a complete development framework for *Bluetooth* Smart application implementers.
The *Bluetooth* Smart software supports two architectural modes:

- **Standalone operation:** All software including *Bluetooth* 4.0 stack, profiles and end user application all run on the Bluegiga's *Bluetooth* 4.0 hardware
- **Host assisted operation:** The *Bluetooth* 4.0 single mode stack and profiles run on the Bluegiga 4.0 single mode hardware but the end user application runs on a separate host (a micro controller for example)

The benefits of the development suite in either of the use cases is that it provides a complete *Bluetooth* 4.0 single mode stack so that no *Bluetooth* development is required, a well-defined transport protocol exists between the host and the *Bluetooth* hardware and also simple development tools are available for embedding the end user applications on the *Bluetooth* 4.0 single mode hardware.

The *Bluetooth* 4.0 single mode development suite consists of several components:

- A *Bluetooth* 4.0 single mode stack
- Binary based BGAPI protocol between the host (MCU) and the *Bluetooth* stack
- A C library (called BGLib) for the host that implements the BGAPI protocol
- BGScript scripting language and interpreter for implementing stand-alone applications on the *Bluetooth* 4.0 single mode hardware
- A Profile Toolkit for quick and easy development of GATT based *Bluetooth* services and profiles

3.5.1 *Bluetooth* Smart software

The *Bluetooth* Smart software is a full, embedded implementation of *Bluetooth* v.4.0 single mode stack software and it's dedicated for Bluegiga's *Bluetooth* Smart modules. The stack implements all mandatory functionality for a single mode device.

The structure and layers of the stack are illustrated in the figure below.
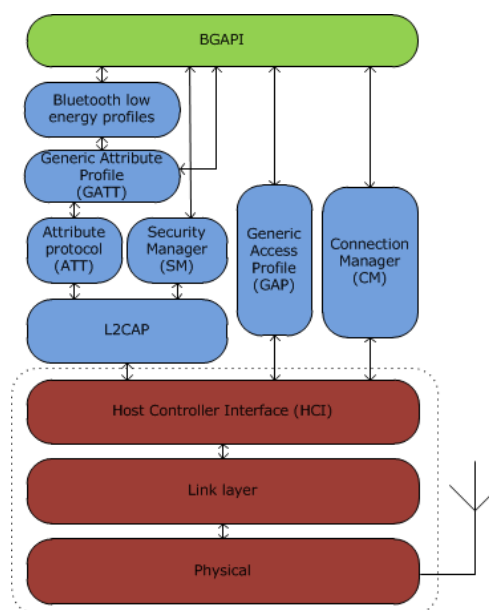
Figure 1: Bluetooth 4.0 single mode stack

3.5.2 BGAPI protocol

For applications where a separate host is used to implement the end user application, a transport protocol is needed between the host and the *Bluetooth* Smart stack. The transport protocol is used to communicate with the *Bluetooth* stack as well to transmit and receive data packets. his protocol is called BGAPI and it's a binary based communication protocol designed specifically for ease of implementation within host devices with limited resources.

The BGAPI provides access to the following layers:

- **Generic Access Profile** - GAP allows the management of discoverability and connetability modes and open connections
- **Security manager** - Provides access the *Bluetooth* low energy security functions
- **Attribute database** - An class to access the local attribute database
- **Attribute client** - Provides an interface to discover, read and write remote attributes
- **Connection** - Provides an interface to manage *Bluetooth* low energy connections
- **Hardware** - An interface to access the various hardware layers such as timers, ADC and other hardware interfaces
- **Persistent Store** - User to access the parameters of the radio hardware and read/write data to non-volatile memory
- **System** - Various system functions, such as querying the hardware status or reset it

The BGAPI protocol is intended to be used with:

- a serial UART link or
- a USB connection

3.5.3 BGLib library

For easy implementation of BGAPI protocol a host library written with ANSI C is available. The library is easily portable ANSI C code delivered within the _Bluetooth Smart _software development kit. The purpose is to simplify the application development to various host environments.
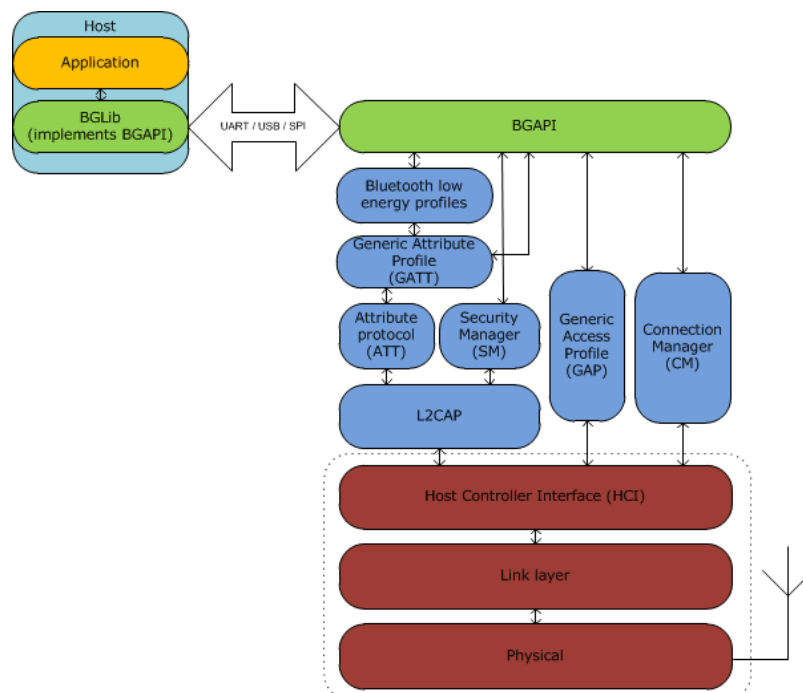

Figure 2: Host using BGLib

3.5.4 BGScript scripting language

Bluegiga's *Bluetooth* Smart products allow application developers to create standalone devices without the need of a separate host processor. The *Bluetooth* Smart modules can run simple applications along the *Bluetooth* stack and this provides a benefit when one needs to minimize the end product size, cost and current consumption. For developing standalone *Bluetooth* Smart applications the development suite provides a simple BGScript scripting language. With BGScript provides access to the same software and hardware interfaces as the BGAPI protocol. The BGScript code can be developed and compiled with free tools provided by Bluegiga.

When the BGScript approach is used the BGAPI host interface is not needed nor is it available.
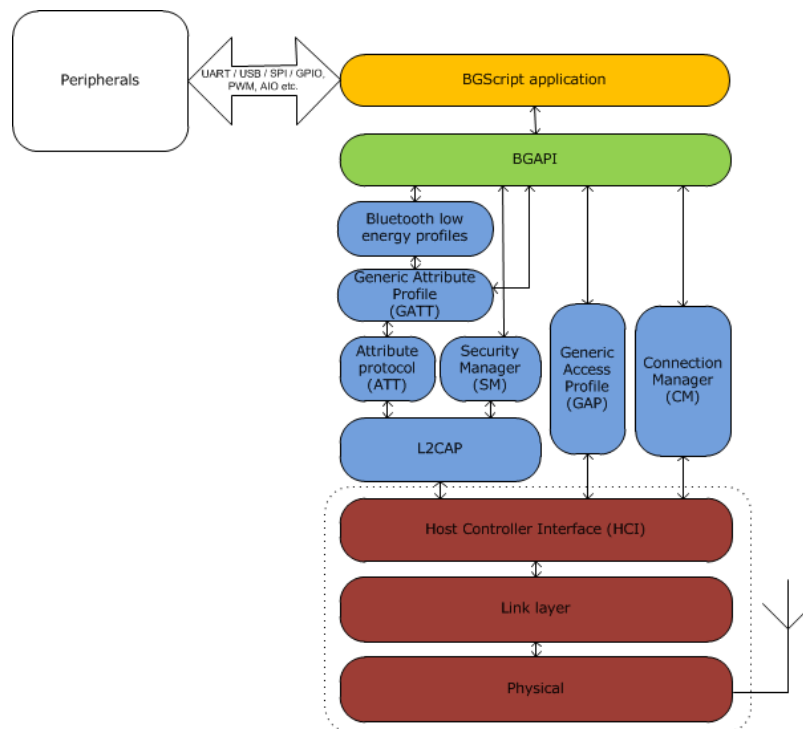
Figure 3: Standalone application model

A BGScript code example:

```
# System Started
event system_boot(major, minor, patch, build, ll_version, protocol_version,
hw)

  #Enable advertising mode
  call gap_set_mode(gap_general_discoverable,gap_undirected_connectable)

  #Enable bondable mode
  call sm_set_bondable_mode(1)

  #Start timer at 1 second interval (32768 = crystal frequency)
  call hardware_set_soft_timer(32768)
end
```

3.5.5 Profile Toolkit

The *Bluetooth* low energy profile toolkit a simple set of tools, which can used to create GATT based *Bluetooth* services and profiles. The profile toolkit consists of a simple XML based description language , which is used to describe the devices local GATT database as a set of services. The profile toolkit also contains a compiler, which converts the XML to binary format and generates API to access the characteristic values.

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

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

      <characteristic uuid="2a00">
        <properties read="true" const="true" />
        <value>BGDemo sensor</value>
      </characteristic>

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

</configuration>
```
Figure 4: A profile toolkit example of GAP service

3.6 More information

More information about the products can be found from:

- Bluegiga web pages
- Bluegiga Tech Forum

4 Getting started with Bluetooth 4.0 development

If you have not implemented a Bluetooth Smart application with Bluegiga's products before. This section briefly describes the recommended path to stat the implementation and describes the available documents, tools and examples, which help you to get started.
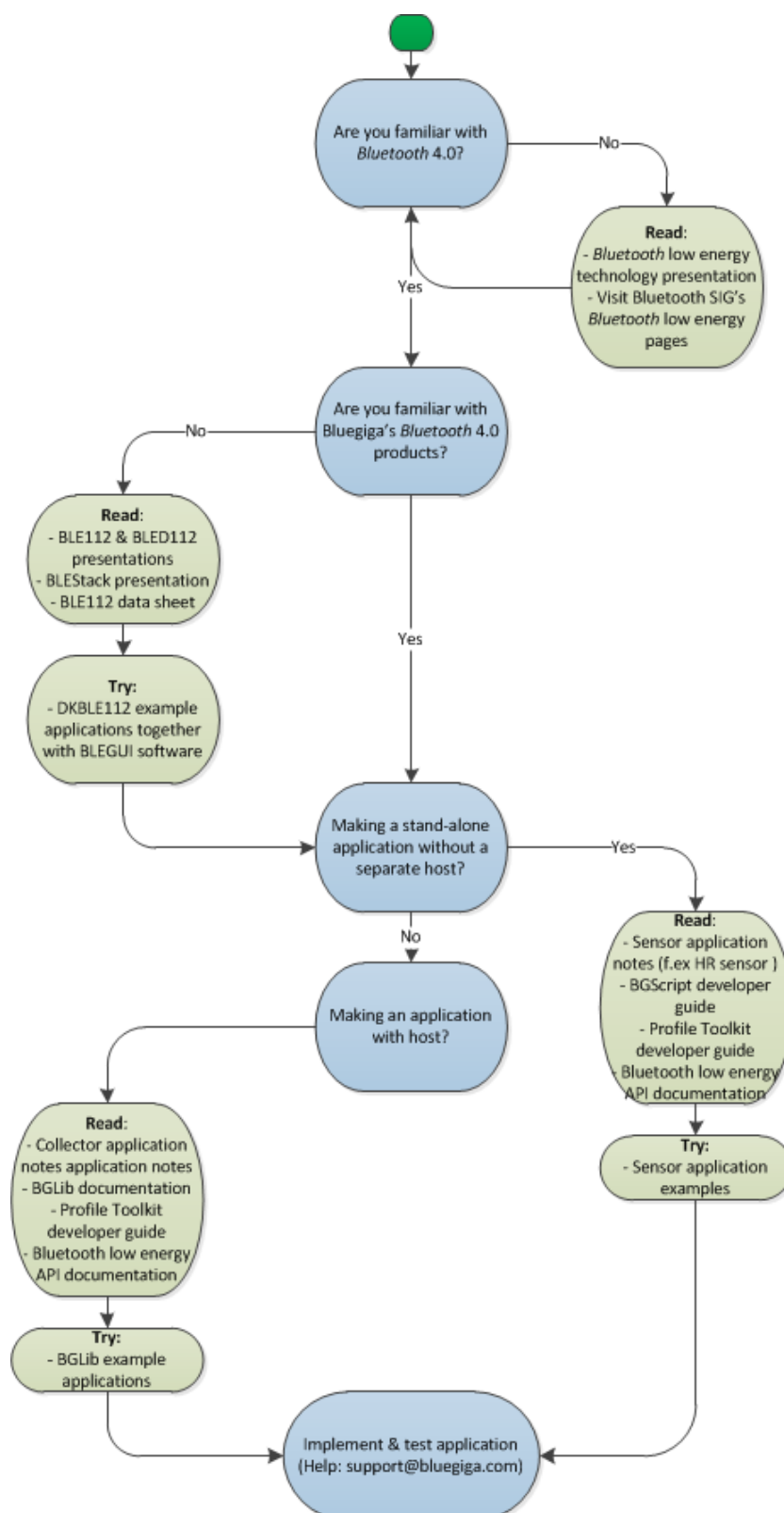
Figure 5: Recommended development path

4.1 Documentation and Tools

This section briefly summarizes the available *Bluetooth* low energy tools and documentation supporting the application development.

Tools:

- **BLEGUI** : This application can be used to control BLE112 or BLED112 over UART or USB. BLEGUI sends the BGAPI command to the hardware and parses the responses. It's a useful tool to get familiar with the products and try out Bluetooth low energy applications.

- **BGBuild** : BGBuild application compiles the hardware configuration file, GATT database, BGScript and the Bluetooth 4.0 single mode stack into a single binary image (.hex), which can be installed into BLE112 or BLED112 hardware.

- **DFUTool** : DFUTool can be used to update the firmware of BLE112 or BLED112 using USB DFU protocol.

- **Thermometer-demo:** Thermometer demo is a Windows command line application, which implements Thermometer collector using BGLib. It can scan Bluetooth 4.0 single-mode devices, and read temperature values from them.

- **Collector demo:** Collector demo implements a simple Windows HR collector application, which scans, connects and reads HR and Battery status values from a HR sensor

- **TI Flash programmer :** TI's flash programmer application can be used to update the firmware of BLE112 over the debug/programming interface.

Documentation:

- *Bluetooth* **low energy - getting started** : This document, describes the very basics of *Bluetooth* low energy and related Bluegiga products

- **BGScript developer guide** : Describes the BGScript scripting language, it's features and limitations. Contains also practical BGScript examples.

- **Profile developer toolkit developer guide** : Describes the basics of *Bluetooth* LE profile development, as well the features and syntax of hardware and GATT XML files. Contains also practical examples.

- *Bluetooth* **4.0 single mode stack API reference** : This document contains the BGAPI, BGLib and BGScript API. Describes the available commands, responses, events and their parameters. API reference document also explains the basics of *Bluetooth* low energy technology.

- **BLEGUI User Guide** : The document describes how the BLEGUI application works and how to use it

- **Application notes:** Various application notes describe specific use cases like for example Heart Rate Sensor or Health Thermometer collector and walk through the necessary development steps required to implement those.

Presentations:

- *Bluetooth* **low energy technology presentation :** A more in-depth presentation about *Bluetooth* low energy technology, how it works and what applications it's target for.

- **BLE112 Product presentation :** A short introduction to BLE112 *Bluetooth* 4.0 single mode module

- **BLED112 Product presentation** : A short introduction to BLED112 *Bluetooth* 4.0 single mode USB dongle

- **Low energy design :** Practical considerations and tips for implementing low energy applications

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