Whitepaper

Bluetooth Low Energy

Release r03

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1 Introduction

Bluetooth low energy is an addition to the classic Bluetooth BR/EDR technology. Although it shares the name and radio, it is an entirely different technology that is not compatible with classic Bluetooth BR/EDR. It is designed for very specific use cases with small, discrete data transfer.

Bluetooth low energy enables use cases in which Bluetooth only consumes a fraction of the power of classic Bluetooth radios and makes it possible to operate coin cell powered devices for more than a year without recharging.

2 Bluetooth Low Energy

Bluetooth low energy differentiates between single mode (Bluetooth Smart) and dual mode (Bluetooth Smart Ready) devices. Together with Bluetooth BR/EDR that gives us a total of three possible ways to implement Bluetooth technology today. The following chart shows which transport is used between two specific Bluetooth devices. Because not every Bluetooth implementation can communicate with another implementation it is very important to describe exactly which Bluetooth version is used in a product.

	BR/EDR	**Single Mode**	**Dual Mode**
BR/EDR	BR/EDR	-	BR/EDR
Single Mode	-	low energy	low energy
Dual Mode	BR/EDR	low energy	BR/EDR

2.1 Single Mode

Single mode devices are called Bluetooth Smart devices and have their own logo:

Small devices like watches and sports sensors will be based on a single mode Bluetooth low energy implementation. To enable very low power consumption hardware and software is optimized for that use case and these devices support Bluetooth low energy only. Bluetooth single mode chips typically come with a single

mode protocol stack on board. This protocol stack is provided by the chip vendor for free.

2.2 Dual Mode

Dual mode devices are called Bluetooth Smart Ready devices and have their own logo:

Dual Mode devices support Bluetooth BR/EDR and Bluetooth low energy. Both technologies share the same radio and antenna in dual mode devices. Typical dual mode devices are smartphones, tablets, PCs or gateways. These devices are able to collect data from single mode and Bluetooth BR/EDR devices and often have an external power supply. If the dual mode device communicates with a remote low energy device power consumption will be lower than communication with a remote BR/EDR device. Dual mode solutions require an external application processor that is able to run the Bluetooth protocol stack.

3 Application

Bluetooth low energy should be used where devices are small and battery driven. There are 5 main markets that are addressed by the technology right now.

3.1 Medical and Healthcare

Related to Healthcare application Bluetooth low energy is aimed mainly at devices that are used for monitoring vital data. Typical devices are blood glucose meter, blood pressure cuffs and pulse ox meters. Bluetooth low energy was chosen by the Continua Health Alliance as a transport for interoperable end to end communication.

3.2 Sports and Fitness

In the sports and fitness segment Bluetooth low energy is used in devices for positioning as well as monitoring vital data. Typical devices in this market are heart rate monitors, body temperature thermometers, pedometers, cadence meters, altimeter, positioning / GPS tracking and watches displaying information from sensors.

3.3 Industrial

In the automation application area Bluetooth low energy is mainly used for transport of I/O signals. Bluetooth low energy can be used to monitor and control motors, actuators, values and entire processes.

3.4 Entertainment

Bluetooth technology is already used in a wide variety of devices in the entertainment sector, namely set-top boxes / gaming consoles. Bluetooth low energy is expected to further increase the use of Bluetooth technology in devices like TV / DVD / STB / Media Player, remote controls, gaming controller, wireless mouse/keyboard.

3.5 Home Automation

Bluetooth low energy technology can provide a low power yet secure way to control lights, temperature, humidity, security locks, windows, doors, etc.

It also aims for the use in smart meters.

4 Profiles

Bluetooth low energy does not support classic Bluetooth BR/EDR profiles. For example there is nothing like the Serial Port Profile (SPP) in Bluetooth low energy. Instead all Bluetooth low energy profiles/services are based on GATT (Generic Attribute Profile). Some of the classic Bluetooth profiles like HID have been ported to Bluetooth low energy though. In Bluetooth low energy you have to differentiate between services and profiles.

Services describe the characteristics (and their UUID).They describe which content and form the characteristics have, how these characteristics can be accessed (read/write) and what security is required.

A Bluetooth low energy profile defines the used service, whether it is the sensor or collector side, the GATT role (server/client) and the GAP role (peripheral/central).

GATT based profiles are quite simple compared to classic Bluetooth BR/EDR, because all functionality is implemented in GATT and the profiles just use what GATT is offering.

The following Bluetooth low energy profiles/services exist at the moment (07/2013):

GATT-Based Specifications (Qualifiable)		**Adopted Version**
ANP	Alert Notification Profile	1.0
ANS	Alert Notification Service	1.0
BAS	Battery Service	1.0
BLP	Blood Pressure Profile	1.0
BLS	Blood Pressure Service	1.0
CPP	Cycling Power Profile	1.0
CPS	Cycling Power Service	1.0
CSCP	Cycling Speed and Cadence Profile	1.0
CSCS	Cycling Speed and Cadence Service	1.0
CTS	Current Time Service	1.0
DIS	Device Information Service	1.1
FMP	Find Me Profile	1.0
GLP	Glucose Profile	1.0
GLS	Glucose Service	1.0

HIDS	HID Service	1.0
HOGP	HID over GATT Profile	1.0
HTP	Health Thermometer Profile	1.0
HTS	Health Thermometer Service	1.0
HRP	Heart Rate Profile	1.0
HRS	Heart Rate Service	1.0
IAS	Immediate Alert Service	1.0
LLS	Link Loss Service	1.0
LNP	Location and Navigation Profile	1.0
LNS	Location and Navigation Service	1.0
NDCS	Next DST Change Service	1.0
PASP	Phone Alert Status Profile	1.0
PASS	Phone Alert Status Service	1.0
PXP	Proximity Profile	1.0
RSCP	Running Speed and Cadence Profile	1.0
RSCS	Running Speed and Cadence Service	1.0

RTUS	Reference Time Update Service	1.0
ScPP	Scan Parameters Profile	1.0
ScPS	Scan Parameters Service	1.0
TIP	Time Profile	1.0
TPS	Tx Power Service	1.0

5 Technology

The lower power consumption of Bluetooth low energy is not achieved by an optimized active radio transport, but by the design of the protocol. Generally speaking to achieve the goal of very little power consumption the Bluetooth low energy protocol is designed to keep the radio off, except when it is needed. This is done by shorter stand by times, faster connection setup and lower peak power (depending on the used chip) in comparison to classic Bluetooth BR/EDR.

The shorter stand by time is reached by using only 3 advertising channels and optimized protocols for low duty cycle operations. Because a device that is advertising automatically connects to a scanning device it is possible to connect and transfer data in about 3ms.

The low power consumption design comes with some limitation. It is not possible to transfer audio data over Bluetooth low energy.

Bluetooth low energy is still a very robust technology. It supports frequency hopping (reduced to 37 channels) and has an increased GFSK modulation index for a better link budget. It also is a very secure technology, offering 128 bit AES encryption on chip level.

Single mode devices can be master or slave but not at the same time. That means Bluetooth low energy only supports a simple star topology, but no scatter net.

The Bluetooth low energy radio specification defines a maximum data rate of 305 kbps, but these are only theoretically values. In the real world the throughput is limited by the protocol overhead and very dependent on things like UART speed, processor power and the Master device.

High throughput with Bluetooth low energy is only possible with proprietary solutions and/or ATT notification. Furthermore at high data rates or high data volume it is generally more power efficient to use Bluetooth BR/EDR.

5.1 Definitions

GATT – Generic Attribute Profile is built on top of the Attribute Protocol (ATT) and establishes common operations and a framework for the data transported and stored by the Attribute Protocol.

ATT – Attribute Protocol that transports data. ATT only allows half-duplex data transfer.

GAP – Generic Access Profile defines the basic requirements of a Bluetooth device.

Server – GATT role that stores the data transported over the Attribute Protocol and sends responses to requests and when configured, sends indication and notifications asynchronously to the GATT client.

Client – GATT role that actively sends Attribute Protocol requests, commands and confirmations to the GATT server.

Peripheral – LE GAP role optimized for devices that support a single connection and are less complex than central devices. Require Controller with slave role.

Central – LE GAP role supports multiple connections and is the initiator for all connections with devices in the peripheral role. Requires controller with master role.

Broadcaster – LE GAP role optimized for transmitter only applications. Devices supporting the broadcaster role use advertising to broadcast data. The broadcaster role does not support connections.

Observer – LE GAP role optimized for receiver only applications. Devices supporting the observer role are the complementary device for a broadcaster and receive broadcast data contained in advertisements. The observer role does not support connections.

Initiator – The initiator listens for connectable advertising packets. An initiator may make a connection request using the same advertising PHY channel on which it received the connectable advertising packet from the acceptor. Once a connection is established, the initiator becomes the master device.

Acceptor – The acceptor can use a connectable advertising event to show an initiator device that it wants to set up a connection. The advertising event is ended and connection events begin if the advertiser receives and accepts the request for a connection to be initiated. Once a connection is established, the acceptor becomes the slave device.

5.2 Apps

Often Bluetooth low energy is used in small sensor devices that want to communicate with smartphones or tablets. At the moment only few smartphones and tablets (iPhone 4S or later, Motorola Razr and the new iPad or later) support Bluetooth low energy. BLE support for Android is announced for Android but no release date is known. Smartphones and tablets have a dual mode baseband and dual mode Bluetooth stack up to GATT, but do not have any specific profile implementations onboard. The profiles have to be implemented on application level and use the vendor specific GATT API. This enables vendors not only to easily implement a specific profile on the smartphone side it makes it also possible to easily create proprietary solutions based on GATT.

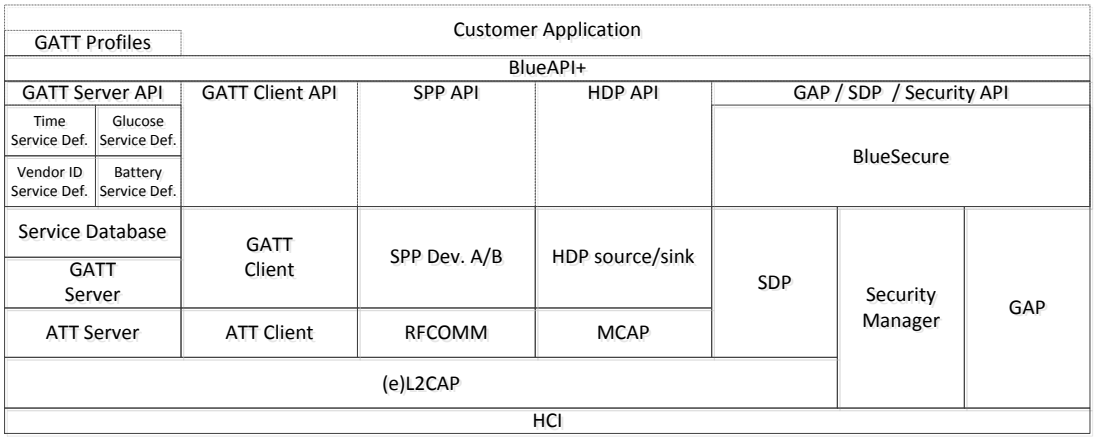
Especially when used with Apple products Bluetooth low energy offers a big advantage compared to classic Bluetooth BR/EDR as there is no requirement to use the Apple authentication chip and join the MFi program.

5.3 Comparison Bluetooth low energy and classic Bluetooth BR/EDR

	Bluetooth BR/EDR	**Bluetooth low energy**
Frequency	2400-2483.5 MHz	2400-2483.5 MHz
Deep Sleep	~80 µA	<5 µA
Idle	~8 mA	~1 mA
Peak Current	22-40 mA	10-30 mA
Range	500m (Class 1) / 50m (Class 2)	100m
Min. Output Power	0 dBm (Class 1) / -6 dBm (Class 2)	-20 dBm
Max. Output Power	+20 dBm (Class 1) / +4 dBm (Class 2)	+10 dBm
Receiver Sensitivity	≥ -70 dBm	≥ -70 dBm
Encryption	64 bit / 128 bit	AES-128 bit
Connection Time	100 ms	3 ms
Frequency Hopping	Yes	Yes
Advertising Channel	32	3
Data Channel	79	37
Voice capable	Yes	No

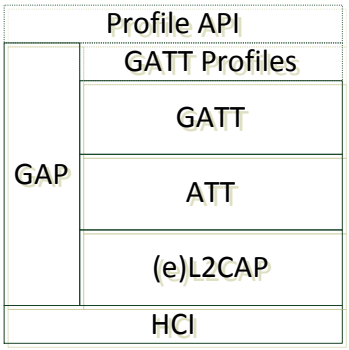
5.4 Dual Mode Stack

The following drawing shows BlueCode+SR Stollmann's dual mode stack. It shows all components that are required for SPP, HDP and GATT operations.



5.5 Single Mode Stack

The following drawing shows a typical single mode stack design. Profiles often are not part of the stack. As profile implementation is always application specific and thus occurs on application layer (in contrast to Bluetooth classic profiles, that are deeply integrated in the stack).



Compared to a dual mode stack that always requires a host processor, very small and power efficient implementation are possible.

Most low energy single mode chips / modules come with a stack onboard.

As the Bluetooth low energy single mode stack is implemented up to GATT only, it is always necessary to implement the needed profiles on the chip. Nearly every chip vendor offers SDKs with sample code for the released profiles. But there are no solutions on product level available.

6 Integration

There are several ways how Bluetooth technology can be integrated in your device. There are differences between single mode and dual mode solutions though.

6.1 Modules

The most easy and fastest way is to take a complete embedded module. These modules come with antenna, an embedded protocol stack and have different interfaces like UART, USB, SPI or I²C to connect to your host processor. They offer an easy to use interface for control of the Bluetooth functionality. Most vendors also made country specific radio certifications like CE, FCC and IC. Such modules are available as Bluetooth BR/EDR only, dual mode or single mode modules.

For Bluetooth BR/EDR and dual mode there are also HCI modules available. HCI modules offer the same as the embedded modules, but come without the Bluetooth protocol stack so they are cheaper. They only offer a hardware interface. In this case a third party protocol stack, which can be run on the host processor – like Stollmann's BlueCode+SR – is needed. An HCI module solution does require software porting of the protocol stack to the target hardware.

Theoretically it is also possible to offer single mode HCI modules, but since all chip vendors already integrate GATT in their chips, there is no pure HCI chip available (see chapter 5.5).

6.2 Chips

Chip integration is BOM wise the cheapest way to integrate Bluetooth technology but takes a lot of time and effort initially. It requires not only the software porting of the protocol stack to the target platform, but also a lot of hardware and RF know how for layout and antenna design. Bluetooth low energy chips are available from e.g. Broadcom, CSR, EM Microelectronic, Nordic Semiconductor and Texas Instruments.

7 History

Version	Release Date	By	Change description
r01	24.04.2012	FH	First release
r02	07.12.2012	FH	Update chapter 5
r03	22.07.2013	FH	Updated chapter 4 and 5.2

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