White Paper

High Data Throughput using Bluetooth® Low Energy for Low-Power Wireless Communication

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Overview

IoT has been a buzzword for several years and is so common now that all sorts of devices are connected to a network. Most smartphones are equipped with Bluetooth for short-range wireless communication, and the demand for Bluetooth Low Energy, a low-power wireless communication format, is on the rise. Bluetooth Low Energy communication even supports 2Mbps (high-speed) operation on smartphones, and manufacturers are now rushing to respond to the demand for high data throughput for devices connected to smartphones.

Introduction

Smartphones have been integrating Bluetooth Low Energy ever since the Bluetooth standard appeared on the scene. You would be hard-pressed to find a smartphone these days that does not come with Bluetooth as a standard feature. In particular, Bluetooth Low Energy offers low energy communications enabling sensor devices and monitoring devices to serve as beacons to transmit location information. The continually expanding realm of Bluetooth Low Energy application ranges from wearable devices in sports and fitness apparel, to home appliances, buildings, industrial equipment, toys, and PC peripheral devices.

This white paper explains the features of Bluetooth 5.0 Low Energy and how to implement it.

Bluetooth Low Energy Basics

Bluetooth Low Energy is a standardized short-range wireless network that features lower power consumption than other wireless standards.

Although Bluetooth Low Energy shares the same Bluetooth name as the classic Bluetooth technology used in voice transmission, it is a significantly different spec. Bluetooth Low Energy transmits data using 40 channels over an 80-MHz bandwidth, from 2,400 MHz to 2,480 MHZ, with 2MHz spacing.

- **Advertising channels: 3 channels are used to discover/connect slave devices**
- **Data channels: when connected, 37 channels are used for hopping frequencies to transmit/receive**

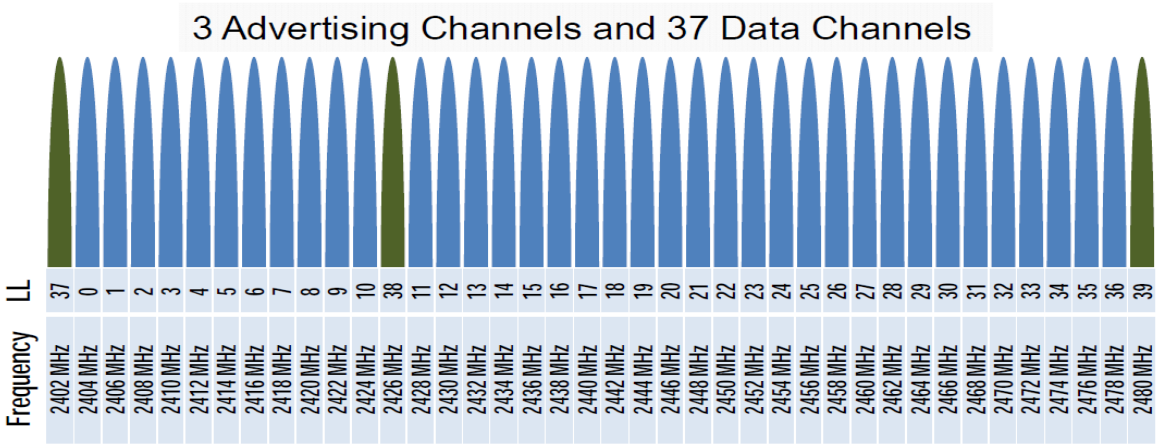

Figure 1: Bluetooth Low Energy Frequency Channels

The following section describes how to use each channel.

Peripheral devices send advertisement packets in advertising channels.

Advertising packets are used by a master device to broadcast (transmit) its presence to nearby peripheral devices (slaves). Each advertising packet transmits a broadcast to 3 channels every advertising interval, searching for a device to connect with. The BT5 specification offers an extended channel specification for advertising, with 37 other channels for use as secondary channels.

Once the connection is established between master and slave, the data channels are used for devices to send data to one another. The data channel uses the Adaptive Frequency Hopping (AFH) mechanism to send data, which switches from one frequency channel to another (among 37 channels) every connection interval. This is also called the adaptive mechanism because it avoids crowded channels, using known good channels to minimize interference from other devices. When waiting during a time out period, the AFH mechanism employs frequency hopping to skip blocked channels due to crowding, enabling continuous data transmission. Devices can keep communicating by hopping to open channels, even while some channels are occupied.

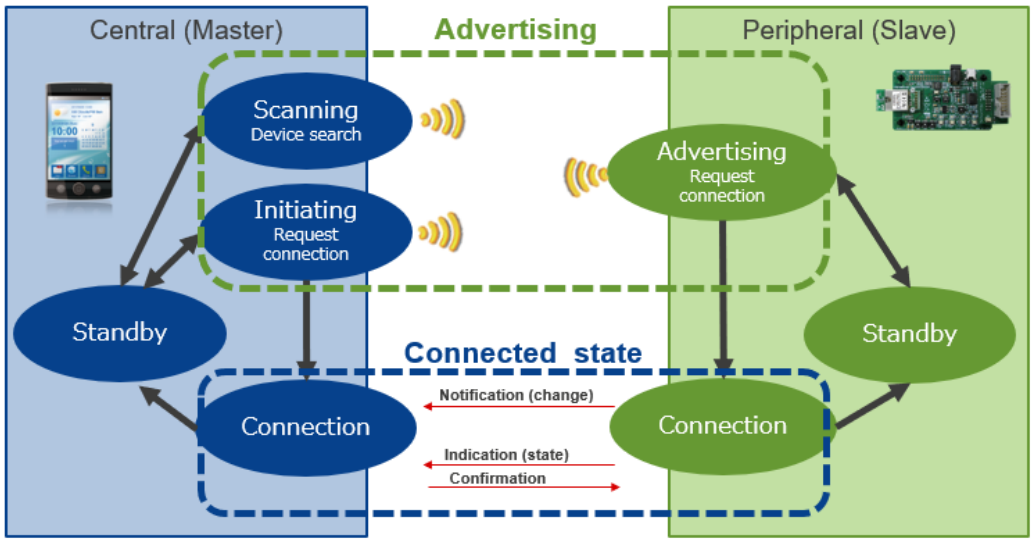

Figure 2: Advertising and Connected Communication States

With advertising, a device announces its presence to nearby peripherals; in connected state transmissions, data is received and transmitted at regular intervals.

Application data is transmitted in the client/server model. The following six packet types can be used.

Packet Type	Sender	Description
Request	Client	The client sends a request to the server.
Response	Server	The server receives a request from the server and sends a response.
Command	Client	The client sends instructions in a command to the server. No response is sent.
Notification	Server	The server sends data in a notification to the client. Confirmation from the client is not necessary.
Indication	Server	The server sends data in an indication to the client. The client sends a confirmation to the server.
Confirmation	Client	The client responds to the server in a confirmation.

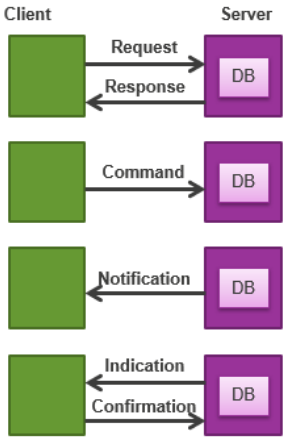

Figure 3: Client/Server Model of Communication Protocols

As data is shared between client and server in a connected transmission, the Generic Attribute Profile, or GATT database is defined in the server. The GATT database is constructed in minimum units of attributes, each of which contain the following information:

- Handle: A 16-bit index, used by client for data access.
- Type: Indicates the type of data, identified by UUIDs (Universal Unique Identifier).
- Value: The actual data.

GATT attributes are defined by a characteristic declaration, a characteristic value, and a characteristic descriptor. These attributes collectively make up the characteristics—the data shared in connected transmissions. The server collects all characteristics, organizes them into services, and provides them to the client as the GATT database.

Once a connection is established, the client obtains the service information from the server database in order to gain the attribute handle. The client then uses the handle to access the database.

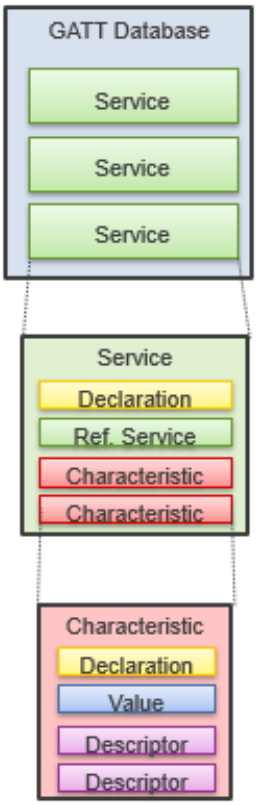

Figure 4: GATT Database Structure

New Bluetooth 5 Specification

Table 1 provides a description of the new Bluetooth 5 specification. Boasting a faster data rate, Bluetooth 5 offers higher data throughput as well as a long-range mode, significantly enhancing transmission distance.

Feature/Function	Description	Purpose
2 Mbps LE	2Mbps PHY data rate	Higher data throughput
LE Long Range	500kbps and 125kbps PHY data rate	Extended transmission range
LE Advertising Extensions	Advertising on secondary channels Longer advertising data length; max: 1650B Long range-based advertising Periodic advertising	Reduced wireless interference Extended beacon information (URL, etc.) A way to take advantage of the secondary advertising channels
Channel Selection Algorithm #2	Improved channel hopping algorithm	Reduced wireless interference

High Duty Cycle NC Advertising	Minimum advertising interval reduced from 100ms → 20ms	High frequency beacon transmission

Table 1: New Bluetooth 5 Specification

Note that not all devices indicating compliance with Bluetooth 5 support all the above features.

Bluetooth 5 Implementation

Developers should take the following three points into consideration before implementing the Bluetooth 5 functions introduced here.

Point 1: Select a device that supports the functions required for advertising.

Point 2: When using a dedicated IC for communication, the mounting area may be crowded with the system controller and other required components. Space reduction on the board may be required.

Point 3: Facilitate easy development of peripheral functions required for Bluetooth Low Energy.

Conclusion

Resolving these points requires a development environment that facilitates system development with Bluetooth Low Energy, and the introduction of products that incorporate all Bluetooth 5 functions.

The RX23W from Renesas fully supports the new Bluetooth 5 specification. In addition to Bluetooth Low Energy communication functions, it comes with a high-performance, low-energy CPU, and ample built-in peripherals. In addition to Bluetooth Low Energy transmissions, RX23W is installed with a separate encryption key control module and boasts enhanced security functions. Renesas also offers a development environment able to generate protocol stacks and drivers with GUI for Bluetooth Low Energy and other peripherals.

Learn more about the RX23W ›