Bluetooth Smart: How it Operates, and How it May Be Used

By: Allen Cabreros, Advanced Engineer, Future Electronics

Bluetooth® Smart wireless technology is the new ultra-power efficient, app-friendly version of the Bluetooth radio which has enjoyed such success in end products such as wireless speakers and hands-free accessories for the mobile phone.

Offering robust RF performance and very low power consumption, Bluetooth Smart is now opening up new opportunities and applications in industry sectors such as consumer electronics, medical equipment, home automation and wearable electronics.

There are two main drivers of the growth in shipments of Bluetooth Smart devices:

- The low power consumption, which enables products to run from power supplied by tiny batteries for periods of months or years
- Compatibility with a wide variety of applications hosted on smartphones and tablets that consumers already own

The developer-friendly Bluetooth Smart architecture is now supported by all major operating systems natively. This makes it easy for developers to create apps that link smartphones and tablets to common objects such as heart-rate monitors, toothbrushes and even shoes. Now sales of Bluetooth Smart and Bluetooth Smart Ready devices are expected to dwarf those of Classic Bluetooth devices in the next few years, see Figure 1.

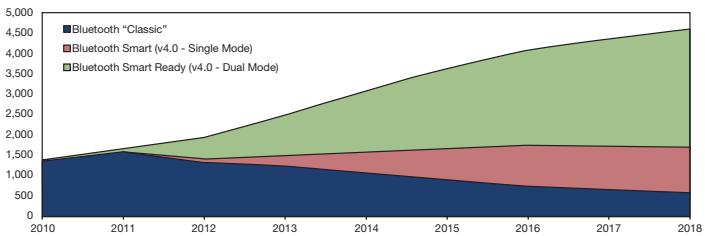

Figure 1: forecast for shipments of Bluetooth devices. Source: ABI Research

Which Applications is Bluetooth Smart Suited to?

Bluetooth Smart is intended for applications that require low bandwidth and low latency, and that send data infrequently.

If a designer needs to know the maximum data throughput of Bluetooth Smart in any given application, it is probably the wrong technology to use. In fact, Bluetooth Smart is perfect for communicating state data, just as ANT/ANT+ and ZigBee® are. State data enable command and control (turning a system on and off), the monitoring of low resolution sensors, and status indication.

End products such as pedometers, heart-rate monitors, thermometers, position sensors and proximity sensors all call for the near-instant communication of small bursts of data, and all are very suitable for Bluetooth Smart.

To put it another way: Classic Bluetooth is widely regarded as a 'cable replacement' technology; Bluetooth Smart may be viewed as a 'wire replacement' technology.

Differences Between Bluetooth Smart and Classic Bluetooth

Bluetooth Smart shares many basic technical elements with Classic Bluetooth. But in order to meet the primary requirement for ultra low power consumption, changes were made to the Bluetooth baseband, link management layer and upper data management layers.

The same Gaussian Frequency Shift Keying (GFSK) modulation scheme is used in Bluetooth Smart as in Classic Bluetooth, although the data throughput is reduced to a nominal 270kbits/s from the Classic Bluetooth range of 0.7-2.1Mbits/s.

But changes affecting the duty cycle of the radio when performing link establishment and link management have a dramatic effect on power use. For example, Classic Bluetooth radio packets need to be acknowledged immediately by the receiving end before the next packet transmission. This means that the receiving device has to transmit an ACK packet and stay awake for an additional time slot before it can decide whether to go into a low power mode.

In Bluetooth Smart, the received packet does not need to be acknowledged immediately. As a result, the device can go into a low power mode for a certain amount of time before waking to send an ACK packet. So the Bluetooth Smart device can receive or even send data without using precious battery power on acknowledgements.

Channel spacing, the modulation index, the maximum output power and packet types are other items that are different in Bluetooth Smart. One consequence of this is that Classic Bluetooth is not compatible with Bluetooth Smart. If a device is to support both Bluetooth Smart and Classic Bluetooth, it must be a dual-mode Bluetooth Smart Ready device. A (single-mode) Bluetooth Smart device cannot interoperate with a (single-mode) Classic Bluetooth device.

Many Bluetooth Smart Ready devices are already on the market, including Apple® iPhone® smartphones (from the 4S model onwards), and iPad® tablets (from the model 3 onwards). Many smartphones and tablets built on the Android™ platform and laptops running the Windows® operating system are also Bluetooth Smart Ready.

New Roles and Data Modes

Another important difference between Bluetooth Smart and Classic Bluetooth is in the roles and device types supported by the new technology. Classic Bluetooth has master and slave roles. Bluetooth Smart has central and peripheral device roles. Roles are defined in profiles; examples of profiles include the heart-rate profile, the environment-sensing profile and the cycling speed and cadence profile. Any device can be either central or peripheral, and can switch roles dynamically.

A central device performs the function of discovering and connecting to peripheral devices, and accessing the available services from them. Smartphones, tablets and laptop PCs are often chosen to be the central device as they provide a display and user interface to enable the user to control the discovery and connection processes, and to view the data provided by peripheral devices.

A peripheral device performs functions such as advertising, to make itself discoverable by central devices, and providing services. Typical peripheral

devices are key fobs, fitness wristbands, smart watches, temperature sensors, mice and wireless keyboards.

Advertisement Mode

One of the big advantages of Bluetooth Smart is the ability to advertise and broadcast data without the need to establish a full connection. Establishing a full connection would require a higher radio duty cycle, and thus consume more power. Some applications and data can use the advertisement mode to save power when they do not require a bi-directional (full duplex) RF link. For instance, a temperature sensor might broadcast temperature readings periodically. A central device would not need to create a full connection to the peripheral device to obtain this small amount of temperature data.

In Advertisement mode, only three channels are used to broadcast data, as shown in Figure 2. These three channels are dedicated to advertising, scanning and connecting to Bluetooth Smart devices. This leaves 37 other channels for application data. This is a total of 40 channels with 2MHz spacing. (Classic Bluetooth Classic uses 80 channels with 1MHz spacing.)

The three advertising channels are strategically placed at 2,402MHz, 2,426MHz and 2,480MHz to avoid the three non-overlapping Wi-Fi® channels (channel 1, channel 6 and channel 11). In an active connection there are still nine channels that do not overlap with these Wi-Fi channels. The three advertisement channels are also used to discover and create active connections between devices. After discovery and connection requests, the devices then maintain interference-free communication by implementing a frequency-hopping spread-spectrum scheme on the other 37 channels.

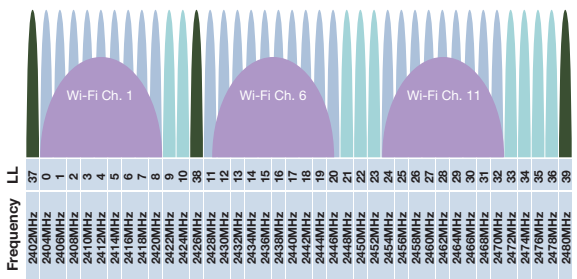

Figure 2: the Bluetooth Smart advertising channels (in green) avoid interference with the three Wi-Fi channels

New Data Structure

Although Bluetooth Smart was described above as a wire-replacement technology, it actually uses a client-server model for data exchange, as shown in Figures 3 and 4. Its service-based architecture makes use of the ATTribute (ATT) protocol, and all communication in Bluetooth Smart takes place within the Generic ATTribute (GATT) profile.

An application or another profile uses the GATT profile so that a client and server can interact in a structured way. The server contains a number of attributes, and the GATT profile defines the way that the ATT protocol will discover, read, write and obtain data. The services are used as defined in the profile specifications, and the GATT profile enables the designer to expose these services and characteristics in the relevant specific profile.

GATT-based profiles in Bluetooth Smart have defined attributes. These attributes have Universally Unique Identifiers (UUIDs). There are 16-bit, 32-bit and 128-bit UUIDs: the 16-bit and 32-bit UUIDs are reserved for current and future Bluetooth Smart applications and profiles. The 128-bit UUIDs can be used for custom profiles and applications, in order to exchange vendor-specific data.

Bluetooth Smart v4.1: the Main Additions

At its introduction, Bluetooth Smart and Bluetooth Smart Ready were part of the v4.0 specification of Bluetooth.

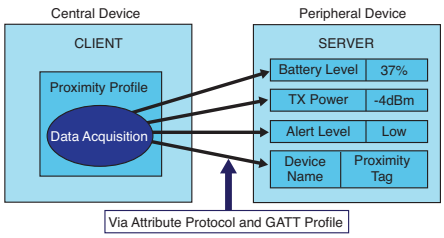

Figure 3: a data exchange model in Bluetooth Smart using the Proximity profile

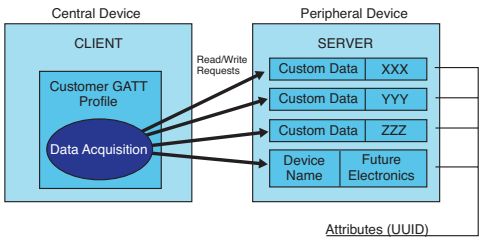

Figure 4: a custom profile in Bluetooth Smart using GATT and custom UUIDs

This specification has since been updated with new versions 4.1 and 4.2. Recent additions to the specification include:

- Added co-existence signalling between Bluetooth Smart and cellular technologies such as LTE
- Improved handling of link supervision time-outs to extend battery life
- Direct connection from Bluetooth Smart to the L2CAP layer

Bluetooth Smart ICs and Modules

Both Systems-on-Chip (SoCs) and modules for Bluetooth Smart are available from Future Electronics and its Future Connectivity Solutions division. Future Electronics has solutions from Atmel, CSR, Cypress, Dialog, Microchip, Murata, NXP, Panasonic, and ST Microelectonics. They are provided with ready-to-use, pre-certified Bluetooth Smart protocol stacks and with application development environments.

Modules and SoCs available from Future Electronics today integrate clocks, buck/boost converters, a balun and antenna, and carry Bluetooth, FCC, IC and CE certifications.

The RF specialists at Future Connectivity Solutions can also help OEM designers to plan future product developments, drawing on information about Bluetooth Smart devices currently in development at various franchised suppliers. These new products will add features such as capacitive touch sensing, accelerometers and other MEMS sensors, advanced low power 32-bit processor cores and energy harvesting.

Any branch of Future Electronics will be able to provide more information and give engineers access to the Future Connectivity Solutions experts.