WHITE PAPER

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TEXAS INSTRUMENTS

Three flavors of Bluetooth®: Which one to choose?

Summary

The Bluetooth® 4.0 specification brought a new form of Bluetooth technology – variously known as Bluetooth LE, Bluetooth low energy, or Bluetooth Smart in communications directed towards the consumer. This new form of Bluetooth technology was developed in order to enable new types of Bluetooth devices in areas where Bluetooth previously hadn't been widely adopted for reasons of battery life or cost. In this article, I'll provide a brief history of Bluetooth low energy and the consumer-facing positioning of Bluetooth Smart and Bluetooth Smart Ready as well as how to select which "flavor" of Bluetooth is the best option for you.

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A very short history of the wireless technology with many names

Bluetooth low energy started out as "Bluetooth lite" inside of Nokia's research labs in the mid-2000s, and was envisioned as a smaller, lighter companion to regular Bluetooth technology in applications where regular Bluetooth was too complex or too power-hungry. Nokia saw promise in this new technology, and put together an industry alliance around this technology together with other wireless and semiconductor companies and christened it Wibree. A year or so later, it became clear that it made the most sense to develop this technology inside the Bluetooth SIG, and the technology was handed over to them. At this point the technology became known as ultra-low power Bluetooth, and would eventually be re-christened Bluetooth low energy. This technology was included in the Bluetooth 4.0 specification when that was released in 2010. For a consumer audience, Bluetooth 4.0 is referred to as Bluetooth Smart or Bluetooth Smart Ready, depending on which form it is presented in.

The current state of Smart

Since its development Bluetooth LE has been integrated into a wide range of devices including heart-rate monitors, watches, smart meters, peripherals and many more (some of which are featured at the Bluetooth SIG's Bluetooth Smart **product showcase**). Similarly, Bluetooth Smart is commonly supported in new mobile phones, tablets and PCs ensuring a healthy ecosystem for the technology.

So what is Bluetooth Smart/Bluetooth low energy really?

There has been some confusion about what Bluetooth Smart really brings to the table. Some people who are not familiar with the inner workings of the Bluetooth technology assume that Bluetooth Smart lowers power consumption for all types of Bluetooth usage, and this is not correct. The benefits of Bluetooth Smart only apply to devices that actually make use of the Bluetooth low energy features, and only in certain use cases. More about that in a moment, let's first examine how Bluetooth Smart is defined from a consumer-facing perspective.

Bluetooth Smart and Bluetooth Smart Ready

From a consumer perspective, Bluetooth devices incorporating Bluetooth low energy technology are branded using the Bluetooth Smart and Bluetooth Smart Ready monikers. These do not necessarily correspond directly to the technical categories we will be exploring later, but have their own definitions rooted in the consumer experience. Bluetooth Smart Ready devices are "hub" devices such as computers, tablets, mobile phones and the like, that support Bluetooth Smart (Bluetooth low energy) and allow additional profiles to be added later, either through the download of apps or drivers or some other method. Bluetooth Smart devices are Bluetooth low energy-based devices that communicate with Bluetooth Smart Ready devices. One important thing to note is that Bluetooth Smart devices by definition cannot communicate with "classic" Bluetooth devices, they can only communicate with Bluetooth Smart Ready devices.

The intention is that when the consumer purchases a Bluetooth Smart device, he or she will know that this will work with other devices bearing the Bluetooth Smart Ready logo, but not with devices only bearing the regular Bluetooth logo.

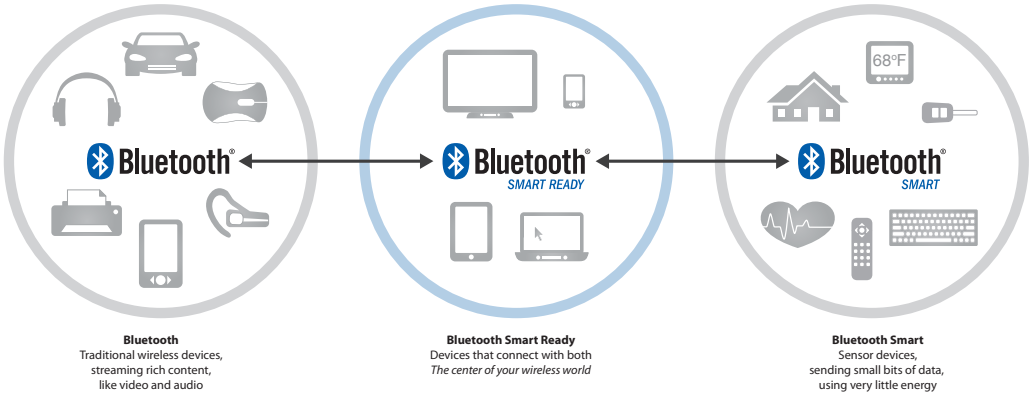

Figure 1. The relationship between Bluetooth Smart and Bluetooth Smart Ready devices (Source: Bluetooth SIG)

The technical perspective

From a technical perspective, there are essentially three different types of devices: "Classic" Bluetooth, Bluetooth dual-mode and Bluetooth single-mode.

The first is the "classic" Bluetooth device as mentioned earlier. These are typically those devices that need a maintained and often high-throughput connection. Going forward, there is every reason to expect that most devices will include Bluetooth low energy support (most modern Bluetooth ICs already do). However, there are going to be some device categories (Bluetooth stereo headsets, for example) where Bluetooth low energy does not provide much benefit, and these will probably remain Bluetooth "classic" devices for the foreseeable future.

The second category is the so-called "dual-mode" devices. These devices support both "classic" Bluetooth and Bluetooth low energy, and can communicate with both "classic" and Bluetooth Smart devices. Dual-mode ICs are found inside Bluetooth Smart Ready devices. These devices do not gain any benefit of

the power consumption improvements enabled by Bluetooth low energy, as they still need to conform to the requirements of legacy Bluetooth devices, but they are an important part of the overall ecosystem.

The third and perhaps most interesting category are the "single-mode" devices, which support Bluetooth low energy as the only form of communication. These devices cannot communicate directly with Bluetooth "classic" devices, but on the other hand they are highly optimized for Bluetooth low energy, and so get the full benefit of this new technology.

Note that Bluetooth low energy was designed and optimized for use-cases that have a relatively low duty-cycle. For example, a heart rate belt may stay connected for several hours during a long work-out, but it only needs to transmit a few bytes every second, so in an optimized protocol, the radio would be on for less than a millisecond. Compare this to a headset or wireless speaker, where the amount of data is measured in the hundreds of kB per second and the radio might be on for a two-digit percentage of the time. The original Bluetooth specification was designed to do general-purpose wireless data transmission, and has been successfully adapted to other use-cases such as input devices and wireless audio. Bluetooth low energy was designed to address use cases that the original Bluetooth specification is less suited for, and therefore extend the overall addressable market for Bluetooth.

Markets for Bluetooth Smart

So far, Bluetooth Smart has seen good adoption in the sports and fitness space. It also has great promise in medical and healthcare, in novel new use-cases such as proximity tags, beacons, computer peripherals and remote user interfaces. In recent months we have seen the rise of a new breed of "connected" devices based on Bluetooth Smart – including for home automation and smart metering, a raft of smart watches, proximity tags, activity monitoring and toothbrushes.

Another way of thinking about Bluetooth Smart is as an enabler of the so-called Internet of Things (IoT). Rather than being directly connected to the Internet, Bluetooth Smart devices interface to the Internet through ubiquitous Bluetooth Smart Ready devices such as smartphones, tablets or PCs. The main benefit of this approach is that the wireless devices can be simpler, lower cost and lower power than devices that would interface to the Internet directly (either through GSM/3G/LTE or Wi-Fi® connections). Also, no extra infrastructure is required; the users already have the equipment needed to interface Bluetooth Smart devices to the Internet.

So how exactly does Bluetooth low energy differ from "classic" Bluetooth? (Please reference Figure 2 on the following page). It begins at the lower layers, where the Bluetooth low energy PHY is a slimmed-down and optimized version of the Bluetooth BR PHY (PHY means physical transport, or how the physical RF transmissions are done, BR and EDR refer to Basic Rate and Enhanced Data Rate, which are the technical terms used to cover the 1 Mbps and 2/3 Mbps modes of "classic" Bluetooth). While the BR PHY hops over 79 channels (can be reduced down to a minimum of 20 channels through adaptive frequency hopping) and performs discovery on 32 channels, the Bluetooth low energy PHY only has 37 channels and does discovery on three channels. Since Bluetooth low energy has a lot fewer channels to go through when doing discovery, the process is much quicker, and a connection can be set up within a few milliseconds rather than the couple of

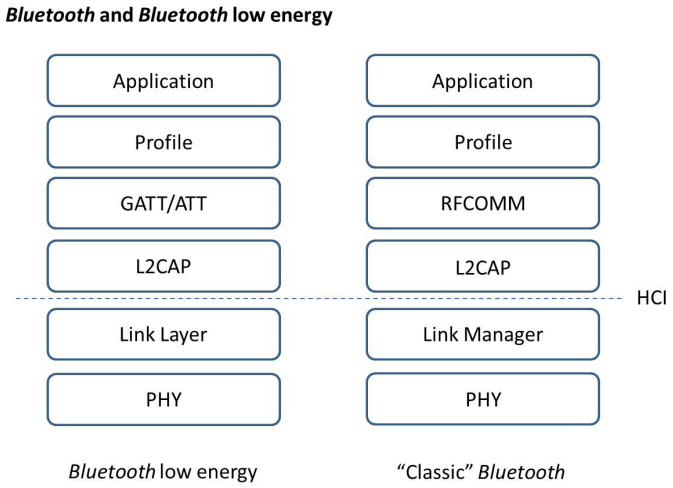

Figure 2. Comparison of Bluetooth low energy (left) and Bluetooth "classic" (right) architecture

seconds required in "classic" Bluetooth. The channel spacing of Bluetooth low energy is 2 MHz in contrast to BR's 1 MHz, this has the effect of reducing demands on RF filtering. Moving up a bit, Bluetooth low energy connections are essentially similar to BR's so-called sniff sub-rating mode. This provides Bluetooth low energy with an energy-efficient way of maintaining connections while keeping the radio off as much as possible. Not immediately apparent from the Bluetooth specifications is the fact that the relaxed requirements allow IC vendors to do a lot of optimizations that are difficult or impossible to make with "classic" Bluetooth, lowering sleep and active currents and shortening switching times. These optimizations enable single-mode chips to be lower power, simpler and lower cost than dual-mode or classic chips.

There are also differences at the profile layer. Bluetooth low energy profiles so far are all layered over GATT, using the GATT/ATT protocol to exchange data. In "classic" Bluetooth, profiles often define their own protocols. This is more flexible, but renders the implementation more complex and increases the amount of code that needs to run.

So, which one should you choose for your design?

Newer ICs are generally dual-mode rather than "classic," so from a hardware perspective, the choice will often be made for you. Certain application-specific devices might continue to be BR- or BR/EDR-only if the application they are targeted at does not make use of Bluetooth low energy. From a software perspective, many commonly-available Bluetooth stacks include low energy support at this point, although again, there may be some that will not.

When it comes to choosing between dual-mode and single-mode ICs or system-on-chips (SoCs), it depends on what application you are targeting. If you need to communicate with "classic" devices, then the choice is simple – you need to use a dual-mode device. If you have flexibility on both sides of the link, then the most important criteria are determined by what and how much data you are moving over the wireless link. If you are moving a lot of data or streaming media, then you should go with a BR/EDR solution. An example of

this type of IC would the **SimpleLink™ Bluetooth dual-mode CC2564** device from TI. This IC contains the Bluetooth 4.1 stack up to the HCI level, with the rest of the stack running on the host microcontroller (MCU).

If you are only transmitting smaller amounts of data then Bluetooth low energy may be a better choice. Bluetooth low energy can provide very long battery life when used in the types of use-cases it was designed for. For example, a sensor communicating with a phone once every second 24/7 will last for more than a year on a CR2032 coin cell. Power consumption (and therefore battery life) scales with the communication period used. The minimum supported period in Bluetooth low energy is 7.5 ms, the maximum is 16 seconds. The 16 second limit is related to a communications time-out; if longer times are needed, it is possible to drop the connection and then reconnect every time as needed. As explained earlier, the fact that only three channels are used for reconnection means that reconnection is much faster than "classic" Bluetooth, on the order of milliseconds rather than seconds.

For single-mode ICs, the industry is moving to ICs that can implement all the functionality in a sensor-type device except the sensing element itself. The **SimpleLink Bluetooth low energy CC2541** wireless MCU from TI is an example of a single-mode Bluetooth low energy wireless MCU solution containing the radio, an MCU and peripherals, as well as on-chip reprogrammable Flash memory.

Other factors may also play a role. For example, if you want your device to communicate with iOS-based devices, then Bluetooth low energy may be an easier way to achieve that. Apple currently requires any BR/EDR devices that support anything other than a set of pre-defined profiles to be certified under the MFI program. For Bluetooth low energy devices there are no such restrictions, and an iOS app running on a reasonably modern Apple device can use a GATT-based API to communicate with Bluetooth low energy devices.

When it comes to other operating systems, Android™ phones supporting Android 4.3 support Bluetooth 4.0 and we expect more to come. Likewise Windows® 8 has full Bluetooth 4.0 support.

The final factor to consider is the ease of development and availability of development tools and documentation. Some single-mode Bluetooth low energy vendors provide royalty-free software stacks and all documentation openly available from a web site. In the "classic" Bluetooth space, it is more common to charge royalties for the protocol stack and keep data sheets and other technical documentation under NDA.

Conclusion

The Bluetooth market has changed dramatically in the past three to four years. The technology has come a long way from being the wireless headset technology to leading the charge to connect innovative fitness monitors, door locks, credit cards, sports equipment, automobiles, gas sensors, light bulbs and a host of other applications. Regardless of what flavor you chose, Bluetooth technology has something to offer and a large install base of phones, tablets and PCs to connect to.

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