Nordic Semiconductor

(Nordic Semiconductor editorial contact:
Steven Keeping, e-mail: steven.keeping@nordicsemi.no, Tel: +61 (0)403 810827)

TITLE: **Inside *Bluetooth* low energy technology**

STANDFIRST: ***Bluetooth* low energy wireless technology employs some clever technology to minimize its power consumption. Kjartan Furset explains**

TEXT:

The Bluetooth Special Interest Group (SIG) has recently formally adopted the latest variant of the popular short-range wireless technology, known as *Bluetooth* Core Specification Version 4.0 ("*Bluetooth* v4.0"). The much-anticipated ultra-low power (ULP) form of the popular wireless technology, *Bluetooth* low energy, is a hallmark feature of this version.

Bluetooth Version 2.1 + EDR and Version 3.0 + HS (commonly referred to as "Classic *Bluetooth* technology") and *Bluetooth* v4.0 have much in common: they are all low cost, short range, interoperable, robust wireless technologies operating in the license-free 2.4GHz Industrial, Scientific and Medical (ISM) RF band.

But there is one critical difference: The *Bluetooth* low energy technology part of *Bluetooth* v4.0 was designed from the outset to be an "ultra-low power" (ULP) wireless technology whereas Classic *Bluetooth* technology forms a "low power" wireless connection.

Classic *Bluetooth* technology is a "connection oriented" radio with a fixed connection interval ideal for high activity connections like mobile phones linking with wireless headsets. In contrast, *Bluetooth* low energy technology employs a variable connection interval that can be set from a few milliseconds to several seconds depending on the application. In addition, because it features a very rapid connection, *Bluetooth* low energy technology can normally be in a "not connected" state (saving power) where the two ends of a link are aware of each other, but only link up when absolutely necessary and then for as short a time as possible.

The operational mode of *Bluetooth* low energy technology ideally suits transmission of data from compact wireless sensors (exchanging data every half second) or other peripherals like remote controls where fully asynchronous communication can be used. These devices send low volumes of data (i.e. a few bytes) infrequently (for example, a few times per second to once every minute or more seldom).

A tale of two chips

There are two types of chips that together form *Bluetooth* low energy architecture: *Bluetooth* low energy devices and *Bluetooth* v4.0 devices. The *Bluetooth* low energy chip is brand new to the *Bluetooth* specification – it's the part of the technology optimized for ULP operation. These devices can communicate with other *Bluetooth* low energy chips and *Bluetooth* v4.0 chips when the latter are using the *Bluetooth* low energy technology part of their architecture to transmit and receive. (See figure 1.) *Bluetooth* v4.0 devices are capable of both Classic *Bluetooth* and *Bluetooth* low energy communication.
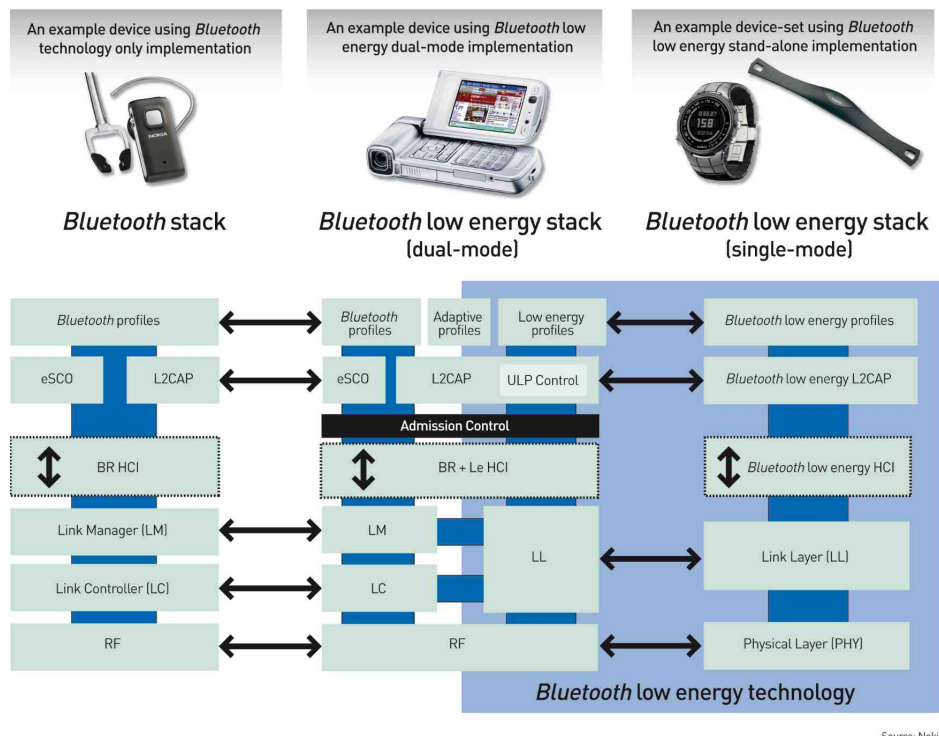
Figure 1: Bluetooth *v4.0 chips will use the* Bluetooth *low energy part of their architecture to communicate with* Bluetooth *low energy devices*

Bluetooth v4.0 chips will be used anywhere a Classic *Bluetooth* chip is used today. The consequence is that cell phones, PCs, Personal Navigation Devices (PNDs) or other applications fitted with the new *Bluetooth* chips will be capable of communicating with all the legacy Classic *Bluetooth* devices already on the market as well as all future *Bluetooth* low energy devices. However, because they are required to perform Classic *Bluetooth* and *Bluetooth* low energy duties, *Bluetooth* v4.0 chips are not optimized for ULP operation to the same degree as *Bluetooth* low energy devices.

Bluetooth low energy chips can operate for long periods (months or even years) from a coin cell battery such as a 3V, 220mAh CR2032. In contrast, Classic *Bluetooth* technology (and *Bluetooth* v4.0) typically requires the capacity of at least two AAA cells (which have 10 to 12 times the capacity of a coin cell and much higher peak current tolerance), and often more, to power them for days or weeks at most (depending on the application). (Note: There are some highly specialized Classic *Bluetooth* applications that can run on batteries with a lower capacity than AAA cells.)

The technology of ultra low power wireless

There are three characteristics of *Bluetooth* low energy technology that underlie its ULP performance: maximized standby time, fast connection, and low peak transmit/receive power.

Switching the radio "on" for anything other than very brief periods dramatically reduces battery life, so any transmitting or receiving that has to be done needs to be done quickly. The first trick *Bluetooth* low energy technology uses to minimize time on air is to employ only three "advertising" channels to search for other devices or promote its own presence to devices that might be looking to make a connection. In comparison, Classic *Bluetooth* technology uses 32 channels.

This means *Bluetooth* low energy technology has to switch "on" for just 0.6 to 1.2ms to scan for other devices, while Classic *Bluetooth* technology requires 22.5ms to scan its 32 channels. Consequently, *Bluetooth* low energy technology uses 10 to 20 times less power than Classic *Bluetooth* technology to locate other radios.

Note that the use of three advertising channels is a slight compromise: it's a trade between "on" time (and hence power) and robustness in what is a very crowded part of the spectrum (with fewer advertising channels there is a greater chance of another radio broadcasting on one of the chosen frequencies and corrupting the signal). The specification's designers are confident they have balanced

this compromise – they have, for example, chosen the advertising channels such that they don't clash with Wi-Fi's default channels. (See figure 2.)

Frequency (MHz)	Bluetooth low energy Advertising channel	Bluetooth low energy Data channel	Wi-Fi Channel
2480	39		
2478		36	
2476		35	
2474		34	
2472		33	11
2470		32	11
2468		31	11
2466		30	11
2464		29	11
2462		28	11
2460		27	11
2458		26	11
2456		25	11
2454		24	11
2452		23	11
2450		22	
2448		21	6
2446		20	6
2444		19	6
2442		18	6
2440		17	6
2438		16	6
2436		15	6
2434		14	6
2432		13	6
2430		12	6
2428		11	6
2426	38		
2424		10	
2422		9	1
2420		8	1
2418		7	1
2416		6	1
2414		5	1
2412		4	1
2410		3	1
2408		2	1
2406		1	1
2404		0	1
2402	37		1

Figure 2: Bluetooth *low energy technology's advertising channels have been carefully chosen to avoid clashes with Wi-Fi*

Once connected, *Bluetooth* low energy technology switches to one of its 37 data channels. During the short data transmission period the radio switches between channels in a pseudo-random pattern using the Adaptive Frequency Hopping (AFH) technology pioneered by Classic *Bluetooth* technology (although Classic *Bluetooth* technology uses 79 data channels).

Another reason why *Bluetooth* low energy technology spends minimal time on air is because it features a raw data bandwidth of 1Mbps – greater bandwidth allows more information to be sent in less time. An alternative technology that features a bandwidth of 250kbps, for example, has to be "on" for eight times as long (using more battery energy) to send the same amount of information.

Bluetooth low energy technology can "complete" a connection (i.e. scan for other devices, link, send data, authenticate, and "gracefully" terminate) in just 3ms. With Classic *Bluetooth* technology, a similar connection cycle is measured in hundreds of milliseconds. Remember, more time on air requires more energy from the battery.

Bluetooth low energy technology also keeps a lid on peak power in two other ways: by employing more "relaxed" RF parameters than its big brother, and by sending very short packets. Both technologies use a Gaussian Frequency Shift Keying (GFSK) modulation, however, *Bluetooth* low energy technology uses a modulation index of 0.5 compared to Classic *Bluetooth* technology 0.35. An index of 0.5 is close to a Gaussian Minimum Shift Keying (GMSK) scheme and lowers the radio's power requirements (the reasons for this are complex and beyond the scope of this article). Two beneficial side effects of the lower modulation index are increased range and enhanced robustness.

Classic *Bluetooth* technology uses a long packet length. When these longer packets are transmitted the radio has to remain in a relatively high power state for a longer duration, heating the silicon. This changes the material's physical characteristics and would alter the transmission frequency (breaking the link) unless the radio was constantly recalibrated. Recalibration costs power (and requires a closed-loop architecture, making the radio more complex and pushing up the device's price).

In contrast, *Bluetooth* low energy technology uses very short packets - which keeps the silicon cool. Consequently, a *Bluetooth* low energy transceiver doesn't require power consuming recalibration and a closed-loop architecture.

Extending the *Bluetooth* ecosystem

Bluetooth low energy technology was designed for applications where Classic *Bluetooth* technology is not viable because of severe power restraints. This is the first time a ULP wireless technology with guaranteed interoperability has been available to electronics designers and promises to kick start hundreds of new applications.

A clue to some of the likely early applications is provided by the Bluetooth SIG's intention to follow up the adoption of *Bluetooth* v4.0 with the release of a family of "Profiles": these Profiles optimize a generic *Bluetooth* low energy chip for a specific application such as Personal User Interface Devices (PUID) (such as watches), Remote Control, Proximity Alarm, Battery Status and Heart Rate Monitor. Other health and fitness monitoring profiles such as blood-glucose and -pressure, cycle cadence, and cycle crank power will follow. (See figure 3.)
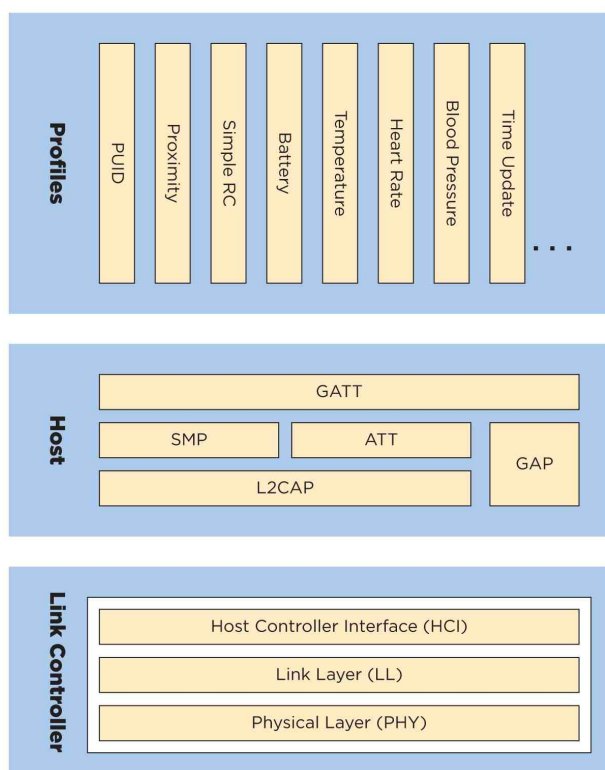

Figure 3: Bluetooth *Core Specification Version 4.0 defines Bluetooth low energy technology's architecture.*

Let's take a look at how *Bluetooth* low energy technology will be used in just two potential applications: Proximity Alarm and Indoor Location (sometimes referred to as "Indoor GPS").

Bluetooth v4.0 chips are being adopted by cell phone and portable PC makers because they'll cost only very slightly more than Classic *Bluetooth* technology yet offer so much more functionality. This will allow cell phone makers to offer a security device comprising a *Bluetooth* low energy powered watch that periodically communicates with the cell phone. If the cell phone moves out of range - and hence can't contact the watch worn by the user – it would automatically lock and the watch would emit an

alarm. This would prevent the cell phone being accidentally left behind and prove a major deterrent for any would-be thief.

The proximity alarm application could be extended to a portable PC that locks when the user moves out of range (and perhaps unlocks to be ready for use when the approaching user presses a button on their watch). The application could also be used as a child safety device where the child's watch communicates with a parent's while they remain in range with an alarm sounding if the child wanders away.

The low cost and low maintenance (because batteries require only infrequent changes) of *Bluetooth* low energy sensors will encourage widespread use in public places. One key application could be indoor location (where there is no GPS signal) whereby sensors around a large public building (such as an airport or rail station) constantly broadcast information about their location. A *Bluetooth* low energy equipped cell phone passing within range could then display that information to its owner.

Sensors could transmit other information such as flight times and gates, location of amenities, or special offers from nearby shops. (See figure 4.)

Figure 4: Bluetooth *low energy equipped sensors around an airport terminal could constantly broadcast information about their location. A cell phone passing within range could then display that information*

Final step

Several silicon vendors are well advanced in the design of their families of *Bluetooth* low energy chips, and have released samples and development kits. Some, including Nordic, have qualified their chips to the *Bluetooth* v4.0 specification.

The first device in Nordic's *µBlue™ Bluetooth* low energy chip family, the nRF8001 (plus a *µBlue* prototype kit and Software Development Kit) was released in January 2011.

By delivering sub 12.5mA peak currents and connected mode average currents as low as sub 12μA (for 1s connection intervals), Nordic claims the nRF8001represents the industry's lowest power *Bluetooth* low energy solution.

The chip is a fully qualified *Bluetooth* v4.0 low energy combining Radio, Link Layer, and Host into one End Product Listing (EPL), enabling designers to easily create new *Bluetooth* end products without any additional listing fees. (See figure 5.)

Figure 5: Nordic Semiconductor's µBlue™ nRF8001 – a Peripheral solution suitable for watches, sensors, and remote controls among other applications – is one of the first Bluetooth *low energy chips on the market*

With the silicon now available from several suppliers, the final piece of the *Bluetooth* low energy puzzle, the Profiles, are imminent. The Bluetooth SIG says the first Profiles – such as Proximity Alarm - will start appearing within weeks. That means electronics designers can finally get their hands on fully qualified chips to begin their product development of proximity applications.

It's taken a while for *Bluetooth* low energy to reach commercialization. But now that the fully qualified silicon is reaching the market, expect a tsunami of *Bluetooth* low energy products to follow. For example, analyst IMS estimates that by 2013, a billion *Bluetooth* low energy devices will be sold every year. That represents the fastest adoption of any wireless technology by far.

About the Author: Kjartan Furset is based in Hong Kong and is a Senior Applications Engineer with 2.4GHz ULP silicon solutions provider Nordic Semiconductor. Nordic Semiconductor is a leading manufacturer of proprietary 2.4GHz ULP silicon solutions and a member of the group that developed the Bluetooth *low energy wireless specification (see www.nordicsemi.com). For more information on these products, go to www.nordicsemi.com. For more on Bluetooth low energy technology, go to http://www.bluetooth.com/English/Products/Pages/Low_Energy.aspx.*

µBlue™ is a registered Trademark of Nordic Semiconductor ASA

DOCUMENT ENDS