Abstract:

Wibree is a short-range wireless protocol optimized for low power consumption. Developed primarily by Nokia, the company has submitted Wibree as an open standard to promote adoption and interoperability. Wibree is intended to compliment Bluetooth communications in certain PAN applications where small, lightweight design makes standard Bluetooth communication unsuitable or difficult. For instance, Bluetooth-enabled wristwatches require relatively large transmitters and batteries, making the devices heavy and uncomfortable. Wibree-enabled wristwatches can use smaller transmitters and smaller batteries, increasing user comfort and reducing fatigue while extending battery life.

Wibree operates in the same 2.4 GHz frequency band as Bluetooth, which ensures backwards hardware compatibility. Due to this, a single antenna can support both protocols, and many existing Bluetooth devices will require only a simple software update to communicate with Wibree devices. While these upgraded devices will not benefit from the size savings dedicated Wibree models enjoy, they will see much improved battery life. Additionally, compatibility with newer Wibree models will help prolong the lifespan of existing equipment.

Wibree is a short range RF communication technology featuring ultra-low power consumption, a lightweight protocol stack and simple integration with Bluetooth. Wibree radio technology complements other local connectivity technologies, consuming only a fraction of the power compared to other such radio technologies, enabling smaller and less costly implementations and being easy to integrate with Bluetooth solutions. Wibree is the first open technology offering connectivity between mobile devices or Personal Computers, and small, button cell battery power devices such as watches, wireless keyboards, toys and sports sensors.

Wibree is complementary to existing technologies. It does not replace them; rather it's intended to operate side-by-side with the existing protocol, offering dual-mode functionality. Wibree, also called "Baby Bluetooth," is a low-power wireless local area network (WLAN) technology that facilitates interoperability among mobile and portable consumer devices.

Wibree is a new interoperable radio technology for small devices. It can be built into products such as watches, wireless keyboards, gaming and sports sensors, which can then connect to host devices such as mobile phones and personal computers. It is essential the missing link between small devices and mobile devices/personal computers.

Wibree is mainly designed for applications where ultra low power consumption, small size and low cost are the critical requirements. Wibree can be seen as Bluetooth enhancer in many ways rather than a bluetooth killer (Wibree is going to compliment bluetooth and not to replace it). Currently Wibree is not yet used in any products.
History

Around 2001, the Nokia Research Center was looking at options for future personal wireless networking. The company realized that there was room for developing an ultra-low power, wireless technology that could interface cost-effectively with a large variety of existing and future devices, which, until now had not been effectively served by available existing technologies. Towards this end, Nokia decided to create a new open wireless protocol, and now, along with its partners Broadcom Corporation, CSR, Epson, and Nordic Semiconductor, is working to bring it to market.

While the Wibree protocol is currently under development, the availability of the Wibree chip depends upon the semiconductor manufacturers' schedules. Wibree is similar in many respects to the now prevalent Bluetooth standard. Both use the 2.45 GHz band to transfer data and have a 1 Mbps transfer rate (although the newer Bluetooth 2.0 standard already incorporates a 3.0 Mbps transfer rate) and a range of about 10 meters (m). The two complementary technologies differ in size, price, and most of all power consumption. Wibree would use only a fraction of the power consumed by today's Bluetooth chips, resulting in a much longer battery life and more compact devices. While Bluetooth can be used to transmit audio and media files, Wibree is designed to extend this network by serving applications that transmit only small amounts of data and where size and cost are priorities. Many applications that were not cost-effective using existing Bluetooth technology, such as wirelessly controlled toys, watches, medical and sports sensors, and a range of other applications that have not been conceived yet, might be developed using Wibree technology.

The Wireless Zoo

Apart from the well known Bluetooth format, which operates at a distance of up to ten m (and the less common Bluetooth Class 1, which can broadcast up to 100 m) and can transmit up to 3.0 Mb/s, there are currently a host of other wireless technologies on the market and even more planned for the next few years. The following is a list of some of the main technologies.
Wi-Fi – Initially conceived in the 1990's, this wireless protocol was developed for wireless local area networks (LANs) and is used to connect computers, mobile phones, VoIP (Voice over Internet Protocol) phones, game consoles, and even TVs and cameras. The protocol has evolved in recent years and now includes several standards (IEEE 802.11a, 802.11b, 802.11g, as well as the upcoming 802.11n). The transfer rate of Wi-Fi has always been considerable - 802.11b, ratified in 1999, reached a maximum data transfer rate of 11 Mb/s; 802.11g, ratified in 2003, reached a maximum data transfer rate of 54 Mb/s; and the future 802.11n might reach a maximum data transfer rate of 540 Mb/s. The range of Wi-Fi is also considerable and can exceed 100 m in some outdoor conditions. One of the main problems with Wi-Fi is its high power consumption, which is the result of the relatively long range and high data transfer rate of the technology. Wi-Fi is also relatively expensive and has higher latency than some of the other wireless technologies.

WiMax – In 2001, work on IEEE 802.16 began. This new standard was meant to create metropolitan wireless networks to accommodate or replace the Wi-Fi's local networks. The WiMax protocol allows for high speed (up to around 70 Mb/s) and long range (several and in some cases several dozen of kilometers) wireless communication. WiMax could potentially allow cheap, high speed wireless communication everywhere and find uses ranging from VoIP mobile phones to high definition wireless TV broadcasting. Like Wi-Fi, the power consumption of WiMax is considerable, and therefore is not suitable for use in small, low power devices.
**Wireless USB** - Wireless USB or WUSB is a new short-range, high speed wireless extension to the USB standard that combines the speed and security of wired technology with the ease-of-use of wireless technology. WUSB is based on ultra-wideband (UWB) wireless technology, capable of sending up to 480 Mb/s at distances of up to 3 m, and 110 Mb/s at up to 10 m. WUSB is intended to compete directly with Bluetooth and find applications in game controllers, printers, scanners, digital cameras, MP3 players, hard drives, flash drives, and even TVs and other video-capable devices. The WUSB technology has suffered some setbacks due to both technical issues and disputes between some of the major players involved in its development.

**Radio Frequency Identification** – Modern Radio Frequency Identification technology (also known as RFID) was first demonstrated by researchers from Los Alamos, California in 1973. The most familiar form of RFID is the RFID tag, consisting of passive, semi-passive, and active RFID chips. Passive RFID chips use the minute electrical current induced in their antennas by incoming radio frequency signals to provide them with just enough power to operate and transmit data in response. Semi-active and active RFID tags include a battery, which helps them to stay on, respond more quickly, and transmit their information more effectively; the trade-off is that when the battery drains, it must be replaced. While passive RFID tags have a typical range of a few meters, active RFID tags can reach dozens or even hundreds of meters. These ranges make them perfect for monitoring product tracking, transport payments, wireless sensors, and various other applications. The main advantage of RFID devices is their very low power consumption (a passive RFID device doesn't even require a battery), but they are unable to store large amounts of information and have a very low data transfer rate (usually measured in Kb/s rather then Mb/s). Recently, HP revealed a new type of wireless technology called Memory Spot that consumes very little energy and does not require a battery. This upcoming technology has a 10 Mb/s transfer rate, but is designed to work only at a very close range (around 1 mm), making it suitable only for a number of applications.
ZigBee – ZigBee is the name of an alliance of companies formed around a standard approved in 2003 called 802.15.4. The ZigBee protocol promises to provide a long battery life (months or even years on a single battery charge) and to be a lower-cost alternative to Bluetooth for wireless sensing and control applications. The ZigBee alliance consists of a group of companies that includes Invensys, Honeywell, Mitsubishi Electric, Motorola, and Philips, to name a few. Its name comes from the zig-zag flight path of bees, forming mesh networks between flowers. Members of the ZigBee alliance believe that mesh networking is the key to unattended wireless systems for smart homes as well as wirelessly-controlled sensors for medical uses and industry. ZigBee also displays very low latency (much lower than Bluetooth, for example), which is critical for certain applications such as heart sensors.

Since Nokia views Wibree as a technology complementary to Bluetooth, its closest competition might be ZigBee. Both technologies offer extended battery life in exchange for a relatively low data transfer rate (1 Mb/s for Wibree and 0.25 Mb/s for ZigBee). ZigBee has a longer range (30 m or more as opposed to Wibree's 10 m range), but this only serves to illustrate the different potential markets of the two. ZigBee can help standardize different smart home technologies such as lighting and heating controls, blind, drapery, and shade controls, and even home appliances such as TVs, DVDs, microwaves, and ovens. Range is less important to Wibree, which is more oriented towards small, low power consumer products such as mobile phones, watches, and input devices, such as mouse and keyboards, as well as toys. The only potential market where the two technologies might compete directly is the medical and sport sensor market; alternatively, both Wibree and ZigBee networks could work side-by-side in different applications over the next few years.

**Architecture**

It has two modes namely dual mode and stand-alone mode.
Stand-alone mode:

Stand-alone Wibree chips would be implemented in small, low cost devices such as wireless mouse and keyboards, sport sensors, watches and toys.

Dual Implementation mode:

The Wibree-Bluetooth dual-mode chips would probably be implemented in future mobile phones, allowing users to benefit from both worlds – Bluetooth 2.0 high speed and Wibree's low power and extended ability to communicate with a new generation of smaller wireless devices. Wibree technology is up to ten times more efficient than Bluetooth and have an output power around -6dbm.

Technical details:

Bluetooth low energy technology operates in the same spectrum range (2402-2480 MHz) as Classic Bluetooth technology, but uses a different set of channels. Instead of Bluetooth technology's 79 1 MHz wide channels, Bluetooth low energy technology has 40 2 MHz wide channels. Bluetooth low energy technology uses a different frequency hopping scheme to Classic
Bluetooth technology; as a result, whilst both FCC and ETSI classify Bluetooth technology as an FHSS scheme, Bluetooth low energy technology is classified as a system using digital modulation techniques or a direct-sequence spread spectrum.

Bluetooth low energy technology is designed with two equally important implementation alternatives: single-mode and dual-mode. Small devices like tokens, watches and sports sensors based on a single-mode Bluetooth low energy implementation will enjoy the low-power consumption advantages enabled for highly integrated and compact devices. In dual-mode implementations Bluetooth low energy functionality is integrated into Classic Bluetooth circuitry. The architecture will share Classic Bluetooth technology radio and antenna, enhancing currently chips with the new low energy stack—enhancing the development of Classic Bluetooth devices with new capabilities.

<table>
<thead>
<tr>
<th>Technical Specification</th>
<th>Classic Bluetooth technology</th>
<th>Bluetooth low energy technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance/Range</td>
<td>100 m (330 ft)</td>
<td>50 m (160 ft)</td>
</tr>
<tr>
<td>Over the air data rate</td>
<td>1-3 Mb/s</td>
<td>1 Mb/s</td>
</tr>
<tr>
<td>Application throughput</td>
<td>0.7-2.1 Mb/s</td>
<td>0.26 Mb/s</td>
</tr>
<tr>
<td>Active slaves</td>
<td>7</td>
<td>Not defined; implementation dependent</td>
</tr>
<tr>
<td>Security</td>
<td>56/128-bit and application layer user defined</td>
<td>128-bit AES with Counter Mode CBC-MAC and application layer user defined</td>
</tr>
<tr>
<td>Robustness</td>
<td>Adaptive fast frequency hopping, FEC, fast ACK</td>
<td>Adaptive frequency hopping, Lazy Acknowledgement, 24-bit CRC, 32-bit Message Integrity Check</td>
</tr>
<tr>
<td>Latency (from a non connected state)</td>
<td>Typically 100 ms</td>
<td>6 ms</td>
</tr>
<tr>
<td>Total time to send data (det.battery life)</td>
<td>100 ms</td>
<td>6 ms[^10] &lt;[^15]</td>
</tr>
<tr>
<td>Voice capable</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Network topology</td>
<td>Scatternet</td>
<td>Star-bus</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1 as the reference</td>
<td>0.01 to 0.5 (depending on use case)</td>
</tr>
<tr>
<td>Peak current consumption</td>
<td>&lt;30 mA</td>
<td>&lt;20 mA (max 15 mA to run on coin cell battery)</td>
</tr>
<tr>
<td>Service discovery</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Profile concept</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary use cases</td>
<td>Mobile phones, gaming, headsets, stereo audio</td>
<td>Mobile phones, gaming, PCs, watches, sports and fitness, healthcare, security &amp;</td>
</tr>
</tbody>
</table>
More technical details may be obtained from official specification as published by the Bluetooth SIG. Note that power consumption is not part of the Bluetooth specification.

Compatibility

The Bluetooth low energy protocol is not backward compatible with classic Bluetooth protocol. However, Bluetooth low energy technology and Bluetooth technology operate on the same spectrum so the underlying hardware is likely to be similar. A given device may be able to operate as a Bluetooth low energy technology and Bluetooth device using the very same chip and radio hardware, though not simultaneously; this is a Bluetooth 4.0 dual-mode device. More smartphones, laptops and tablets that support Bluetooth 4.0 (which includes both Classic Bluetooth technology and Bluetooth low energy technology) are expected to be released in late 2011 and early 2012.

Application profiles

The commonly available specification of Bluetooth low energy application profiles has to be expected prior to commonly available appliances. Currently there are hints that application profiles get commonly published. Membership in Bluetooth SIG is the minimum requirement to get access to readily edited specification documents.

The latest indication of ready designed and agreed profiles was on 2011-07-05 by Nordic Semiconductor.

Consumer profiles

The first simple consumer profiles notified by members of Bluetooth SIG are

- *Find Me*: The *find me* profile shall support electronic leash applications.
- *Proximity*: The *proximity* profile shall support wireless lock applications as well as authentication procedures. There is no indication yet that said proximity profile contributes to qualification procedures according to ISO/IEC 15408.

Health care profiles

Main focus in health care with Bluetooth low energy technology is vital monitoring. A promoter of such applications in cooperation with Bluetooth SIG is The Continua Health Alliance as an industrial standardisation body.

- Health Thermometer Service
- Heart rate Monitor
Qualification of such approaches according to US (Food and Drug Administration) or EU medical devices qualification directives\textsuperscript{[21]} is not reported.

**Sporting profiles**

Main focus in sports with Bluetooth low energy technology is locating as well as vital monitoring. The promoter of such applications is Bluetooth Special Interest Group (SIG)\textsuperscript{[22]} as an industrial standardisation body as well as Continua Health Alliance. Bluetooth low energy technology is in competition with other industry solution standards such as ANT\textsubscript{(network)}\textsuperscript{[23]}

**Use cases**

Bluetooth low energy technology is the hallmark feature of v4.0 of the Bluetooth Core Specification. This enhancement to the Bluetooth Core Specification that will enable new functionality and applications for remote controls, healthcare monitors, sports sensors and other devices. Bluetooth low energy technology will enhance existing use cases and will enable new ones, widening the applicability and functionality of Bluetooth technology.

The respective chips may be integrated into products such as tokens, watches, manual controls, wireless keyboards, gaming pads and body sensors, which may then connect to host devices such as mobile phones, smartphones, personal digital assistants (PDAs), tablet PCs, notebook PCs, laptop PCs and other grades of and personal computers (PCs).

However, currently in the tenth year after earliest publication with inventor Nokia in 2001 (Wibree) there is no implementing on chip-basis or on protocol-basis to any of the current PC-like or PDA-like products or with any mobile phones nor any of the announced appliance products neither disclosed nor announced. All announcement but one is recognised still just with Bluetooth SIG and not beyond (2010-01-27). The notified exception is with a wireless velocometer, probably not recognised as the *killer-application* with mobilephones.

Bluetooth low energy technology hence may extend any personal area network according to the intentions with IEEE 802.15 WPAN to include watches and toys, sports and health care equipment, human interface (HIDs) and entertainment devices.

**Electronic leash**

Existing solutions of the electronic leash concept get improved with the better economised battery consumption of the Bluetooth v4.0 low energy protocols. Several suppliers yet offer the so-called electronic leash solution based on standard Bluetooth v2.1 protocols. This serves for wirelessly tethering mobile appliances with each other. The RSSI estimate serves for a radial metrics, but without any certified calibration. Setting an alarm on unintentional loss is the key service offered with this concept. An advanced aspect has recently been launched with Bluetooth low energy technology for better economised battery life cycle. Special trimming serves for two years operation from a button cell.
Automatic authentication

Connection-based communication allows for design of secure communication under the qualification schemes of ISO/IEC 15408 Common Criteria standard, however connection-free communication limits the suitability of low energy for secure communications. Beyond classic configuration of appliances, a personally carried duet of Bluetooth enabled smartphone and a Bluetooth enabled watch allow for an automatic two-factor authentication en passant. Then the watch delivers just an identity in the mode of active RFID.

Automatic context detection and automatic log-off

Detecting operational context may be implemented by detection of coincidence of two or more Bluetooth v4.0 low energy protocol enabled tokens, appliances and smartphones. This qualifies for better protection of private and corporate data upon access for log-on to networked work positions as well as with mobile network clients.

Whereas currently known solutions rely just on transmission range limitations, the new Bluetooth v4.0 low energy protocol enables for qualified segregation of various operational distances based on assessment of received signal strength. In contrast to known proposals for locating, such unilateral estimation serves for good discrimination of cohesion in operational context, but does not pretend to deliver a certified accuracy, which is impossible due to variations in transmission conditions.

Advantages

Wibree is the first open technology offering connectivity between mobile devices or personal computers, and small, button cell battery power devices such as watches, wireless keyboards, toys, and sports sensors. The technology enables new use-cases and growth potential in this market segment.

Wibree is complementary to existing technologies; it does not replace them. As an example, Nokia remains committed to Bluetooth technology and working with the Bluetooth SIG (the Bluetooth Special Interest Group). Bluetooth is a great technology and its wide adoption globally is witness thereof. However, unfortunately, no technology can address all consumer needs without handing away the very foundation of what made it appealing in the first place – the more compromises you end up making due to a vast amount of targeted use cases, the fewer are the relative benefits experienced in any particular use case. Thus, Nokia believes that Bluetooth, as we today understand it, serves some use cases very well, but is not well equipped to serve others. The same will apply to Wibree, meaning that there will be room for both technologies. As a rule of thumb, as the communication becomes more data-intensive, the power consumption benefits of Wibree will diminish compared to Bluetooth. Thus, Bluetooth is better suited for streaming and data-intensive applications such as audio and file transfer, whereas Wibree is better suited
for use cases where small amounts of data are transferred. Wibree targets four use case domains, as illustrated on the website. It is expected that mobile phones will carry Bluetooth-Wibree dual-mode implementations, enabling them to make some connections over Bluetooth and others over Wibree.

**Wibree's advantages over ZigBee**

Wibree focuses on low power & low cost communications between mobile phones and small sensor devices, whereas ZigBee focuses on home and industry automation. The mobile phones will be more and more multiradio devices having several radios, many in 2.4 GHz, WiBree is cost- and power-wise optimized for sensor connectivity in this environment, whereas ZigBee results in a lot higher radio activity for fulfilling the same use case, and it is more costly to integrate into mobile phones.

In terms of peak power consumption, Wibree and are roughly equal but due to the higher bit rate, Wibree results in better overall power consumption.

Wibree does not support mesh networks as does ZigBee.

**Integration of Wibree & Bluetooth**

Wibree is an independent new technology that can be implemented based on either stand-alone or dual-mode chips. Stand-alone Wibree chips are used by small, low power, critical devices, whereas Bluetooth host devices, with larger battery capacity, can utilize the dual-mode Bluetooth-Wibree implementation. In mobile phone design, the main benefit of using the dual-mode chip supporting simultaneously Bluetooth and Wibree protocols is achieved by sharing one physical radio and antenna. From the user and application point of view, the key benefit is that a mobile phone or a personal computer becomes a gateway to wide area networks (WAN) and internet for the small low power devices.

**Keeping pace**

The community openness of the standard with Bluetooth SIG and compatibility with wireless regulations under the IEEE framework as well as the downward compatibility of the chips allows for a wide acceptance of the additional protocol stack

**Downloading software updates:**

Presuming the availability of the low energy enabled chip and low energy protocol stack on the target device, the respective applications with existing and deployed devices may be opened to
Bluetooth low energy technology by updates. This will enable the Bluetooth software defined radio to receive signals from Bluetooth low energy devices. However, the capability to communicate in duplex mode is limited with the defined frequency allocation schemes for Classic Bluetooth technology. The common appliances such as mobile phones, personal digital assistants (PDAs) and personal computers (PCs) may then receive as host devices for complex applications the signals transmitted from Bluetooth low energy devices.

Bluetooth low energy technology hence may extend any personal area network according to the intentions with IEEE 802.15 (WPAN) to network personally carried simple devices with other appliances for complex local applications as well as for gateway support to transfer information to other networked entities.

**Standardisation:** In the market of proprietary connectivity solutions, Bluetooth low energy technology differentiates itself through its:

- widely adopted industry standard for protocols (Bluetooth SIG Bluetooth v4.0 and future later versions)
- widely commonalised application profiles agreed under the auspices of Bluetooth SIG
- multi vendor availability of respective chips
- internationally adopted industry standard for transmission (IEEE 802.15.1)
- possibility to emulate the protocol stack with compliant 2.45 GHz chips (IEEE 802.15)
- low price through single chip integration
- availability of new application via applet downloads
- continuous compatibility with yet deployed Bluetooth devices (V4.0 or later) via software updates

**Future Wibree-based products**

The goal being to have the new technology available to the market as fast as possible, Nokia is defining the Wibree interoperability specification, together with a group of leading companies representing semiconductor manufacturers, device vendors, and qualification service providers. The technology will be made broadly available to the industry through an open and preferably existing forum enabling wide adoption of the technology. The forum solution is under evaluation and will be defined by the time the specification is finalized. According to the current estimate, the first commercial version of the interoperability specification will be available during the second quarter of 2007. In addition to these comments about the specification and the forum, Nokia is not releasing any availability statements at this stage. However, Nordic Semiconductor has expressed their excitement about Wibree in our press release: “Consumers don’t like wires and they love compact, portable electronics devices that they can carry with them everywhere without fear of running short on battery power. The mobile phone is the perfect example. But to extend its functionality and allow it to interface wirelessly to a huge range of peripherals, the technical challenge is to ensure minimal power consumption under heavy, daily usage. This is Wibree and it is what consumers have been crying out for. This is also why Nordic
Semiconductor is a totally committed partner to enabling this new exciting market for wireless communication and will be ready to ship Wibree chips by the second half of 2007 to help play its part in making Wibree happen.”

Other examples of compatible devices

- Apple's iPhone 4S.
- Bluegiga's BLED112 and BLE112 modules.
- Texas Instruments chip CC2540.
- Nordic Semiconductor's chip nRF8001.
- Apple MacBook air
- Apple Mac Mini

References

2. http://www.wibreeworld.co.uk/