Bluetooth, ZigBee, and Wibree:
A Comparison of WPAN Technologies

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Introduction and Background

Wireless Personal Area Network (WPAN) designs have been flourishing in recent years. The pervasive success of Bluetooth has been a boon to all devices in the IEEE 802.15 working group. As competing and complementary standards are formed within this working group, a successful embedded system designer must understand the differences between the technology standards. It is the goal of this paper to examine three: Bluetooth, ZigBee, and Wibree.

First, a short history: Wibree is a technology that has been under development by Nokia since 2001 [13]. It was originally adapted from the Bluetooth specification, and in 2006, the Bluetooth Special Interest Group (SIG) announced it would be adopting Wibree into the Bluetooth specification [12]. Integrated Bluetooth/Wibree devices are not yet shipping, though Nordic Semiconductor has published a preliminary product specification [14]. While the Wibree and Bluetooth specs are being integrated, the new name of the Wibree technology has changed several times. In this paper, I will continue to use the Wibree name.

While Wibree has been under development, the competing IEEE 802.15.4 technology of ZigBee has been available to the public for several years. ZigBee was designed as a low-power, low-cost, low-speed solution [1], and has many benefits over Bluetooth, though fewer benefits over Wibree.

Detailed Technology Comparison

Below I will analyze a limited set of characteristics for the three technologies.

Frequency Band

All three technologies operate in the unlicensed 2.4 GHz spectrum, while ZigBee can also operate at reduced speeds at 915MHz and 868 MHz [7].

Antenna and Hardware

Wibree's adoption into the Bluetooth spec was directly related to the fact that it can coexist on BT hardware. Devices that wish to take advantage of both Bluetooth and Wibree will not need to add extra hardware; one antenna will do for both. ZigBee support, however, requires its own hardware and antenna. [11]

Power and Battery Life
ZigBee, designed to be a low-power alternative to Bluetooth, offers 30mW performance compared to Bluetooth's 100mW [10]. However, Dr. Bob Iannucci, Senior Vice President and Technology Advisor at Nokia, claims that Wibree is "up to 10 times more energy efficient than Bluetooth" [5], putting Wibree around 10mW.

ZigBee is designed to "run for six months to two years on just two AA batteries" [2]. This results from its ability to lock into a transmission time slot and sleep in between. Bluetooth, however, must stay awake for the convenience of quick response time, which results in battery life on the order of days. This led to Wibree's design goal of 1-2 years on a single battery. [12]

Range
Both Bluetooth and Wibree are designed to operate within a 10m range, though Bluetooth 2.1 now states a maximum range of 30m [10]. ZigBee, being designed to enable "home and industry automation" [4], allows a maximum range of 75m.

Data Rate
Wibree has caught up to Bluetooth's original data rate at 1Mbps [13], while Bluetooth has proceeded to reach maximum rates of 3Mbps. ZigBee intentionally lags far behind these numbers, sacrificing data rates for power savings, and so transmits only 20-250Kbps. [6]

Component Cost
In 2003, when ZigBee was targeting a $2 component cost, Bluetooth support cost $5 per device [2]. Now Bluetooth pricing has fallen to $3, while ZigBee costs $2 [10]. More importantly, integrating Wibree into an existing Bluetooth implementation adds around 20¢, making Wibree a much more attractive addition to Bluetooth-enabled devices than ZigBee.

Network Topologies
Bluetooth and Wibree operate primarily in ad hoc piconets, where a master device controls multiple slaves. These piconets are limited to 8 devices. ZigBee has far greater flexibility in this arena, supporting mesh and star configurations [3]. Mesh networks offer resilience against severed connections, as Coordinator devices can reroute traffic as needed. Star configurations at the ends of the mesh allow clusters of ZigBee devices to interact with the outside world, while the mesh devices focus on data transmission.

Security
All three technologies support state-of-the-art 128-bit encryption, and all three continue to be scrutinized for key distribution vulnerabilities and the like.

Time to Wake and Transmit
One of ZigBee's greatest strengths over Bluetooth has been its freedom to sleep often. This comes from its quick wake-from-sleep design. A ZigBee device "can wake up and get a packet across a network connection in around 15 milliseconds," while a Bluetooth device would take 3 seconds. [2] A Wibree device would presumably behave more like the ZigBee device, but this remains to be seen.

Table of Feature Comparisons
The above analysis is summarized in **Table 1.**

	Bluetooth	Wibree	ZigBee
Band	2.4GHz	2.4GHz	2.4GHz, 868MHz, 915MHz
Antenna/HW	Shared		Independent
Power	100 mW	~10 mW	30 mW
Target Battery Life	Days - months	1-2 years	6 months - 2 years
Range	10-30 m	10 m	10-75 m
Data Rate	1-3 Mbps	1 Mbps	25-250 Kbps
Component Cost	$3	Bluetooth + 20¢	$2
Network Topologies	Ad hoc, point to point, star	Ad hoc, point to point, star	Mesh, ad hoc, star
Security	128-bit encryption	128-bit encryption	128-bit encryption
Time to Wake and Transmit	3s	TBA	15ms

Table 1. Feature Comparison of the Three Technologies [2,6,7,10]

Exemplary Technology Applications

Given the above knowledge of the three wireless technologies' differences, one can make intelligent decisions about which to use in particular applications. Wibree is already being targeted toward **watches**, as low-data, low-battery-drain accessories to mobile phones [8,9]. Meanwhile, industrial automation tasks—like adding **lighting control** to an existing building—requires the resilience of mesh networking, making ZigBee a strong choice. For applications requiring high bit rates over short distances, like **wireless stereo headphones**, Bluetooth remains the best technology of the three.

Future and Conclusion

Given the above analysis of the three technologies, one can see the strategic significance of Wibree's adoption by the Bluetooth SIG. If integrated Wibree devices can be released soon, the combined momentum with the upcoming Bluetooth 3.0 may prove to be a devastating blow to ZigBee, as mesh networking will be left as its only clear selling point over Wibree. Meanwhile, Bluetooth is growing from a single specification to a whole family of WPAN technologies. This is all good news to the embedded systems designer, who will continue to be offered more and faster technologies for wireless communication.

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