Users Make a Beeline for ZigBee Sensor Technology
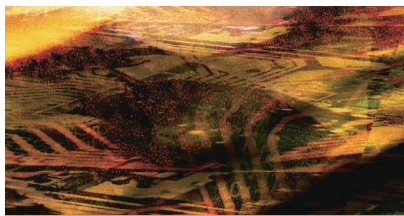
David Geer

As wireless-sensor technology improves, an increasing number of organizations are using it for a wide range of purposes. Users are working with the technology to monitor and automate home, building, industrial, and agricultural systems, including thermostats and security products, said Mareca Hatler, director of research for ON World, a market research firm.

In addition, they are working with sensor networks for checking on environmental quality and the integrity of bridges and other structures, automated meter reading, and even in home healthcare, national security, and military networks, she added.

"ON World forecasts 127 million deployed wireless sensing network nodes in 2010, up from 1.2 million in 2005," she noted.

To achieve technological and marketplace success, the low-power, inexpensive sensor networks need an economical, low-latency, robust, energy-efficient, wireless connectivity infrastructure. With this in mind, users are increasingly working with ZigBee technology.

Other prominent wireless technologies, such as Bluetooth, don't fit the bill because, for example, they are too expensive or use too much energy. Bluetooth is designed to connect high-volume, packet-based devices such as laptops, phones, and major peripherals. ZigBee, on the other hand, connects low-volume devices such as sensors and works with simpler, less expensive, easy-to-use technology.

The ZigBee Alliance (www.zigbee.org) promotes use of the technology, and its 200 members are currently conducting interoperability tests and releasing products. Specification-compliant products receive a ZigBee Alliance logo, noted Nick Dutton, director of business development for Integration Associates, a semiconductor design company and alliance member.

However, ZigBee faces competition from other technologies, as well as marketplace confusion.

INSIDE ZIGBEE

In 1999, the Firefly Working Group, no longer in existence, originated the technology that would become ZigBee.

Today's ZigBee is built on the IEEE 802.15.4 low-rate, wireless, personal-area-network standard, adopted in 2003. The ZigBee Alliance ratified the first ZigBee standard in December 2004 and released it to the public in June of this year.

Technology

Although IEEE 802.15.4 supports mesh and other network technologies, the specification itself operates peer to peer. However, adding network-layer specifications can introduce other capabilities. For example, adding ZigBee atop the 802.15.4 stack lets the technology work directly with other network topologies such as mesh, explained Dutton. ZigBee also adds security to the IEEE standard, as Figure 1 shows.

ZigBee additionally defines the nature of its data communications and routing within networks, as well as the way nodes discover one another.

ZigBee uses IEEE 802.15.4's beaconing technique—in which a node continuously transmits small packets to advertise its presence to other mobile units, which then try to establish a connection—to start networks and let other devices join in, added Philip Orlik, principal technical staff member with the Mitsubishi Electric Research Laboratories (MERL).

The technology also works with the routing discovery approach that ad hoc on-demand networks use, explained Orlik. When a sending node needs a route to a destination, it broadcasts a route-request packet across the network. Nodes then set up backward pointers to the source node in the route tables. The system then builds routes between nodes and maintains them as long as they are needed.

Spectrum and transmission range. ZigBee uses the same unlicensed 2.4-GHz (worldwide), 868-MHz (in Europe), and 915-MHz (in the Americas) radio bands as many cordless telephones. These bands work well for low-cost sensor networks because users don't have to obtain licenses and the spectrum is widely available.

The technology's transmission ranges are 10 meters indoors and 200 meters outdoors for devices using the 2.4-GHz band, and 30 meters indoors and 1,000 meters outdoors for devices using the other bands, according to Dutton.

Data rates. ZigBee transmits data at a relatively slow 250 Kbits per second at 2.4 GHz, 40 Kbps at 915 MHz, and 20 Kbps at 868 MHz, which works well for simple sensor systems that transmit only small amounts of data occasionally, said Orlik. This is considerably slower than other wireless connectivity technologies such as Bluetooth and far too slow for other wireless purposes such as transmitting real-time video.

Security. For security, ZigBee uses 128-bit Advanced Encryption Standard cryptography and trust-center-based authentication, according to David McCartney, vice president of sales and marketing for software vendor Airbee Wireless. A trust center admits devices to a network and hands out ZigBee device and network authentication keys, he explained.

Nodes. Theoretically, ZigBee can support up to 65,536 nodes. However, supporting this many nodes makes network administration unmanageable. To avoid this problem, Dutton said, ZigBee networks should have no more than 3,000 nodes. For situations requiring more nodes, he explained, multiple subnets would work better than trying to make a single large network even bigger.

Low latency. ZigBee is optimized for time-critical applications that won't tolerate latency, such as lighting and power-management controls. ZigBee devices don't have to synchronize with other nodes on a network before joining and beginning communications. Thus, devices require only 30 milliseconds to join a network and 15 milliseconds to access and start communicating with other nodes.

Energy efficiency. Because ZigBee performs just a few specific, simple tasks, the protocol stack can be as small as 28 Kbytes. Thus, system controllers need less memory and consume less power.

In addition, ZigBee devices transmit small amounts of simple data, like those from sensors, which minimizes the amount of energy the systems use, Dutton noted.
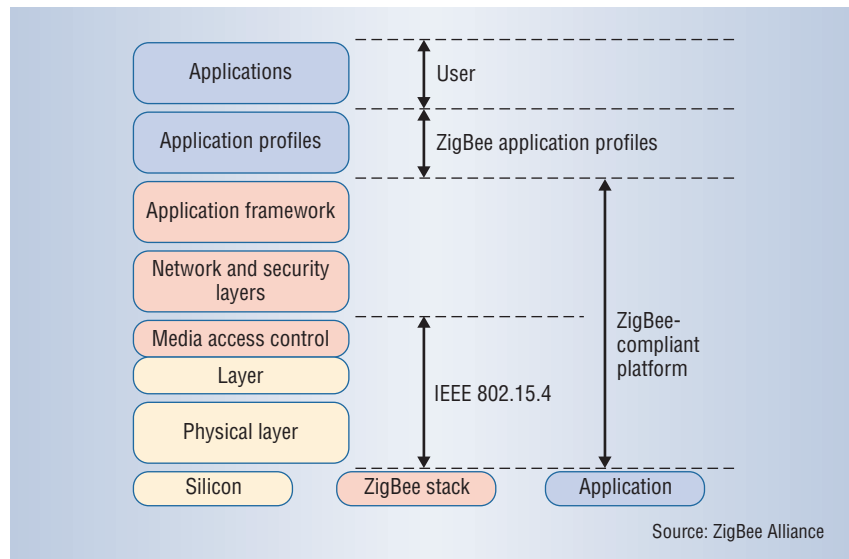
Figure 1. ZigBee is built on the robust physical and media-access-control layers defined by the IEEE 802.15.4 standard. Above these layers, ZigBee defines a mesh network topology with security features and interoperable application profiles.

Also, he said, ZigBee activates devices only when they're needed to pass or act on data, which also contributes to power efficiency.

ZigBee can thus let batteries in devices run for a long time, which is critical for install-and-forget sensor-related tasks such as wireless monitoring and control systems.

Mesh networking

ZigBee uses a full mesh topology, in which all nodes connect to and communicate directly with other nodes within range. Only the intended recipient acts on the transmitted data.

This approach avoids problems—experienced by nonmesh networks that require clear lines of sight between nodes—in which obstacles block radio signals. This is an important consideration in factories or warehouses full of equipment and shelves.

Mesh networking also lets communications pass through any set of nodes between the sender and receiver, which is helpful if a node breaks down or is removed from service. This makes ZigBee networks self-healing, noted Graham Martin, ZigBee business

development director at semiconductor vendor Chipcon.

And because each node can take care of the necessary switching and routing, ZigBee networks don't need separate equipment such as hubs and routers, and thus they can handle network traffic economically.

Implementation

ZigBee is implemented in a device or other node via chips. Currently, ZigBee devices need only an 8-bit controller chip that includes some networking and security functionality; a transceiver chip, which has the radio functionality; a power source; and a few passive components.

Chip makers such as Chipcon and Ember are beginning to combine the controller and transceiver circuitry onto one piece of silicon.

ZigBee's simplicity and plug-and-play capabilities make implementing the technology inexpensive and easy, particularly because it requires little or no network engineering.

And organizations can use gateways to easily integrate ZigBee technology with their back-end maintenance, building automation, automated meter
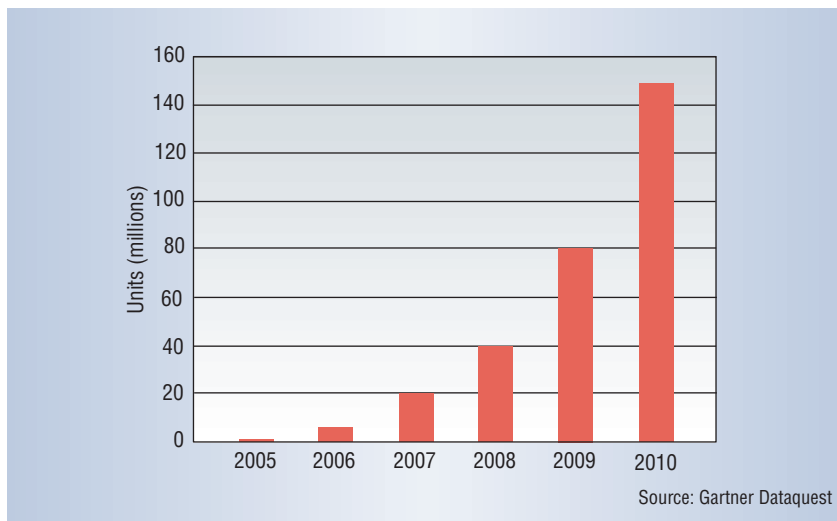
Figure 2. Gartner Dataquest, a market research firm, predicts rapidly growing ZigBee adoption during the next five years.

reading, energy management, and other systems.

"Integrating wireless sensor networks with other systems is essential to the end user in enabling them to not only collect sensor information but also translate it into useful information for data analytics, remote control, and monitoring applications," explained ON World's Hatler. "Wireless sensor networks connected to gateways that are in turn connected to wide area networks enable the sensor information to be transmitted many miles away for processing in a faraway office."

Uses

The ZigBee Alliance is devising application profiles, which let programmers use application-specific commands when setting up ZigBee controllers for related sets of tasks.

The first profile, recently completed, addresses lighting applications and includes information needed to enable dimmers, switches, and lights to communicate with one another, according to ZigBee Alliance chair Bob Heile.

The Alliance will soon release profiles for heating, ventilation, and air conditioning; industrial process control; and building automation, he noted. And some companies like Honeywell are writing profiles that will work only with their own applications.

ZigBee could have many other potential uses, such as transmitting temperature readings from thermostats; on and off requests for wireless light switches, which could eliminate the expensive and time-consuming wiring that traditional switches require; or keystrokes from a wireless keyboard.

Because of its low cost, easy installation, and many potential uses, ZigBee would particularly appeal to builders and homeowners, said Chipcon's Martin.

ZigBee-based monitors could track senior citizens living alone and warn medical personnel about changes that could indicate health or safety problems. ZigBee-powered sprinkler systems could use just enough water to keep plants green. The technology could even enable fleet-management systems to report on vehicle maintenance status, tire conditions, and mileage.

ZIGZAGGING AROUND OBSTACLES

Widespread ZigBee adoption faces several challenges.

Competition

ZigBee must cope with marketplace competition from technologies such as Zensys's Z-Wave and Smarthome's Insteon, which perform many of the same functions.

Z-Wave (www.z-wavealliance.com) and Insteon (www.insteon.net) are proprietary wireless technologies designed mainly for home control and automation.

Z-Wave uses low-power mesh-networked transmitters and repeaters.

Insteon uses radio technology and a home's existing electrical wiring. It works on a peer-to-peer basis and is not routed, like ZigBee and Z-Wave. Insteon thus doesn't require network controllers.

Proponents of the two technologies claim they are better than ZigBee for the residential uses for which they were designed.

For example, because ZigBee was designed to work with many applications in both home and industrial settings, the technology's radios will require more memory and thus will cost more, said Raoul Wijgergangs, Zensys's vice president of business development. Also, the chips will be bigger and more expensive and, therefore, less practical for home use, he added.

Confused marketplace

"Due to the wide range of applications and types of end users, there are many proprietary solutions today that confuse the marketplace by calling themselves 'ZigBee-ready,' " noted ON World's Hatler.

However, she predicted that users who want ZigBee functionality eventually will support only products that use technology based on the standard.

MOVING AHEAD

The ZigBee Alliance is looking at ways to bridge its technology with other types of wireless and wired networks, such as those based on Wi-Fi. Interacting with other types of networks would broaden their usefulness, according to Heile.

For example, bridging could take advantage of both ZigBee's and other networks' capabilities and eliminate

the need for users to base all their desired functionality on ZigBee.

Also, Heile explained, it would be easier to link two ZigBee networks on separate floors of a building via a wired backbone than via a wireless connection.

ZigBee proponents say widespread adoption will require consumer awareness. They are, therefore, focusing on global promotion and marketing such as worldwide open houses with practical demonstrations of devices and applications, Heile noted.

"Research indicates the demand for having security systems at home will drive the adoption of ZigBee. The increasing human dependence on machines to take control of the household will also drive the need for ZigBee in home automation. In fact, by 2006-07, many homes are expected to have a minimum of 100 to 150 ZigBee chips in various appliances," said Deepa Doraiswamy, an analyst for Frost & Sullivan, a market research firm.

According to Chipcon's Martin, energy conservation will motivate Zig-Bee use in Asia and Europe. For example, he said, in some countries, running washing machines at night is either prohibited or incurs higher energy costs. Owners thus may want to use ZigBee to run the machines remotely during the day, when they are not at home.

Stan Bruederle, research vice president at Gartner Dataquest, a market research firm, projects that the number of devices worldwide connected via ZigBee will increase from 400,000 this year to 150 million in 2010, as Figure 2 shows.

Once ZigBee proves itself in its initial implementation with lighting and control systems, it will then play a major role in product tracking, medical monitoring, and industrial sensor networks, said Martin.

Eventually, ZigBee could enable sensor networks to undertake such advanced and promising applications as checking environmental conditions in large industrial complexes, tracking agricultural parameters such as soil moisture and temperature, overseeing wastewater processing, and even monitoring a city for bioterror hazards, said Frost & Sullivan analyst Amit Jain.

The technology has proven to be sound, many companies have supported the ZigBee Alliance, and many people have downloaded the specification or bought development kits, so the issue is when, not if, the technology will take off, stated Martin.

"The market opportunity for ZigBee is huge," said ON World's Hatler. "However, in order for it to reach its full potential, there needs to be more development and investment in networking software, middleware, and sensor applications." ∎

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