

ZigBee Zings

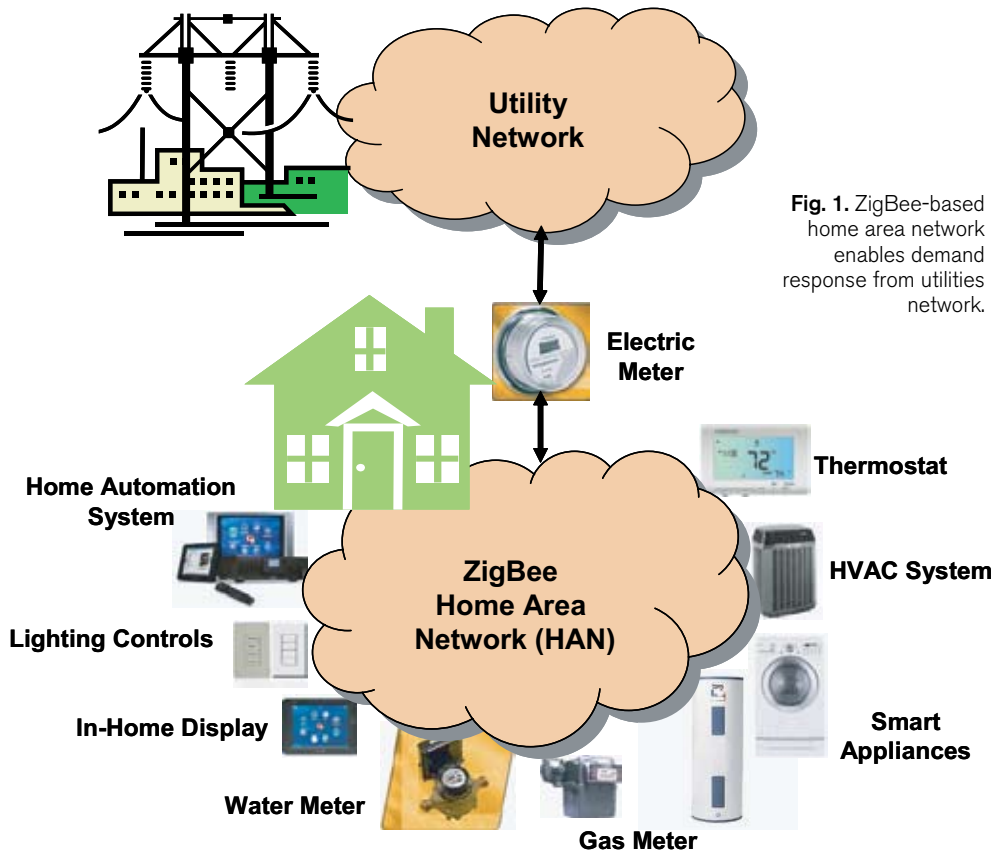


Fig. 1. ZigBee-based home area network enables demand response from utilities network.

Ever since the first Internet toaster was demonstrated at the 1990 Interop conference in San Jose, the concept of the fully connected home — where all the major home systems and appliances talk seamlessly with each other — has been met with a mix of amazement and amusement. While consumers are personally more connected than ever, the various systems and appliances in our homes remain blissful islands unto themselves, with no effective means — or apparent need — to communicate. However, the need for appliances to communicate is rapidly emerging, and fortunately, so are the means with the advent of ZigBee low-cost wireless platforms.

Why communicate?

Public concerns over growing energy demand, shrinking supplies, increasing costs and climate change are everywhere. Under the Energy Star banner, appliance designers have engineered dramatic reductions in appliance energy consumption. Attention is now turning toward the peak-energy demand dilemma, where approximately 10 percent

of total electric generating capacity exists only to be used less than 1 percent of the time. If energy demand can be made responsive to the available energy supply, huge cost and reliability gains can be achieved within the energy grid. This benefit has not escaped the notice of government regulators: the U.S. Federal Energy Policy Act of 2005, California's Title 24, and similar initiatives across North America and Europe, are driving requirements for "demand response" systems in the home.

Demand response systems use Advanced Metering Infrastructure (AMI) networks that provide real-time, two-way communications between electric, gas, and/or water meters and their associated utilities. These increasingly include wireless Home Area Networks (HANs) that connect communicating thermostats, load switches, lighting systems and in-home displays to the meters. Thousands of homes have already been equipped with these systems in pilot projects in Texas and California, with rollouts planned for millions of homes starting early next year. During periods of peak demand, utilities use these networks to throt-

Wireless networking of appliances gets easier.

by **bob gohn**

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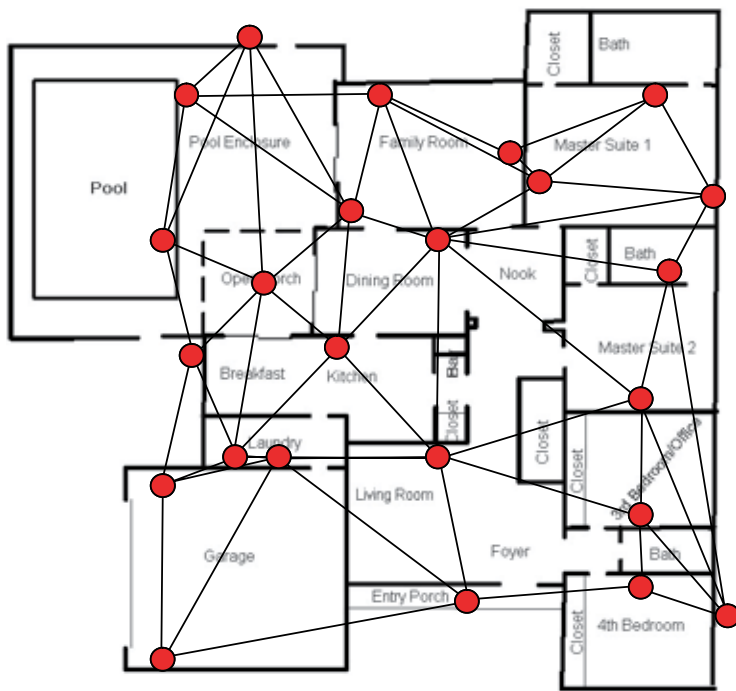


Fig. 2. ZigBee implements a self-forming and self-healing mesh network topology.

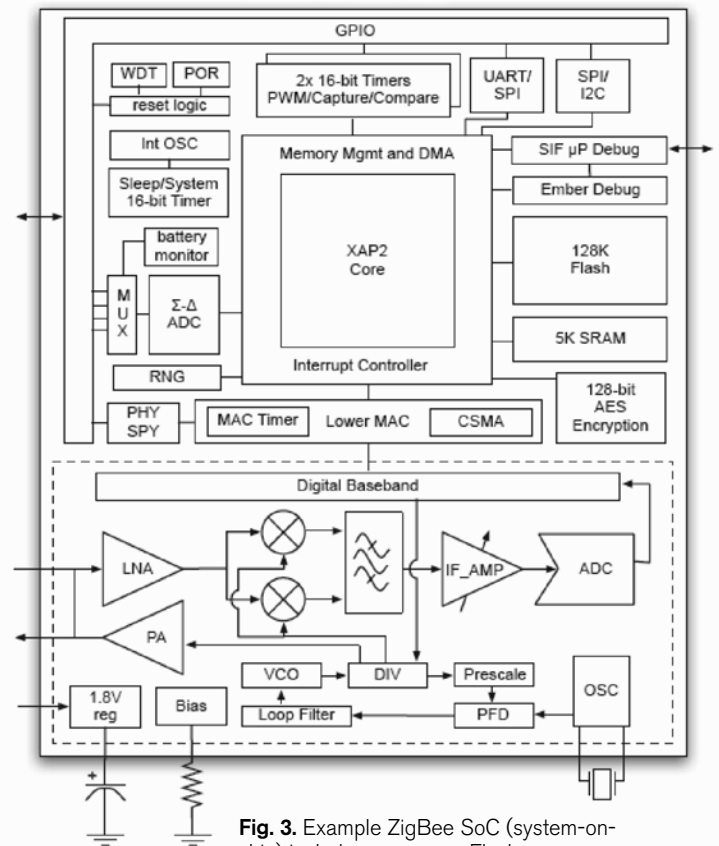


Fig. 3. Example ZigBee SoC (system-on-chip) includes processor, Flash memory, MAC, 2.4 GHz radio, and various peripherals.

the high-load devices in participating homes, such as changing the thermostat setting of the HVAC system. Utilities save in a big way by not having to build new power plants; participants share in the savings through attractive rebates; and communities avoid the ravages of rolling blackouts — the coarsest form of demand response. In other scenarios, utilities may institute “time-of-use” pricing schemes, where the HAN is used to communicate the current price of energy to the consumer. Smart, communicating appliances connected to the HAN can then be set to operate only during low-cost energy periods.

The advent of HANs for energy management coincides with the rapidly growing adoption of wireless technologies for home automation and monitoring products that control entertainment, lighting, climate, and security systems in the home. A recent National Association of Home Builders survey projected that whole-house automation will become standard in upscale homes within seven years, and will make significant inroads even in average homes. And various broadband and wireless telecom service providers are beginning to offer home awareness services that monitor connected home systems over the

Internet or cell phones.

Whether through government mandate, attractive energy cost savings, or simple convenience, consumer demand for smart, networked appliances is on the way. But is the technology ready? Just as Wi-Fi grew to meet the demand for wireless data networking, and Bluetooth for wireless cell phone connectivity, ZigBee has emerged as the standard for wireless control and automation networks.

The ZigBee standard

For those not familiar with it, ZigBee is a wireless networking standard designed specifically for highly reliable, low-power, and low-cost control and monitoring applications. Similar to the way Wi-Fi specifications leverage the IEEE 802.11 standards, ZigBee is built on top of IEEE 802.15.4, and enables devices to self-assemble into wireless mesh networks that can operate for years on low-cost batteries. The 15.4 standard defines the physical and MAC layers, typically operating at 250 kbps on one of 16 selectable channels in the 2.4 GHz band, which is uniquely unlicensed in most of the world.

ZigBee further specifies a complete and reliable

network stack that defines how the mesh network forms and operates, including device association and addressing, routing, security, and management. ZigBee also defines application profiles that specify device types and messages for various applications, such as lighting controls, HVAC controls and so on.

The ZigBee standards are specified by the ZigBee Alliance, made up of more than 220 member companies, including many well-known global brands. The Alliance has independent labs which test, verify and certify ZigBee platforms and products for conformance to the specifications, insuring interoperability. (See www.ZigBee.org.)

ZigBee is designed to be easy to incorporate into a wide range of devices, and be easily deployable. However, this does not mean ZigBee is a simplistic protocol. In comparison to earlier proprietary solutions aimed at home networking, ZigBee is highly scalable, supporting thousands of devices in a very robust and reliable self-configuring and self-healing mesh network. ZigBee also provides strong security capabilities to prevent mischief, and is extremely tolerant of interference from other

radio devices, including Wi-Fi and Bluetooth. In fact, typical home automation/entertainment products often build in both Wi-Fi and ZigBee in the same device.

ZigBee defines three different types of nodes: ZigBee Coordinator (ZC), which is responsible for initial configuration and continuing control of the network; ZigBee Router (ZR), which can relay and/or respond to messages in the network; and a ZigBee End Device (ZED), which can send and receive, but not relay messages. There is one coordinator in each ZigBee network, and in typical home networks, this may reside in the electric meter, home gateway, or central home automation controller. Any device may be a ZigBee router, though these are generally line-powered devices, as they need to be continually active in order to forward messages through the network. The simplest ZigBee devices are the ZEDs, which may implement various sleep modes in order to allow a very long operating life with low-cost batteries.

Implementing ZigBee

Even though the ZigBee protocols are quite sophisticated, ZigBee can be fully implemented with low-cost analog/digital hardware and software running on a small microcontroller. Most designs use single-chip SoCs (system-on-chips), that integrate the IEEE 802.15.4 radio, MAC, embedded microcontroller core, AES encryption engine, RAM, Flash, and peripherals for SPI, UART, I2C, GPIO, ADC, and timers. Very few

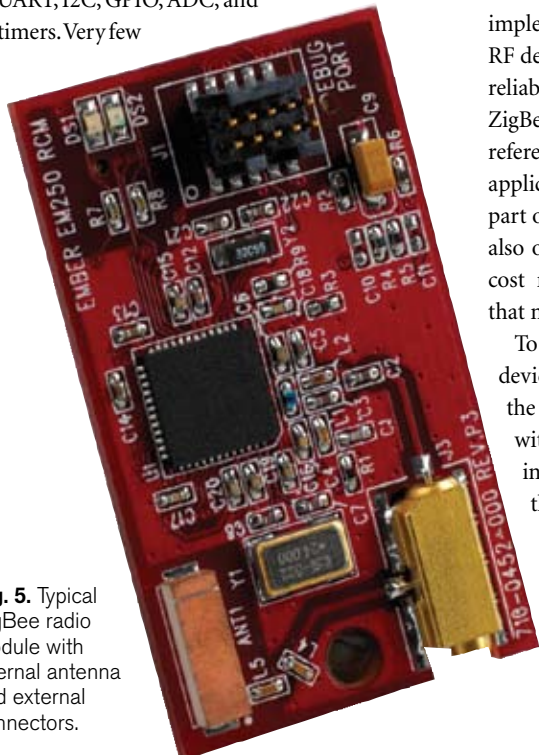


Fig. 5. Typical ZigBee radio module with internal antenna and external connectors.

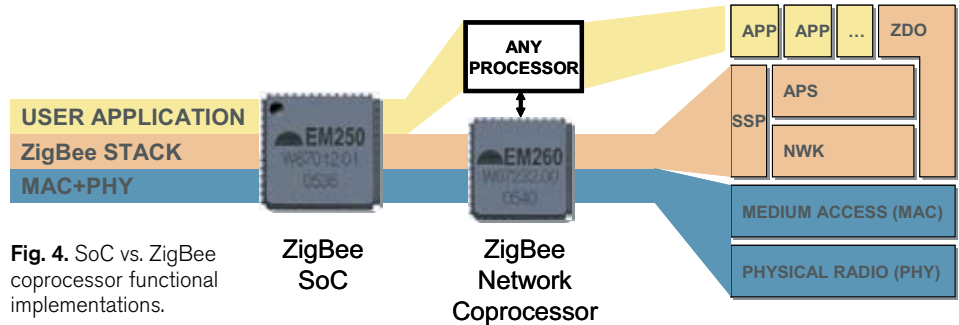


Fig. 4. SoC vs. ZigBee coprocessor functional implementations.

external components are required. The ZigBee stack runs as software on the core and is stored in the integrated Flash memory. The device application (such as a wireless light switch, temperature sensor, load switch, etc.) is also compiled to the embedded core, sharing cycles and memory with the ZigBee stack.

Sometimes a separate microcontroller is desired for the device application, such as when ZigBee is being added to an existing design, or when the application is reasonably complex. Here, a ZigBee network coprocessor may be used. In this case, the device application interacts with the ZigBee stack (fully implemented in the coprocessor) via a simple serial (SPI or UART-based) interface. These options permit ZigBee connectivity to be added to existing smart-appliance designs in a relatively simple and straightforward way, and at low additional cost.

Many designers with extensive experience in embedded microcontroller and software development may not have experienced the challenges of implementing RF radios in their designs. A poor RF design will dramatically impact the range and reliability of the final product. Fortunately, most ZigBee suppliers provide complete and proven reference designs for a wide range of different application scenarios, greatly simplifying this part of the design. Partners of these suppliers can also offer design services or even complete, low-cost modules that make implementing ZigBee that much simpler.

To assure interoperability with other ZigBee devices at the protocol level, and to earn use of the ZigBee Alliance logo, designers must start with a ZigBee-Compliant Platform, consisting of the SoC or coprocessor hardware and the software stack, that has been tested by one of the Alliance-designated test houses. Use of the ZigBee-defined application profiles, such as the Home Automation profile, additionally assures interoperability at the device message level, and allows designers to have their end products tested

as ZigBee Certified Products.

ZigBee has prevailed over earlier proprietary offerings for HAN and advanced home automation applications not only for technical superiority, but also because it is an open, multi-vendor standard that provides designers many choices of platforms to use. There are several important questions to consider when evaluating ZigBee platforms:

- ▶ What is the maturity of the platform implementation, especially relative to the enhancements offered in the latest ZigBee specifications?
- ▶ How robust is the ZigBee stack implementation? Has it been adopted by many of the providers of HAN and home automation systems vendors?
- ▶ How capable are the hardware and software tools provided as part of the platform? Virtually all vendor development kits are easy to use out of the box, but are they easy to use when testing a complex network of many nodes?

The right choice of platform can assure a successful ZigBee implementation.

While smart appliances have proven to be a boon for consumers, smart appliances that communicate will enable societal benefits as well as greater convenience to consumers. With the emergence of complete platforms implementing the ZigBee wireless standard, designers can now deliver these benefits simply and cost-effectively. And perhaps now the fully connected home foreshadowed by the Internet toaster will be viewed with even more amazement, and far less amusement. ■

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