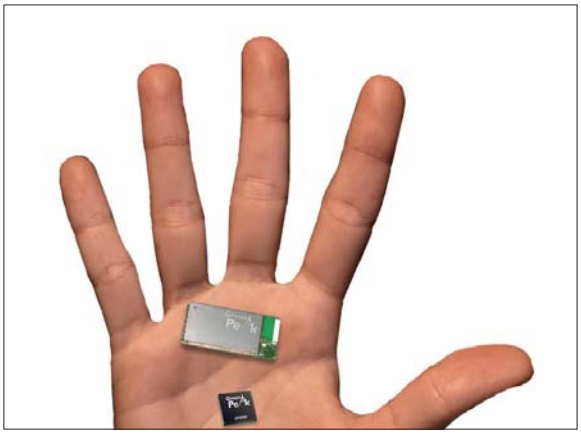
Latest standards for extreme low-power wireless networks

By Wim De Kimpe, GreenPeak

Wireless networking is moving towards the adoption of extreme low-power standards for industrial, home, enterprise, sense and control applications. Powered by batteries and energy-harvesting devices, genuinely wireless products and technology for sensing and control applications are becoming reality.



The ongoing development and acceptance of technology standards is an important factor for adoption of new technologies. Product integrators require technology standards because they provide product interoperability, a large body of knowledge and development sources, second sourcing flexibility, etc. Sensor applications have totally different requirements to most wireless networks. Power consumption is probably the most apparent difference: sensors often have to work for years on a non-rechargeable coin-cell battery, or on energy harvested from the environment through a solar panel or a vibration harvester.

Other sensor-specific application requirements are related to automatic network organization, reliability, communication range, the large number of nodes to be supported in a single network, etc. For wireless sensor transceivers, the dominant standard, and probably only real standard, is the IEEE 802.15.4 specification. The first version was ratified in 2003, with an update in 2006. Several vendors offer transceiver chips. Some of them are a minimal implementation of the standard. Others offer add-ons which are useful in some application segments, such as the GreenPeak GP500 transceiver, which has many power-reducing features targeted towards coin-cell and batteryless applications. There have been efforts to use Bluetooth and Wi-Fi for sensor applications. In those cases, Bluetooth and Wi-Fi were used in a non-standard way, adapting the principles of IEEE 802.15.4 in their native implementation. It is nowadays widely accepted that the IEEE 802.15.4 offers the best basis for wireless sensor applications, as this protocol is specifically designed for low-power networks. Besides the IEEE 802.15.4 standard, a number of technology suppliers have chosen to build a proprietary transceiver. The main motivation seems to be a reduction of the complexity and thus a potentially lower cost point. It remains to be seen if a proprietary solution will ever reach sufficient volumes to actually reach that theoretically lower cost point. Additionally, reducing the complexity automatically goes hand in hand with sacrificing performance and thus limiting the applicability. In essence the network stack has two responsibilities. First, it forms and maintains the network. An important consideration in wireless network stack design is the ability to cope with the constantly varying quality of the wireless links between nodes. For example in a building automation application, the effect of people moving around has a formidable effect on the link quality, because when a person stands in between two nodes the link quality will reduce drastically. So the network stack needs to take into account that links can disappear at any moment, possibly isolating a network node or even a whole branch of the network. In response, the network stack needs to reorganize the communication routes through the network, by establishing new links in order to provide uninterrupted connectivity to all parts of the network.

The other responsibility of the network is to ensure that messages can travel from a source node to a destination node in a reliable and efficient way. Efficiency here means that latency requirements - this is the travel time of a message through the network - should be met, and that bottlenecks in the routing of messages need to be avoided.

Parameter	IEEE 802.15.4	Bluetooth
Wireless frequency	2.4GHz / 868MHz / 915MHz	2.4GHz
Nominal data rate	20 kbps up to 250kbps	1000 kbps
Typical average power consumption	1 microampere	5000 microampere
Network size	Up to 65536	Up to 8 nodes
Range	30-300ft (10-100m)	30-300ft (10m-100m)

Table 1. Listing of the main IEEE 802.15.4 parameters, compared to Bluetooth

The broad application space has widely varying requirements and thus calls for flexibility in the communication technology. Hardware alone cannot offer this flexibility. The network stack comes to rescue here, because a large part of it is generally implemented in software. And software, as compared to hardware, does not have as high an up-front investment cost, meaning that a software investment can live with lower volumes than hardware and still lead to a healthy return. The consequence of these economics is that today we see several network stacks standardized, some of them in progress, others already completed. All the current standards build on top of the IEEE 802.15.4 specification. In other words these standards assume an IEEE 802.15.4 foundation and sit on top of it.

The ZigBee Alliance is an independent standardization organization that is driven by a large group of technology providers and OEM companies. The most recent milestone the alliance achieved at the end of 2007 was to finalize the specification of two network stacks: the ZigBee network stack and the ZigBee PRO network stack. In essence ZigBee PRO is a superset of ZigBee, adding functionalities related to the ability to scale up the network size and to better cope with wireless interference from other technologies. From a usage point of view the ZigBee network stack is very suitable for residential home applications, where home networks typically contains tens or maximum a few hundreds of devices. The ZigBee PRO features make it especially suitable for larger application, very often in commercial building space. The drawback of ZigBee PRO versus ZigBee is that the extra features require a larger program memory size, which automatically translates into higher cost. In the extremely cost-sensitive consumer market every extra cost limits the likelihood of adoption. However, thanks to the ever-decreasing cost of silicon, we predict that in the short term the cost difference between ZigBee and ZigBee PRO will be negligible, and that most applications will adopt ZigBee PRO.

Although the ZigBee Alliance does not explicitly rule out industrial applications, a number of large industrial automation companies have identified the need for extra features which are not on the ZigBee top priority list. The two most important industrial features are deterministic latency and deterministic reliability. Latency is the time a message needs to travel from the source to the destination. If the source is a PLC and the destination is a machine, it is easy to see why tight control over latency is important. That is why the standards that explicitly target industrial automation exploit the IEEE 802.15.4 feature called guaranteed time slots to offer latency determinism. In different words, the IEEE 802.15.4 has a feature that allows to better control when a message will arrive. Guaranteed time slots are not exploited by ZigBee. The second most visible add-on in industrial automation standards is related to reliability. Reliability is related to the availability or absence of a communication path between two wireless devices. The most important enemy of reliability is wireless interference coming from other users of the same wireless frequency band. The most notable interferers for IEEE 802.15.4 based devices that operate in the 2.4GHz frequency band are Wi-Fi transceivers. Most interferers will not fully block out an IEEE 802.15.4 device, but will cause some wireless packets to get lost, regardless of the network stack operating on top of it. The industrial standards provide a mechanism that allows packet losses to become evenly spread out over time, even if the number of lost packets does not substantially decrease. The result can be called deterministic reliability.

ISA-100 and Wireless HART are the two driving industrial wireless automation standards. ISA-100 is the brainchild of the Instrumentation, Systems, and Automation Society (ISA), a non-profit technical society for focusing on industrial automation. The ISA-100 is expected to deliver a standard specification in the course of 2008-2009. Wireless HART is not a full indus-

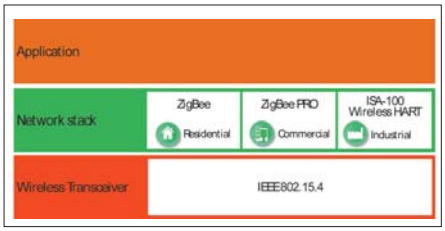


Figure 1: Review of the most prominent sensor network stack standards

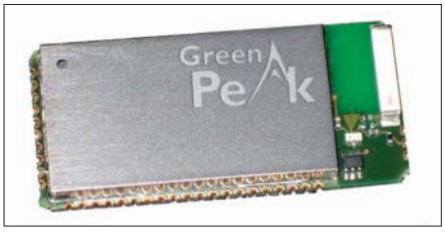


Figure 2: The GreenPeak ultra-low-power wireless module

trial sensor protocol but an add-on to the old but very popular HART industrial (wired) bus standard for industrial automation. In essence Wireless HART provides an alternative to the wired message transmission protocol of HART.

As ISA-100 and Wireless HART are fundamentally solving the same problems, they have recently joined hands in an effort to examine whether both standards can be merged into one. In a first version they will most likely not be interoperable and require a gateway – a translator between the two systems – to interface. A follow up version might define a common language.

The advantages of the industrial standards are not totally meaningless in commercial building automation, but probably not essential to it either. At the same time the industrial standard features add substantial cost, which residential and commercial applications are not likely to accept as they are typically much more cost-sensitive than industrial applications. As in all fields of technology, there are proprietary wireless sensor technologies. We define proprietary as a technology which is dominated by a single company. Proprietary does not mean that the specification is not open, because sometimes it is, but a single company still controls the direction of the technology, effectively leading to a monopoly. Proprietary standards have often been designed around a single or a limited set of applications. In practice, a proprietary technology can develop much faster than a technology standard because there is no need to reach consensus among different companies. Sometimes the proprietary standard may have advantages over the standards when used within their limited set of target applications. Conversely it is uncommon for a proprietary technology to be able to address the broader space of applications that a standard addresses. One of the most notable proprietary technologies in wireless sensor communication is Zensys Z-Wave. Z-Wave is targeted towards residential automation, such as exemplified by the support of a maximum of 237 nodes. This number is sufficient for homes, but is not suitable for larger commercial installations such as hotels and office buildings.

Even within the boundaries of standards, technology providers discover differentiation opportunities. As an example GreenPeak has provided transceiver and network stack technology compliant to the IEEE 802.15.4 standard, and with additional functionalities for ultra-low-power applications. An ultra-low-power application is an application that is able to live off a coin-cell battery or off energy harvested from the environment through a solar cell, a vibration energy harvester or any other environment energy converter. Another evolution that is likely to appear soon in standards is low-power routing (LPR). In an LPR network, battery-powered devices are able to receive messages from nearby devices and forward these further down a longer communication chain. Standards offer this functionality only for mains-powered devices, because a device is required to be in a continuous listening state, consuming a significant amount of power. LPR adds a time synchronization mechanism to the network, allowing devices to wake up simultaneously to initiate communication and avoid the need to be always on. ■

Feature	ZigBee	ZigBee PRO	ISA-100	Wireless HART
Transceiver technology	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4
Support for wireless mesh routing	Yes	Yes	Yes	Yes
Ability to cope with very large networks	No	Yes	Yes	Yes
Latency determinism	No	No	Yes	Yes
Reliability determinism	No	No	Yes	Yes
Built in security features	Yes	Yes	Yes	Yes

Table 2. Listing and comparison of some features of the standards discussed in this article