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Small, smaller, smallest—RF communication protocols for low-power wireless systems

With the ability to connect up to 65,000 nodes in a network, the ZigBee® protocol is naturally an attractive choice for multi node low-power wireless systems—battery-operated systems that communicate over a short or long distance via a radio frequency. But there are alternatives. This article tries to explain how IEEE 802.15.4, ZigBee and other protocols relate to each other.

IEEE 802.15.4

Several data communication standards are based on IEEE 802.15.4, so a brief explanation of it might make things easier to understand. This standard for wireless personal area networks uses radio-frequency (RF) for communication. It is intended for applications that have low requirements on data rate but high requirements on battery life and security. There is a wide range of products and application areas that fit into this category—safety, security and control of homes and commercial buildings, mobile services within business and healthcare, industrial automation, smart metering, home entertainment, asset management and much more.

IEEE 802.15.4 specifies the lower protocol layers: the physical layer and the media access control (MAC). The physical layer provides the data transmission service by managing the Physical RF transceiver. This can work in one of three open unlicensed frequency bands:

- the European 868.0-868.6 MHz: One communication channel
- or North America 902-928 MHz: Up to thirty channels
- Worldwide 2400-2483.5 MHz: Up to sixteen channels

The main function of the MAC is to handle the data service to the PHY, but also to handle several services such as validation, time slot handling and the management interface.

The standard also specifies two different setups on how the network can be constructed, peer-to-peer and star network. There are two different node types:

- Full-function device (FFD) that can serve as the coordinator of a network as well as a common node
- Reduced-function devices (RFD). These are meant to be extremely simple devices with very modest resource and communication requirements, only capable to communicate with FFDs. This also makes them cheap and low power.

ZigBee and other standards use the IEEE802.15.4 as a base on top of which further layers are specified.

ZigBee®

ZigBee specifies a high-level protocol for wireless communication. One of the first points addressed was the need for an automated ad-hoc construction of a network. Apart from the two methods of connection specified in IEEE 802.15.4, peer-to-peer and star network, the mesh network was added.

There are three types of nodes:

- ZigBee Coordinator. May bridge different networks, one in each network
- ZigBee Router. Can also run an application function.
- ZigBee End Device. Can only talk to its parent. Low Power.

The ZigBee standard is proprietary to the ZigBee Alliance, an association of chip manufacturers, tool vendors and adopters of the standard. In order to secure different devices operate to work together, different profiles are decided, and also compliance testing is formalized. The different profiles are:

- ZigBee Home Automation. Control of appliances, lighting, environment, energy management, safety, and security.
- ZigBee Smart Energy. Secure, easy-to-use wireless home area networks (HAN) for managing energy.
- ZigBee Building Automation. Integrate and centralize management of lighting, heating, cooling and security.
- ZigBee Health Care. Interoperable wireless devices enabling secure and reliable monitoring and management of noncritical, low-acuity healthcare services targeted at chronic disease.
- ZigBee RF4CE. Multi-vendor interoperable remote control solutions for consumer electronics.
- ZigBee Telecommunication Services. Mobile devices for innovative lifestyles are in development and will be available soon.

6LoWPLAN

Just like the ZigBee standard, 6LoWPAN is intended for low-power RF-based applications but with a need for wireless Internet connectivity. As its name indicates, 6LoWPAN is a low-power wireless personal area network that is based on IPv6, the next generation Internet protocol.

6LoWPAN allows IPv6 packets to be sent to and received using the IEEE802.15.4 PHY and MAC. The range of application areas is vast—wireless sensor networks for home control, building automation, industrial automation and control, smart metering, health and medical monitoring just to mention a few. The standard is under development at the Internet Engineering Task Force.

WirelessHART

Also based on the IEEE802.15.4 standard, WirelessHART is aimed at industrial process control.

Vendors

Not all wireless applications need all the functionality that for instance ZigBee can offer; other applications might need a bit more.

There are several other protocols that can be used, some based on IEEE802.15.4. To understand why, let’s look at some of the RF offerings from different chip vendors.

Freescale

Freescale have several IEEE802.15.4 stacks for different uses. Why? If we look at them one at a time we will understand.

Name	*Memory*	*Features*	*Data throughput*	*Chip price*
BeeStack ZigBee	50–100K	ZigBee 2007 and ZigBee Pro	30–70K	$3–5
BeeStack Consumer (ZigBee RF4CE®)	32K	RF control of consumer electronic products	30–115K	$2–3
SynkroRF®	32K	Cable replacement, wireless control	70–100K	$3–4
802.15.4 MAC	30–40K	Fully compliant IEEE MAC with Optional feature	90–115K	$2–3
SMAC	3–8K	Propriety MAC on IEEE PHY	50–115K	$1–2

So cutting down on functionality gives you a smaller device, and possibly faster data throughput. These stacks run on different chips from small 8-bit S08 to ARM7.

Of course, other companies have similar ideas.

Texas Instruments

Z-Stack is TI's award-winning ZigBee stack. It supports both the ZigBee 2007 standard and ZigBee Pro. It runs both on SoCs based on 8051 and MSP430, and also MCUs from the MSP430 family.

TIMAC is an IEEE802.15.4 MAC software stack running on SOCs and MCUs.

SimpliciTI is a small, proprietary protocol for RF networks. It is available both for MSP430 and 8051 devices. It is intended for small networks of sensoring and metering devices. The protocol is simple; it uses an API of only five commands.

Ember

Ember have gone in another direction, their EmberZNet PRO is a fully compliant ZigBee Pro stack that also incorporates Ember specific enhancements. It runs on Ember's EM300 series ARM Cortex-M3 based SoCs and also their older EM250 System-on-Chip, the EM260 Network Co-Processor and EM2420 transceivers from Ember.

Atmel

Atmel's BitCloud is a full-featured ZigBee Pro stack. They also have an IEEE802.15.4 Mac and a 6LoWPAN stack, all written for the RZAPV chipset with AVR ATmega MCUs.

Homemade RF protocols

If your RF application is small and simple, you might want to consider writing your own RF protocol using a RF device working in one of the free frequency bands. This gives you full flexibility, but also quite a lot of work.

So as usual, what communication stack you should use depends on what you want to achieve, but whatever that is, your friends—the chip vendors—probably have something that can help you.