



[FPGA Judgment Day: Rise of Second Generation Structured ASICs](#)

BY NARINDER LALL, EASIC

This paper introduces a new technology, the second generation Structured ASIC, that is tipped to reenergize the path to innovation within the electronics industry.

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The wireless toolbox

As wireless technologies continue to evolve, more radios and protocols will arise to meet specific demands.

By



John Schwartz
 DIGI INTERNATIONAL



One of the more petite and unique small form factors available today is a modular radio form factor called XBee. To provide some background on why the form factor was created and how it can simplify designs, John describes the technology and thinking behind these modular radios.

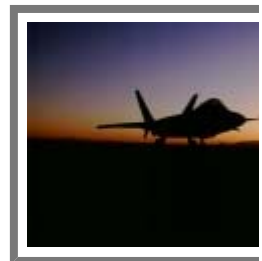
I remember one of the first times I went out to the garage to help my dad change the oil and do other maintenance on the car. I was absolutely amazed

at the sheer number of tools in the various boxes and drawers. There appeared to be an endless array of wrenches, sockets, and screwdrivers of all shapes and sizes. After listening to some brief lessons on the function of each tool, I remember thinking that someone could do almost anything with an adjustable crescent wrench. All the sockets and open-ended wrenches seemed like extraneous tools that were sometimes handy but

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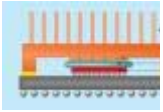
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mostly just used to impress the neighbors.

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I believed my initial impression to be correct until I started working on cars myself. I realized that while a crescent wrench sometimes works, a socket can be much faster. Also, on occasion, the working area can be too restrictive for a bulky crescent wrench, and only thinner, open-ended, or specialized wrenches fit.



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Radios vary widely

The wireless world similarly presents a virtually endless array of protocols, frequencies, and options to select from. As a case in point, Digi has steadily created and added to an entire radio module product portfolio called the XBee radio family (see Figure 1), which offers different frequencies, output power, and network topologies in a pin-compatible form factor.

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Those who are new to the industry often ask questions like, "Isn't a radio pretty much a radio?" and "Why develop so many different types?" As with the wrenches, the short answer is that different radios and protocols fit better in some situations and applications than others. Point-to-multipoint has certain advantages over mesh and vice versa. More output power equates to longer range but more current draw. Some frequencies are not accepted in certain countries.



Figure 1: The XBee radio module enables advanced, low-power mesh networking.

(click image to zoom by 1.9x)

There is no question that in practically all vertical markets, devices are trending toward having some kind of wireless connectivity. Embedding a module often can provide more flexibility than other options, especially if the end product will be deployed in several environments or with different products.

Why different frequencies?

Every device that intentionally emits radio signals must comply with government regulations in the country where the device is deployed. Tested modules with precertifications are available to make this process easier. The United States has Industrial, Scientific, and Medical (ISM) bands at 902-928 MHz, 2,400-2,483.5 MHz, and 5.8 GHz. Because these frequencies allow use without the need for specific site licenses, they tend to be the most popular and the easiest to implement. In Europe, the ISM bands vary somewhat – 2.4 GHz and 5.8 GHz are available, but 868 MHz is used instead of 900 MHz because of cell phone frequencies.

Lower frequencies have better range and obstacle penetration than higher frequencies. If a 900 MHz radio and a 2.4 GHz radio had the same output power and receive sensitivity, the wave from the 900 MHz would go approximately twice as far or penetrate twice as many walls as the 2.4 GHz signal. In some applications, manufacturers prefer the advantage of lower frequencies and ship 868 MHz products to Europe, 900 MHz products to the United States and Canada, and 2.4 GHz products to Japan, where neither of the lower-frequency options is allowed. If the radio modules have the proper certifications, they can save tens of thousands of dollars in required testing and shave months off time to market.

In addition to agency certifications, some module families are designed so they can be interchanged with each other without modification to the host PCB. It is typical for modules to be pin-compatible and interface with the host MCU over a 3.3 V UART. Digi's XBee modules (listed in Table 1) can also operate with either a transparent mode or a standard, compatible API that allows the modules to be exchanged without having to change the host MCU's firmware. Because the radio module is essentially a daughtercard to the main system, modules can be interchanged within the same system whenever necessary as long as a similar form factor is used.


Radio module options 			
Radio module	Frequency	Output power	Topology
XBee 802.15.4	2.4 GHz ISM	1 mW	Point-to-multipoint
XBee-PRO 802.15.4	2.4 GHz ISM	60 mW	Point-to-multipoint
XBee-PRO 868	868 MHz ISM	500 mW	Point-to-multipoint
XBee-PRO 900	900 MHz ISM	50 mW	Point-to-multipoint
XBee-PRO XSC	900 MHz ISM	100 mW	Point-to-multipoint
XBee ZB	2.4 GHz ISM	2 mW	Mesh
XBee-PRO ZB	2.4 GHz ISM	50 mW	Mesh
XBee DigiMesh	2.4 GHz ISM	1 mW	Mesh
XBee-PRO DigiMesh	2.4 GHz ISM	60 mW	Mesh
XBee-PRO DigiMesh 900	900 MHz ISM	50 mW	Mesh

Table 1: Available in different frequencies and topologies, XBee modules can be interchanged without modifying the host PCB.

(click graphic to zoom by 1.8x)

Protocols and architectures

If frequency usage was the only constraint, it would simplify device selection, although radios would not be as flexible or fit into as many applications. Point-to-point and point-to-multipoint are the simplest types of networks.

A point-to-point network consists of only two radios, with one radio acting as a transmitter and a second radio acting as a receiver or with both radios acting as transceivers. In a point-to-multipoint network, several radios are located within range and share data among themselves or sometimes with one master radio polling device acting as a communications arbiter.

Besides being simple to install and implement, the main advantage of point-to-point and point-to-multipoint networks is that they have the best latency and bandwidth performance. Because all devices are within range, no time needs to be spent routing discoveries or forwarding messages through multiple hops. If all installations are within range, going with a simpler network will save design time and offer the best download time for large data chunks at a given over-the-air data rate.

Moving to mesh

What if all nodes aren't within range of each other? With RF, simple repeaters can be used, but mesh takes the repeater concept to a higher level. In most mesh networks, not every device repeats every message. Instead, devices generally use a process to discover routes and then maintain a list of only those routes that are used most frequently.

Different mesh topologies fit better into some applications than others. [ZigBee](#) uses

three different device types within a network. The ZigBee coordinator is responsible for picking a channel and forming a Personal Area Network (PAN). A ZigBee router is always powered and can either receive packets or forward them on to the appropriate destination. ZigBee end devices can operate in extremely low-power sleep modes that in some cases can enable batteries to last for more than five years. ZigBee networks work best in applications like home automation, where routers are connected to lights or other devices that have continual access to power, while end devices such as light switches operate on batteries.

Other mesh technologies allow all devices to sleep and can operate by having all devices wake and sleep in a synchronized fashion (see Figure 2). With DigiMesh, Digi's proprietary mesh networking protocol, all devices initially act as peers and nominate a coordinator from the nodes within the PAN. The nominated coordinator sends out periodic sync messages that allow the other nodes to coordinate their sleep/wake intervals. Messages can be sent only when the whole network is awake, so message latency can take up to the sleep interval time.

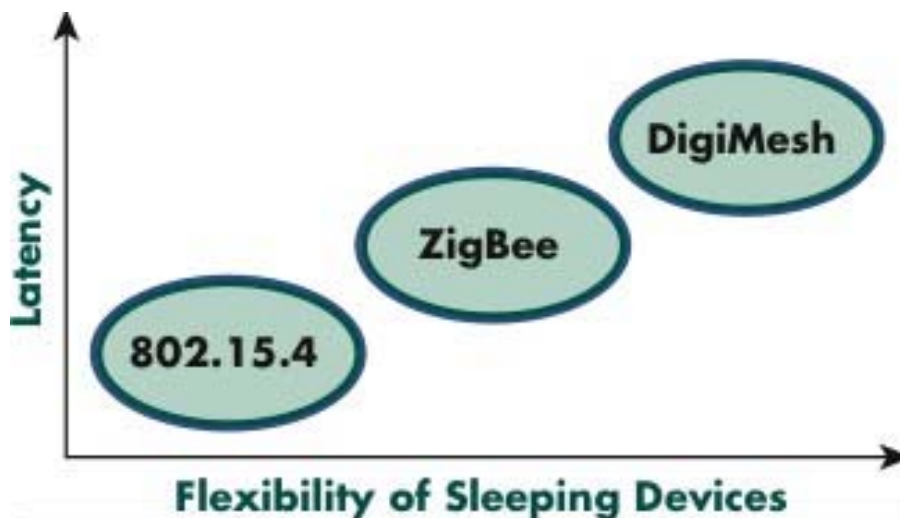


Figure 2: In the DigiMesh networking protocol, a nominated coordinator transmits messages that allow other nodes to coordinate their sleep/wake intervals.

The sleep interval for the network is programmable from 10 ms on the low end to four hours on the high end. Battery life depends on the length of the sleep interval, the amount of time the network is awake during each interval, and the number of times a given unit has to transmit. If the nominated coordinator is damaged or goes offline, the network can automatically nominate a new coordinator to keep the units synchronized.

Applications that deal with remote sensing often have minimal data communication needs, but because of where they are deployed, battery or energy harvesting power is a

must. In these applications, mesh is often a requirement, and the additional latency of the sleeping network is worth whatever latency penalties are incurred.

Modular radios create options

There is no technical reason why designers couldn't put a handful of useful protocols on a single processor; it would even be possible to put multiple RF front ends on a single PCB, rendering several different frequency options. However, putting every mesh topology onto a single processor would require a significant amount of memory, and multiple front ends could get bulky relatively quickly. Either approach could drive up the device costs to the point where they would exceed design cost targets.

By offering a selection of modules with a specific firmware load, different frequencies, and different transmit power, device costs can be kept to a minimum and still allow the flexibility of switching to another option as solutions require.

As wireless technologies continue to evolve, more options and changes will arise to meet specific demands. At some point, the market may see an easily adjustable wireless technology that is the equivalent of a crescent wrench. But until then, all applications have the exact same requirements, and options will exist and continue to expand to meet demand.

John Schwartz is a technology strategist at Digi International, based in Minnetonka, Minnesota, where he evaluates new standards and technologies, provides product training, and supports technical media relations and white paper development. Prior to joining Digi, John served as director of applications engineering at Maxstream, a Digi-acquired company. John has more than 10 years of embedded, RF design, and project management experience and holds BS and MS degrees in Electrical Engineering from Utah State University.

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