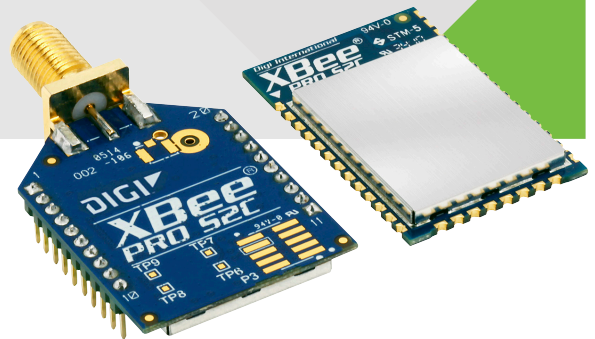


# **XBEE® 802.15.4** **PROTOCOL COMPARISON**





## Abstract

Creating wireless networks can be done using a variety of RF protocols. Some protocols are proprietary to individual vendors, others are industry standards. This Technical Brief will explore the ZigBee® protocol industry standard for data transmission, and the Institute for Electrical and Electronics Engineers (IEEE) 802.15.4 protocol upon which it was built.

We will also touch on Wi-Fi® and Bluetooth®. We will define the frequencies used, the bandwidth occupied, and networking features unique to these protocols. We will also briefly dwell on coexistence strategies.

## 802.15.4

802.15.4 is a standard for wireless communication by the IEEE. The IEEE is a technical professional association that has numerous standards to promote growth and interoperability of existing and emerging technologies. IEEE has published the standards that define communication in areas such as the Internet, PC peripherals, industrial communication and wireless technology. For example, the IEEE 802.11 (Wi-Fi) standard defines communication for wireless LAN, and 802.16 defines communication for broadband wireless Metropolitan Area Networks.

While both wireless standards address higher bandwidth Internet access applications, 802.15.4 was developed with lower data rate, simple connectivity and battery application in mind. The 802.15.4 standard specifies that communication can occur in the 868-868.8 MHz, the 902-928 MHz or the 2.400-2.4835 GHz Industrial Scientific and Medical (ISM) bands. While any of these bands can technically be used by 802.15.4 devices, the 2.4 GHz band is more popular as it is open in most of the countries worldwide. The 868 MHz band is specified primarily for European use, whereas the 902-928 MHz band can only be used in the United States, Canada and a few other countries and territories that accept the FCC regulations.

The 802.15.4 standard specifies that communication should occur in 5 MHz channels ranging from 2.405 to 2.480 GHz. While the standard specifies 5 MHz channels, only approximately 2 MHz of the channel is consumed with the occupied bandwidth.

In the 2.4 GHz band, a maximum over-the-air data rate of 250 kbps is specified, but due to the overhead of the protocol the actual theoretical maximum data rate is approximately half of that.

### Contents

#### Abstract

802.15.4 ..... 2

ZigBee ..... 4

#### Alternative Considerations: Wi-Fi and Bluetooth..... 5

Wi-Fi ..... 5

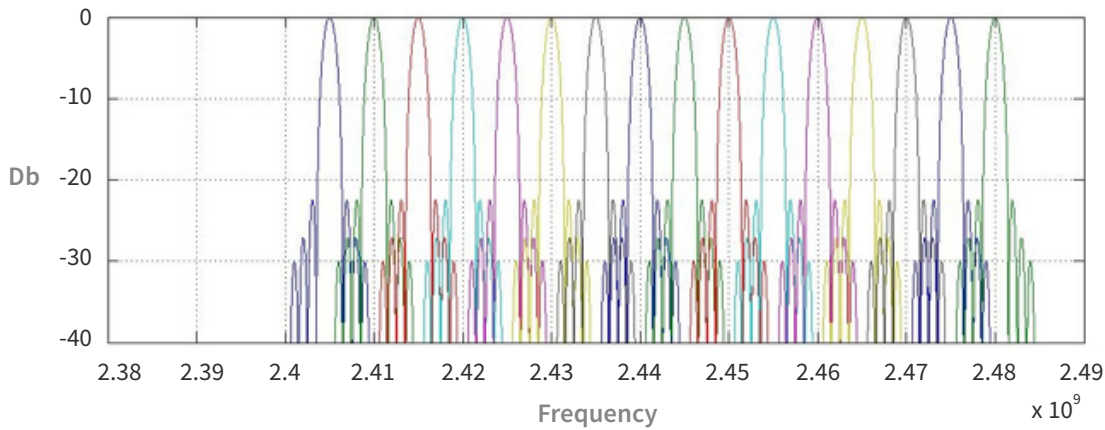
Bluetooth ..... 5

#### Interference—Or, Who Turned on the Microwave Oven? ..... 6

A New Era of Flexibility ..... 7

Conclusion ..... 7

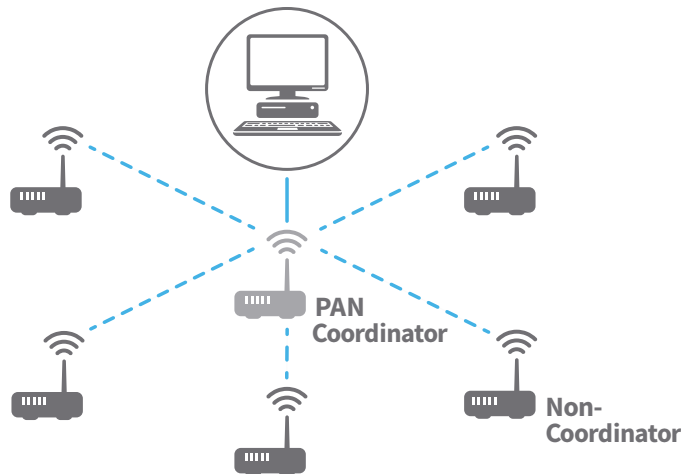
For interference immunity, 802.15.4 specifies the use of Direct Sequence Spread Spectrum (DSSS) and uses an Offset Quadrature Phase Shift Keying (O-QPSK) with half-sine pulse shaping to modulate the RF carrier. The graph below shows the various channels at the spacing specified by 802.15.4.



**FIGURE 1**  
Channels at the spacing specified by 802.15.4.

Digi's XBee® 802.15.4 family of radios can be set up to operate in a point-to-point, point-to-multipoint or a peer-to-peer configuration. This is often referred to as a Star Network. See figure below.

While standard 802.15.4 always requires a coordinator, the Digi 801.15.4 radios are set up so that a coordinator is not required, making these modules fast and simple to get a wireless network up and running.



**FIGURE 2**  
The 802.15.4 standard allows for communication in a point-to-point or a point-to-multipoint configuration.

The 802.15.4 protocol forms the basis for many protocols such as ZigBee, 6LowPan, DigiMesh® and Thread. That is, these protocols are designed to rest on top of the 802.15.4 stack. Also it is very useful in enabling protocols such as Modbus® protocol and SCADA systems which were built on a wired technology called RS-485 which is a bus enabled communication system. 802.15.4 lends itself readily to this concept being able to do a multicast out and yet have the heavy data loads handled by the more reliable unicast when responding to—as an example—a Modbus request.

802.15.4 is commonly used in lighting, digital signage, industrial automation, and simple/fast networking where the leaner of code of the 802.15.4 protocol means that the network is faster—it has more bandwidth and less latency than the protocols that are built on top of the 802.15.4 stack such as ZigBee and DigiMesh. While devices using the 802.15.4 protocol may not

be able to hop messages from node to node such as ZigBee devices can do, the latency differences and greater bandwidth make 802.15.4 the prime choice for applications that do not require meshing to hop around RF obstacles or extend the area that the wireless network covers.

Specifically, Digi 802.15.4 is very simple to configure so that time to configure and deploy is minimal using Digi's AT or API command set.

Another 802.15.4 based protocol is ZigBee, which is similar in many ways to 802.15.4, but also has some key differences.

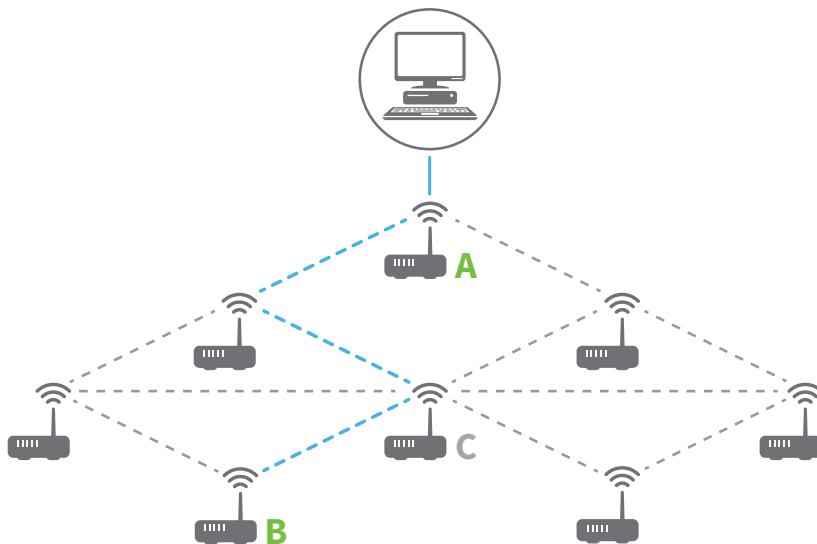
## ZigBee

ZigBee is an open, global wireless standard developed to address the unique needs of low-cost, low-power wireless M2M networks.

The ZigBee protocol was created and ratified by member companies of the ZigBee Alliance. More than 300 leading semiconductor manufacturers, technology firms, OEMs and service companies comprise the ZigBee Alliance membership. The ZigBee protocol was designed to provide an easy-to-use wireless data solution characterized by secure, reliable wireless network architectures.

In comparison to basic 802.15.4, ZigBee is a higher latency, lower bandwidth, asynchronous protocol that uses the 802.15.4 standard as a baseline and adds additional routing and networking functionality. Since the ZigBee protocol uses the 802.15.4 standard to define the PHY and MAC layers, the frequency, signal bandwidth and modulation techniques are identical.

The ZigBee protocol is designed to add mesh networking to the underlying 802.15.4 radio. Mesh networking is used in applications where the range between two points may be beyond the range of the two radios located at those points, but intermediate radios are in place that could forward on any messages to and from the desired radios.



**FIGURE 3**  
ZigBee PRO standard mesh network example.

As shown in Figure 3 above, suppose we wanted to transmit data from point A to point B, but the distance was too great between the points. The message could be transmitted through point C and a few other radios to reach the destination. Therefore, this multi-hopping capability allows the network to maximize range while also allowing a meshing capability.

With meshing, packets are broadcast across the network to multiple radios and paths, so that if a radio were removed or unable to communicate for some reason (like interference or a blocked signal caused by an obstacle) a new path would be used to route messages. This route redundancy makes the network more robust and reliable which can be a major advantage in certain situations.

The ZigBee protocol enables broad-based deployment of wireless networks with low-cost, low-power solutions. It provides the ability to run for years on inexpensive batteries for a host of monitoring and control applications. Smart energy/smart grid, Automatic Meter Reading (AMR), lighting controls, building automation systems, tank monitoring, HVAC control, medical devices and retail applications are just some of the many spaces where ZigBee technology is making significant advancements.

While the versatility of the ZigBee protocol can be a great advantage, it can introduce unnecessary complications due to different node roles, routing tables, retries and acknowledgments, etc. If all that is needed is a simple point-to-point connection, a basic 802.15.4 radio or a sub-GHz radio with more range may be the better choice.



## Alternative Considerations: Wi-Fi and Bluetooth

### Wi-Fi

Wi-Fi is another popular open standard in the 2.4 GHz arena, based on the IEEE 802.11 standard.

Utilizing wide 22 MHz bands in the 2.4 GHz frequency range, Wi-Fi uses its massive bandwidth to achieve very fast data rates. When compared to the smaller, more intense energy of 802.15.4 channels, Wi-Fi spreads all over the spectrum making coexistence with 802.15.4 and Bluetooth difficult.

This bandwidth capability however makes Wi-Fi the wireless connection of choice for many of today's general networking needs in the home or workplace for things like larger data files, images or video streaming. Wi-Fi is typically easy to setup and provides standard security features. In addition, because of its open standard, Wi-Fi also has a wide range of interoperability with other devices.

Wi-Fi moving all this data is power-intensive as mentioned earlier, which means it is not good for battery-powered applications since it usually requires a wired power source. In addition, it is not capable of meshing; connectivity is limited to wherever the gateway or access point can reach, typically a few hundred feet.

### Bluetooth

Bluetooth is another popular open standard that is growing significantly. Conceived in 1994 as the wireless replacement for RS-232, a very short-range wired serial communication protocol, Bluetooth has evolved to connect just about any device you can think of to your PC, laptop or smartphone. Bluetooth uses the same 2.4 GHz frequency range as is used by 802.15.4 and Wi-Fi. Bluetooth packetizes the data and transmits each packet on one of 79 designated Bluetooth

channels. Each channel has a bandwidth of 1 MHz, typically performing 800 hops per second, with Adaptive Frequency-Hopping (AFH) enabled. Bluetooth low energy uses 2 MHz spacing, which accommodates 40 channels. When encountering interference, Bluetooth simply hops to a new band and resends.

The major advantage of Bluetooth is its low power consumption relative to its decent bandwidth capabilities, especially the Bluetooth Low Energy (BLE) version of the spec that has recently emerged. This makes the technology very useful for mobile devices and wearables. Similar to Wi-Fi in its ease of use, and very low cost, the simple point-to-point connectivity and relatively decent bandwidth has also helped make the technology ubiquitous today.

While the standard continues to evolve, it has its drawbacks. Lower in power than Wi-Fi, its bandwidth still consumes enough power to make battery operation limited. In addition its range is limited to usually a few meters in practical use. While the standard has announced plans to support mesh in the future, which will help its range and scale, due to its architecture it will still be limited when compared to alternatives, like ZigBee or even Thread. Its security is also very limited today, making it unsafe for critical infrastructure.



## Interference—Or, Who Turned on the Microwave Oven?

One of the major issues of RF is interference—both intentional and unintentional. Wi-Fi, Bluetooth, 802.15.4 and Microwave ovens all reside in the same frequency range and are typically installed in the same physical area. Proper selection of the bands of operation for Wi-Fi and 802.15.4 can allow those two protocols to coexist.

Notice in Figure 4 below that some 802.15.4 channels are in the clear if the Wi-Fi network is set up with non-interfering channels.

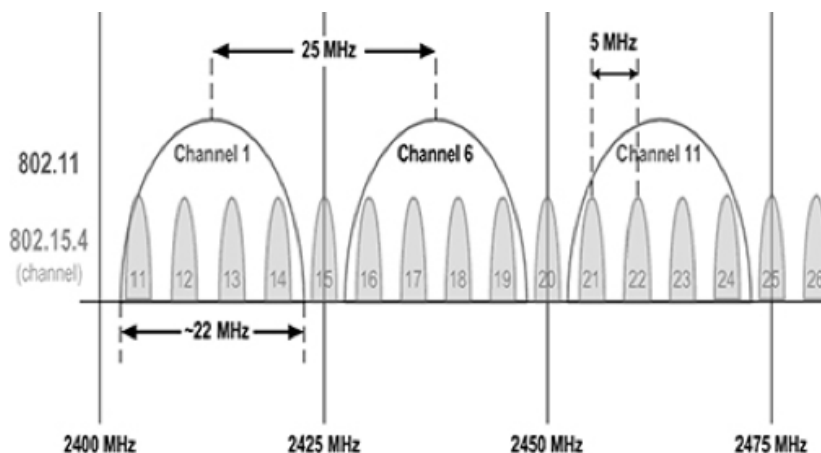


FIGURE 4

Courtesy the International Standards Association

Bluetooth also uses the same spectrum as Wi-Fi, but uses Frequency-Hopping Spread Spectrum (FHSS) for interference immunity.

To defend against interference from other technologies, Wi-Fi slows down and tries again. Bluetooth just hops away and 802.15.4 based protocols are simply patient and persistent.

Other types of interference such as the microwave in the lunch room next door, which is operating in the same 2.4 GHz band of your Wi-Fi and 802.15.4 network, can best be solved by making sure that the device is properly maintained and functional.

In a corporate environment it is recommended that an RF site survey be conducted, using appropriate tools such as a frequency spectrum analyzer, by a qualified technician during the planning stage, prior to installation.

## A New Era of Flexibility

The ability of ZigBee to utilize the IEEE 802.15.4 protocol is based on the Open Systems Interconnection model. OSI is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard to their underlying internal structure and technology. The model partitions a communication system into abstraction layers. Thus developers can build on the existing layers that handle such things as the physical interface to the hardware. Progressive layers of abstraction allow the developer to design at a high level of abstraction without worrying about the mundane chip level minutia.

With the new release of the Digi 802.15.4 firmware using S2C hardware, Digi has ushered in a new age of hardware to allow multiple protocols—including 802.15.4, ZigBee and DigiMesh—to be uploaded on a single hardware platform.

This means that if you purchase a basic 802.15.4 module and find that you need a mesh network instead, it is a simple matter to re-flash the firmware with the appropriate firmware solution. The reverse is also true. All too often the lure of a mesh network yields ground to the practicality of the lower latency and higher bandwidth of the 802.15.4 solution.

## Conclusion

If the application strictly needs to communicate serially in a point-to-point or a point-to-multipoint fashion over larger than Bluetooth distances to greater than Wi-Fi distances, then 802.15.4 is your answer. 802.15.4 will be able to handle all the communications between your devices and will be simpler to implement than trying to use a protocol with mesh to accomplish the same goal. 802.15.4 is also faster (reduced latency) and has a wider data bandwidth (more bits per second of your data) than mesh (ZigBee and DigiMesh). If you need to use a mesh networking functionality for range extension via routers or routing the data around RF obstacles, then Digi's new XBee S2C module with 802.15.4 is your answer, as you can re-flash the 802.15.4 to a mesh solution with little effort.

## Key Takeaways:

- ✓ IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is the basis for the ZigBee, ISA100.11a, WirelessHART, MiWi, and Thread specifications, each of which further extends the standard by developing the upper layers which are not defined in the 802.15.4 standard.
- ✓ XBee and ZigBee are not synonymous, but the XBee ZigBee module is compatible with any ZigBee network.
- ✓ Digi offers several products for commissioning over 802.15.4 including DigiMesh, XBee modules, gateways and routers.

All registered trademarks or trademarks are property of their respective owners.

## Contact a Digi expert and get started today

PH: 877-912-3444

[www.digi.com](http://www.digi.com)

### Digi International Worldwide HQ

11001 Bren Road East  
Minnetonka, MN 55343

### Digi International - France

+33-1-55-61-98-98

### Digi International - Japan

+81-3-5428-0261

### Digi International - Singapore

+65-6213-5380

### Digi International - China

+86-21-5049-2199



/digi.international



@DigiDotCom



/digi-international

© Copyright 2016 Digi International Inc. All rights reserved. 91003380 A1/516

While every reasonable effort has been made to ensure that this information is accurate, complete and up-to-date, all information is provided "AS IS" without warranty of any kind. We disclaim liability for any reliance on this information. All registered trademarks or trademarks are property of their respective owners.