Demystifying 802.15.4 and ZigBee®

White Paper

Abstract

Creating wireless networks can be done using a variety of RF protocols. Some protocols are proprietary to individual vendors, and others are industry standards. This white paper explores the ZigBee protocol industry standard for data transmission, and the IEEE 802.15.4 protocol on which it was built. This paper defines the frequencies used, the bandwidth it occupies, and networking features unique to each of these protocols and explore the features they were designed to use.
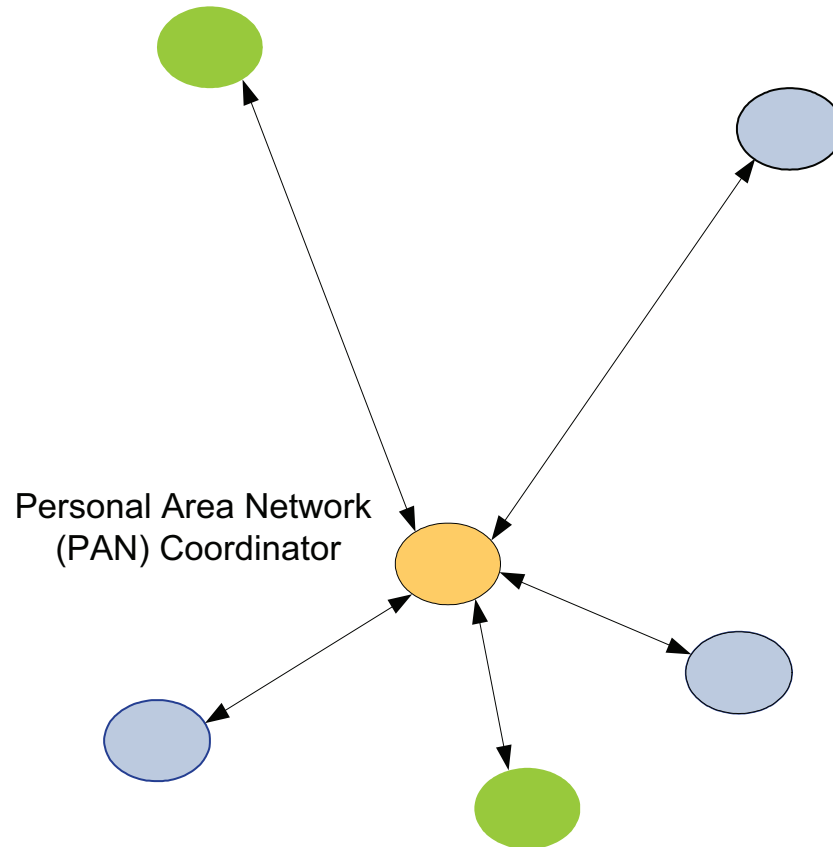
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802.15.4

802.15.4 is a standard for wireless communication issued by the IEEE (Institute for Electrical and Electronics Engineers). The IEEE is a technical professional association that has written 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. As a few examples, the IEEE 802.11 standard defines communication for wireless LAN and 802.16 defines communication for broadband wireless Metropolitan Area Networks.

While both of those wireless standards are concerned with 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. 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. While the standard specifies 5 MHz channels, only approximately 2 MHz of the channel is consumed with the occupied bandwidth. At 2.4 GHz, 802.15.4 specifies the use of Direct Sequence Spread Spectrum 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.
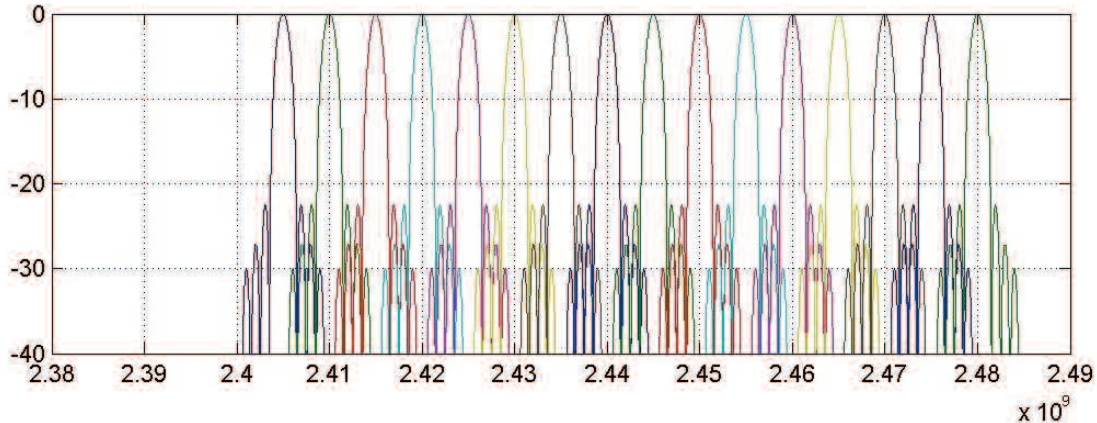
The 802.15.4 standard allows for communication in a point-to-point or a point-to-multipoint configuration. A typical application involves a central coordinator with multiple remote nodes connecting back to this central host.

Personal Area Network
(PAN) Coordinator

Digi's XBee™ 802.15.4 OEM RF modules can be set up to operate in a point-to-point, point-to-multipoint or a peer-to-peer configuration. While standard 802.15.4 always requires a coordinator, the Digi radios are set up so that a coordinator is not required.

ZigBee

ZigBee is a protocol that uses the 802.15.4 standard as a baseline and adds additional routing and networking functionality. The ZigBee protocol was developed by the ZigBee Alliance. The ZigBee Alliance is a group of companies that worked in cooperation to develop a network protocol that can be used in a variety of commercial and industrial low data rate applications. ZigBee 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.
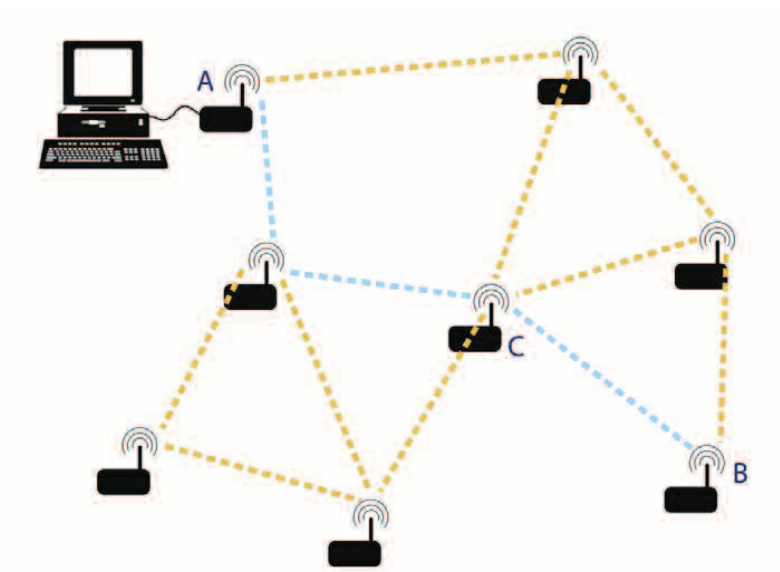
As an example, in the figure above suppose you want to transmit data from point A to point B, but the distance was too great between the points. The message could be transmitted through point C and a few other radios to reach the destination.

The ZigBee protocol is designed so that if a number of different radios were deployed as in the figure above, the radios would automatically form a network without user intervention. The ZigBee protocol within the radios will take care of retries, acknowledgements and data message routing. ZigBee also has the ability to self-heal the network. If the radio at point C was removed for some reason, a new path would be used to route messages from A to B.

Devices in the ZigBee specification can either be used as End Devices, Routers or Coordinators. Routers can also be used as End Devices. 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.

Because ZigBee was designed for low power applications, it fits well into embedded systems and those markets where reliability and versatility are important but a high bandwidth is not. The following table offers a comparison of features with several other popular wireless technologies and their different applications.

	ZigBee and 802.15.4	GSM/GPRS CDMA	802.11	Bluetooth
Focus Application	Monitoring and Control	Wide Area Voice and Data	High-Speed Internet	Device Connectivity
Battery Life	Years	1 Week	1 Week	1 Week
Bandwidth	250 Kbps	Up to 2 Mbps	Up to 54 Mbps	720 Kbps
Typical Range	100+ Meters	Several Kilometers	50-100 Meters	10-100 Meters
Advantages	Low Power, Cost	Existing Infrastructure	Speed, Ubiquity	Convenience

The lower data rate of the ZigBee devices allows for better sensitivity and range, but of course offers less throughput. The primary advantage of ZigBee lies in its ability to offer low power and extended battery life.

Conclusion

Digi offers several products for communication over 802.15.4 or ZigBee. The XBee and XBee-PRO 802.15.4 modules provide point-to-point 802.15.4 communications, and the XBee ZNet 2.5 modules provide ZigBee-compliant mesh.

If the application strictly needs to communicate in a point-to-point or a point-to-multipoint fashion, 802.15.4 will be able handle all the communications between your devices and will be simpler to implement than trying to use a module with ZigBee firmware to accomplish the same goal. ZigBee is necessary if you need to use repeating or mesh networking functionality in your system.

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