The 802.11 Standards

by Sophia

WHAT'S COVERED

In this lesson, you will be learning in more depth about the 802.11 standards that regulate wireless networking.

Specifically, this lesson will cover the following:

1. 802.11 Standards

In this lesson, we will introduce each of the most popular 802.11 wireless standards.

BIG IDEA

Many wireless products that are 802.11 compliant are referred to as **Wi-Fi**, which stands for wireless fidelity. Wi-Fi-designated products have to pass the certification testing for 802.11 interoperability to ensure that all 802.11a/b/g/n/ac/ax wireless devices communicate seamlessly.

TERM TO KNOW

Wi-Fi

Any of several IEEE 802.11 standards for short-range wireless data transmission.

1a. 802.11b

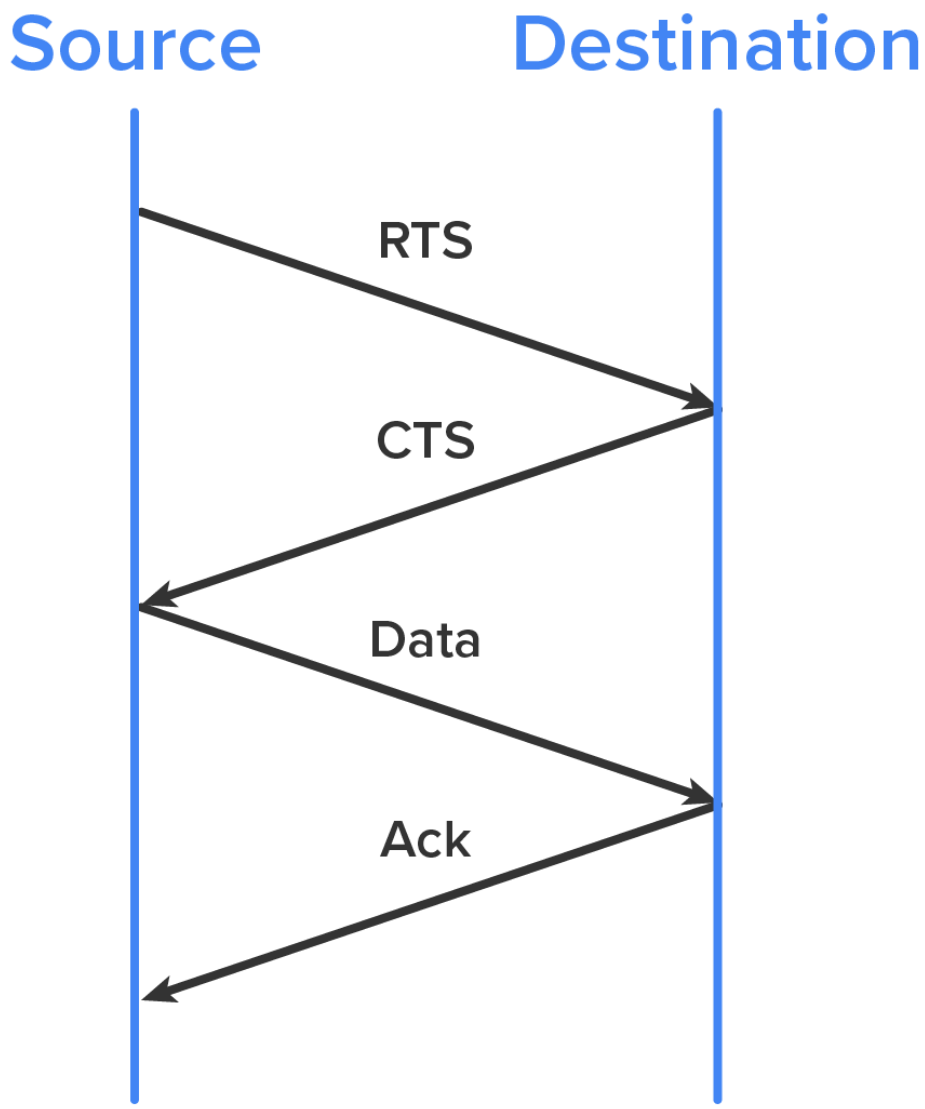
The **802.11b** standard was ratified in 1999. A widely deployed wireless standard, it operates in the 2.4 GHz unlicensed radio band that delivers a maximum data rate of 11 Mbps. The 802.11b standard has been widely adopted by both vendors and customers who found that its 11 Mbps data rate worked pretty well for most applications. However, 802.11b is now legacy and has been largely replaced by newer standards.

An interesting thing about all 802.11 WLAN products is that they have the ability to data rate shift while moving. This allows the person operating at 11 Mbps to shift to 5.5 Mbps, then shift to 2 Mbps, and finally still communicate farthest from the access point (AP) at 1 Mbps. Furthermore, this rate shifting happens without losing the connection and with no interaction from the user. Rate shifting also occurs on a transmission-by-transmission basis. This is important because it means that the AP can support multiple clients at varying speeds depending on the location of each client.

The problem with all 802.11b communication lies in how the data link layer is dealt with. In order to solve problems in the RF spectrum, a type of Ethernet contention management was created called carrier-sense multiple access with collision avoidance (CSMA/CA). This is needed because all the devices on a single AP are in the same collision domain.

CSMA/CA also has an optional implementation called Request to Send, Clear to Send (RTS/CTS) because of the way that hosts must communicate with the AP. For every packet sent, an RTS/CTS and acknowledgment must be received, and because of this rather cumbersome process, it is kind of hard to believe it all actually works when you use this!

To get a clear picture of this, check out the diagram below. We see a Request to Send sent from the source. The Clear to Send direction was provided by the destination. The data are sent from the source and the destination acknowledges the sent data.



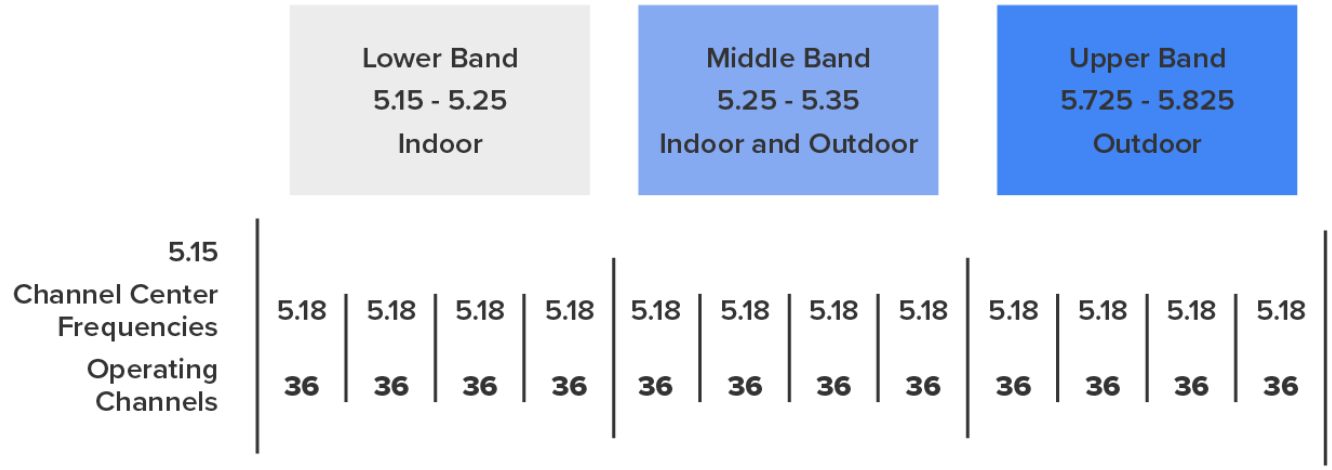
TERM TO KNOW

802.11b

A wireless networking specification that extends throughput up to 11 Mbps using the same 2.4 GHz band.

1b. 802.11a

The IEEE ratified the **802.11a** standard in 1999, but the first 802.11a products did not begin appearing on the market until late 2001. The 802.11a standard delivers a maximum data rate of 54 Mbps with 12 nonoverlapping frequency channels. The diagram below shows the U-NII bands.



Operating in the 5 GHz radio band, 802.11a is also immune to interference from devices that operate in the 2.4 GHz band, like microwave ovens, cordless phones, and Bluetooth devices. 802.11a is not backward compatible with 802.11b because they are different frequencies, so you do not get to just upgrade part of your network and expect everything to work together in perfect harmony. A definite plus for 802.11a is that it can work in the same physical environment without interference from 802.11b users.

Similar to the 802.11b radios, all 802.11a products also have the ability to data rate shift while moving. The 802.11a products allow the person operating at 54 Mbps to shift to 48 Mbps, 36 Mbps, 24 Mbps, 18 Mbps, 12 Mbps, and 9 Mbps, and finally, still communicate farthest from the AP at 6 Mbps.

TERM TO KNOW

802.11a

A wireless networking specification that defined the requirements for an orthogonal frequency-division multiplexing (OFDM) communication system.

1c. 802.11g

The **802.11g** standard was ratified in June 2003 and is backward compatible with 802.11b. The 802.11g standard delivers the same 54 Mbps maximum data rate as you will find in the 802.11a range but runs in the 2.4 GHz range—the same as 802.11b.

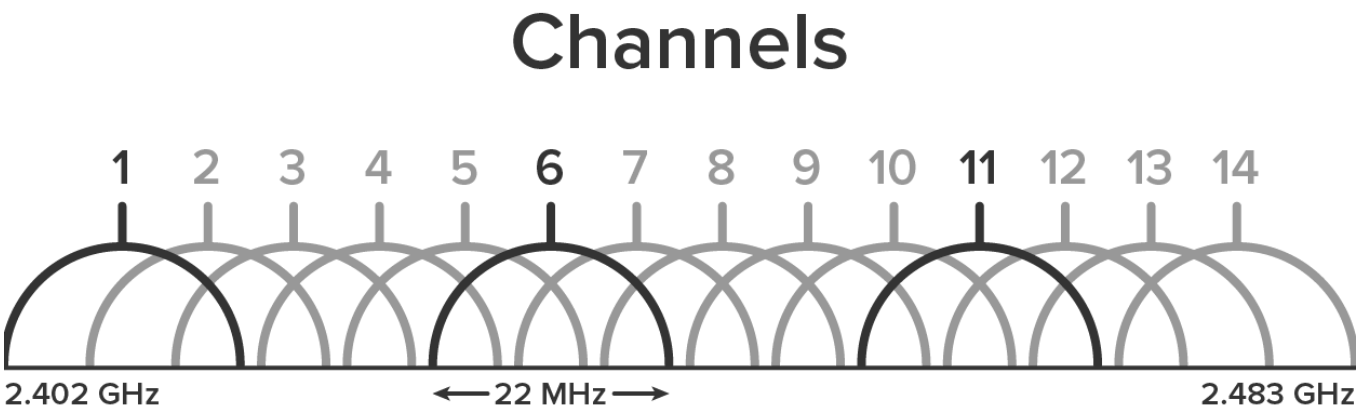
Because 802.11b/g operates in the same 2.4 GHz unlicensed band, migrating to 802.11g is an affordable choice for organizations with existing 802.11b wireless infrastructures. Just keep in mind that 802.11b products cannot be software upgraded to 802.11g. This limitation is because 802.11g radios use a different chipset in order to deliver a higher data rate.

802.11b uses a modulation technique called *direct-sequence spread spectrum* (DSSS) that is just not as robust as the *orthogonal frequency-division multiplexing* (OFDM) modulation used by both 802.11g and 802.11a. 802.11g clients using OFDM enjoy much better performance at the same ranges as 802.11b clients do, but when 802.11g clients operate at the 802.11b rates (11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps), they actually use the same modulation 802.11b uses.

802.11b has a top throughput of 11 Mbps, and 802.11g has a top throughput of 54 Mbps. However, the actual data throughput for the user is typically much less because about 70% or more of the RF bandwidth is used for the management of the wireless network itself. The actual bandwidth the user experiences using an application is called goodput, even though you will not hear this term used a lot. Just remember that *goodput* refers to the actual data throughput, not the theoretical number that the standards describe.

HINT

The diagram below shows the 14 different channels (each of which is 22 MHz wide) that the FCC released in the 2.4 GHz range.



In the United States, only 11 channels are configurable, with channels 1, 6, and 11 being nonoverlapping. This allows you to have three APs in the same area without experiencing interference. You must be aware of the channels when installing APs in a large environment so you do not overlap channels. If you configure one AP with Channel 1, then the next AP would be configured in Channel 11, the channel farthest from that configured on the first AP.

TERM TO KNOW

802.11g

A wireless networking specification that operates in the 2.4 GHz microwave band with throughput of up to 54 Mbps.

1d. 802.11n

802.11n builds on previous 802.11 standards by adding *multiple input, multiple output* (MIMO), which employs multiple transmitters and receiver antennas to increase the data throughput. 802.11n can have up to eight antennas, but most of today's APs use four. These are sometimes referred to as *smart antennas*, and if you did have four of them, two would be used for transmitting simultaneously, with the other two receiving simultaneously. This setup would allow for much higher data rates than 802.11a/b/g. In fact, the marketing people claim it will provide about 250 Mbps.

HINT

Unlike 802.11a and 802.11g, which are locked into using the 5.0 GHz and 2.4 GHz spectrums, respectively, with 802.11n, you can control which of the spectrums (or both) you want to allow in your WLAN.

Listed next are some additional components of 802.11n that give people reason to say that 802.11n has greater reliability and predictability:

- 40 MHz Channels: 802.11g and 802.11a use 20 MHz channels, and the tones on the sides of each channel are not used to protect the main carrier, which means that 11 Mbps is unused or wasted. 802.11n aggregates two carriers to double the speed from 54 Mbps to 108 Mbps. Add the 11 Mbps that we gain from not wasting the side tones, and we have 119 Mbps.
- MAC Efficiency: 802.11 protocols require the acknowledgment of each and every frame. 802.11n can pass many packets before an acknowledgment is required, which saves you on overhead. This is called *block acknowledgment*.

Multiple Input, Multiple Output (MIMO)
Several frames are sent by several antennas over several paths and are then recombined by another set of antennas to optimize throughput and multipath resistance. This is called *spatial multiplexing*.

TERM TO KNOW

802.11n

A wireless networking specification that uses multiple antennas to increase data rates and can be used in the 2.4 GHz or 5 GHz frequency bands.

1e. 802.11ac

802.11ac is a Wi-Fi standard that works in the 5 GHz range and delivers up to 1 Gb throughput that was approved by the 802.11 standards committee in January 2014.

802.1ac gets more MIMO spatial streams than we can with 802.11n—up to eight, whereas 802.11n only supported four. Furthermore, and optionally, a downlink of multiuser MIMO (MU-MIMO) supports up to four clients and, most importantly, a modulation of QAM-256 compared to the modulation of QAM-64 supported by 802.11a/g.

802.11n had added fields in the wireless frame to identify 802.11a and 802.11g as high throughput (HT), whereas 802.11ac adds four fields to identify the frames as very high throughput (VHT).

TERM TO KNOW

802.11ac

A wireless networking specification providing high-throughput wireless local area networks (WLANs) in the 5 GHz band.

1f. 802.11ax

802.11ax was adopted by the IEEE in 2019 as the successor to 802.11ac, and is designated by the Wi-Fi Alliance as Wi-Fi 6. 802.11x. 802.11x is a standard to be deployed in enterprise computing WLAN environments and operates simultaneously in the 2.4 GHz, 5 GHz, and 6 GHz ranges. 802.11ax is designed to provide a very high-speed wireless performance of up to 9,608 Mbps in networks that are densely populated by users.

TERM TO KNOW

802.11ax

A wireless networking specification that is designed to operate in license-exempt bands between 1 and 7.125 GHz, including the 2.4 and 5 GHz bands already in common use as well as the much wider 6 GHz band.

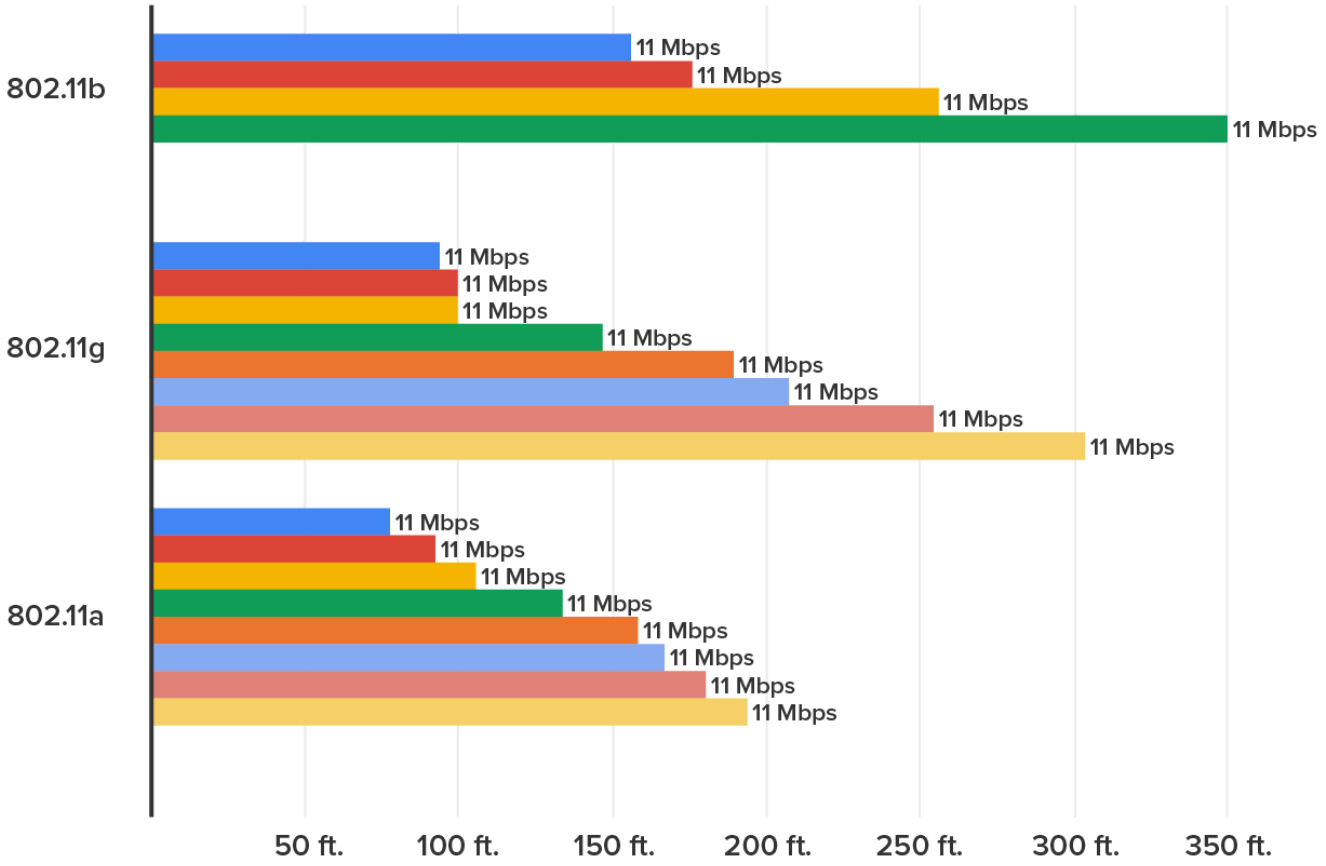
1g. Comparing 802.11 Standards

Take a look at the table below that lists, for each of the IEEE standards in use today, the year of ratification as well as the frequency, the number of nonoverlapping channels, physical layer transmission techniques, and data rates.

	802.11	802.11b	802.11a	802.11g		802.11n	802.11ac
Ratified	1997	1999	1999	2003		2010	2013
Frequency Band	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz		2.4 GHz–5 GHz	5 GHz
No. of Channels	3	3	Upt to 23	3		Varies	Varies
Transmission	IR, FHSS, DSSS	DSSS	OFDM	DSSS	OFDM	DSSS, CCK, OFDM	OFDM
Data Rates (Mbps)	1, 2	1, 2, 5.5, 11	6, 9, 12, 18, 24, 36, 48, 54	1, 2, 5.5, 11	6, 9, 12, 18, 24, 36, 48, 54	100+	1,000+

1h. Range Comparisons

Now, let us take a look at the illustration below, which delimits the range comparisons of each 802.11 standard and shows these different ranges using an indoor open-office environment as a factor



You can see that to get the full 54 Mbps benefit of both 802.11a and 802.11g, you need to be between 50 ft and 100 ft (maximum) away, which will likely be even less if there happen to be any obstructions between the client and the AP. 802.11n gives more distance than all three standards shown in the figure (up to twice the distance); understand that 802.11ac just will not give you more distance than 802.11n.

SUMMARY

In this lesson, you learned some of the technical specifications of various IEEE **802.11 standards** that regulate wireless networking.

Source: This content and supplemental material has been adapted from CompTIA Network+ Study Guide: Exam N10-007, 4th Edition. Source **Lammle: CompTIA Network+ Study Guide: Exam N10-007, 4th Edition - Instructor Companion Site (wiley.com)**

TERMS TO KNOW

802.11a

A wireless networking specification that defined requirements for an orthogonal frequency-division multiplexing (OFDM) communication system.

802.11ac

A wireless networking specification providing high-throughput wireless local area networks (WLANs) in the 5 GHz band.

802.11ax

A wireless networking specification that is designed to operate in license-exempt bands between 1 and 7.125 GHz, including the 2.4 and 5 GHz bands already in common use as well as the much wider 6 GHz band.

802.11b

A wireless networking specification that extends throughput up to 11 Mbps using the same 2.4 GHz band.

802.11g

A wireless networking specification that operates in the 2.4 GHz microwave band with throughput to up to 54 Mbps.

802.11n

A wireless networking specification that uses multiple antennas to increase data rates, and can be used in the 2.4 GHz or 5 GHz frequency bands.

Wi-Fi

Any of several IEEE 802.11 standards for short-range wireless data transmission.