IEEE 802.11 Standards

Wireless devices must follow a set of wireless standards or protocols, known as IEEE 802.11, to wirelessly communicate with other devices. The WiFi standards were created by the Institute of Electrical and Electronics Engineers and are certified by the WiFi Alliance.

The IEEE working groups have developed over 1,100 standards, with over 600 standards under development. Out of those 1,100, over 40 are part of the 802.11 family.

802.11 standards are developed every couple of years to fill holes in the current one and to account for the development of new wireless technology. New standards can be developed to improve speeds, range, security, or establish new frequency bands when applicable.

IEEE 802.11
In 1997, the first WLAN standard was released - IEEE 802.11. It was developed to operate on the 2.4 GHz band and supported speeds of 1 Mbps - 2 Mbps. Compared to the speeds we have now, it would take longer to download files and cause challenges with group video calls, online gaming, and streaming. The 802.11 standard became the "umbrella" for the standards that followed. Basically, it set the foundation.

IEEE 802.11a
802.11a was one of the first standards issued under the 802.11 umbrella in 1999. Rather than using the 2.4 GHz band, it opted into using the 5 GHz frequency band. Generally, higher frequencies are coupled with faster speeds but shorter range. Since 802.11a operated under the 5 GHz band, it made the products more expensive. Therefore, it was mostly used in business networks.

IEEE 802.11b
While 802.11a was being developed, so was the 802.11b standard; it was also published in 1999. 802.11b uses a modulation method used to reduce signal interference - in the 2.4 GHz band, allowing it to have speeds up to 11 Mbps. The 2.4 band does a good job at penetrating obstacles to provide more WiFi coverage. Unfortunately, the data travels at a much slower rate, especially when it's coupled with network interferences caused by devices operating on the same frequency, such as baby monitors, microwave ovens, cordless phones, appliances, and Bluetooth devices. Luckily, interferences can be mitigated by keeping your 802.11b devices away from the mentioned equipment.

Since 802.11b only used the 2.4 band, the products were much cheaper than 802.11a, making it more popular for home networks. In addition, considering that 802.11b and 802.11a products don't use the same frequency band, they are not compatible with each other. So, an 802.11b computer will not work with an 802.11a access point (AP) because the wireless adapter inside the computer will not register the AP, and vice versa.

IEEE 802.11g

To fulfill a growing demand for faster internet under the 2.4 GHz band, 802.11g joined the 802.11 family in 2003. The developers took the best qualities of 802.11a and 802.11b to create the 802.11g standard. It supports a networking bandwidth up to 54 Mbps and operates under the 2.4 GHz band.

At the time backward compatibility was a must because many people still had access points and computers that used the previous standards. 802.11g is backward compatible with 802.11b products. However, WiFi products are only capable of tapping into the standard under which they operate. An 802.11b computer connected to an 802.11g AP can only go as fast as what the b standard allows. On the flip side, a g device connected to a b AP will only go as fast as what the AP offers.

IEEE 802.11n

IEEE 802.11n was developed in 2009 to improve speeds, reliability, and extend the range of wireless transmissions. It uses a series of antennas to receive more data from one device at a time, which results in faster data transmissions. In addition, it was the first to allow the usage of two radio frequencies – 2.4 GHz and 5 GHz. The use of both frequencies makes the 802.11n standard compatible with 802.11a/b/g devices.

With all its improved functionalities, IEEE 802.11n supported bandwidth speeds up to 600 Mbps and a had theoretical range of 230 ft indoors, which is a huge upgrade from the previous standards.

IEEE 802.11ac

The 5th generation of WiFi was established in 2013. It was developed to operate under the 5 GHz band. Many 802.11ac WiFi devices are advertised as “dual-band” – technology that uses two frequency bands for wireless communication. To make that possible, some vendors incorporated IEEE 802.11n technology to make ac products compatible with the 2.4 GHz band. Data rates differ based on which frequency is being used, bandwidth speeds up to 1300 Mbps can be achieved on the 5 GHz band, while the 2.4 GHz band has a max speed of 450 Mbps.

With the help of IEEE 802.11n technology, 802.11ac is compatible with 802.11a/b/g/n.

IEEE 802.11ad

Designed to provide a wireless system with high throughput data, 802.11ad became part of the 802.11 series in 2012. It achieved blazingly fast speeds - up to 6.7 Gbps. Unlike the previous standards, it didn’t use the 2.4 or 5 GHz bands, it operated under the 60 GHz band. Under perfect conditions, 802.11ad devices need to be about 30 ft from the access point.

IEEE 802.11ah

Adopted in May 2017, 802.11ah aimed to use frequency bands below 1 GHz. Its purpose was to establish lower energy consumption and create extended-range WLANs that surpassed that of the 2.4/5 GHz bands.

IEEE 802.11ah operated on the 900 MHz band, allowing it to have a theoretical range of 543m indoors (1,781.5 ft) and data transfer speeds up to 347 Mbps. Due to its low energy needs, 802.11ah is beneficial for devices trying to communicate over long ranges without using a lot of energy.

IEEE 802.11ax

As of 2019, the 802.11ax standard has become the newest WiFi standard. Designed to deliver faster speeds, support more devices simultaneously, decrease latency, improve security, and increase bandwidth. With all of its improvements, it has a theoretical maximum speed of 10 Gbps.

In addition, it operates on the 2.4 and 5 GHz bands, which hasn't been done since 802.11n. This allows it to be compatible with 802.11a/b/g/n/ac.