What is Wi-Fi 6?

White paper

Contents

1 Standardization bodies name Wi-Fi differently

The term “Wi-Fi” is a trademark of the Wi-Fi Alliance. This organization promotes Wi-Fi adoption, by ensuring interoperability between its devices

The primary standardization body that defines Wi-Fi standards is the IEEE. More specifically, the IEEE 802.11 task group defines the foundational wireless LAN (WLAN) standards.

The IEEE standard terminology is not well suited to consumers, so the Wi-Fi Alliance introduced simplified names for the various Wi-Fi generations:

Table 1. Wi-Fi Alliance WLAN standards

IEEE	Wi-Fi Alliance	Spectrum bands
IEEE 802.11n	Wi-Fi 4	2.4 GHz and 5 GHz
IEEE 802.11ac	Wi-Fi 5	5 GHz
IEEE 802.11ax	Wi-Fi 6 and Wi-Fi 6E	2.4 GHz and 5 GHz (Wi-Fi 6E includes the 6 GHz band)
IEEE 802.11be	Wi-Fi 7	2.4 GHz, 5 GHz and 6 GHz

2 Focus on Wi-Fi 6

2.1 Who would not be interested in Wi-Fi 6?

Wi-Fi 6 has created quite some expectations from the public; the promise of higher throughput and lower latency makes this new generation of Wi-Fi very appealing. In the sections that follow, we will cover the key features of Wi-Fi 6.

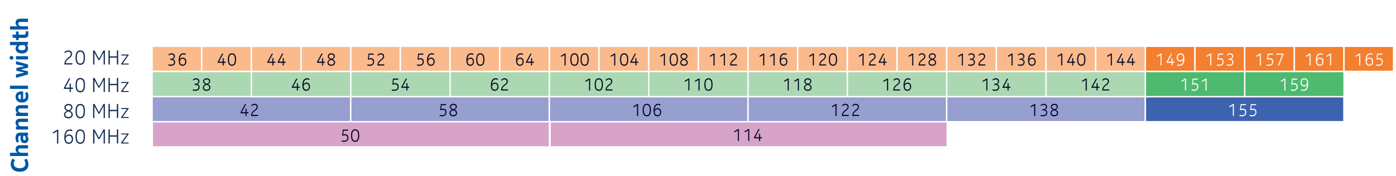
2.2 Better use of spectrum

As shown in Table 1, Wi-Fi 6 can operate in the 2.4 GHz and/or the 5 GHz bands.

(Note, that Wi-Fi 6E extends the Wi-Fi 6 capability to include the 6 GHz band (see section 3, “What about Wi-Fi 6E?”).

Each Wi-Fi channel has a specific channel width [1]. Typically, this is 20 or 40 MHz for Wi-Fi 4; 40 or 80 MHz for Wi-Fi 5 (even though 160 MHz was allowed as well, but not many devices supported this width), and up to 160 MHz for Wi-Fi 6. The wider the channel, the higher the theoretical throughput. However, since the spectrum band is fixed, using wider channels leads to higher contention, as fewer devices can operate in the band simultaneously.

Figure 1. Wi-Fi channels



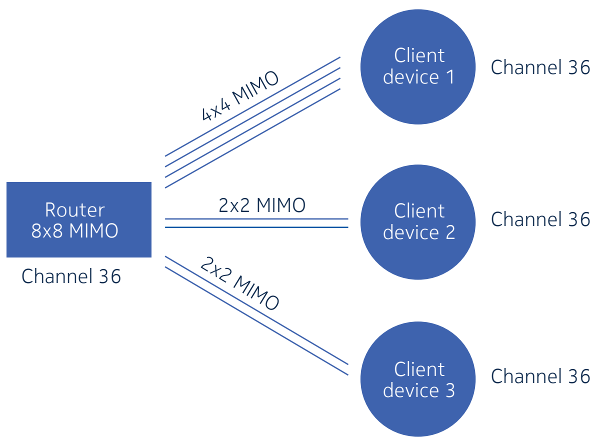
But even if we consider the same 80 MHz channel on 5 GHz, Wi-Fi 6 uses the spectrum more efficiently compared to Wi-Fi 5, as explained below.

1 See also “Optimize your Wi-Fi”

2.3 Maximizing the throughput

To boost the throughput, "multiple spatial streams" can be used. This is a technique where, for a given channel, multiple streams are used in parallel, multiplying the throughput with the number of streams. In essence, this technique leverages multiple senders on one end, and multiple receivers on the other. This technique is referred to as multiple input, multiple output (MIMO). A typical example would be 2x2 MIMO, with 2 senders and 2 receivers. In Wi-Fi 6, you can go up to 8 spatial streams (8x8 MIMO). What makes this technique even more interesting is that you can split the streams across multiple users. For example, if you have an access point (AP) supporting 8 spatial streams, you could serve one client device with 4 spatial streams (4x4 MIMO), and 2 additional client devices with 2 spatial streams (2x2 MIMO) for a total of 8 spatial streams. This is called multi-user MIMO, or MU-MIMO.

Figure 2. Using multiple spatial streams in a single channel

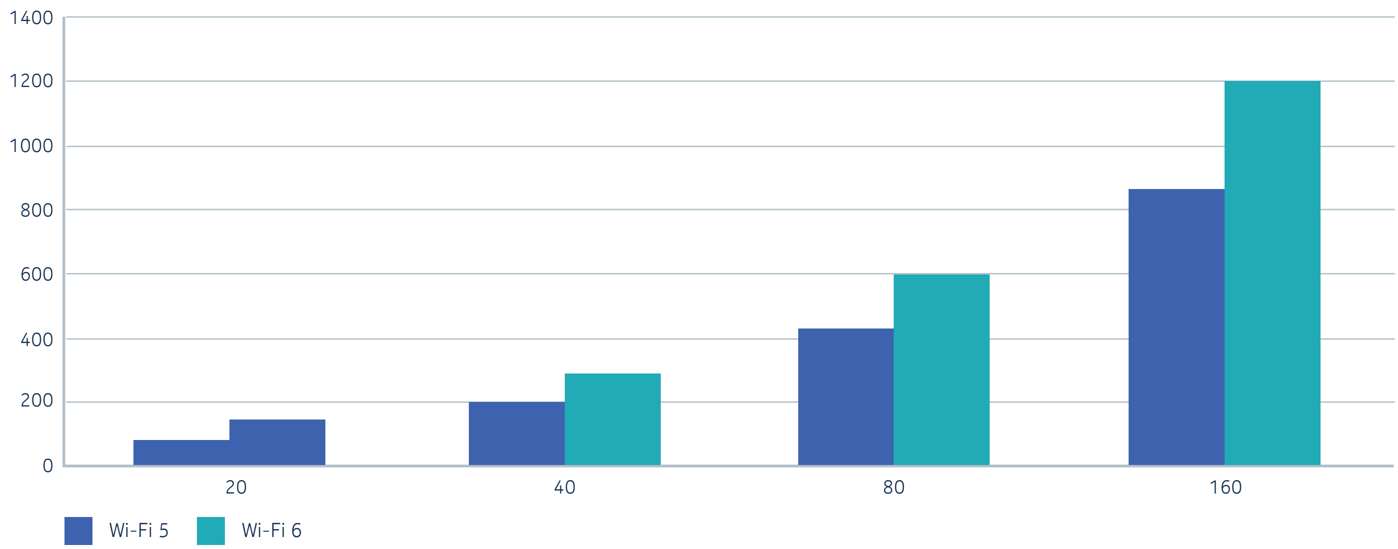


2.4 Higher throughput per stream

Throughput is expressed in megabits per second (Mb/s) or in gigabits per second (Gb/s). so, somehow, we need to "convert" the frequencies' channel bandwidths (MHz) into channel capacity (Mb/s or Gb/s). The key technology for this is called quadrature amplitude modulation (QAM). And it is here that Wi-Fi 6 outperforms previous generations of Wi-Fi.

On 5 GHz, Wi-Fi 5 uses up to 256-QAM, while Wi-Fi 6 uses up to 1024-QAM, if the signal-to-noise ratio (SNR) is high enough to allow a higher QAM. Wi-Fi 6 includes other factors that contribute to greater spectral efficiency. The net result is that on the 5GHz spectrum, Wi-Fi 5 typically reaches up to 433 Mb/s on a single stream, while Wi-Fi 6 reaches up to 600 Mb/s, which is a 39% increase on a comparable channel width of 80 MHz.

Figure 3. Comparison of Wi-Fi 5 and Wi-Fi 6 throughput per channel



On the 2.4 GHz spectrum, the difference is even bigger: Wi-Fi 5 does not operate in the 2.4 GHz band, and Wi-Fi 4 only uses up to 64-QAM, while Wi-Fi 6 uses up to 1024-QAM. Where Wi-Fi 4 gives you a throughput of 150 Mb/s, Wi-Fi 6 gives you 287 Mb/s if we take all the improvements in spectral efficiency of Wi-Fi 6 into account.

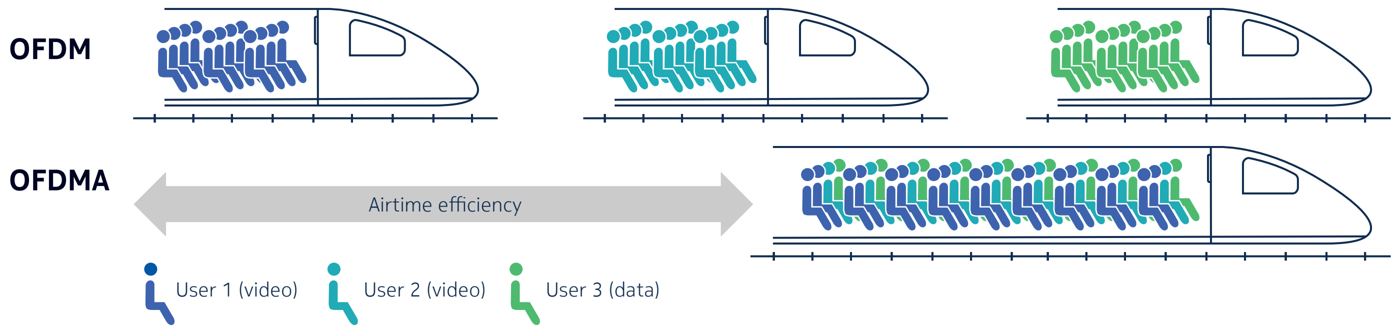
Let's take an average router, with a 2+2 MIMO (multiple input, multiple output) arrangement. This means it has a 2x2 MIMO setup on the 2.4 GHz, and equally a 2x2 MIMO setup on the 5 GHz. With this setup, the increase in throughput is up to 50%.

2.5 Lower latency

In simple terms, "latency" is the delay you experience on any digital connection between sending a request and receiving the reply. The latency needs to be as small as possible, to maximize the user experience. Gamers are especially sensitive to latency.

Wi-Fi 6 uses a technique to reduce the latency dramatically: it allows up to 30 client devices to be served nearly simultaneously per channel using a technique called orthogonal frequency division multiple access (OFDMA). OFDMA is also used in 4G and 5G mobile connections to reduce the latency and for other reasons.

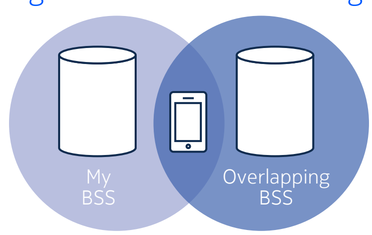
Figure 4. Visualizing orthogonal frequency division multiple access



2.6 Higher throughput in dense areas

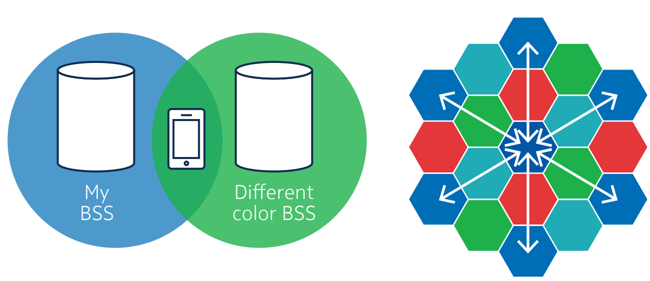
In dense areas, people, as well as their Wi-Fi networks, live close to each other. Therefore, you have a higher chance that your neighbor uses the same channel as you do. Contention for channel airtime reduces throughput.

Figure 5. Using the same channel as a neighbor reduces the throughput



Hence, Wi-Fi 6 introduced "BSS coloring" (BSS stands for basic service set) to reduce interference in dense environments. This adds a "color code" to each transmission that is used to determine whether simultaneous use of the channel is permissible. If you use the same channel as your neighbor, but your router uses a different BSS color, the routers will be able to identify their own devices and will not interfere with each other. Hence, with this BSS coloring, the throughput, especially in dense areas, is higher. Up to 63 different "colors" can be used.

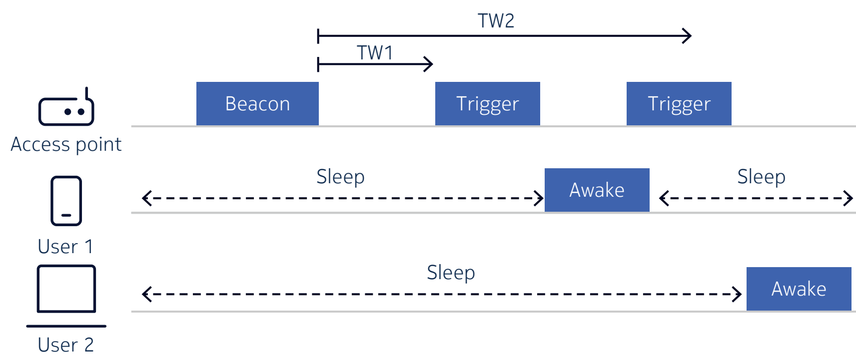
Figure 6. BSS coloring



2.7 Better battery life

Internet of Things (IoT) devices, like temperature sensors, or remote doorbells, are only active every now and then. So, if the device could be put to sleep when they are not used, it would reduce power consumption and extend battery life considerably. Wi-Fi 6 enables this behavior by introducing the target wake time (TWT).

Figure 7. Target wake time



Target wake time uses a scheduling mechanism where the Wi-Fi 6 access point can schedule when a device is to wake up, and when the device is awake the access point can trigger the device and let it know it has a transmission opportunity.

2.8 Longer range

Beamforming is a technique where the signal is transmitted from an array of antennas, while the phase of the signal is slightly altered at each antenna. The result is that the signal-to-noise ratio at the receiver is increased without increasing the transmit power. This improves the Wi-Fi performance and extends the Wi-Fi range.

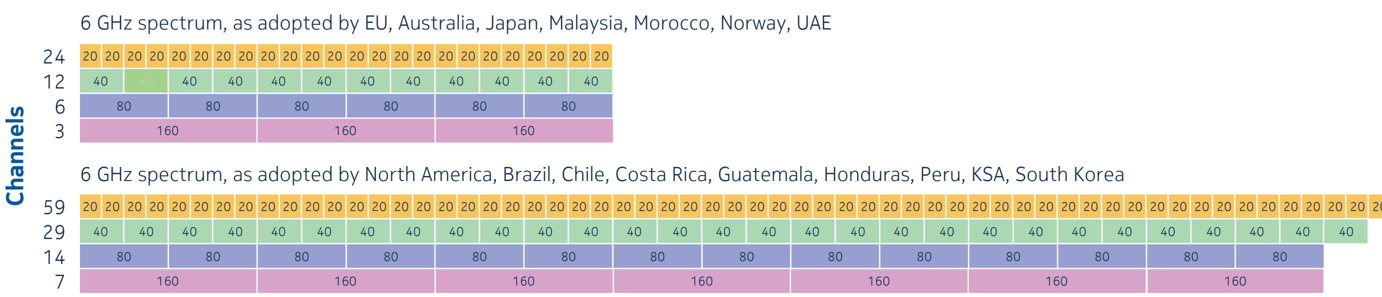
Figure 8. Beamforming

3 What about Wi-Fi 6E?

Wi-Fi 6E uses the same underlying technologies as Wi-Fi 6 (802.11ax) but extends the spectrum to include the 6 GHz band. As newly opened up spectrum, the 6 GHz band is not polluted by any household devices or older Wi-Fi points. This means that this new band promises higher throughput and more stable connections. Even though 160 MHz channels are allowed in 5 GHz the scarcity of spectrum makes the use of 160 MHz channels not feasible in many environments. However, the amount of relatively clean spectrum in 6 GHz makes 160 MHz channels practical.

There is a big difference between geographies and how regulators have defined usage of this new band. Let's have a closer look at the European Union and the United States:

Figure 9. Wi-Fi 6E spectrum adoption by country



- In the EU, the European Commission provided guidance to the local (national) regulators. They allowed the 6 GHz band to be used from 5925 MHz to 6425 MHz, which gives 500 MHz. This enables three 160 MHz channels. In addition, they indicated that the maximum transmit power (or EIRP) could be up to 200 mW.
- In the US, the FCC regulated usage of the 6 GHz band, foreseeing frequencies between 5925 MHz and 7125 MHz, which gives 1200 MHz. This enables seven 160 MHz channels. The maximum EIRP has been defined up to 1 W when used with an automated frequency coordination system.

So, both in terms of the width of the 6 GHz band, and in terms of maximum EIRP, usage of this new band (and hence Wi-Fi 6E) is much more favorable in the US and some other countries than in the EU.

A downside of Wi-Fi 6E (and the additional 6 GHz band) is that, by definition, a Wi-Fi point needs to be a tri-band device, adding to the cost of the Wi-Fi point.

4 Acronyms

AP	Access point
BSS	Basic service set
EIRP	Equivalent isotropic radiated power
EU	European Union
FCC	Federal Communications Commission
IoT	Internet of Things
MIMO	Multiple input, multiple output
MU-MIMO	Multi-user MIMO
OFDMA	Orthogonal frequency division multiple access
QAM	Quadrature amplitude modulation
SNR	Signal-to-noise ratio
TWT	Target wake time
WLAN	Wireless local area network

For more information about Nokia's WiFi solution, click here.

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