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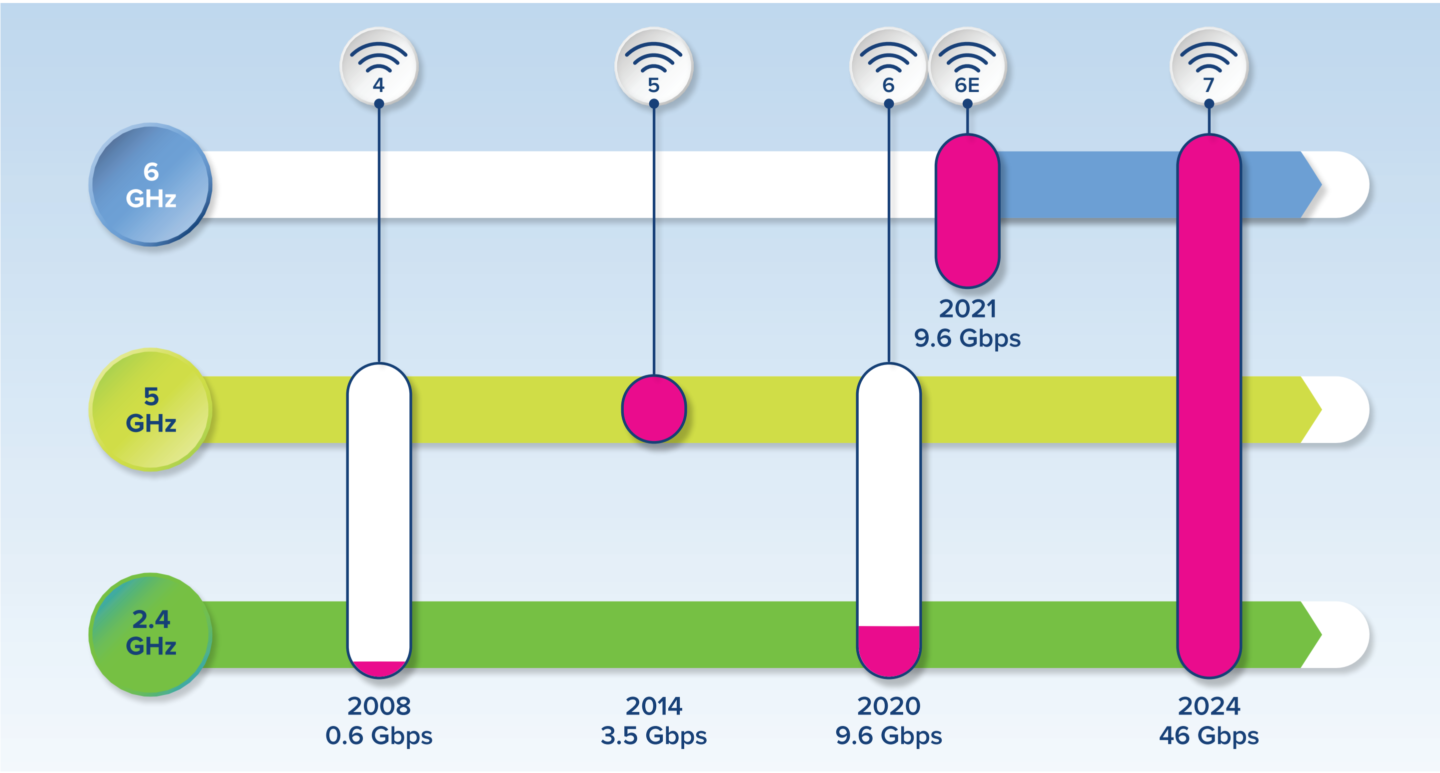
Discover the Future of Wi-Fi 7 Technology

Wi-Fi 7 is the seventh generation of Wi-Fi based on the IEEE 802.11be standard.

While the draft version of the standard itself is not expected to be ratified until the end of 2024, with it being nearly complete, the Wi-Fi alliance introduced the Wi-Fi 7 certification program early in 2024. We're already seeing availability of the first of Wi-Fi 7 client devices, and Enterprise Wi-Fi 7 networks have started deployment in early 2024. Wi-Fi 7 is expected to continue to see rapid adoption, as has been the case for recent versions of Wi-Fi standards.



Retrospective

The 802.11ac, retroactively named Wi-Fi 5 by the Wi-Fi Alliance, was the first Wi-Fi standard to break the 1 Gbps barrier and was available in the 5 GHz band. Its successor, 802.11ax or Wi-Fi 6, focused on improving the efficiency of Wi-Fi and was available across both the 2.4 GHz and 5 GHz bands. It was later extended to the new 6 GHz band as Wi-Fi 6E.

Wi-Fi 7 is available in all bands: 2.4 GHz, 5 GHz, and 6 GHz. While it does improve the throughput, up to a theoretical maximum PHY rate of 46 Gbps, it also introduces features that improve reliability and provide more deterministic latency.

Features that improve reliability and provide more deterministic latency.

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HEADLINE FEATURES

Multi-link Operation

Multi-link Operation (MLO) is the most significant feature in Wi-Fi 7. This allows Wi-Fi 7 devices to aggregate channels across frequency bands. This requires a multi-radio AP and a client with either one radio that can switch across channels or bands as required, or, for the best results, a client with at least two radios, both of which can be used to transmit and receive packets. This can improve throughput, but its most important benefit is reducing worst-case latency and improving reliability. It comes in four flavors.

- **Multi-link Single Radio (MLSR).** The client has a single radio but negotiates a link to multiple radios on a single Wi-Fi AP. It can transmit or receive on only one channel at a time. When congestion is detected, the client can quickly switch over to another radio on the AP, which, hopefully, is on a less congested channel. This does not require additional hardware on the client but does not provide as many benefits as the other versions.
- **Enhanced Multi-link Single Radio (eMLSR).** The client includes a second radio that can listen for congestion on channels other than the one in active use. Compared to MLSR, the client can make a better decision based on current RF conditions on whether switching channels will improve performance. The second client radio can be an RX-only radio and, hence, much less expensive in hardware compared to a TX capable radio.
- **Multi-link Multi-Radio, Simultaneous Transmit and Receive (MLMR-STR),** also known as asynchronous MLMR. This requires at least two radios on the device. The device can transmit and receive on either radio. Transmissions on one radio can overlap with frame reception on the other. For any packet that needs to be transmitted, the device assesses the interference and congestion on each channel and can pick a radio based on which channel will provide the earliest next transmit opportunity and hence the lowest latency. The device could also simply use both links for transmission, aggregating the bandwidth and increasing the wireless throughput. If reliability is the target, the device can repeat transmission of the packet on all links and the receiver deduplicates the traffic and picks one.
- **Multi-link Multi-Radio, Non-Simultaneous Transmit and Receive (MLMR-NSTR),** also known as synchronous MLMR, is a more limited version of MLMR-STR. MLMR-STR requires additional shielding between radios because a receiving a frame on one radio can overlap with transmitting one on other. MLMR-NSTR attempts to simplify radio design and reduce cost by requiring transmissions on the two radios to be synchronized. However, this takes away some of the latency benefits of MLMR and the cost savings are not likely to be worth the loss in performance.

Mulit-link Operation

- Multi-link Single Radio
- Enhanced Multi-link Single Radio
- Multi-link Multi-Radio, Simultaneous Transmit and Receive
- Multi-link Multi-Radio, Non-Simultaneous Transmit and Receive

Improving Throughput

The higher throughput for Wi-Fi 7 is achieved primarily through three changes:

- **Wider channels** in the 6 GHz band. Wi-Fi 7 supports 320 MHz channels, doubling the throughput when compared to 160 MHz channels in Wi-Fi 6E.

- Modulation up to **4096-QAM** is defined, versus the previous best of 1024-QAM. This improves throughput by around 20%.
- Up to **16 spatial streams** are allowed. However, this is likely to remain a theoretical bound for the most part and Wi-Fi APs with more than 4 spatial streams on a single radio will not be common.

In practice, Wi-Fi 7 clients may experience up to 2x the throughput compared to Wi-Fi 6E in the 6 GHz band. Performance improvements in the other bands will likely be lower and provided by other efficiencies introduced in the standard.

Improving Efficiency

- 512 MPDU Compressed Block-ack
- Multiple resource units (Multi RU) per User
- Preamble Puncturing

Improving Efficiency

There are several features that improve efficiency in Wi-Fi 7. Among them are:

- **512 MPDU Compressed Block-ack.** Every unicast Wi-Fi data frame transmission requires an acknowledgement, which reduces efficiency due to the back-and-forth messaging. Block aggregation, where a single message from the receiver confirms reception of multiple transmissions, improves efficiency. Wi-Fi 7 increases the number of MAC Protocol Data Units (MPDUs) that can be simultaneously acknowledged to 512, further improving performance at high data rates.
- **Multiple resource units (Multi RU) per User,** Wi-Fi 6 introduced Orthogonal Frequency Division Multiplexing (OFDMA), which allows the Wi-Fi AP to serve multiple clients at a time, improving latency. Each client is allocated a chunk of the channel, called a Resource Unit. Wi-Fi 7 adds on the ability to let the AP allocate multiple RUs to a single client, further improving efficiency.
- **Preamble Puncturing.** This was an optional feature in Wi-Fi 6. A problem with wider channels is that if even a part of a channel is suffering from interference, the entire channel is unusable. Preamble puncturing allows the transmitter to dynamically mask out the part of the channel as required and use the rest. However, client support was limited. Wi-Fi 7 makes this a required feature, enabling more efficient use of wider channels.

Improving Latency

Many of the previously discussed features play a role in providing lower, deterministic latency. This includes MLMR as well as the features that improve efficiency. In addition, the AP can set up a **Restricted Service Period**, where certain periods of time are reserved for specific devices, with other devices connected to that AP staying silent. This improves latency for devices assigned to the Restricted Service Period. **Restricted Target Wait Time** improves latencies for battery power devices, which often try to save power by periodically shutting down their radios. This feature allows the AP reserve time slots for a subset of devices, which can optionally wake up and transmit without contending with other devices associated to that AP. All these features improve the user experience with latency sensitive applications.

Deploying Wi-Fi 7 Networks

Wi-Fi 7 really shines when you can make use of its capabilities in the 6 GHz band. For instance, this band provides 1200 MHz of new spectrum in the US, versus around 400 MHz previously available in the other bands. Around 500 MHz is available in many European countries. Most nations have either already adopted rules opening up 6 GHz or are considering rules to do so.

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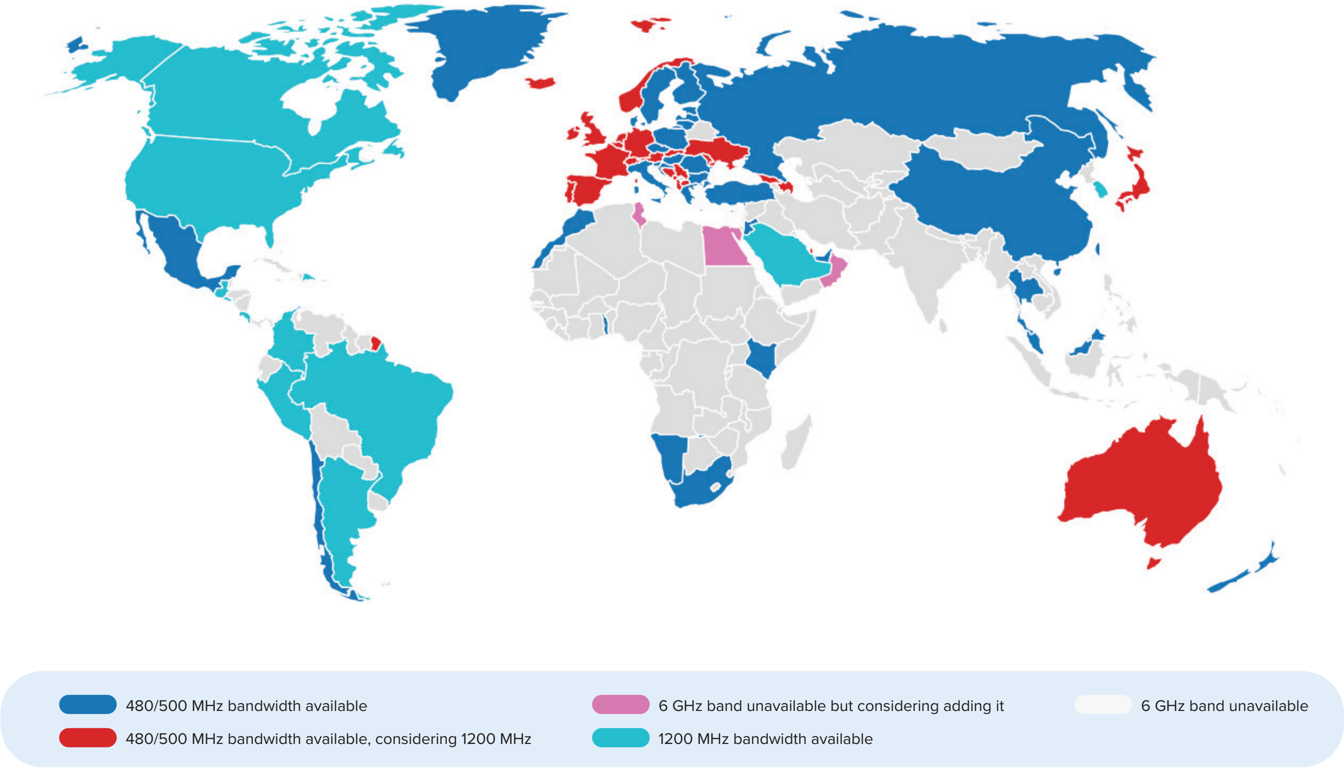

Two Wi-Fi 7 features that improve throughput — wider channels and 4096-QAM — will likely only be practical in the 6 GHz band, which both has the wide swath of spectrum for use of multiple 80 MHz or 160 MHz channels in the enterprise as well as the lower noise floor required for 4096-QAM. So it's important that your Wi-Fi 7 design incorporates tri-band APs that will support this band. MLO will also likely provide the most compelling economics with 5 GHz and 6 GHz radios. When designing such networks, keep in mind the new rules for max transmission power in this band. For 2.4 GHz and 5 GHz, this is determined by the Equivalent Isotropically Radiated Power (EIRP), which is constant regardless of the channel width. In 6 GHz, that's determined by the Power Spectral Density (PSD), which specifies a maximum power transmitted per megahertz of spectrum in use. What this means in practice is that in 5 GHz, the Signal-to-Noise Ratio (SNR) gets worse with wider channels. In 6 GHz, this effect is mitigated by the higher signal level that can be used by the transmitter when using wider channels. This will further encourage the use of wider channels with Wi-Fi 7 in the 6 GHz band. It will be important for Wi-Fi design tools to consider the power levels and propagation characteristics of this band.

The latency improvements in Wi-Fi 7 will support advanced AR/VR applications. MLO will be critical in this regard, but the other features listed in the previous section will also come into play. Again, 6 GHz will provide the best opportunity, but the latency gains will also be significant in 5 GHz.

The 2.4 GHz band will increasingly shift over for use by low-bandwidth, low-cost IoT devices. This band will need to be set up for compatibility with older generations of Wi-Fi, so lower data rates will continue to be enabled and used here. As very low cost Wi-Fi 7 client radios are introduced over the coming years, these devices will shift over to using Wi-Fi 7 in 2.4 GHz.

With most clients expected to have multi-band 1x1 or 2x2 radios, the value tier of Wi-Fi 7 APs will be tri-band 2x2 radios, in contrast with the dual-band 2x2 radios with Wi-Fi 6.

Usage of standard power (as opposed to low power) Wi-Fi radios in 6 GHz indoors as well as usage of 6 GHz outdoors will requires an Automatic Frequency Coordination (AFC) System in countries where such usage is permitted. The rules for indoors usage are still evolving. The industry has learned from the experience of deploying outdoor Wi-Fi 6E APs. It will be important to deploy a Wi-Fi ecosystem that will provide a path to easy deployment of AFC compliant Wi-Fi APs, where necessary.

Summary

Wi-Fi 7 pushes the envelope on wireless throughput and opens up the avenue for new applications that can rely on improved reliability of packet delivery and more deterministic latency. Careful deployment of tri-band Wi-Fi APs will be critical to ensuring your network makes full use of Wi-Fi 7 capabilities as clients and applications shift to making use of the features in this new standard.

Premium smartphones, such as Google Pixel 8 and Samsung Galaxy S24 Ultra, already support Wi-Fi 7. Higher-end laptops announced for 2024 also include Wi-Fi 7 with client chipsets from Intel and Realtek. Service providers and network administrators need to prepare their networks for mass adoption of Wi-Fi 7 that will gain pace in 2025.

About Cambium Networks

Cambium Networks enables service providers, enterprises, industrial organizations, and governments to deliver exceptional digital experiences and device connectivity with compelling economics. Our ONE Network platform simplifies management of Cambium Networks' wired and wireless broadband and network edge technologies. Our customers can focus more resources on managing their business rather than the network. We make connectivity that just works.

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2000 Center Drive Suite East A401, Hoffman Estates, Illinois 60192 USA