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Taking Full Advantage of the Advancements in Wi-Fi 6 and 6E

By: Andy Ross, Product Manager, Laird Connectivity

Wi-Fi has become such an indispensable connectivity platform for consumer, industrial. and commercial devices that it is easy to forget its very humble beginnings. Introduced 25 years ago, its technical origin was in cashier systems where it provided rudimentary connectivity between retail devices with very low data transfer rates. It would have taken a tremendous leap of imagination to envision that version of Wi-Fi evolving into one of the most important technologies for our lives today. But that is exactly what has happened as the Wi-Fi Alliance has guided development of the technology toward the kind of performance, interoperability, security, and reliability that make it so ubiquitous today.

The Wi-Fi Alliance has launched two new versions of Wi-Fi that deliver significant advancements in performance, efficiency, latency, and other key areas: Wi-Fi 6 and 6E. These two new versions of the technology represent major leaps forward in Wi-Fi that make it an even stronger foundation for consumer smart devices, IoT networks, and a wide range of enterprise and industrial use cases. News of the new versions of Wi-Fi were rightfully met with excitement from industry experts. This article by a respected industry analyst equates the significance of this Wi-Fi upgrade to the leap that cellular technology is making from 4G to 5G. And this article published by Network World reports that adoption of Wi-Fi 6 and 6E will be rapid and widespread because the enhancements are so compelling. This is a major new technology upgrade for engineering teams that design wirelessly-connected products, and it will reshape the pipeline of design projects that engineers work on in the coming months and years.

The advancements in Wi-Fi 6 and 6E are significant, enabling the technology to support existing applications more effectively while also making it possible to support new use cases that were previously difficult or impossible using Wi-Fi connectivity. The key advancements include:

- Greatly-increased performance in terms of both throughput and device density
- Significantly-increased spectrum that gives engineers more flexibility, reliability, and performance
- Much higher efficiency that extends battery life and enables device networks to perform at higher levels
- Far lower latency that makes Wi-Fi networks a strong complement to other low-latency technologies like 5G
- And other technical advancements that support new applications in consumer, enterprise, and industrial use cases

Performance for Speed and Density

This side-by-side comparison of the key specifications and performance metrics of Wi-Fi 6 and 6E compared to earlier versions underscore how significant the leap is.

The first thing that is likely to jump off the page is the massive increase in data throughput. This is not an incremental bump. To illustrate that, the article cited above by industry analyst Jeff Kagan reports that testing organizations have achieved increases in download speeds of 1,000 percent. This is a game changer for Wi-Fi as a connectivity platform that allows it to support data-intensive use cases such as HD video distribution, advanced factory and building automation applications, large scale outdoor IoT networks, warehouse logistics applications,

Feature	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 6E
Chanel Bandwidth	20,40	20,40,80, 80+80, 160	20,40,80, 80+80, 160	20,40,80, 80+80, 160
Frequency Bands	2.4 and 5 GHz	2.4 and 5 GHz	2.4 and 5 GHz	2.4, 5 and 6 GHz
Maximum Data Rate	150 Mbps	3.5 Gbps	9.6 Gbps	9.6 Gbps
Highest Subcarrier Modulation	64-QAM	256-QAM	1024-QAM	1024-QAM
Spatial Streams	1	4	8	8
Underlying Technology	IEEE 802.11n	IEEE 802.11ac	IEEE 802.11ax	IEEE 802.11ax

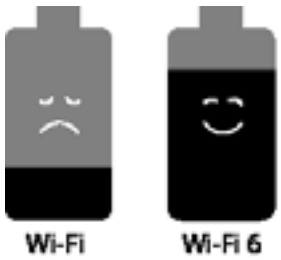
and more. It will also have a huge impact on the user experience for consumer devices that have traditionally relied on Wi-Fi networks.
The key enhancements that enable this major leap forward in data throughput are:

- Highly-efficient Quadrature Amplitude Modulation (QAM) architecture
- Newly-approved access to wider channels including those in the 6 GHz spectrum, a historic expansion of usable spectrum
- A doubling of the available spatial streams using MU-MIMO technologies and beamforming techniques

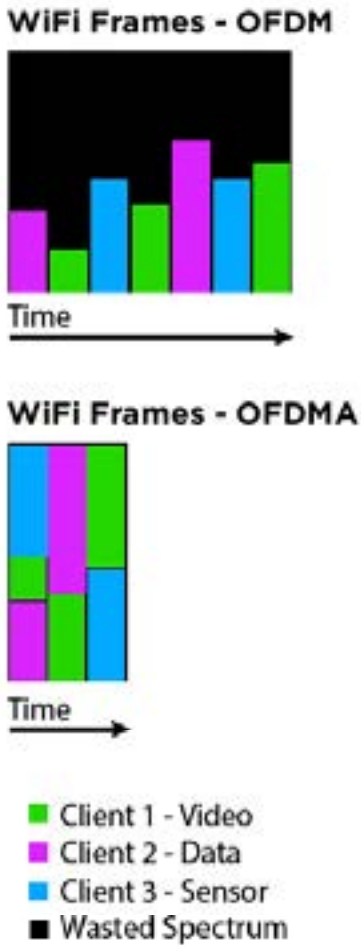
For those who want a deeper dive into these features of Wi-Fi 6 and 6E, please read this in-depth blog post that discusses each of those enhancements in detail. The key takeaway for engineering teams is that this combination of factors makes Wi-Fi 6 and 6E capable of serving far more devices with lower latency and higher performance in a way that is optimized for specific applications. This makes it a stronger platform not only for data-intensive applications like 4K TV streaming, but also for applications of every shape, size, and data usage. That includes low-bandwidth sensors and IoT networks that one may not immediately think of as benefiting from higher performance. This new version of Wi-Fi enables engineering teams to better support applications of every type, even on the same network as traditional applications, by dedicating categories of devices to different portions of the spectrum. This optimizes performance for each even as device numbers and data volumes grow.

Lower Latency for Speed and Battery Life

The far lower latency of Wi-Fi 6 and 6E is another enormously impactful enhancement that supports existing applications of Wi-Fi while also supporting new use cases for the first time. This will allow product designers to rely on Wi-Fi connectivity for latency-sensitive industrial and commercial applications like machine controls, robotics, and lighting controls that Wi-Fi could not previously support. Lower latency is also big news for consumer devices for entertainment where lagging latency negatively impacts user experience. It also has wide-ranging positive impacts on battery usage, data processing, and more, which are each influenced by latency rates. I should note however that while latency is lower in Wi-Fi 6/6E, it does not meet the ultra-low latency requirements of certain critical safety and medical applications. For devices that require latency at those levels, other connectivity technologies will be a better option than Wi-Fi.
Wi-Fi 6 and 6E deliver roughly 3x lower latency than prior versions of Wi-Fi. The exact rate you will achieve depends on a number of variables,



but the 3x metric is a reliable estimate based on testing my team has done and testing results I have read from other organizations. Just as importantly, that lower latency is combined with architecture that removes the empty space between packets so that network utilization approaches 100%. This is a dramatic improvement over the latency and packet management of prior versions of Wi-Fi. This is achieved with a technology called orthogonal frequency-division multiple access (OFDMA), which has been proven in other wireless technologies like LTE. By incorporating OFDMA into Wi-Fi, devices and networks automatically manage packets in far more efficient ways that are attuned to the needs of each application and device. As an example, an entire 20 MHz channel can be divided into 234 multi-user subchannels in Wi-Fi 6, and those subchannels can be assigned to the clients as needed with efficient management of packets to optimize traffic and to optimize performance of each device and application.



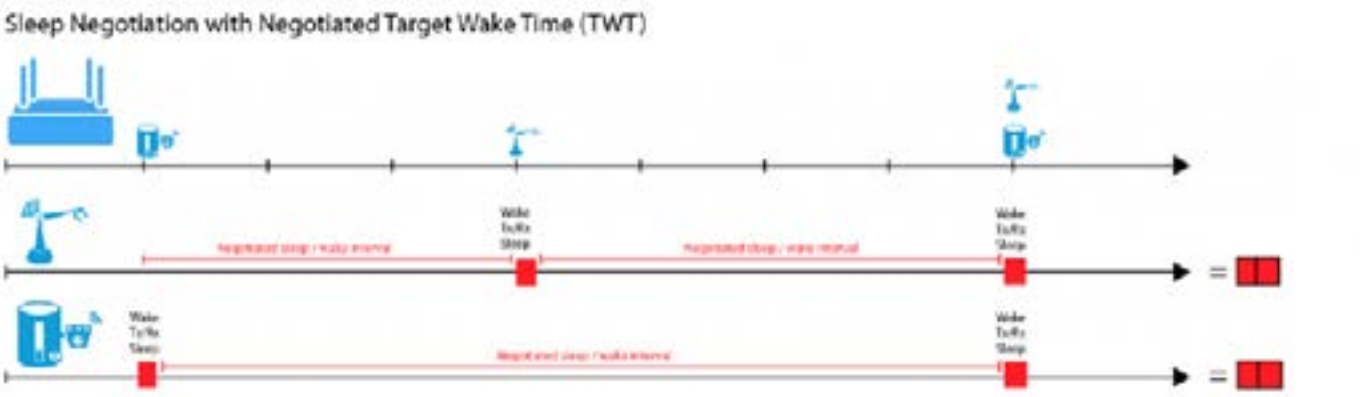
I should also note that Wi-Fi's lower latency also has a major side benefit: the ability to lengthen battery life for devices. The architecture I discuss above reduces the amount of time it takes for devices to transmit and receive data, which is one of the most power-intensive activities for a connected device. By requiring less time for processing and transmitting, devices can conserve power each time data transfer is occurring. My team plans to conduct detailed testing to determine precise metrics for this impact on battery life, but I fully expect it to add months or even years to the life span of batteries in many common IoT deployments.

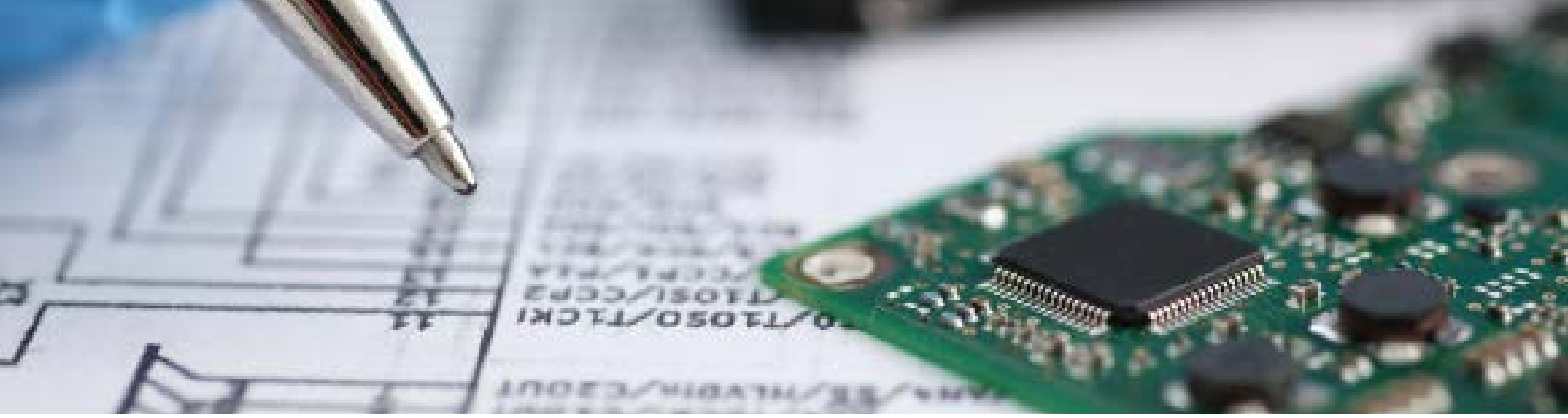
Device Density for Complex Environments

As the number of Wi-Fi connected devices increase, Wi-Fi networks can become overwhelmed not only by the number of devices making demands on the network but also the RF complexity of so many networks and devices competing with one another. Every family that has multiple devices competing for Wi-Fi bandwidth on their home network might experience this on any given weeknight. And those same network congestion and performance issues are major factors for engineers to contend with in complex RF environments like hospitals, schools, performance venues, sports stadiums, and airports.

Wi-Fi 6/6E utilizes OFDMA and Multi-User Multiple-In Multiple-Out (MU-MIMO) to organize spectrum temporally and physically to achieve higher density than prior versions of Wi-Fi. OFDMA, which I discussed above as a key to achieving lower latency, also enables engineers to achieve higher density. Its architecture allows Wi-Fi 6/6E to talk to multiple devices within a given period, that are within close proximity of each other.

The other technology that allows higher density is MU-MIMO, which enables spatial streams that focus RF activity in the physical direction of the intended device. This is achieved by using two antennas and creating an intentional interference pattern to focus signal toward the intended device or groups of devices – creating a stronger link with each device using up to eight spatial streams. This not only boosts the strength of each device's connection but also reduces unfocused RF noise and utilizes less power in the process. This has the added benefit of reducing the overall volume of interference in environments with many gateways and devices, preventing the physical space from becoming saturated in signals that potentially interfere with the performance of the networks, devices, and applications.





Together, OFDMA, MU-MIMO, and other features like BSS Coloring allow engineering teams to support far more devices in a given physical space without the congestion and performance issues that have often plagued high-density environments in the past.

Enhanced Low-Power Capabilities

The centerpiece of Wi-Fi 6 and 6E's low power strategy is Target Wake Time (TWT) technology. Prior technologies like PS-Poll (DTIM) and WMM (APSD) are still supported in Wi-Fi 6 and 6E, but most engineering teams will want to take full advantage of TWT because it enables much longer sleep times for clients that preserve battery through extended inactivity while still remaining connected to the network. For devices whose role can enable sleep for long periods of time, TWT dramatically improves power scheduling, extends battery life, and lowers network congestion.

I should also note that, in conjunction with other enhancements in Wi-Fi 6 and 6E that intelligently manage device connections and data packet traffic, TWT allows engineering teams to improve the performance of wireless networks while also reducing RF noise. As Wi-Fi continues to grow as the most prevalent foundation for wireless networks, the value of these "clean RF" features cannot be overstated. With the addition of 6 GHz spectrum, this provides engineering teams with not only far more real estate for Wi-Fi networks but also the ability to manage each area of spectrum in a more precise, cleaner, more customized way that supports all types of devices and applications. Our blog series at lairdconnect.com will include a detailed analysis of how impactful this 6 GHz spectrum is for the growth and evolution of Wi-Fi.

Other Key Updates

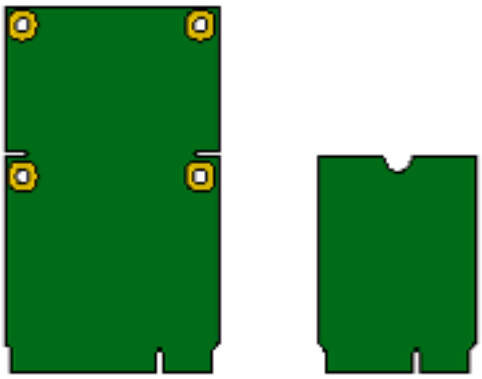
The enhancements to Wi-Fi 6 and 6E also include some significant changes related to hardware, software, and form factor that engineering teams will need to factor into their design strategies. This includes changes to the kinds of hardware interfaces and logical interfaces, which is different in some cases from prior versions of Wi-Fi.

One noteworthy change involves modernized interfaces for Wi-Fi communication between the host device and the Wi-Fi module. Prior versions of Wi-Fi utilized PCIE, SDIO and USB for the hardware's Wi-Fi interface. Wi-Fi 6 and 6E phases out USB in favor of PCIE v4 and SDIO v3.

Wi-Fi 6 and 6E also modernize antenna strategy by adding support for MU-MIMO, bi-directional antennas that can operate in the 6 GHz range while also supporting key features such as beamforming and intelligent stream management.

Other key changes to be aware of include:

- Broader OS support for Linux, Android, and RTOS
- Full support for Bluetooth 5.2 and higher, which is commonly paired with Wi-Fi in IoT networks
  - Previous generations of Bluetooth/Wi-Fi combo modules had supported a very limited set of Bluetooth Low Energy (LE) functions – the new Bluetooth radios in the Wi-Fi 6 combo radios are fully featured BT 5.x radios
- Wider temperature ranges for operations in even more environments
- Updates to the available form factors
  - The move to the M.2 standard seems to be complete for Wi-Fi 6 devices with the M.2 2230 formfactor taking over form the mini PCIE card



Collectively the enhancements and updates that I have discussed in this white paper represent a pivotal shift in the evolution of Wi-Fi that requires a re-thinking of what Wi-Fi is capable of. This is the most comprehensive overhaul of Wi-Fi in more than a decade, and it will reshape Wi-Fi networks for decades to come. Laird Connectivity helps companies simplify their Wi-Fi 6/6E strategy by providing modules and antennas that take full advantage of these Wi-Fi enhancements, accelerating design and time to market.

To help engineers in this large-scale adoption of Wi-Fi 6 and 6E, Laird Connectivity has published an ongoing series of practical resources about how to work with next-generation Wi-Fi and fully leverage its enhancements. This series of blog posts, videos, and webinars provides engineering teams with deep dives about how to design with Wi-Fi 6 and 6E as well as key use cases that are possible with the enhancements in the newest version of Wi-Fi – use cases such as connected devices for:

- Hospitals and healthcare clinics
- At-home medical monitoring and healthcare delivery
- Smart factories and manufacturing automation
- Warehouse and operational logistics
- Outdoor sensors and lighting systems
- Smart buildings applications
- Sustainability and environmental use cases
- HD video distribution
- Transportation centers and other high-density public venues
- AI learning data acquisition and distribution
- Surveillance and physical security systems
- Handheld devices, tablets, and scanners used by workers in the field
- Smart utilities use cases
- Low-power IoT device networks

The hub for these resources will be this portion of our website: www.lairdconnect.com/market/wifi-6-and-wifi-6e#follow-our-wifi-6-series. I encourage you to sign up for updates about that content to continue getting the latest insights and design tips we share.

About the Author

Andy Ross is a Senior Product Manager at Laird Connectivity, where he leads the company's product development for Wi-Fi technology. He is responsible for development of Laird Connectivity solutions that help companies around the world take advantage of the next generation of Wi-Fi. Ross has more than 30 years of engineering experience in electronic design, including prominent engineering and product development roles at Silex Technology, B&B Electronics, Quatech, DPAC Technologies and Mosaic Semiconductor.

About Laird Connectivity

Laird Connectivity simplifies wireless connectivity with market-leading RF modules, internal antennas, IoT devices, and custom wireless solutions. Our products are trusted by companies around the world for their performance and reliability. With best-in-class support and comprehensive product development services, we reduce your risk and improve your time-to-market. When you need unmatched wireless performance to connect your applications with security and confidence, Laird Connectivity delivers – no matter what.

Learn more at www.lairdconnect.com.