Successful WiFi 6 Deployment to Customer Homes

A service provider's guide to intelligently controlling and optimizing the WiFi 6 home network
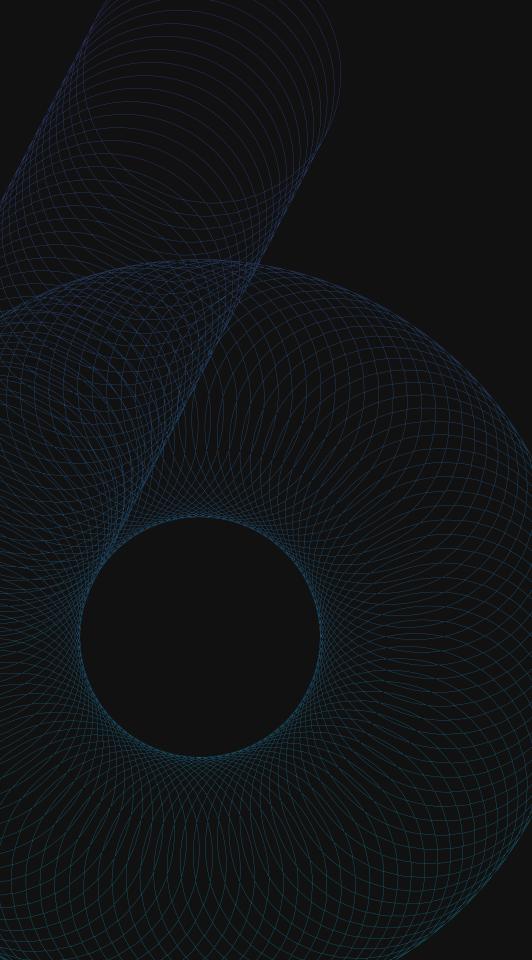
Plume®

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Executive summary

Following a few years of anticipation, WiFi 6 is making its way to homes and other connected places. The industry views WiFi 6 as a transformative technology that will be one of the leading trends of the 21st century and will drastically change the consumer experience. Market adoption began in earnest in 2020, and analysts and industry experts expect to see a brisk pace of growth.

Indeed, WiFi 6 brings many exciting improvements to a technology that's now two decades old. Its new features and capabilities are designed to provide advancements such as higher throughput and improved transmission efficiency and capacity. These will be welcome enhancements in connected environments—including the smart home, where the home network is growing more congested.

Many of the new WiFi 6 capabilities, however, come with drawbacks and limitations. For the technology to achieve its promised potential, Communications Services Providers (CSPs) will need to intelligently manage the home network. Despite all its breakthroughs, WiFi 6 requires more, not less, optimization than previous WiFi generations— and its performance will depend largely on the system controlling it.

Introduction

Hailed as a new era for WiFi connectivity, 802.11ax—known better as WiFi 6—has created much excitement and anticipation. Capable of more than doubling speeds of its predecessor, 802.11ac (or WiFi 5), WiFi 6 promises to transform the home network.

As well as boosting throughputs, this new technology improves overall system capacity, security, and even power consumption and battery life. And the timing couldn't be better. Not only are consumers relying on home WiFi more than ever, but the smart home is also evolving to include more connected devices, immersive experiences, and bandwidth-hungry applications.

The Wi-Fi Alliance anticipates nearly 2 billion WiFi 6 devices to be shipped in 2021 to consumers and organizations.[1] WiFi 6 products entering the market will spark renewed consumer interest in WiFi upgrades, including deployments of WiFi 6 home networks. It's an exciting opportunity for CSPs to elevate their offerings to subscribers.

There's no doubt that the new capabilities of WiFi 6 will improve the user experience in all connected spaces. But maximizing its full potential means optimizing WiFi networks in ways that are both more critical and more complex.

WiFi 6 connectivity in any space is only as good as the system controlling it. To deliver on the promise of this new technology for their customers, CSPs must understand the limitations of WiFi 6 home deployments and the requirements for intelligently managing the networks.

Nearly 2 billion WiFi 6 devices will be shipped in 2021 to consumers and organizations

[1] "Wi-Fi Alliance® Wi-Fi® predictions for 2021," Wi-Fi Alliance, January 2021

The state of the WiFi 6 industry and the market

WiFi has become as ubiquitous as the internet itself. Considering that WiFi 6 brings the first major improvement to 2.4 GHz band in a decade, the buzz surrounding it is understandable.

And a lot has changed in that decade. The home network is much more complicated and customers are increasingly relying on that WiFi connectivity for work, school, and entertainment.

The excitement about WiFi 6 can be best summarized in the words of Federal Communication Commission (FCC) Chairman Ajit Pai, who said, "The American consumer's wireless experience is about to be transformed for the better."[2]

The WiFi 6 market is just emerging. But the technology's potential to transform the home network is tremendous, especially as the smart home and work-from-home (WFH) trends gain momentum. Research firm Strategy Analytics sees the wireless home becoming "one of the leading technology trends of the early 21st century."[3]

HERE'S JUST A GLIMPSE OF WHAT THE INDUSTRY FORECASTS:

- 17 billion home devices will be in use by 2030 globally, with WiFi 6 accounting for a third of device sales by 2023.[3]
- WiFi 6 will become the predominant WiFi standard both for consumers and enterprises by 2023.[4]
- On the public WiFi front, WiFi 6 hotspots will grow 13-fold between 2020 and 2023, comprising 11% of public WiFi hotspots by 2023.[5]
- 2 billion WiFi 6 devices will be shipped in 2021 to consumers, enterprises, and public agencies.[6]

14.5

Connected devices are used in the average US household served by Plume[7]

28%

of consumers use smart home devices such as cameras and thermostats[8]

71%

growth expected for the number of global shipments of smart devices between 2019 and 2023 (from 814.8 million to 1.4 billion)[9]

[2] "Chairman Pai on FCC Authorization of First 6 GHz Wi-Fi Device," Federal Communications Commission, December 2020
[3] "Smart Home Will Drive Third Wave in Wireless Home Evolution," Strategy Analytics, August 2019
[4] "Work/School from Home Fuels 223 Million SOHO Consumer Wi-Fi CPE Shipments in 2020," ABI Research, October 2020
[5] "Cisco Annual Internet Report (2018–2023)," Cisco, Updated March 2020

[6] "Wi-Fi Alliance® Wi-Fi® predictions for 2021," Wi-Fi Alliance, January 2021
[7] PlumeIQ February, 2021
[8] "Connectivity and Mobile Trends Survey," Deloitte, 2019
[9] "Smart Homes 2020," eMarketer, December 2019

Market developments

Rapid growth of the WiFi 6 market began when the Wi-Fi Alliance launched its Wi-Fi CERTIFIED 6™ certification program, based on the IEEE 802.11ax standards, in September 2019. Even before that, some industry players—including networking vendors—began building the next-generation WiFi infrastructure.

By February 2021, the Wi-Fi Alliance had certified nearly 1,400 different WiFi 6 products. More than a third of those were in the router category, including home gateways.[10] While the smart home category included only a few certified devices initially, some smart TVs, tablets, and even a couple of gaming systems were already available. It's only a matter of time before the consumer market explodes.

Momentum was also built in 2020 for WiFi 6E (the E stands for Extended). WiFi 6E is simply WiFi 6 operating in the 6 GHz frequency band. The 6 GHz band has recently been allocated for WiFi in the US, EU, and other geos.[11] While this band promises more spectrum, better availability of 160 MHz wide channels, and lower interference levels, it requires more sophisticated management.

338 million+

WiFi 6E devices will come on the market in 2021

Nearly 1/5

of all WiFi 6 devices shipped by 2022 will support 6 GHz

More than 338 million WiFi 6E devices will come on the market in 2021, and nearly one-fifth of all WiFi 6 devices shipped by 2022 will support 6 GHz, analyst firm IDC forecasts.[12]

NOTABLE WIFI 6E EVENTS INCLUDE:

- Broadcomm announced a portfolio of residential and enterprise access point (AP) solutions for 6 GHz WLAN in January 2020, followed by a February announcement of a WiFi 6E chipset.

- In April 2020, the United States became the first country to open the 6 GHz spectrum, and some have called the decision by the FCC historic and monumental.

- In December 2020, FCC authorized the first WiFi 6E device, a Broadcom low-power indoor transmitter. In his statement, FCC Chairman Ajit Pai said this was "an exciting glimpse of America's WiFi future."[13]

- In early January 2021, the Wi-Fi Alliance introduced WiFi 6E certifications, which will use enhanced WPA3 security. The Alliance has certified more than a dozen products, including routers, from vendors such as Intel, Qualcomm, and Samsung, as of February.[14]

WIFI 6 V 6E DEVICES

WiFi 6E devices will be backward compatible with WiFi 6 and previous WiFi standards. But to take advantage of those new 6 GHz channels in WiFi 6E, you'll need to be using devices that support it. In other words, you'll only be using WiFi 6E once you pair a 6E-enabled client device (like a laptop or smartphone) and a 6E-enabled access point. WiFi 6 devices paired with a 6E-enabled router will still be using the typical 5 GHz or 2.4 GHz channels.
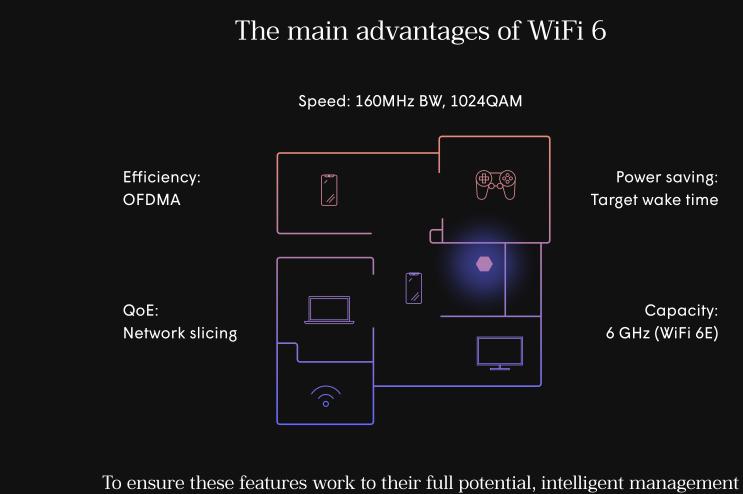
[10] Data aggregated from the Wi-Fi Alliance Product Finder, last accessed February 2, 2021
[11] "A closer look at where select countries stand in opening up 6 GHz for unlicensed Wi-Fi," RCR Wireless News, January 2021
[12] "Wi-Fi Alliance® delivers Wi-Fi 6E certification program," Wi-Fi Alliance, January 2021
[13] "Chairman Pai on FCC Authorization of First 6 GHz Wi-Fi Device," Federal Communications Commission, December 2020
[14] Data aggregated from the Wi-Fi Alliance, last accessed February 2, 2021

Key WiFi 6 features and benefits

In the home environment, the network is becoming more congested as a larger number of devices connect to WiFi and customers run more bandwidth-heavy applications such as 4K video streaming, virtual reality (VR) gaming, and video conferencing. WiFi 6 brings key changes to several areas, including:

• 2x higher throughput in low-congested environments

• Improved power efficiency

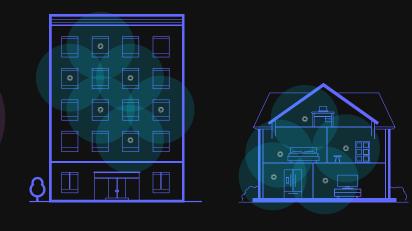• 2x more devices that can be supported efficiently (to 8)

The new features are designed to better handle different types of traffic simultaneously from multiple users, as well as improve coverage for overlapping networks and dense environments. In practice, however, many of the new capabilities have limitations and drawbacks. Mitigating the issues will require advanced tools that manage and optimize the home networks.

The main advantages of WiFi 6

Speed: 160MHz BW, 1024QAM

Efficiency: OFDMA

Power saving: Target wake time

QoE: Network slicing

Capacity: 6 GHz (WiFi 6E)

To ensure these features work to their full potential, intelligent management is critical, especially in today's congested home WiFi environments.

In neighborhoods   In MDUs   In homes

An overview of new WiFi 6 features

160 MHZ CHANNEL BANDWIDTH:

The wider the channel used, the higher the data rate. While the WiFi 5 technology officially supported 160 MHz capabilities, few devices actually offered channel bandwidths greater than 80 MHz. Although this is technically not a new feature, the expectation is for most WiFi 6 devices coming to the market to support 160 MHz channel bandwidths.
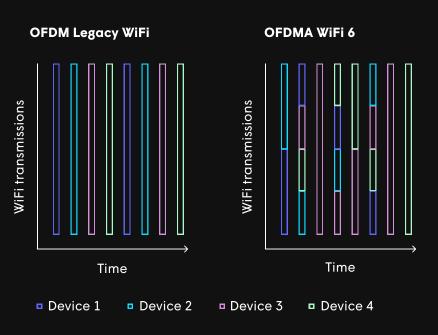
OFDMA:

Uplink and downlink orthogonal frequency- division multiple access, or OFDMA, is a marquee feature of WiFi 6, which allows for a single transmission to communicate with a large number of devices. It greatly improves efficiency and capacity by subdividing the channel into smaller frequency allocations (resource units) that are transmitted from one AP in parallel.
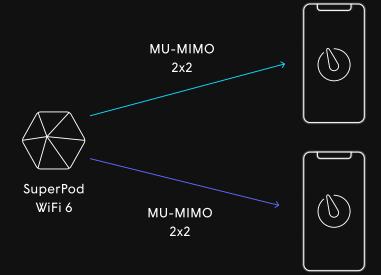
1024-QAM:

WiFi 6 goes from 256 quadrature amplitude modulation (256-QAM) to 1024-QAM, increasing the physical layer data rate by 25% at short range. Essentially, this modulation brings a more dense packing of bits into the signal, thereby boosting the network speed by increasing the data rate for the channel.

UL-MU-MIMO:

The Uplink Multi-User Multiple Input Multiple Output (UL-MU-MIMO) is the companion to Downlink (DL) MU-MIMO that was standardized and implemented in WiFi 5. UL-MU-MIMO allows multiple devices to be transmitting at the same time to the same AP, improving efficiency and uplink capacity. With OFDMA, the different devices transmitting at the same time use different parts of the frequency spectrum. In the MU-MIMO case, the devices involved rely on multiple antennas to separate the traffic by spatial means, so the AP can independently receive signals coming from clients in different directions.

OFDM Legacy WiFi — OFDMA WiFi 6

WiFi transmissions / Time

Device 1 · Device 2 · Device 3 · Device 4

MU-MIMO Simultaneous Transmission

MU-MIMO 2x2

SuperPod WiFi 6

MU-MIMO 2x2

RESOURCE UNIT RESERVATIONS:

The resource units, or smaller frequency slices, that OFDMA operates with can get allocated to particular clients. This allocation changes dynamically over time, which is what allows a single, wide, efficient transmission to serve multiple clients at once. Reserving resource units for particular clients or data flows provides guaranteed Quality of Service (QoS) to those clients or flows because a fixed amount of bandwidth within the network is allocated specifically for that traffic.

TARGET WAKE TIME:

First developed for 802.11 ah (900 MHz WiFi, branded "Wi-Fi HaLow" by the Wi-Fi Alliance), target wake time (TWT) is expected to be deployed widely with WiFi 6. This mechanism improves battery life for devices that are transmitting only occasionally or at a low-duty cycle. The AP creates a schedule with specific times for each client to be awake and reserves that time so no other devices can transmit during that window, giving the waking devices clear airwaves to quickly communicate and return to sleep.

BSS COLOR:

Basic Service Set (BSS) color added with WiFi 6 allows more efficient airtime usage between overlapping networks that are on the same frequency channel. This technique marks (or "color-codes") shared frequencies in the very beginning of the packet to indicate which network the packet belongs to and enables devices to make a very quick assessment if they are safe to transmit or must defer to traffic coming from a network with a different color.

6 GHZ FREQUENCY:

WiFi 6E extends WiFi 6 capabilities to the 6 GHz spectrum, previously only available to licensed users. This is considered a big step, as the need has become more urgent to prevent congestion on existing frequencies. The industry has been advocating for some time for the allocation of more bandwidth for unlicensed use. The new spectrum makes available up to seven superwide 160 MHz channels that can support high-bandwidth applications such as unified communications and industrial IoT. For home networks, use cases that can benefit from the low-latency, higher-speed WiFi include augmented reality and virtual reality.

WiFi 6 network optimization and controls

As highlighted earlier, the new or enhanced WiFi 6 capabilities are not without issues. To ensure these features work to their full potential and truly benefit customers, CSPs need to implement sophisticated controls and optimize the network. These controls are especially critical in today's congested home WiFi environments and in dense areas where issues such as interference arise.

160 MHz channel bandwidth

Doubling the channel width from 80 MHz to 160 MHz should double throughput. So, in theory, customers would see twice-as-fast downloads, double resolution, and so forth, with the double data rate. The problem is that, in most countries, only two independent 160 MHz channels are available. In a dense environment, such as an apartment complex or even suburban homes on small lots, two different customers are likely to use an overlapping channel, leading to significant interference.

This issue can be mitigated with proper network configuration, which requires three factors:

- Intelligent sensing and prediction of the interference on 80 MHz subchannels of the 160 MHz transmissions.
- Intelligent channel allocation and bandwidth selection.
- Consideration of the complete interference picture in an environment, optimizing channel allocation across entire apartment complexes or neighboring homes.

Simple, locally managed networks can't achieve these factors. CSPs will need to handle them centrally through the cloud. For example, cloud-based interference analysis factors, loads, and device types. When considering what channel bandwidth to assign to each AP, the platform knows the history and current set of clients and loads that are present in the network at each access point. The system can then apply 160 MHz bandwidth channels where they are most needed and avoid them where they are not. Central cloud management also allows the optimal selection of channel bandwidths and frequency channels across an entire apartment building. Frequency channels can be "tiled" across the apartments, minimizing the conflicts between neighboring apartments. In cases where re-use of the same channel is unavoidable, the cloud based optimization system can select apartments that are most able to share frequency channels based on their historical activity.

In a dense environment, such as an apartment complex or even suburban homes on small lots, two different customers are likely to use an overlapping channel, leading to significant interference.

OFDMA

This signature WiFi 6 feature stemmed from observing the poor efficiency of the small packets typically emanating from Internet of Things (IoT) and other low-data-rate devices. Each 802.11 packet has significant overhead, and to avoid collision with other transmitters, each transmitter must listen first to the medium for some time. Even if each transmission sends a modest amount of data, the overhead consumes a lot of airtime.

OFDMA allows transmission to multiple users simultaneously in one packet, eliminating overhead and wasted time. This capability only improves efficiency when a significant number of IoT devices are on the same AP, each device

sending or receiving a modest amount of data. But, modern WiFi networks in smart homes will not always end up with a significant number of IoT devices on the same AP.
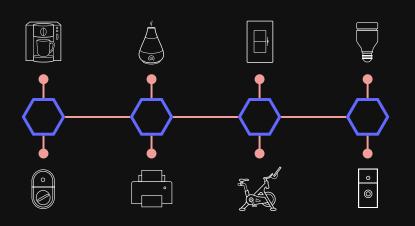
Here's why: Home networks have migrated to multi-AP topologies using mesh networks, repeaters, or multiple gateways. If the IoT devices in the home were to simply connect to the nearest AP, each AP would have few devices appropriate for grouping into OFDMA transmissions. On the other hand, forcing devices to connect to an AP that is too distant will force the data rates of these connections to drop, compromising efficiency in a different way.

Consequently, OFDMA operation requires OFDMA-aware client steering. To make complex decisions, a centralized, intelligent network controller would need:
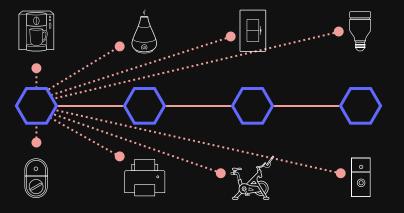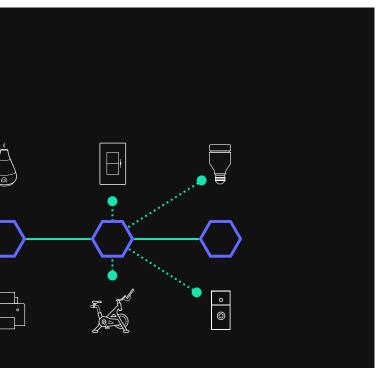
- Knowledge of which APs and clients are WiFi 6 capable.
- Historical observation and forward prediction of the data needs of each device in the home.
- The ability to make intelligent, optimized choices about which of the multiple APs each device in the home should connect to considering the capabilities, traffic load, signal strength, and data rate each device can achieve.
- The ability to steer and hold devices on the correct AP.

For all the APs and clients to work efficiently, the best arrangement must be created through rigorous optimization. This should include the ability to steer clients to APs and hold them there, even if those aren't the closest APs. The steering mechanism must be specific to each type of device because different devices behave differently to various steering mechanisms.

OFDMA-aware steering

Too distributed   Too centralized   Just right

Network slicing

A QoS mechanism, network slicing is another way of allocating frequencies and time among different clients. This is essentially a time-division multiple access (TDMA) method (where transmissions occur at reserved times) but has the added overlay of a divided frequency spectrum. In a home with multiple APs or in an MDU, network slicing can lead to high collision rates when both networks schedule the same time periods. The result is poor QoS, defeating the point of the time/frequency reservations. Centralized, intelligent controls can mitigate this issue by coordinating among the multiple APs.

6 GHz frequency band

To protect point-to-point microwave systems that operate on the same 6 GHz spectrum, WiFi 6E devices must use one of two modes:

- A low power (18dBm/63mW) that uses the low-power spectrum rules: This mode can't transmit as far or at as high a data rate because the signal is not very strong.
- Under the command of an AP that has an automated frequency control (AFC) system (30dBm/1 Watt allowed): In the US, for example, the AFC systems must check the data in an FCC database to ensure there are no microwave systems in the vicinity of the AP. There are currently around 100,000 microwave links in the US used by mobile carriers, industrial and business entities, and

public safety agencies.[15] By avoiding a frequency channel used by nearby microwave systems, the AP and its clients can operate at the high-power level, enjoying full range and data rates.

These operating modes will require different types of controls:

- For the low-power transmission, more complicated, multi-AP configurations will be required for an optimization system to select the appropriate network topologies, frequency assignments, and client-steering options.
- For the AFC systems, the AP will need to communicate with a smart controller that can look up the FCC database, factor in the geo data, calculate interference levels, then deliver instructions back to the AP.

For either mode, the control system needs to take into account the client types, loads, and capabilities to decide how to allocate the network's radio resources. Depending on the capabilities of the clients in the network, it is not always optimal to put one of the AP's radios in the 6 GHz band. For example, using a 6 GHz channel for the backhaul connection may help the backhaul, but it may take away the high performance radio in the AP from the 5 GHz band. High performance clients that do not have a 6 GHz capability may therefore connect at lower speeds, actually degrading the experience in the home.
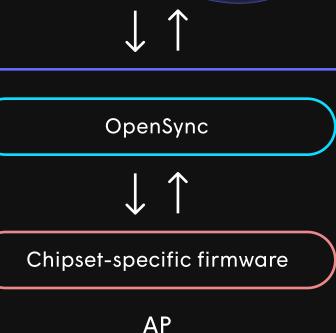
Intelligent management imperative for CSPs

WiFi 6 brings long-anticipated improvements to a technology that's now 20 years old. The new features will solve many challenges created by the ever-expanding, increasingly more congested home network. It's undisputed that this technology takes the home network to a new level. However, WiFi 6 brings additional complexities, such that simple controls can no longer satisfy the requirements of this evolved ecosystem.

To maintain the Quality of Experience (QoE; a metric developed by Plume to improve upon QoS) for their customers, CSPs will need to adopt an intelligent management approach. With centralized controls, ideally based in the cloud, CSPs can ensure that they're achieving the performance potential of WiFi 6. More sophisticated controls, coordination, and optimization will become especially critical as smart home adoption picks up the pace, putting further pressure on connectivity and performance.

CSPs should harness the power of the cloud and artificial intelligence (AI) to make sure their subscribers' home networks are ready to support the exciting capabilities of WiFi 6. The cloud offers practically infinite memory and computing power, supporting AI-driven innovation.

Cloud-based monitoring, learning, and control

↓ ↑

OpenSync

↓ ↑

Chipset-specific firmware

AP

How Plume does it

Plume's innovative platform provides WiFi operational enhancements that increase the home network's speed and capacity. The Plume SuperPod with WiFi 6, coupled with the Plume Cloud™, addresses the WiFi 6 demand for added intelligence.

Plume's cloud-based, AI-driven algorithms learn from data collected across millions of networks and clients to identify the best steering techniques, predict interference, and perform complicated analyses to apply dynamic controls and rigorous optimization to networks with multiple APs or in MDUs.

Plume's SuperPod with WiFi 6 uses a tri-band design that more than doubles spectrum efficiency and more flexibly adapts to any home topology without performance compromises, compared with dual-band design.

Conclusion

As with most new technologies, it will take a few years for WiFi 6 to become ubiquitous. But the possibilities are thrilling once the technology is fully developed and implemented. The greatly enhanced speed and performance of WiFi 6 will open new doors for emerging technologies such as IoT and AR/VR. It's not only a new era for consumers but also an opportunity for CSPs to take advantage of the technology to enhance and expand services.

WiFi 6 is, indeed, powerful. But it doesn't eliminate the need to optimize the network—on the contrary, the complexity of this technology creates an even greater demand for intelligent management. CSPs should take advantage of the advanced management solutions that future-proof their customer deployments while meeting customer demand and maintaining QoE.