Wi-Fi 6:
The (Much) Bigger Picture

A Farpoint Group White Paper

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With both the IEEE 802.11ax standard and a corresponding certification process from the Wi-Fi Alliance now essentially complete, Wi-Fi 6 is arriving in the marketplace in a wide variety of products from a broad array of vendors. Building upon a three-decade legacy of remarkable advances in wireless-LAN technologies, Wi-Fi 6 includes significant new innovations with benefits that promise even greater throughput, application support, convenience, and, perhaps most importantly, end-user productivity. While many IT shops will still proceed with 802.11ac (Wi-Fi 5) rollouts already underway, Farpoint Group is encouraging the deployment of Wi-Fi 6-based products even in installations where backwards compatibility to Wi-Fi 5 and even Wi-Fi 4 (802.11n) is the overriding concern. As has been the case with previous generational Wi-Fi advances, the performance enhancements embodied in Wi-Fi 6 will yield improved results over previous generations even if utilization of the latest airlink technology is not an immediate requirement. And, of course, having the most current Wi-Fi technology in place is clearly the future-proof operational strategy of choice as the installed base of Wi-Fi 6-capable clients, including Apple's recent iPhone 11, continues to grow.

But even with all of the benefits inherent in Wi-Fi 6 itself, Farpoint Group believes that *specific capabilities embodied in individual vendor solutions over and above the standard itself are where the ultimate value of Wi-Fi 6 resides*. These include advanced network management capabilities, integrated operational assurance features, the automation of a wide variety of both common and exceptional operations tasks, real-time analytics, policy-based service definition, the application of artificial intelligence (AI) to a broad range of needs, enhanced IT integration (such as Cloud-based services, APIs, and DevOps), broadly improved location and tracking, and much more. Individually and collectively, these advances enhance the returns on an investment in Wi-Fi 6 via new capabilities beyond the standard, improving the value proposition of Wi-Fi 6 for network operations teams, IT shops, and ultimately, of course, end-users within organizations of all types and missions overall. We believe that success with Wi-Fi 6 will in fact be *defined* by *reductions in operating expense* and *improvements in both IT-staff productivity and end-user quality of experience (QoE)* across the organization, with these accruing *much* greater value than is implied in the (granted, significant if not in fact *exciting*) features and benefits of the 802.11ax standard alone.

This Farpoint Group White Paper will begin with an brief examination of the key advances in Wi-Fi 6, but, much more importantly, we will explore why the deployment of Wi-Fi 6-based solutions employing innovations enabled by but still beyond the standard itself will yield benefits far exceeding those implied in the core traditional and long-standing driver of Wi-Fi investments: improvements in throughput alone.

Key Technology Advances in Wi-Fi 6: *From Serial to Parallel*

Let's begin with the magic number: Wi-Fi 6 can indeed (at least in theory) get us to a physical-layer (PHY) rate of 10 Gbps. But as has always been the case, this metric is in fact both the number that marketing departments across the industry will guarantee their

products will never exceed, and a theoretical maximum that is completely useless as a comparative metric or justification for upgrading one's wireless-LAN infrastructure in the first place. Instead, an entirely new and somewhat more complex basis for evaluation and comparison is required, as we'll discuss in the next section of this White Paper.

Regardless, one should never underestimate the value inherent in any of the technological advances that have characterized each of the six generations of Wi-Fi (see Table 1). And Wi-Fi 6 is no exception here, with a number of innovations that enhance not just throughput, but overall network *capacity* and *efficiency*. Among the key advances in Wi-Fi 6 are the following:

- *OFDMA (Orthogonal Frequency-Division Multiple Access)* – Many networking professionals are of course familiar with orthogonal frequency-division multiplexing (OFDM), which is just that: a multiplexing technique that converts a single high-speed data stream into multiple, simultaneous, and non-interfering (that's the "orthogonal" element) low-speed data streams, usually yielding improved reliability and thus often higher throughput. The low-speed streams are commonly called *tones*, and the net aggregate capacity of all tones accrues to a single client at any given moment in time. OFDMA builds upon OFDM, but evolves the technique into a multiple-access discipline, potentially supporting multiple clients during a single transmit cycle. OFDMA thus assigns a portion of those low-speed streams to each of some number of simultaneous clients, improving overall system efficiency.

Wi-Fi Generation	IEEE Standard	Date	Nominal Peak Throughput (Mbps)	Generational Improvement (X)	Notes
1	802.11	1997	2		
2	802.11b	1999	11	5.50	
3	802.11g	2003	54	4.91	
4	802.11n	2009	600	11.11	Four streams, MCS 7, 40 MHz. channel, 800 ns. GI
5	802.11ac	2013	800	1.33	Four streams, MCS 9, 40 MHz. channel, 800 ns. GI
6	802.11ax	2020	917.6	1.15	Four streams, MCS 9, 40 MHz. channel, 800 ns. GI

Table 1 – Comparing WI-Fi performance between – *or even within* – generations can be complex given the large number of operational parameters at work and the likelihood of constant automatic adjustments to these during operation. This comparison illustrates just one example but holds key parameters (modulation and coding rate, channel bandwidth, and guard interval) as constant as possible between generations. Note the dramatic increase in throughput resulting from MIMO in Wi-Fi 4 and later, but also decreasing per-stream improvements in performance in subsequent generations. This reality places a correspondingly greater importance on the above-the-standard capabilities we explore in this document in achieving optimal performance – and not just higher throughput. *Source:* Farpoint Group.

- *1024 QAM (Quadrature Amplitude Modulation)* – QAM is a modulation technique that encodes digital information on a carrier wave at a given frequency using a combination of both amplitude and frequency modulation, again improving reliability and spectral efficiency. While QAM has been used in a broad variety of wireless systems over the years, including Wi-Fi 4 and 5, 1024 QAM is standardized in Wi-Fi 6, with the 1024 referring the encoding of 10 bits (2^{10} is 1024) in a single transmitted symbol – the waveform representing the digital information encoded. Two important points: due to the complexity of the resulting physical signal, 1024-QAM is likely to work well only across relatively

short distances between endpoints, meaning that the AP dense-deployment strategy we've long recommended is still important. And, of course, Wi-Fi 6 can vary the actual amount of information encoded and transmitted at any given moment in time based on instantaneous radio conditions, with these themselves varying often dramatically from transmission to transmission.

- *Bidirectional MU-MIMO (Multi-User Multiple-Input/Multiple Output)* – The introduction of MIMO in Wi-Fi 4 was one of most notable and important advances in Wi-Fi of all time. In a nutshell, MIMO adds a third "spatial" dimension to the otherwise two-dimensional (amplitude and frequency) domain of a given electromagnetic wave traveling through space. Since three physical dimensions can hold a lot more information than two, throughput can (and usually does) increase dramatically over non-MIMO implementations. Analogous to the tones in OFDM, MIMO introduces the concept of *streams*, with multiple streams able to be transmitted simultaneously. Just as OFDMA enables multiple clients (or users) to transmit simultaneously, sharing available channel bandwidth without interfering with one another, MU-MIMO does the same: a single transmit cycle can contain information unique to each of multiple receivers. Wi-Fi 5 included only downlink (from the AP to multiple clients) MU-MIMO; Wi-Fi 6 extends this capability to the uplink as well.

- *BSS Coloring* – This facility, which derives from an application of mathematical graph theory, enables a given transmitter to decide if a signal already present in the channel being used by the transmitter actually does represent harmful interference, rather than, as has been the case in the past, always so assuming. The net benefit is better channel utilization and improved overall *spectral efficiency* – more data transferred per unit of time and bandwidth.

- *Target Wake Time (TWT)* – Power-saving protocols have been a part of 802.11 standard since the early days, and TWT further enhances this capability by adding greater determinism and thus efficiency to the process. Improved battery life, clearly, will always be a desirable benefit in any mobile or otherwise battery-powered application, including and perhaps especially applications for the Internet of Things (IoT).

All of the above in fact contribute to a key objective of Wi-Fi 6: *addressing the needs of multiple clients simultaneously in place of the historical emphasis on raw or per-client throughput alone*. This makes sense – few applications require multi-gigabit throughput, and growth in overall *aggregate* demand requires strategies and facilities that enable *multiple* clients to be served simultaneously rather than having to wait for serialized access to the network. And, as has for example been the case historically with high-performance computing, Wi-Fi 6 utilizes technologies that take advantage of *parallelism* and trade per-user maximum throughput for *simultaneous* multi-user network access. As we'll expand upon in the next section, this re-thinking yields *precisely* what organizations need today.

But here's the tricky part – even with all of the enhancements discussed above, it's regardless impossible to optimize all of the above facilities and other capabilities within the standard simultaneously at any given moment in time. In addition to this being a classic "more variables than equations" problem, there are simply more strategies and settings possible, again at any given moment in time, than any human operator would be able to constantly consider, adjust, and thus utilize effectively. Due to the essential nature of the unlicensed bands (limited bandwidth, potential interference, motion, range, instantaneous prevailing radio environment, and etc.), realized throughput will consequently vary significantly, and, again, usually from moment to moment. As we've already seen with management capabilities that dynamically adjust channel assignments and transmit power, vendor-specific solutions that employ advanced capabilities *above and beyond the standard itself* are thus vital in obtaining optimal value from an investment in Wi-Fi 6 products. In short: *the standard defines facilities and capabilities; individual vendor implementations decide how to take advantage of these.*

IT and Network Operations: *The Core Challenges Today*

While there are many, the most obvious challenge for all organizations today is how to address the ever-increasing rise in network traffic volumes, often with a decreasing tolerance for latency. It's thus critical to design networks with greater *headroom* than has traditionally been the case, especially given time-bounded traffic like VoIP and streaming video on demand. But even without the consideration of real-time media, most organizations already deal with the reality of high-demand traffic volumes driven by a constantly-growing base of end-users and a simultaneous increase in the number of operational mobile devices per user. Likewise, the demand resulting from new applications of IoT, particularly as applied to facility safety, security, energy conservation, and other management necessities, is also becoming a challenge in many organizations. And given the evolution of IT towards the Cloud as the primary host for essentially *all* applications and communications services, including real-time collaboration, Wi-Fi networks everywhere are seeing increasing demands for *reliability, coverage,* and especially *aggregate capacity*.

These availability and capacity challenges introduce our next concern, *operations-staff productivity*. Given all of the features, variables, and possibilities inherent both in Wi-Fi 6 alone and in individual vendor product and system implementations – and, again, the need to support very large and growing user bases and essentially every IT application – network operations professionals are finding it more challenging than ever to provide the services essential to network and IT success today. A consequence of the do-more-with-less ethic that persists from before the Great Recession of 2008/2009 and the difficulty inherent in finding, recruiting, maintaining, and rewarding network operations professionals, organizations continue to deal with staffing-centric constraints including the staff education and training essential in planning, deploying, operating, and growing their networks. Even the simple requirement for sleep and other downtime is a fundamental limitation on network operations, especially as waking-hour staff productivity has often already been stretched to the limit.

This state of affairs motivates a deeper consideration of operating expense (OpEx) and return on investment (RoI), and, adding this to the aforementioned challenges, Farpoint Group believes that meaningful boosts to operations-staff productivity depend upon additional capital spending (CapEx) on new services and operational capabilities – including but again still beyond the benefits of Wi-Fi 6 alone – that enable operations teams to truly do more with less.

Getting the Most from Wi-Fi 6: *Beyond the Standard*

So, given all of the above requirements and constraints, what should network operations teams look for over and above the standard when deploying Wi-Fi 6? While we've seen some capabilities in Wi-Fi 5 systems that point the way here, Farpoint Group believes that further deployment of all of the following capabilities will in fact *define* success in both Wi-Fi 6 vendor offerings and organizational networks going forward (see Figure 1):

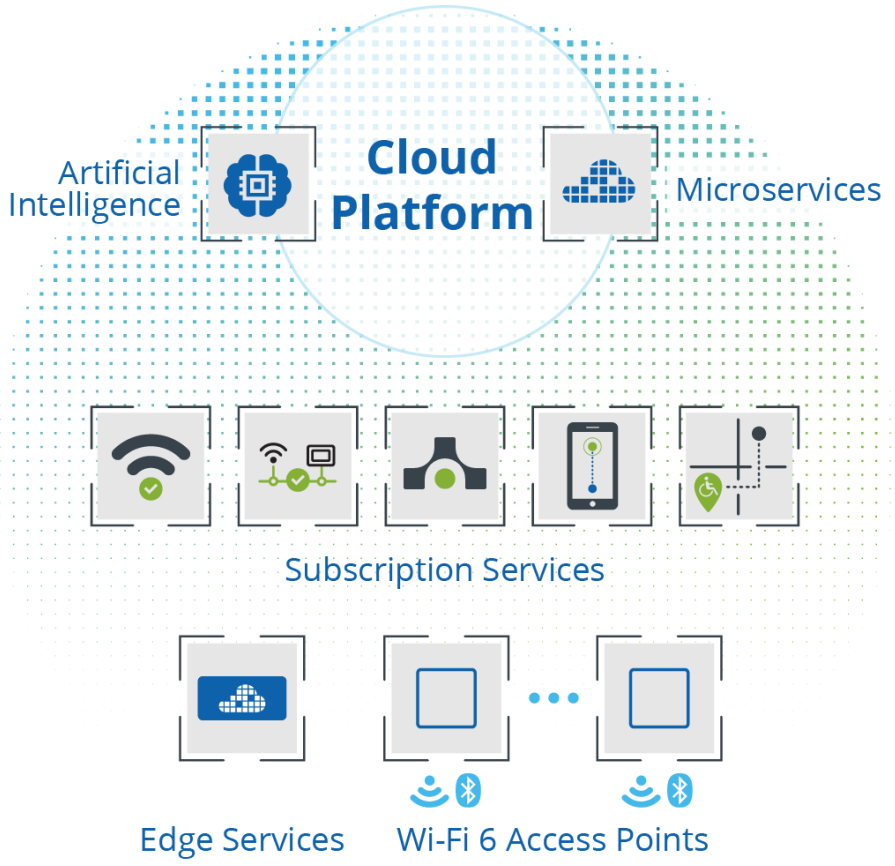

Figure 1 – Wi-Fi system vendors are employing a much greater range of function above the standard to enable their users to maximize ease-of-use, productivity, and flexibility – for end-users and operations teams alike. Note the emphasis in the example here on both Cloud-based services and applications of artificial intelligence (AI). *Source:* Mist, a Juniper Company.

- *Advanced management*– The network management systems (NMS) has, of course, been a key element in networking since well before the advent of wireless, but the need for operational visibility and control has become critical in wireless given the statistical behavior of radio signals. Included here should be policy definition, cloud-based implementations for easy scalability/reliability and reduced operating cost, simplified integration via APIs, and especially ease-of-use capabilities for operators. For more on this, see the Sidebar, Above the Standard: *A Few Examples.*

- *Artificial intelligence (AI)* – Because of the scope, scale, and large number of variables involved in Wi-Fi 6 implementations, it's now essentially impossible for mere-mortal humans to efficiently configure, monitor, and remediate (as required) these networks today. Fortunately, applications of AI are already hard at work doing exactly that (see Figure 2). We thus now view AI, including machine learning and, increasingly, the application of natural-language interfaces, as a core requirement in any Wi-Fi 6 deployment.

- *Analytics* – As we've discussed in previous publications, analytics is the set of tools and techniques applied when (colloquially speaking) one doesn't know what one is looking for. AI-based analytics can be incredibly powerful in finding both obscure anomalies and evolving patterns of network behavior that enable rapid problem identification and resolution.

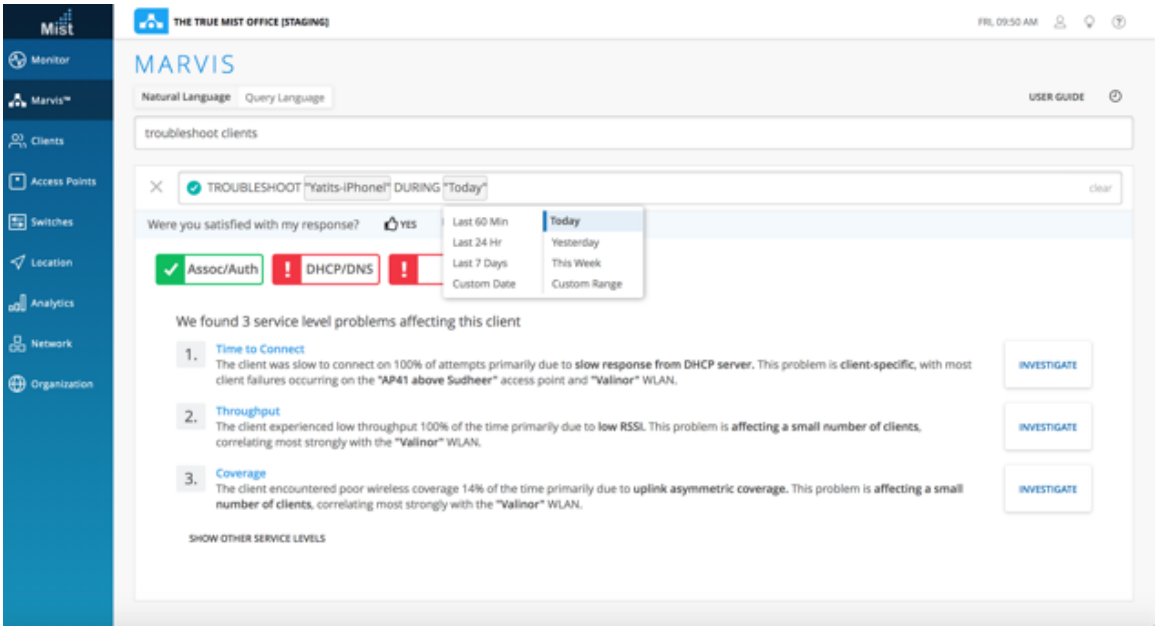

Figure 2 – Natural-language interfaces are increasingly becoming a key element in boosting operations-staff productivity. Tools such as these enable rapid resolution of a wide variety of problems, improving network performance and reliability. *Source:* Mist, a Juniper Company.

- *Automation* – Automating routine tasks is a great way to save time and improve reliability, but we expect capabilities within successful Wi-Fi 6 products to increasingly provide not just real-time reporting and closed-loop control, but also both corrective and *proactive* automated remediation as well.

- *Integral assurance* – Verifying that the network is operating at desired service levels as per policy and provisioning such vital capabilities as intrusion prevention and detection are the domain of Wi-Fi assurance solutions. While a case can still be made in some cases for separating this functionality, integrating assurance with operational management simplifies operations and reduces costs.

- *Wired-network integration* – Unified management with at least minimal visibility into the wired network is today essential in resolving problems that span across the wired and wireless domains, and we expect fully integrated and unified wired/wireless management to become the norm over the next decade.

- *Location and tracking* – And, finally, Farpoint Group recommends that this capability be included in all Wi-Fi 6 deployments for safety, security, environmental, IoT, and many other evolving applications. Both Wi-Fi and BLE-based solutions are widely available today, with excellent spatial and temporal resolution and a remarkable range of functionality.

We should also mention here that our long-standing advice on configuring and operating Wi-Fi networks – including dense deployments of APs where capacity demands so dictate, assuring cabling and power over Ethernet (PoE) requirements (802.3at, or even 802.3bt in some cases), generally applying narrower channel bandwidths (20-40, but sometimes 80 MHz.) for even greater parallelism in operations, the application of bandsteering, and upgrading switches to 802.3bz compliance (with 2.5GE or 5GE, and possibly 10 GE as warranted) – remains. And knowing that the really complex operational issues beyond these are being continually and automatically addressed is, again, the key to success and where the ultimate value of Wi-Fi 6 deployments resides. Note that the use of 80- and perhaps in some cases 160-MHz. channels *may* become more valuable as OFDMA and MU-MIMO become more common – but we also expect that AI-based solutions will be making the decisions here, not human operators.

Above Wi-Fi 6: *The Keys to Wi-Fi and Network Success*

Wi-Fi 6 is indeed the embodiment of the most valuable thinking in standards-based wireless-LAN technology to date. And make no mistake; we expect Wi-Fi 6 to eventually replace all previous generations of Wi-Fi, although this will take perhaps a decade especially in the case of those Wi-Fi 5 networks still being deployed today. Yes, the additional throughput and especially the improvement in capacity inherent in Wi-Fi 6 is tempting and perhaps even a justification for deployment all by itself in some cases, but Farpoint Group believes that *adding more throughput alone is ultimately a false economy*.

Above the Standard: *A Few Examples*

We're privileged to have the opportunity to participate in many vendor briefings each year, and the advent of Wi-Fi 6 has kept us rather busy. The genesis of this Farpoint Group White Paper was just such a briefing with Mist, a Juniper company, and a major player in organizational-class Wi-Fi solutions. This particular briefing was unusual in that Mist spent very little time discussing the clearly interesting and indeed *essential* technical innovations in the 802.11ax standard. Instead, they focused on the innovations enabled by but above the standard, which is clearly where our thinking has gone as well.

In our discussion with Sudheer Matta, VP of Products for Mist, we spent considerable time exploring Mist's robust feature set, the result of significant investment in features designed to enhance reliability and productivity while reducing operating expense. We started with AI.

"The concept of AI applied to Wi-Fi has really taken off," Sudheer noted. "What we and our customers are excited about is being able to continually obtain and apply operational data to solving problems that are otherwise insoluble, a capability absolutely not addressed in the standard." The key here was in architecting the Mist solution to both gather vast amounts of operational data and to leverage the scalability and cost-effectiveness of the Cloud in order to improve outcomes and operational results.

"We found through a detailed examination of support tickets that two fundamental problems – getting connected in the first place, and subsequent poor quality of experience in terms of throughput, service unavailability, and other problems like VLAN configuration – have dominated day-to-day operational challenges," Sudheer continued. "We then developed solutions that enable a high percentage of these problems to be addressed much more easily via AI." The key, Sudheer told us, is in using AI to look for patterns that might not be obvious to a human network operator, especially considering the vast amount of data involved. "Our Marvis natural-language interface makes it easy for even less-experienced operators to resolve issues quickly, thereby assuring optimal end-user productivity. Even if a problem isn't automatically resolved, operators will have a good head start."

So, where do we go from here? "Today we can automatically resolve issues in many cases. And we're heading towards a full self-driving, self-healing future, again the result of large-scale data gathering via monitoring and machine learning." This could be the ultimate solution to the network-operations-staff-productivity challenge.

Constant, continuous operational improvement. Quickly resolving more-variables-than-equations situations. Enhancing reliability. And maybe allowing operations teams a weekend off now and then. In short, *a future worth investing in* – enabled by Wi-Fi 6, but extending very far beyond.

Instead, we have reached a somewhat non-obvious and surprising conclusion in this Farpoint Group White Paper: even as Wi-Fi 6 meaningfully shifts our thinking away from an emphasis on throughput alone to capacity as the key metric, Wi-Fi 6 by itself is insufficient in addressing the core operational and cost challenges we have discussed in this document. Instead, the advent of Wi-Fi 6 and its deployment in both existing and greenfield settings have created a key opportunity for the WLAN system-vendor community to apply tools, techniques, and technologies well beyond the standard – capabilities that, as we have discussed above, we believe will indeed enable IT organizations everywhere to meet the capacity, reliability, and cost objectives required for network success in 2020 – and across the next decade.

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