Wi-Fi 6 Arrives:
The Future of the Organizational LAN

A Farpoint Group White Paper

Document FPG 2019-4104.1
April 2019

Farpoint Group

The arrival of wireless LAN (WLAN) products based on the IEEE 802.11ax standard – increasingly known by its Wi-Fi Alliance nomenclature, *Wi-Fi 6* – is yet another remarkable milestone for WLANs, a broad set of technologies that have re-defined the organizational LAN over the past 25 years. While raw throughput – increasingly today well above 1 Gbps – remains the primary metric for measuring advances in WLANs, this factor alone no longer addresses the core requirements for Wi-Fi today; more interesting and important metrics include availability, reliability and security, with the most important of these being *capacity*, the ability to handle the large, growing, diverse, and in many cases time-bounded traffic streams today essential to the productivity of a workforce that depends upon robust, continuous, and transparent connectivity.

Our primary objectives for this Farpoint Group White Paper are to discuss how Wi-Fi 6 will replace all previous generations of Wi-Fi over the next decade along with its key features, benefits, and technologies. We will also review the challenges facing adoption and provide our recommendations as to what network and IT managers should do now to get the most out this major advance.

And we will also examine the relationship between Wi-Fi 6 and 5G. While Wi-Fi today *defines* the edge of the organizational network and is the preferred access for all users and applications in most indoor and even many campus and public settings, the concurrent rise of 5G cellular does indeed raise some interesting questions of great importance to IT and network managers everywhere. There is, perhaps surprisingly, a more-cooperative-than-competitive relationship between Wi-Fi 6 and 5G, and we'll reveal our analysis on this point later in this document.

Building on Legacy, but Built for Today

Given massive and continually-increasing traffic volumes, Wi-Fi is clearly the dominant indoor organizational (and residential) connectivity option. It also has a strong presence in commercial (such as retail) settings and in many high-population-density outdoor locales as well. Behind this success is the ongoing ability of the IEEE 802.11 Working Groups (see "IEEE 802.11, the Wi-Fi Alliance, and Upcoming Milestones" below for more on 802.11) to take advantage of advances in wireless and semiconductor technologies to continually enhance standards, and for resulting products to continue to provision the levels of performance essential to staff productivity today and going forward (see Table 1). While the technologies at the heart of Wi-Fi 6 are sophisticated, the advances embodied in every generation of Wi-Fi have proven their value over decades of deployment across the planet. See "Wi-Fi 6: Key Technology Advances" below for more on the core technological innovations in this new standard.

Even as Wi-Fi 6 continues the long-standing tradition of each new WLAN standard improving single-stream throughput – for example, assuming a 40-MHz. channel, a single Wi-Fi 6 stream offers up to a 43.5% improvement in raw throughput (287 vs. 200 Mbps) over the immediately-preceding standard – the key motivation behind Wi-Fi 6

PHY Standard	Year	Throughput	Bands	Improvements Over Previous Generation
802.11 (Wi-Fi 1)	1997	1-2 Mbps	900, 2.4, IR	Initial standard
802.11b (Wi-Fi 2)	1999	11 Mbps	2.4	More than 5X improvement in raw throughput
802.11a	1999	54 Mbps	5	Initial use of 5 GHz. band; not commercially successful
802.11g (Wi-Fi 3)	2003	54 Mbps	2.4	5X improvement in throughput
802.11n (Wi-Fi 4)	2009	300-600 Mbps	2.4, 5	MIMO/OFDM, 40 MHz. channels, 6X+ improvement in throughput
802.11ac (Wi-Fi 5)	2013	433-1270 Mbps	5	80-MHz. channels
802.11ac (Wave 2)	2015	2167 Mbps	5	160 MHz-channels, more than 3 MIMO streams, multi-user MIMO
802.11ad	2012	7 Gbps	60	3+ Gbps effective throughput
802.11ax (Wi-Fi 6)	2019	10 Gbps	2.4, 5	10 Gbps, bi-directional MU-MIMO; likely Wave 2
802.11ay	2020	20+ Gbps	45+	Potentially 100+ Gbps

Table 1 – Major IEEE wireless-LAN standards. *Source:* Farpoint Group.

Wi-Fi 6: Key Technology Advances

Wi-Fi 6 continues Wi-Fi's long tradition of taking remarkably complex radio and semiconductor technologies and putting these to work in low-cost, compact, power-efficient, and reliable components suitable for a broad range of devices and applications. Wi-Fi 6 builds upon advances initially pioneered in 802.11n (Wi-Fi 4), and in this case MIMO and orthogonal frequency-division multiplexing (OFDM), and the additional spatial streams, multi-user MIMO (MU-MIMO), and beamforming from 802.11ac (Wi-Fi 5). Wi-Fi 6 is practically a quantum leap over its predecessors, however, with these key innovations:

- *Orthogonal Frequency-Division Multiple Access (OFDMA)* – This technique enables multiple users to each be assigned a portion of the total bandwidth available in a single transmission from an AP to client devices. As any given user is likely to require only a (potentially small) fraction of the throughput available in a given single transmission, OFDMA enhances efficiency and minimizes latency.

- *1024-QAM* – Quadrature-Amplitude Modulation (QAM) is a proven technique for the highly-efficient communication of information. With 1024-QAM, up to 10 bits of information can be sent during a given transmission, again enhancing efficiency and capacity.

- *Bi-Directional MU-MIMO* – This innovation enables an AP to receive transmissions from multiple clients simultaneously, complementing the downstream technique pioneered in Wi-Fi 5.

- *BSS Coloring* – This technique enables a given transmitter to determine if a nearby signal on the same channel is likely to be a source of interference or not, rather than assuming the affirmative in every case.

- *Target Wake Time* – Finally, this enhancement to already-present power-saving protocols should considerably enhance the battery life of mobile devices, always a welcome outcome.

A key emerging theme from the above, then, is *concurrency* – whereas Wi-Fi historically provisioned a serial connection between on a single transmitter and a single receiver on a given channel at a given moment in time, Wi-Fi 6 instead places the emphasis begun with Wi-Fi 5's MU-MIMO on *sharing* and parallel/simultaneous access instead. The net result is precisely the optimal use of available capacity essential to meeting today's – and tomorrow's – traffic demands.

shifts to improving the *quality of experience (QoE)* for all users sharing access within a given installation and doing so by minimizing overall latency. Improved spectral efficiency (more bits successfully transferred per unit of frequency, time, and, with MIMO, space) and the efficient and productive sharing of that spectrum, then, is today's key to optimal capacity. And, as can be seen in Figure 1, the benefits of Wi-Fi 6 are already clear.

Opportunities and Benefits

Achieving optimal capacity is particularly important when the nature of demand seen in Wi-Fi installations today is examined. First, we've got a growing base of users, each often equipped with multiple BYOD handsets, tablets, and notebooks. The highly-respected 2018 Cisco Visual Networking Index reveals that the number of mobile devices used in business is expected to reach 12.3 billion in 2022, a 12% compound annual growth rate (CAGR). Each of these devices is often running multiple simultaneous applications, with many, like voice telephony (for example, as part of a mobile unified communications facility) and streaming video, representing time-bounded traffic that by definition demands minimal network latency. Media capabilities are also a core driver of traffic volume – while streaming video might require as little as two Mbps, up to on the order of 40-80 Mbps for full-frame 4K traffic, any delay due to congestion, RF interference, or ineffective Wi-Fi deployments resulting from under-provisioning or configuration errors, will result in a poor QoE, and thus disappointed and less-than-optimally-productive users. And if *any* network isn't assuring end-user productivity, then it's clearly not delivering the value required.

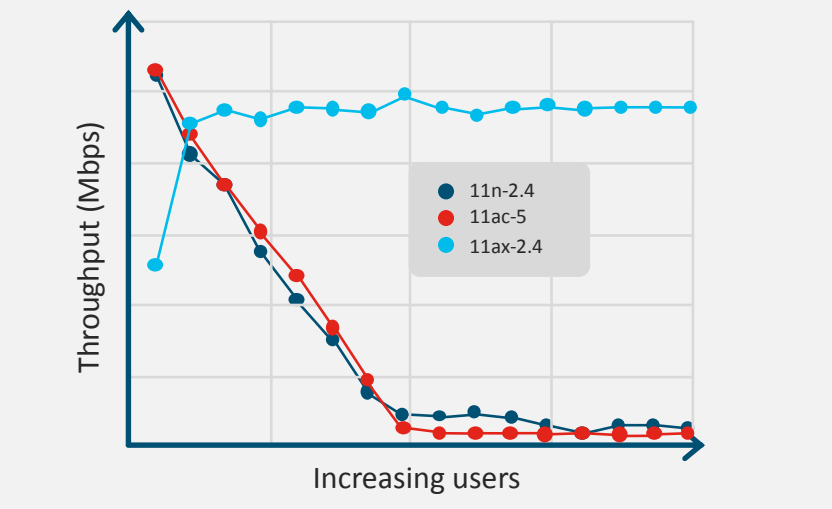

Figure 1 – The ability of Wi-Fi 6 to improve capacity is clearly revealed in this chart of test results. Unlike previous generations, per-user throughput is maintained even as traffic volumes grow. *Source:* Cisco Systems.

Now let's add in growing demand from an as-yet underappreciated source, the Internet of Things (IoT). Farpoint Group believes that Wi-Fi will become the most popular choice for wireless IoT connectivity because organizations can leverage the infrastructure already in place to provision such applications as environmental control, energy management, and physical security, including automated video surveillance. And while individual nodes in a given IoT applications might put only a light load on the network,

the aggregate demand from all such sources will often be considerable, and with some IoT applications very demanding indeed. Growth in IoT, along with ever-present patterns of increasing network traffic overall, is a key reason why Wi-Fi 6 will see accelerating adoption and achieve dominance in organizational networks over the next few years. Once again referencing the Cisco VNI, Wi-Fi-based IoT will be at the core of more than 50% of global connected devices by 2022.

And when we add in rapidly-emerging, high-traffic-demand applications like augmented and virtual reality (AR/VR), it's easy to see how simply meeting application demands alone will drive the adoption of W-Fi 6 at a very significant pace.

IEEE 802.11, the Wi-Fi Alliance, and Upcoming Milestones

Wi-Fi 6, based on the IEEE 802.11ax standard, is the result of years of work, with engineers from across the industry and in fact the globe exploring intricate but vital details and producing a standard that, in the long tradition of the Institute of Electrical and Electronics Engineers, is rigorous, fair, comprehensive, and essentially representing the force of law around the world.

But as rigorous, fair, and comprehensive as the 802.11 standards may be (no, they *are*), IEEE standards do not specify conformance, compliance or tests for interoperability. That work is left to Wi-Fi Alliance, the trade association responsible for all of these requirements, additional features as the market may require (like WPA authentication, for example), and the consideration of how best to match Wi-Fi technologies to applications.

As of this writing, the 802.11ax Working Group is essentially finished, with additional groups within the IEEE Standards Association now verifying, certifying, and finalizing their efforts. Wi-Fi Alliance has begun its work on interoperability, and we expect procedures from them in the second half of 2019. As has been common for all generations of Wi-Fi, deployments of production products are proceeding in advance of the availability of formal standards and specifications. This ordering of events shouldn't be a concern, since we expect, and as has always been the case, that any incompatibilities in implementations will be fixed in the field via firmware and/or software updates. Wi-Fi 6 APs are thus available now, and we expect a reasonable number of client devices so equipped by the end of 2019. We expect all newly-manufactured organization-class client devices to have Wi-Fi 6 capability by the end of 2021, and APs supporting advanced features like bi-directional MU-MIMO by early 2021 as well. So 2021 looks like the year when all new infrastructure deployments will utilize Wi-Fi 6 – and we expect these deployments, with additional APs as required, to carry most organizations to at least 2030, and perhaps beyond – and, of course, we expect almost all Wi-Fi 4 and 5 installation to be upgraded to Wi-Fi 6 by then as well.

One might think at this point that the technologies available within Wi-Fi are so advanced that it's getting close to the time where we might want to shut the patent office – but one would be wrong. Work continues on such diverse opportunities as advancing the precision of Wi-Fi-based location and tracking, even more effective battery power conservation, cellular-like authentication to simplify roaming, handoff between Wi-Fi and cellular services, IoT, vehicular applications, and many more. And just in case the tremendous capacity of Wi-Fi 6 needs a little boost down the road, there's yet another technology – *massive MIMO* – on the horizon to address precisely that, but such needn't be a concern in decisions that need to proceed now. It is, regardless, nice to know that Wi-Fi will be ready to serve our (yes, always-increasing) demands for capacity beyond any planning horizon of today.

Wi-Fi 6 and 5G

There has always been at least a subtle tension between the worlds of Wi-Fi and carrier-based cellular communications. At first glance, Wi-Fi is focused on indoor broadband services wherein the owner and/or operator of a given facility provisions the network. Cellular is offered by carriers and has historically utilized cells covering kilometers of radius between the cell and client, with a historical focus more on voice than data.

Today, however, we see broad overlap between Wi-Fi and cellular in terms of not just core technologies, but also mission as well. Both are broadband, and both offer support for all applications, from e-mail and Web access to time-bounded voice and video to IoT. And 5G, the latest but still-emerging incarnation of cellular, completes the decades-long evolution of cellular from landline-telephony augmentation to all-IP broadband connectivity and, thus, landline *replacement*.

It's perhaps unsurprising, then, that Wi-Fi 6 and 5G are so similar in specification, with both offering 1+ Gbps throughput, and in underlying technologies and overall system architecture. Wi-Fi pioneered the concept of *microcells* – access points separated by tens of meters, interconnected (and powered) by a wired LAN, and easily deployed. Cellular has historically focused on, as noted above, large and expensive cells with tall antenna towers, but 5G is going to be deployed at least in high-population-density areas more like Wi-Fi, using small, inexpensive microcells, with some of these even interconnected via a wireless mesh, a technique also pioneered and popularized by Wi-Fi.

The fundamental differences between Wi-Fi and 5G are thus reduced to two simple elements. 5G primarily uses *licensed* spectrum, purchased by and reserved to a given carrier, and Wi-Fi 6 will continue to use *unlicensed* spectrum, freely available to devices that meet the associated technical requirements. But whereas a given carrier in a given locale will typically have access to only a few tens to hundreds of megahertz of spectrum, Wi-Fi can take advantage of on the order to *two gigahertz* of spectrum (assuming a pending allocation from the FCC in the 6-GHz. band), with this spectrum managed and re-used over short distances, thus augmenting overall spectral efficiency – and providing clear motivation for the small-cell strategy in 5G.

The second is that cellular is offered by carriers to end-users for a fee; Wi-Fi is available for the cost of the equipment and any ongoing operational expense, which decreases with advances in management, analytics, assurance, and automation, as these enhance the productivity of operations staffs, and thus reduce operating expense. While unlicensed spectrum can't be reserved, building owners and operators do, in fact, often have a high degree of control over what services may be deployed in these bands within their walls. While 4G and 5G could be deployed in the unlicensed bands in facilities where Wi-Fi is already operational, we expect little actual mutual interference – and, instead, significant *cooperation* over time.

As we expect handsets manufactured in 2020 and beyond to support both 5G and Wi-Fi 6, the ability to hand off a connection between these two domains will become the most

popular approach to maximizing spectral efficiency. Such a strategy also reduces costs by minimizing or even eliminating the need for indoor 5G deployments, distributed antenna systems, and the time spent troubleshooting potential but unnecessary interference within the unlicensed bands.

Finally, Farpoint Group in fact defines Wi-Fi 6 as a 5G technology. No, it's not the same as the 5G NR technology expected to be at the heart of carrier offerings. But the technologies utilized and performance realized are so similar that – and here's the real value – *applications will not know the difference*. As "it's all about the apps" is not an unfair description of the most important requirement for networks today, we think the coexistence and interworking of 5G and Wi-Fi 6 will yield huge benefits and thus will be a key and mutual goal of Wi-Fi 6 vendors and the cellular industry alike.

Inhibitors and Concerns

Any generational transition of a vital IT facility deserves a complete examination beyond the obvious benefits. So, to be fair, a number of inhibitors and concerns must be addressed as part of any consideration of Wi-Fi 6. These include:

- *802.11ac is not fully-deployed or fully-depreciated* – Wi-Fi 6 can (and with early deployments, mostly will) operate backwards-compatible with Wi-Fi 5 (802.11ac) and even 4 (802.11n), and with improved performance likely in every case. We do not recommend mixed-generation operations on a given channel over the long term, but the clear convenience of this approach and improved generation-over-generation performance reduce any concerns here.

- *Deployment and assurance tools are not yet widely available* – These are, however, progressing rapidly; check with your vendor regarding their product roadmaps. Tools that enhance security, minimize interference, and maximize spectral efficiency will always remain important even with Wi-Fi 6, and with vendor-specific differentiation often constituting the key elements in any decision to deploy (see Figure 2).

- *Immaturity of vendor offerings* – This is always a valid concern during generational transitions, given the new chips, systems, firmware, drivers, software, and management and analytics involved. Again, this is a key discussion point for vendors, and BYOD procedures for integrating new devices should also be reviewed and updated as required. We expect that post-deployment field upgrades of firmware and software will address, as is always the case, any concerns that arise, so we believe that any risk here is low.

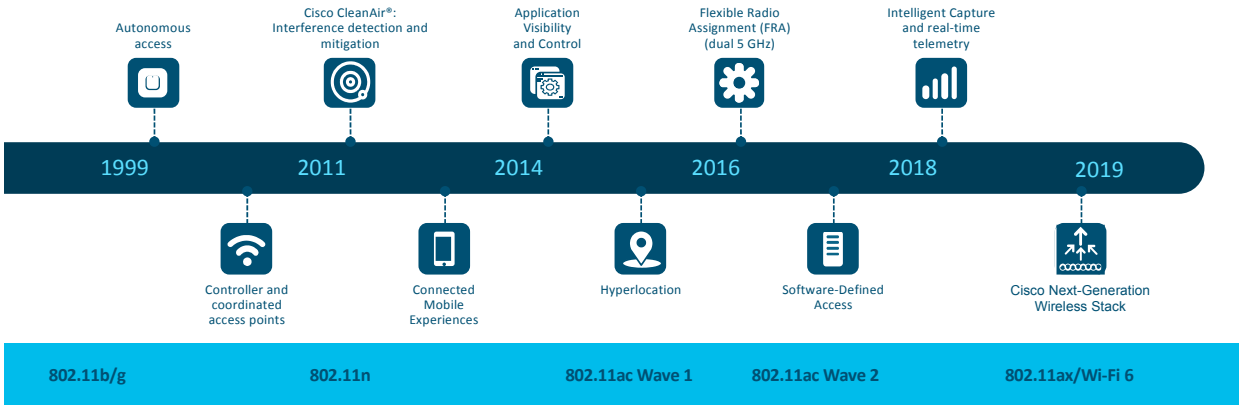

Figure 2 – Each new generation of Wi-Fi presents system vendors with opportunities to innovate beyond the standard, realizing significant benefits for customers and end-users alike. Cisco Systems has been a major proponent of this strategy, and Wi-Fi 6 brings a new focus on security, high availability, and other WLAN elements essential to organizations. *Source:* Cisco Systems.

- *Lack of client devices* – While we expect to see a few handsets and other mobile devices supporting Wi-Fi 6 during 2019, the floodgates will open in 2020, with tens of millions of Wi-Fi 6 devices in use by the end of that year. Yes, backwards compatibility will remain important, but growing network demand, as we noted above, will significantly motivate infrastructure-side support for Wi-Fi 6 within that timeframe.

- *No Wi-Fi Alliance interoperability specifications* – To be fair, the IEEE standard itself is not complete as of this writing either. But, as has generally been the case with earlier Wi-Fi specifications, we do not expect any changes requiring hardware modifications to be involved from this point forward.

- *Waiting for "Wave 2"* – As was the case with Wi-Fi 5, it is likely that all of the features and benefits possible with Wi-Fi 6 may not be present in products initially available, with some additional capabilities reserved by vendors for a "Wave 2" (an informal term) release. A decision to wait based on this element may also be dictated by budgetary constraints. It is important to point out, however, that waiting may also result in suboptimal network capabilities in the interim, and that the return on investment (ROI) obtained even from initial products may in fact more than justify the capital expense required.

What to Do Now

The bottom line? Simple, Wi-Fi 6 is here, and it's time to get started in gaining experience with the new technologies involved and products required. Our suggested plan is simple: first, contact your vendor and get up to speed on their offerings and availability. Next, examine traffic patterns, locations, and trends; this will assist in prioritizing and scheduling upgrades. We're not expecting major demand from new Wi-Fi-6-equipped clients for a couple of years, so there's a bit of breathing room in this

process. But as we also expect that, again based on historical evidence, that Wi-Fi 6 APs operated in Wi-Fi 5 and even Wi-Fi 4 mode will yield improved performance over their predecessors, so an immediate ROI can indeed be realized by proceeding with operational deployments in the near term. We also recommend that any WLAN technologies before Wi-Fi 4 be decommissioned as soon as possible for both security and performance reasons.

Cisco Systems and Wi-Fi 6

Cisco Systems has been a leader in every generation of Wi-Fi, and is today the largest supplier of Wi-Fi equipment in the world. So whenever we have the opportunity to speak with them, we're all ears – and the advent of Wi-Fi 6 is clearly an opportune time for an update.

"Cisco has expanded the Catalyst brand to include wireless, and our Next Generation Wireless Architecture includes Cisco's first Wi-Fi 6 Access Points, the Catalyst 9100 series, the Catalyst 9800 Series Controller, and new Meraki MR45 and MR55 APs as well," Greg Dorai, Vice President, Product Management, Enterprise Wireless at Cisco, told us in a recent briefing. "The mission-critical 9120 AP features real-time RF analytics, which, when combined with Cisco DNA Assurance [see below], allows network managers to gain the RF intelligence and visibility that simplify operations and dramatically increase efficiency and reliability."

Since Cisco's own VNI data shows explosive growth in IoT applications, we asked about Cisco's plans here. "The Cisco Catalyst 9100 access points also offer multi-lingual support and application hosting of IoT protocols such as Wi-Fi, BLE, and Zigbee," Greg Dorai added. That's a valuable strategic capability given today's IoT wireless diversity, and enables operations teams to match the best IoT product to the needs at hand. We also asked about the Catalyst 9800 Series Controller. "It's built from the ground up specifically for intent-based networking," Greg told us. "And the 9800 runs IOS-XE, which is common across Catalyst switches, and can be deployed anywhere including the Cloud, on-premise, or virtualized in a Catalyst switch."

We also wanted to know about the new Meraki APs as well. Jeevan Patil, Head of Product Marketing for the Meraki Portfolio at Cisco, told us that "the MR45 and MR55 have been designed with an open and extensible multi-lingual quad-radio architecture, and with a dedicated scanning radio for security, location, analytics as well. These APs offer high throughput, enterprise-grade security, simple management and offer big-data-driven WirelessHealth assurance. They are perfect for anyone deploying in wireless-first, cloud-optimized, data-driven situations like offices, schools, hospitals, shops, and hotels."

All of these new products are tied together via Cisco Digital Network Architecture (Cisco DNA), providing both automation and assurance. Two key elements of Cisco DNA directly benefit the new wireless products, Greg Dorai told us. "Cisco DNA Assurance provides RF intelligence and visibility across the network enabling IT to operate the network more efficiently while addressing wireless network challenges today and tomorrow. And Cisco Software Defined Access (SD-Access) provisions automated end-to-end segmentation to separate user, device and application traffic without having to redesign the network. SD-Access automates user access policy, so organizations can make sure the right policies are established for any user or device with any application across the network. SD-Access also addresses the growing number of IoT devices by securely segmenting the IoT traffic from the rest of an enterprise network."

What impressed us most about these announcements was how, even with advancing performance and features, there's a clear emphasis on both operations productivity and diverse application requirements, all the way to IoT. And, to be sure, we have here significant additional evidence of the value that organizations everywhere will soon realize with Wi-Fi 6.

But even if production deployments aren't on the current to-do list, we recommend that organizations begin obtaining experience with Wi-Fi-6 now. We suggest an internal "alpha" deployment test system, with formal testing conducted as clients become available this year, along with the evaluation of new management, assurance (IDS/IPS, spectral monitoring, and more), and analytics capabilities, along with end-user support requirements. This is also a great opportunity to examine current and required switch (edge *and* core) capacity and facilities, power over Ethernet (PoE) requirements, and wiring/cabling specifications as required. This work can proceed when required to a beta test capability in advance of volume deployments over the next few years. Regardless – consider the overall network *ecosystem*, and not just the wireless elements alone, as part of the transition to Wi-Fi 6.

And, finally, keep in mind that all products based on a given standard will not offer the same performance, feature sets, flexibility, and related characteristics, so carefully matching what's available to what's required is perhaps the key to overall success. As an example of where one leading vendor is placing the emphasis, see "Cisco Systems and Wi-Fi 6" below.

Conclusion: It's Time to Get Started

One might think, after over two decades of Wi-Fi and over three decades of WLANs, that we'd somehow be "done" when it comes to wireless LANs. But just as is the case with the rest of network and IT overall, "done" is and will remain an abstract, theoretical concept. Instead, Wi-Fi 6 is yet another in a long line of opportunities for *beneficial innovation*, *enhanced end-user and operations-staff productivity*, *lower costs and improved RoI*, and – *the real bottom line – overall organizational success*. Wi-Fi 6 is going to dominate the WLAN space over the next decade – and the time to take advantage of all that it has to offer is, in fact, *now*.

Ashland MA USA
508-881-6467
www.farpointgroup.com
info@farpointgroup.com

The information and analysis contained in this document are based upon publicly-available information sources believed to be correct as of the date of publication. Farpoint Group assumes no liability for any inaccuracies that may be present in these sources. Revisions to this document may be issued, without notice, from time to time.