Wi-Fi Innovation and Future Spectrum Allocation

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This whitepaper analyzes the current state of the consumer Wi-Fi market and its future demand trajectory to highlight the spectrum challenges the technology will face going forward. The research sheds light on the underappreciated importance of additional spectrum resources in meeting consumers' growing demand for devices and data, stimulating the rapid growth, innovation, and evolution of the digital economy, and strengthening American leadership in Wi-Fi technologies.

Wi-Fi has become a foundational technology in Americans' daily lives. In one leading example, Wi-Fi carries between 82% and 89% of all mobile data traffic. Wi-Fi also supports a rapidly increasing volume and diversity of connected devices, and manages traffic from a more densely-arrayed set of devices. While the Federal Communication Commission's (FCC) 2020 allocation of additional unlicensed bandwidth has provided some relief to consumer demand for Wi-Fi that historically has increased rapidly, the need for additional unlicensed spectrum to support future growth flows from a range of factors. These include the increasing amount of time consumers spend online, ongoing advances in Wi-Fi technology, continued improvements in the speed, capacity, and penetration of advanced broadband networks, growing consumer appetite for more devices and data-intensive uses in the home, and the expected emergence of new Artificial Intelligence (AI)-driven applications and services.

Understanding device growth and consumer usage trends better enables us to ascertain how spectrum requirements are changing and how new allocations of unlicensed spectrum will help the United States keep ahead of rapidly growing consumer demand. The report shows that Wi-Fi's spectrum needs are increasing significantly, and additional unlicensed spectrum allocation is vital to advancing innovation and maintaining U.S. leadership in Wi-Fi technologies.

Key Facts Driving Increased Consumer Demand for Services Supported by Wi-Fi:

- Annual 6 Gigahertz (GHz) enabled consumer devices shipping to North America will grow from 95 million in 2024 to an estimated 367 million in 2029—an increase of 288%.
- By the end of the decade, the majority of U.S. households will be served with Access Points (APs) supporting multi-gigabit Wi-Fi speeds and configured to use the latest 320 Megahertz-wide channels, with annual North American shipments increasing from 4 million in 2024 to 66 million by 2030.
- Wi-Fi needs multiple 320 Megahertz channels to support the growing number of devices and high-performance applications, particularly in dense networking environments.
- Demand for next-generation consumer applications requiring 320 Megahertz channels for delivering high throughputs and low latencies is set to grow exponentially over the coming years. For example, in North America, between 2024 and 2030, smart glasses shipments will expand at a 74.4% Compound Annual Growth Rate (CAGR) and Virtual Reality (VR) Head-Mounted Displays (HMDs) will see a 17.2% CAGR.
- Wi-Fi mesh networks that use spectrum more intensively at multiple APs to provide whole-home coverage represent the fastest growing category of APs, growing at an 11.9% CAGR between 2024 and 2029 with annual shipments of nearly 20 million.
- The embedded base of Wi-Fi devices that support sensing will reach nearly 115 million in North America by 2030, putting additional pressure on unlicensed spectrum that is being used for communications.
- Hybrid work and remote learning, which significantly rely on unlicensed spectrum, are now entrenched in the U.S. economy.

Key Policy Conclusions:

- To promote ongoing innovation and expansion of existing and new Wi-Fi-supported devices and applications, regulators should prioritize releasing additional unlicensed spectrum now to support the current trajectory of explosive device and data growth, and the rapid diffusion of, and innovation in, advanced Wi-Fi technology and devices. This best supports ongoing U.S. leadership in Wi-Fi.
- New unlicensed allocations allowing Wi-Fi to expand into the 7 GHz band offer consumers a unique, near-term opportunity to support solutions that are well suited to the needs of home networks, leveraging the existing 6 GHz band to create more contiguous, wide Wi-Fi channels to serve consumers' substantial data needs.
- This report reveals that Wi-Fi is the technology best positioned to extract the maximum value and deliver the greatest societal benefit from 7 GHz spectrum assets and will be key to ensuring that U.S. consumers realize the full benefits of the substantial wireline broadband investments being made in the United States to support the rapid and ubiquitous expansion of gigabit broadband infrastructure.
- In light of these findings, the authors of this report recommend that policymakers act proactively by allocating and releasing additional spectrum for Wi-Fi that will fully support the skyrocketing expansion of demand for existing and new uses of Wi-Fi.

INTRODUCTION

Wi-Fi, a wireless networking technology based on the IEEE 802.11 family of standards, is the only technology on the market capable of meeting the future home connectivity demands of American consumers. It is neither practical nor cost-effective to have physical Ethernet cables connecting the plethora of consumer devices in the home today, and traffic on cellular networks, a technology optimized for outdoor mobile applications, is typically offloaded onto Wi-Fi indoors, with 82% to 89% of mobile data usage in the home consumed over Wi-Fi. The ubiquity of Wi-Fi, combined with a lack of viable alternatives, means that Wi-Fi handles the vast majority of all residential Internet traffic, and in the 2010s, this traffic roughly doubled every 3 years in North America. The swelling burden this placed on the 2.4 GHz and 5 GHz bands led to a gradual degradation of quality of experience as congestion became a common occurrence, and the throughputs and latencies required for everyday consumer applications became harder and harder to achieve.

The additional capacity unlocked by the allocation of the unlicensed 6 GHz spectrum provided some respite, but this will not resolve the issue indefinitely. Going forward, a steady increase in the number of Wi-Fi devices in the home and the volume of data they consume, the continual increase in the time spent online by consumers, the shift to more data-intensive content such as collaborative video and social media, and the higher bandwidth and lower latency demands of new categories of devices and applications mean that it is all but certain that the 6 GHz band will ultimately also face unsustainable levels of congestion. Indeed, one study has forecast that, between 2024 and 2027, total Wi-Fi traffic in the United States is set to increase by 83%, from 26 Exabytes (EB) per month to 48 EB per month. Should spectrum capacity not keep pace with the increase in demand, U.S. leadership in the Wi-Fi ecosystem will be at stake.

High-quality reliable Wi-Fi is not simply a nice-to-have, it is integral to the functioning of the U.S. economy. Wi-Fi is the foundational technology underpinning everything from the delivery of streaming services and the enabling of online gaming, to the powering of remote work and distance learning. Considering the centrality of Wi-Fi to so much of modern life, it is perhaps not surprising that its value to the U.S. economy is substantial, with estimates placing it close to US$1.6 trillion in 2024, increasing to US$2.4 trillion in 2027. Given that Wi-Fi itself depends on unlicensed spectrum, depriving the technology of sufficient spectrum resources would indirectly put a choke hold on the U.S. economy.

This paper provides a comprehensive overview of unlicensed spectrum for Wi-Fi in the United States, answering the question as to whether Wi-Fi innovations and an expanding ecosystem will make it necessary to allocate further additional spectrum resources for the technology in the near future. We will begin in Section 3 with a look at the current and future pressures on unlicensed spectrum, exploring how the growing number of Wi-Fi devices, particularly those built to leverage the 6 GHz band, is set to result in congestion on this new band, too. We will then proceed to analyze the latest advancements in Wi-Fi technology—from the introduction of Wi-Fi 7, Wi-Fi mesh, and Integrated Sensing and Communications (ISAC)—explaining how the unlocking of additional spectrum resources is necessary in order for these innovations to realize their full potential. In Section 4, we will then investigate the broadband access revolution currently underway in the United States, and reveal that sufficient spectrum is pivotal to ensuring both strong Return on Investment (ROI) on fixed infrastructure investments and unlocking the performance enhancements that these infrastructure upgrades make possible. This will be followed by Section 5, which will outline the case for releasing unlicensed spectrum, and methods of spectrum reassignment and spectrum sharing. Finally, the whitepaper will conclude in Section 6 with a series of strategic recommendations for the industry, and a summary of the key findings of this paper. These findings determine that additional unlicensed spectrum allocation is vital toward stimulating further Wi-Fi innovation and maintaining U.S. leadership in Wi-Fi technologies.

GROWING DEMAND FOR UNLICENSED SPECTRUM

Historical Perspective

Wi-Fi leverages unlicensed spectrum for its communications. When the technology was first introduced back in the late 1990s, it was compatible with just the unlicensed 2.4 GHz and 5 GHz bands, which combined to offer approximately 570 Megahertz of available bandwidth (although portions of the 5 GHz band may become unavailable when government radar is operating). At that time, this amount of spectrum was adequate, as there were few Wi-Fi devices in consumer homes, and the early Wi-Fi standards required only narrow bandwidths for operation. Yet, over the ensuing years, the number of Wi-Fi devices steadily increased, with the global installed base of Wi-Fi-enabled devices increasing from just 280 million in 2005 to 1.9 billion in 2010, and then up to 10.5 billion in 2020. At the same time, the capabilities of Wi-Fi continued to advance to meet consumers' demands, and to keep pace with increasing wireline bandwidth and speeds. Indeed, within the space of just over 10 years, the maximum theoretical data rate of Wi-Fi technologies had leaped from Wi-Fi 4's 600 Megabits per Second (Mbps) (introduced in 2009), to Wi-Fi 5's 6.9 Gigabits per Second (Gbps) (introduced in 2013), to Wi-Fi 6's 9.6 Gbps (introduced in 2020). By way of comparison, today's Wi-Fi 7 has a maximum theoretical data rate of 46.4 Gbps. These higher throughputs demanded wider channels, and with the number of devices leveraging these broad channels steadily growing, pressure was mounting on the limited frequencies available for Wi-Fi technologies, resulting in congestion and degraded consumer experiences. Recognizing the growing spectrum deficit, in 2020, the FCC acted to allocate the 6 GHz spectrum for unlicensed use.

Opening up the 6 GHz band in the United States made available an additional 1200 Megahertz for Wi-Fi, more than double the amount accessible compared to just the 2.4 GHz and 5 GHz bands. There is a caveat though. Due to the presence of diverse incumbents, the U.S. rules for Wi-Fi in 6 GHz promote coexistence and are, therefore, different than those for the pre-existing bands, including restricting power levels to below those available at 5 GHz. Some other nations, such as Canada, have followed the FCC's lead in assigning the entire band for unlicensed, although many others, including some within the European Union (EU), have opted for an initial allocation of just the lower 500 Megahertz of the spectrum, while postponing a decision on the upper 700 Megahertz. As noted by many, including the Wi-Fi Alliance, this restrictive unlicensed access to the 6 GHz spectrum jeopardizes the achievement of Europe's gigabit connectivity goals by causing a bottleneck in the network. Other nations, including China, have not yet chosen to assign any of the 6 GHz spectrum for unlicensed, a decision that will deprive Wi-Fi of adequate spectrum resources. Favorable and forward-looking 6 GHz policies have helped the United States retain its leadership of the Wi-Fi industry and ensured that consumers have available sufficient bandwidth capacity to enjoy reliable, high quality of experience Wi-Fi.

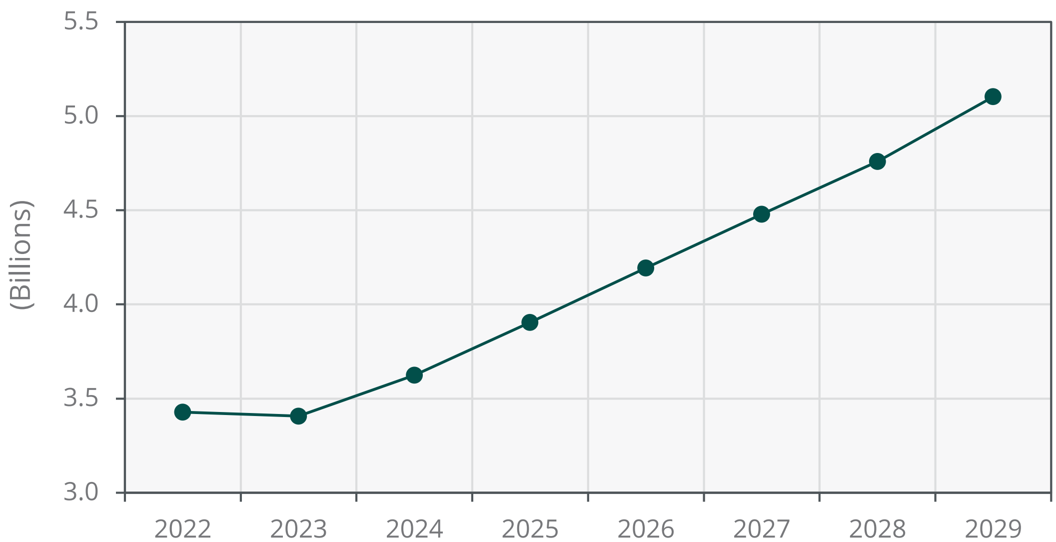
Given the significant growth of Wi-Fi devices and demand shown in this study, the 6 GHz spectrum band, like the 2.4 GHz and 5 GHz bands before it, is likely to also become congested in the near future, depriving Wi-Fi of the sufficient spectrum resources required to sustain further Wi-Fi innovation. Indeed, data and market analysis show a forthcoming significant increase in the volume and performance demands of consumer Wi-Fi devices. This volume and demand are being driven by the future advances in Wi-Fi technology, deeper penetration of Wi-Fi into consumer electronics, growth in broadband capacity, and the entrenchment of trends such as hybrid working, remote learning, and the emergence of ubiquitous AI-driven applications. We take a closer look at these dynamics in the following sub-sections.

Expanding Penetration Of Wi-Fi Devices

The steady increase of the global installed base of Wi-Fi-enabled home devices has continued unabated since the FCC opened the 6 GHz spectrum in 2020, climbing 11.8% between 2020 and 2023 to reach 11.7 billion. Going forward, the installed base is forecast to continue growing at a CAGR of 5.7% between 2024 and 2029, to reach 15.9 billion. This expanding installed base will be driven by a steady 7.1% rise in the CAGR of global annual shipments of Wi-Fi enabled devices, as illustrated in Chart 1.

Chart 1: Global Annual Shipments of Wi-Fi-Enabled Devices World Markets: 2022 to 2029

(Source: ABI Research)



A key factor behind this expansion in the number of Wi-Fi-connected devices is the penetration of Wi-Fi into all kinds of consumer electronics. For example, shipments to North America between 2023 and 2029 of Wi-Fi-connected countertop appliances is projected to expand at a 35.1% CAGR, washing machines at a 25.7% CAGR, refrigerators and freezers at a 23.4% CAGR, and residential smart lighting at a 20.9% CAGR. Wi-Fi integration into consumer devices is steadily increasing because it helps add value and increase the performance of the products by enabling new functionality and supporting wireless firmware updates. This large expansion of Wi-Fi devices is a sign of the growing diversity of Wi-Fi devices, with the technology now being used for everything from high-performance VR experiences to simple Internet of Things (IoT) applications.

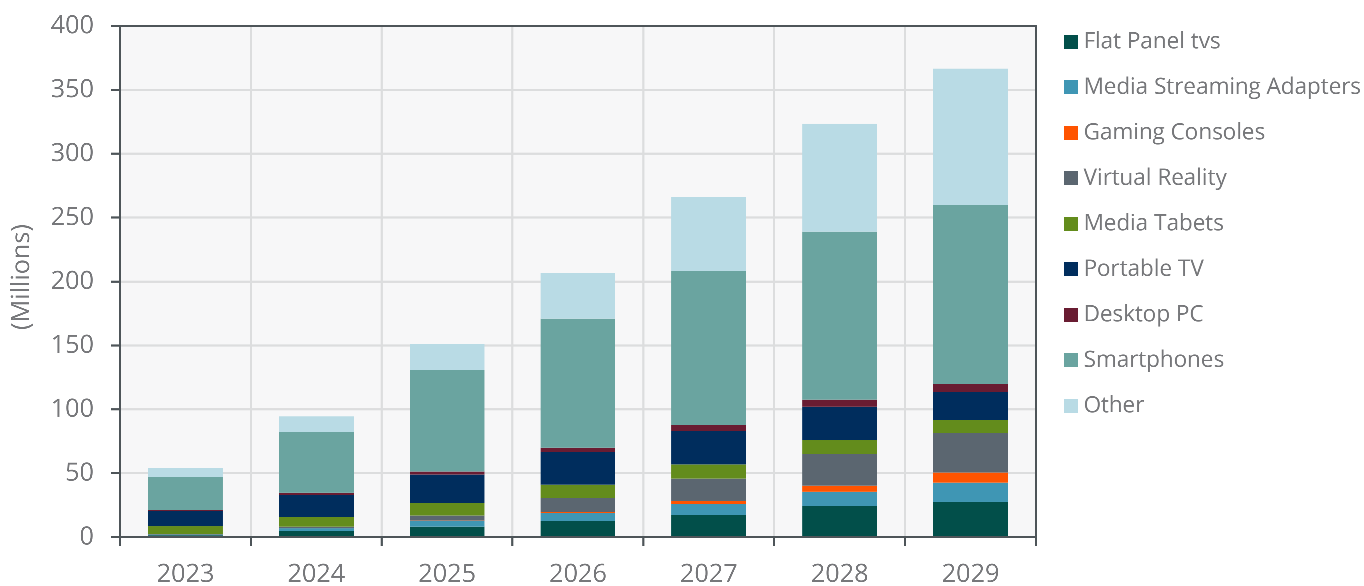
The growth in the number of Wi-Fi devices results in higher network density, which further exacerbates strain on spectrum resources as more devices contest the same finite spectrum. Surveys have pegged the average number of Wi-Fi devices per household at 17 in 2023, with forecasts for 2027 averaging 24 per household. Device density is particularly challenging for multi-tenant buildings such as apartment complexes, university dormitories, or assisted living facilities, which are home to just under 25% of the U.S. population according to the 2021 U.S. Census. This is because these home networks are dependent on the same spectrum as neighboring properties, increasing congestion and capacity challenges.

Mounting Pressures On Existing Spectrum

The allocation of the 6 GHz band for unlicensed use in 2020 was a much-needed action in the development of the U.S. Wi-Fi industry, providing the necessary boost to U.S. Wi-Fi innovation that helped the country become a world leader in innovations such as Wi-Fi 6E, standard power 6 GHz, and Wi-Fi 7 (more on these standards below). Yet, while the recently released 6 GHz band remains uncongested in the United States at this moment, as in the past with other unlicensed spectrum bands, it is expected to become more congested over the coming years as the number of devices using 6 GHz grows. This ever-growing burden that will be imposed on the 6 GHz spectrum is clearly illustrated in Chart 2 and Chart 3. Chart 2 displays the 37.6% CAGR between 2023 and 2029 in shipments to North America of 6 GHz-enabled chipsets for consumer devices. This includes items such as 6 GHz-enabled flat panel Televisions (TVs), which are projected to increase from 1.3 million in 2023 to 27.7 million in 2029, corresponding to a staggering 67.6% CAGR over the period. A rapid increase in 6 GHz-enabled media streamers is also forecast, with shipments jumping from 0.8 million to 15.0 million over the same period, the equivalent of a 62.1% CAGR. Going forward, with little other spectrum to turn to, the 6 GHz spectrum will become increasingly vital for enabling these devices to satisfy the heightened bandwidth demands of the next-generation consumer applications, and the sheer number of these devices will result in an immense load on available unlicensed spectrum.

Chart 2: Shipments of 6 GHz-Enabled Chipsets for Consumer Devices North America: 2023 to 2030

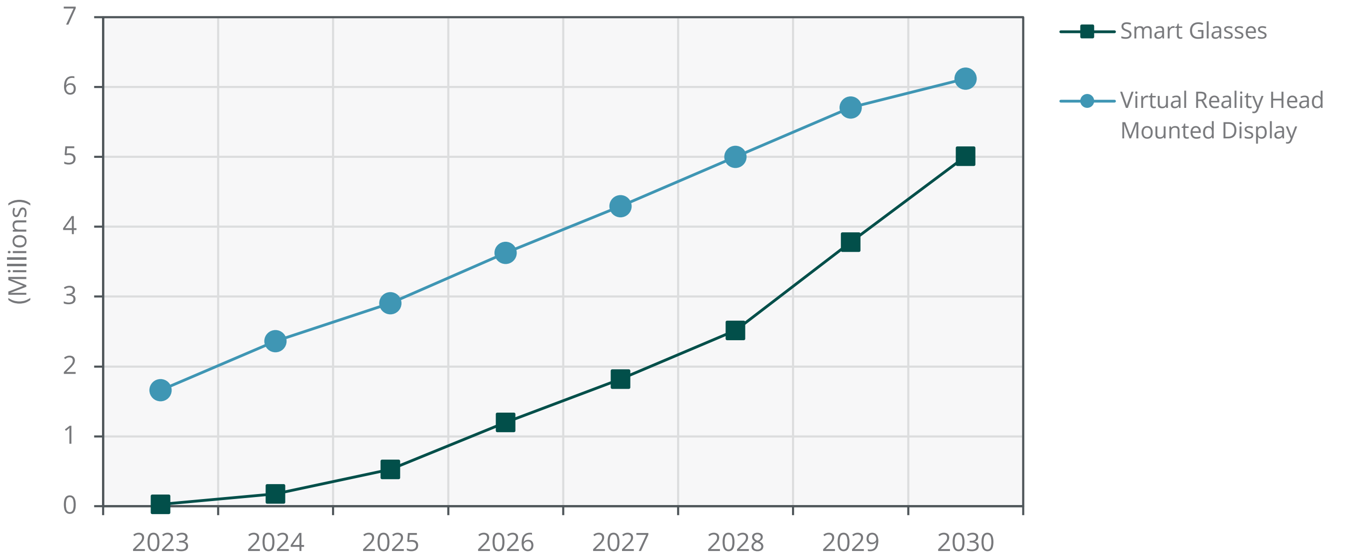
(Source: ABI Research)



The devices that will exert the heaviest strain on the new 6 GHz band will be emerging consumer devices like smart glasses VR HMDs, which, although not shipping in the same volume as the consumer devices above, will cause an outsized impact on home networks due to their high-performance demands. As Chart 3 highlights, within North America alone, shipments of smart glasses are projected to jump from a mere 0.03 million in 2023 to a gigantic 5.01 million in 2030, corresponding to a phenomenal 74.4% CAGR between 2024 and 2030. Shipments of VR HMDs are forecast to increase at a slightly slower, but no less impressive, 17.2% CAGR over the same period, jumping from 1.66 million in 2023 to 6.12 million in 2030.

Chart 3: High-Performance Consumer Device Shipments North America: 2023 to 2030

(Source: ABI Research)



Bandwidth capacity in the home must also evolve to support the emergence of ubiquitous AI, which will be leveraged for tasks ranging from the smart home to home robotics. While on-device Edge AI can be leveraged for simple tasks locally, such as for productivity-augmenting applications on home PCs, many devices will continue to rely on cloud-based AI for demanding applications, as this offers higher processing power and larger storage, as well as greater scalability and centralized management and resource allocation. As AI applications continue to mature, sufficient spectrum will become essential for facilitating the high throughputs and low latencies that cloud processing demands. An example might be the combination of AI and the rise of sensor networks that are expected to substantially advance society's ability to rely on home healthcare. Unlicensed spectrum should, therefore, be considered a key component of the U.S. strategy toward AI, with the resource factored in as a means to support the nation's leadership in the industry, and by extension, as a tool to secure the Unites States' pivotal role in global AI governance.

Necessity Of Wider Channels

The fast throughputs and ultra-low latencies that the next wave of consumer devices enable, especially high-performance devices like smart glasses and VR HMDs, will only be achievable with the use of 320 Megahertz channels. These enlarged channel widths, introduced in 2024 with Wi-Fi 7, are twice the previous maximum possible with Wi-Fi 6. Leveraging wider channels will both provide the capacity necessary to realize the promised performance of the latest Wi-Fi technologies and to extend the benefits of capacity gains in wired infrastructure all the way down to the device. Table 1 lists the number of channels of different widths that each spectrum band can support, revealing that three contiguous 320 Megahertz channels are possible with the existing unlicensed spectrum, all in the 6 GHz band. Yet, this is a theoretical number likely only to be attained in pristine environments. In real word scenarios involving unlicensed spectrum, where myriad other devices will also be vying to leverage the 6 GHz spectrum, sourcing 3 blocks of 320 Megahertz without contention from other devices operating with smaller channels will be highly challenging.

Table 1: Theoretical Number of Available Channels on Each Unlicensed Spectrum Band

(Source: ABI Research)

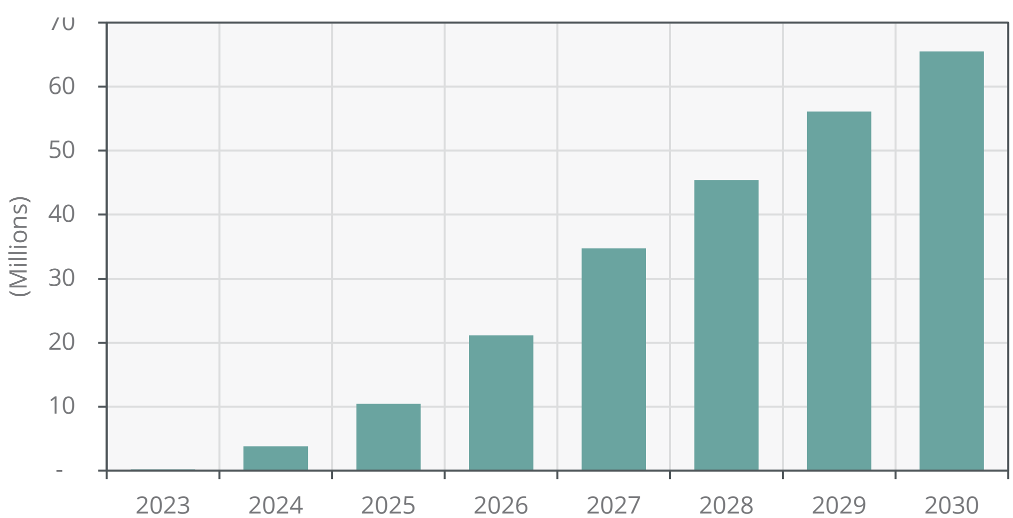
Spectrum Band	20 Megahertz	40 Megahertz	80 Megahertz	160 Megahertz	320 Megahertz
2.4 GHz	11	2	N/A	N/A	N/A
5 GHz	37	18	9	4	N/A
6 GHz	59	29	14	7	3

This inability to secure multiple 320 Megahertz channels is set to pose a challenge to high-performance consumer applications going forward, particularly for VR HMDs and cloud gaming. This is because, in typical home environments, a single 320 Megahertz channel would be unable to deliver the end-to-end reliable latency that VR applications require. Research has shown that three non-overlapping 320 Megahertz channels are necessary for VR applications to support increased demand and keep performance at acceptable levels. As devices pour into the band, usage increases, and devices and applications contend for available spectrum, three 320 Megahertz channels is not sufficient. Given this, extending unlicensed spectrum access into the 7 GHz band is a uniquely smart choice for regulators to consider, as these frequencies are adjacent to the existing 6 GHz band, face similar co-existence constraints from incumbent users, and could, in part, be accessed with existing Wi-Fi chips through software upgrades—all allowing for the access of more contiguous 320 Megahertz channels.

Alongside the expansion of 320 Megahertz-enabled consumer devices will be the commensurate increase in residential Wi-Fi Consumer Premises Equipment (CPE) supporting 320 Megahertz channels in North America, as large numbers are deployed by wireline and wireless Internet Service Providers (ISPs) in order to meet consumer demand. Chart 4 displays the forecast rapid shipment increase of these advanced CPE, at a CAGR of 60.9% between 2024 and 2030. By the end of the decade, the majority of U.S. broadband subscribers will be served with 320 Megahertz-compatible Wi-Fi CPE, and the demand for 320 Megahertz channels will expand swiftly. If sufficient 320 Megahertz channels are not available due to a lack of available spectrum, then quality of experience will be impaired. This is especially true of multi-tenant buildings, in which more 320 Megahertz channels will be necessary to ensure that there are enough for all users.

Chart 4: Shipments of Residential Wi-Fi Access Points Supporting 320 Megahertz Channels North America: 2023 to 2030

(Source: ABI Research)



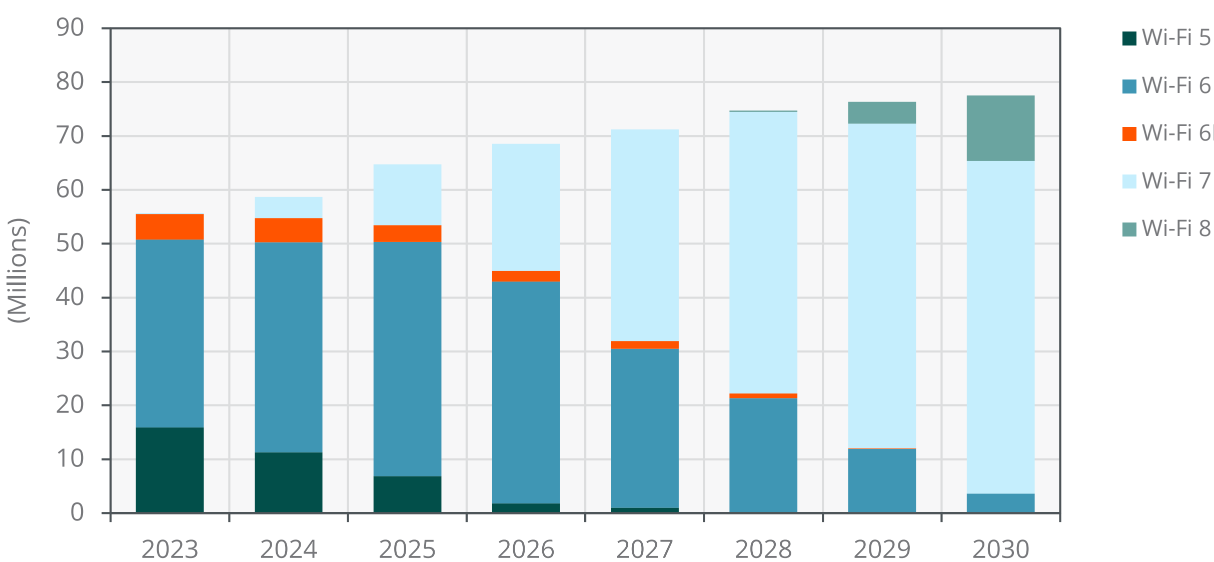
Advancing Wi-Fi Standards

The latest Wi-Fi standard, Wi-Fi 7, was officially introduced by the Wi-Fi Alliance in January 2024. As Wi-Fi 7's assigned IEEE working name "Extremely High Throughput" suggests, the standard was developed with a focus on delivering enhanced speeds, enlarged capacity, and improved reliability that the future of the connected home requires. The theoretical maximum throughput of Wi-Fi 7 is 46.4 Gbps, over 4X that of the previous generation Wi-Fi 6's 9.6 Gbps peak data rate. The new standard achieves this through a combination of novel features such as 320 Megahertz channel widths, Multi-Link Operation (MLO), 4K Quadrature Amplitude Modulation (QAM), and Multi Resource Unit (Multi-RU) puncturing. Furthermore, Wi-Fi 7's doubling of the maximum number of spatial streams (loosely, radio links between an AP and devices in its network) from 8 to 16 also facilitates an increase in device density, as it increases the number of devices that can be simultaneously connected to a single Wi-Fi AP. Wi-Fi 7's improved capabilities are necessary to handle more challenging consumer applications, including high-resolution streaming, low-latency gaming, and larger file downloads, as well as more complex networking challenges when heterogenous use cases compete for spectrum.

As visualized in Chart 5, the North American market is projected to rapidly migrate away from the legacy Wi-Fi 6 standard toward Wi-Fi 7, with consumer demand for the improved performance offered by Wi-Fi 7 underpinning a 58.6% CAGR of Wi-Fi 7 CPE shipments to North America between 2024 and 2030. Yet, Wi-Fi innovation will not stop with Wi-Fi 7, as the next standard, Wi-Fi 8, is already under development and on track for an official release by the Wi-Fi Alliance in 2028. Wi-Fi 8 has the IEEE working name of "Ultra High Reliability (URH)." Wi-Fi 8's focus on UHR is crucial for supporting devices and applications that rely on consistent and dependable radio links with extremely low latency. Wider and clearer channels, as opposed to channels that are experiencing spectrum contention, will be required. As for Wi-Fi 7, optimizing Wi-Fi 8 technology depends on having sufficient spectrum availability to enable the technology to perform at its best. As we are seeing with Wi-Fi 7, Wi-Fi 8 adoption is likewise projected to be rapid in North America, with more than 12.1 million projected Wi-Fi 8 CPE shipments in 2030. By 2030, virtually every Wi-Fi CPE shipped to the United States, with the exception of basic entry-level models targeted at cost-sensitive demographics, will support either Wi-Fi 7 or Wi-Fi 8.

Chart 5: Shipments of Wi-Fi CPE by Wi-Fi Protocol North America: 2023 to 2030

(Source: ABI Research)



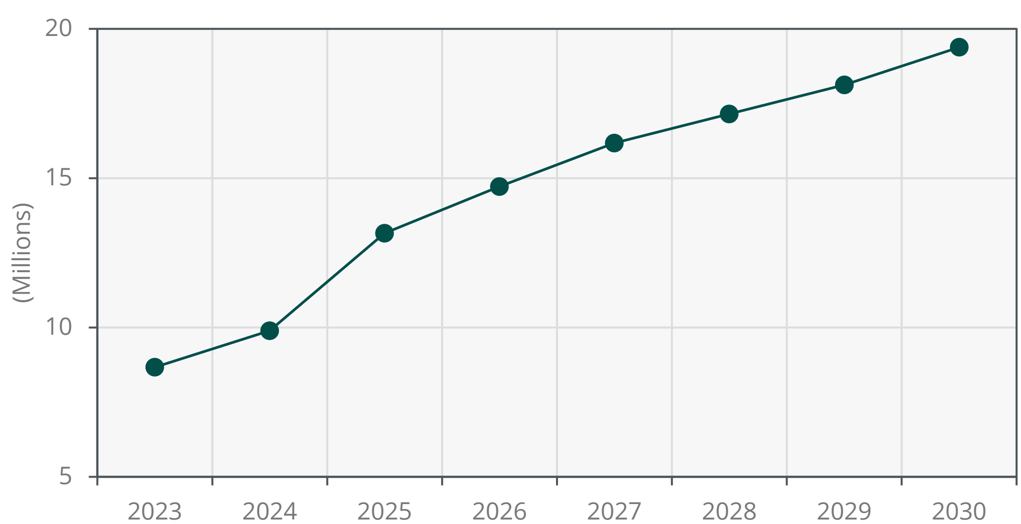
In summary, the realization of the advanced capabilities possible with Wi-Fi 7 and Wi-Fi 8 is contingent on there being sufficient spectrum availability, and although with the release of 6 GHz this spectrum deficit is thankfully not an issue in the United States today, the forecast rapid increase in the volume and capacity demands of Wi-Fi devices will begin the march from spectrum contention to spectrum congestion. While Wi-Fi networks are technically capable of supporting an array of device and application innovations made possible by the functionality of Wi-Fi 7 and Wi-Fi 8, whether those innovations occur is contingent on how well Wi-Fi 7 and 8 networks operate. Innovation depends on ensuring that there is a spectrum path that supports quality of experience over the long term. An outcome where Wi-Fi innovation in the United States stalls leads directly to putting U.S. leadership in Wi-Fi technologies at risk.

Mesh Networking

Another Wi-Fi innovation with major implications for spectrum usage is the spread of Wi-Fi "mesh" networks. These consist of a core hub and a number of hubs dispersed throughout a home, business, or other communal space that are all part of one interconnected, uninterrupted mesh network. This mesh topology helps extend Wi-Fi coverage further beyond the core hub, resolve blind spots, and ensure seamless and consistent connectivity performance throughout the home. The number of North American consumers turning to mesh networks to address their Wi-Fi coverage challenges is constantly growing, and as Chart 6 shows, there will be more than twice as many mesh nodes shipped in North America in 2030 as there were in 2023. This makes Wi-Fi mesh networking the fastest growing Wi-Fi product type in North America, with shipments forecast to increase at a 11.9% CAGR between 2024 and 2030. Mesh nodes typically communicate between each other and the main hub through a backhaul link, most commonly on the 5 GHz spectrum, although increasingly on 6 GHz, too. A Wi-Fi mesh network's use of unlicensed spectrum for backhaul further adds to the strain on the finite spectrum resources available for home Wi-Fi networks. Without adequate spectrum, mesh networking may not have the requisite uncongested spectrum available for backhaul, restricting consumers' ability to enjoy consistent performance throughout the home. This makes mesh adoption another major factor driving the need for additional spectrum resources.

Chart 6: Shipments of Wi-Fi Mesh CPE North America: 2023 to 2030

(Source: ABI Research)

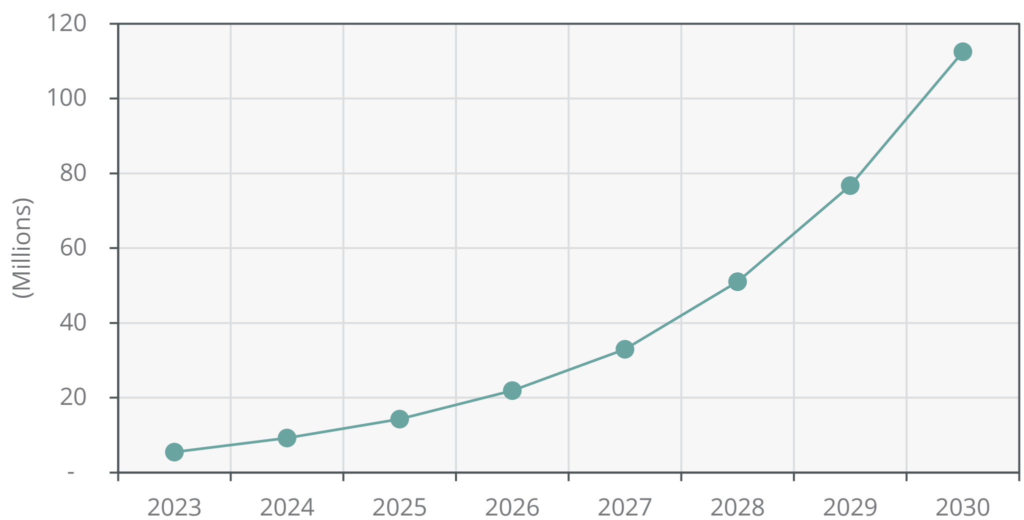


Wi-Fi Sensing

Wi-Fi Sensing is a nascent positioning solution that measures variations in the attenuation of Wi-Fi Radio Frequency (RF) waves to detect presence and motion. This technology is both low-cost and simple to implement because it is designed to harness the pre-existing Wi-Fi infrastructure already deployed in consumer homes and the same unlicensed (and therefore, free of charge) spectrum relied upon for Wi-Fi communications. Confident in the potential of the technology, all major Wi-Fi chipset vendors have committed to supporting Wi-Fi Sensing in their Wi-Fi networking chipsets, and several service providers have already begun commercializing the technology in the United States for remote healthcare, security, and smart home automation tasks. The number and diversity of sensing applications is expected to increase rapidly following the final approval of the 802.11bf Wi-Fi Sensing standard, currently scheduled for June 2025, and the emergence of new Wi-Fi Sensing-based value-added services will lead to an exponential surge in the Wi-Fi Sensing-enabled CPE installed base in North America, as Chart 7 illustrates.

Chart 7: Installed Base of Wi-Fi Sensing-Compatible CPE in the United States North America: 2023 to 2030

(Source: ABI Research)



Wi-Fi Sensing is an Integrated Sensing and Communication technology, meaning that the same infrastructure and spectrum are leveraged for both tasks. While this can help increase the potential value that can be derived from these assets, it also results in both communication and sensing competing for the same spectrum resources, raising the prospect of congestion and impaired performance of both mediums, unless sufficient spectrum for unlicensed operations is made available. Moreover, 320 Megahertz channels are required for enabling high-fidelity sensing tasks, such as people identification or gesture recognition. Therefore, if Wi-Fi Sensing is to realize its potential and maximize its serviceable market, additional unlicensed spectrum may be required to ensure that communications and sensing can operate simultaneously. It should be noted that the existing range of unlicensed spectrum was allocated based on considerations for communications only, so national regulators need to consider releasing additional spectrum capacity to account for the new requirements of Wi-Fi Sensing.

Societal Trends

Available evidence continues to point toward consumers increasing their use of digital technologies for a range of activities that predominantly occur at home, utilizing Wi-Fi. Every year the average daily video watch time on social media platforms, which is largely attributable to the four dominant platforms of YouTube, TikTok, Instagram, and Facebook, grows substantially, and streaming has now become the most watched TV medium, surpassing cable with a record 40.3% of total TV usage time in June 2024. A greater share of the economy is also shifting online as consumers become more accustomed to spending online, for everything from Internet shopping to in-game purchases. Continuing its steady increase, the total amount spent for online activities hit a record US$1.3 trillion in 2023. It should be noted that the United States is not alone in this, and similar trends exist in other developed economies, with streaming video and social media use continuing to lead. Reflecting this, one recent study has forecast that the data consumed by fixed broadband traffic in Europe will increase from its 2022 level of 225 Gigabytes (GB)/month to 900 GB/month in 2030, representing an annual growth rate of 20%.

While the greater reliance on Wi-Fi is driven, in part, by next-generation entertainment experiences, such as 4k/8k streaming, VR HMDs, and smartphones streaming 4k, this is not the full story. There are several other societal trends that are elevating the centrality of Wi-Fi to everyday life. Notably, since 2020, we have seen an entrenchment of hybrid working arrangements, with the percentage of paid full days worked from home in the United States increasing from around 7% pre-COVID-19 to roughly 28% in September 2024, a rate that has remained fairly consistent since mid-2022. Another significant change has been the expansion of remote learning, as the percentage of undergraduate students enrolled in at least one distance education courses increased from 36% in 2019 to 61% in 2021. Both hybrid work and remote learning harness high-throughput, low-latency applications for collaborative work platforms such as telepresence and video streaming. Importantly, unlike many entertainment-based applications, these can be considered mission-critical, so interference and downtime cannot be tolerated. Adequate spectrum resources are central to preventing any disruption.

One durable trend is the amount of time spent on Wi-Fi, and the amount of data that Wi-Fi networks carry. According to a recent report from OpenSignal, when U.S. subscribers to the major cellular providers are using their smartphones, between 89% and 96% of their on-screen time is, in fact, on Wi-Fi when at home—and 77% to 88% when away from home. The extraordinarily high percentage of time the devices are communicating via Wi-Fi is a reflection of the ubiquity of Wi-Fi at home, at work, and in public places (shopping centers, transportation hubs, arenas, and more).

Not only are smartphone devices using Wi-Fi most of the time, but also most of the data sent or received happens over Wi-Fi networks. Between 82% and 89% of smartphone data consumed at home uses a Wi-Fi network, not a cellular one. The overweighting of Wi-Fi of data consumed is nothing new, but the OpenSignal report offers fresh evidence of this continuing trend. The same study also reported how smartphones consume data when the user is away from home. When the consumer leaves home, that same smartphone continues its reliance on Wi-Fi—between 74% and 84% of data consumed on smartphones when away from home uses Wi-Fi. This is further evidence of the widespread availability of Wi-Fi in public places and work locations, and consumers' reliance on it.

NEXT-GENERATION ACCESS TECHNOLOGIES

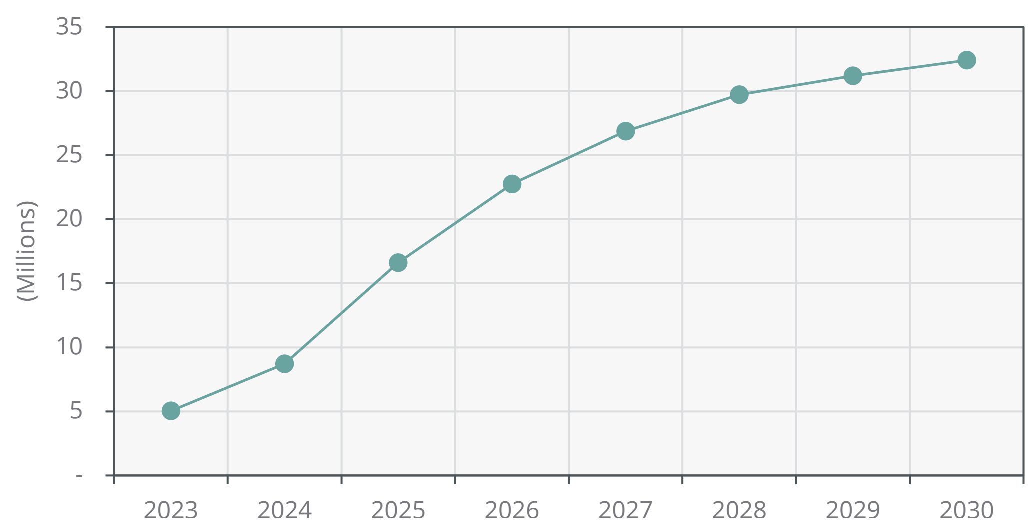
Rollout of DOCSIS 4.0 and Fiber Optic

Wireline broadband access in the United States is also in the midst of a revolution. Cable broadband, the predominant access technology in the United States (representing over 68% of fixed-access broadband subscribers) is seeing a wholesale upgrade as ISPs begin converting their networks to Data Over Cable Service Interface Specification (DOCSIS) 4.0. DOCSIS 4.0, the latest standard supporting broadband over cable's Hybrid Fiber Coax (HFC) networks, which can deliver symmetrical multi-gigabit speeds, while supporting high reliability, high security, and low latency. The story does not end with DOCSIS 4.0 though, as work has already begun on the follow-up standard DOCSIS 5.0. Fiber optic is also seeing rapid rollouts by a wide range of ISPs, with the US$42.45 billion Broadband Equity, Access, and Development (BEAD) program spurring fiber deployment in unserved or underserved locations. Gigabit Passive Optical Network (GPON) is the predominant fiber technology today, but shipments of the more advanced Gigabit Symmetric Passive Optical Network (XGS-PON) are anticipated to supersede those of GPON in the coming years, with sizable shipments of the ultra-fast 25G Passive Optical Network (PON) and 50G PON arriving at the tail end of the decade.

The transition to next-generation access technologies in the United States is illustrated by Chart 8, which tracks the shipment growth for DOCSIS 4.0, XGS-PON, 25G-PON, and 50G-PON CPE. The penetration of this CPE into American homes will deliver significant boosts to the wireline broadband access speeds in U.S. homes. These advanced speeds will be necessary to underpin the performance of a range of high-performance emerging applications and provide the breadth of capacity to handle the ever-growing number of Wi-Fi devices in the home. Yet, because future connectivity needs will extend all the way to the consumer device and not just to the modem or gateway, it is imperative that the Wi-Fi performance of residential CPE keeps pace with the advances in broadband access technology, or else Wi-Fi will become the network bottleneck, limiting the economic returns that consumers should reap from these significant wireline broadband infrastructure investments. While migration to more advanced Wi-Fi protocols is a central component to this, the availability of sufficient spectrum to support the multiplicity of Wi-Fi applications and use cases is equally as important, particularly because wider channels are necessary to unleash the faster throughputs and lower latencies that advanced access technologies make possible. Thus, without adequate spectrum resources, capacity will be strained, potentially resulting in serious impairment of Wi-Fi performance, hindering future Wi-Fi innovation and limiting economic returns for consumers.

Chart 8: Shipments of Modems and Gateways Supporting Next-Generation Access Technologies North America: 2023 to 2030

(Source: ABI Research)



SPECTRUM REGULATION AND CHALLENGES

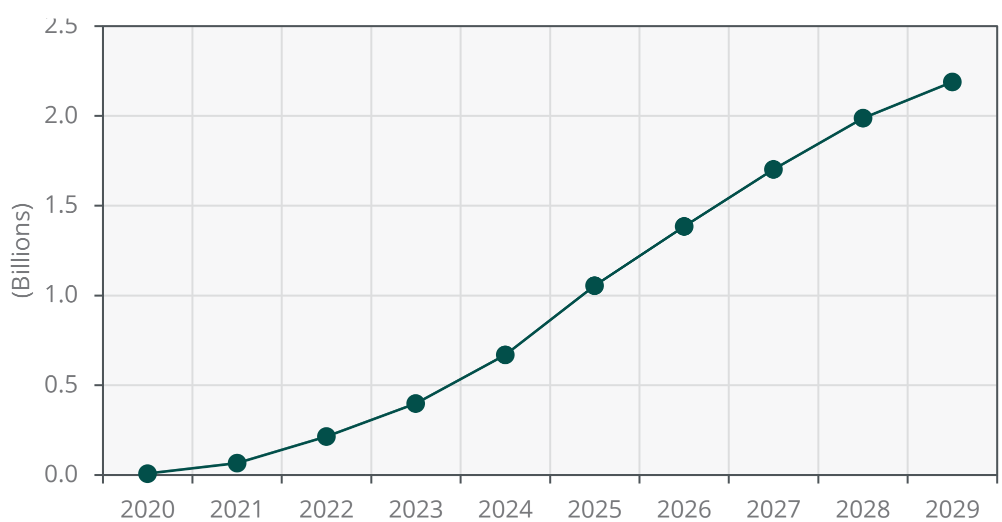
The Case For Unlicensed Spectrum

Spectrum forms the invisible foundation of Wi-Fi networking. Just as abundant unlicensed spectrum can unleash the true potential of Wi-Fi, insufficient spectrum has the potential to handicap the technology, resulting not just in negatively impacted consumer experiences, but also a drag on the economy due to inefficient communications and impaired productivity. Acutely aware that the 6 GHz spectrum will one day also face the same congestion challenges that afflicted other Wi-Fi bands, the industry and policy makers are beginning to explore additional spectrum frequencies that may be suitable for unlicensed allocation. One such band is the 7 GHz band. As previously discussed, the 7 GHz band is uniquely suited to support the expansion of Wi-Fi technology's future capabilities and its status as a band that could support future commercial wireless use in the near future is currently under review by the FCC and other agencies. Wi-Fi's need for additional spectrum to match demand and the evolution of technology, as the above sections have outlined, helps make a strong case for assigning the band for the technology.

Wi-Fi is well positioned to swiftly generate additional value from new spectrum resources. This is demonstrated by the comprehensive 6 GHz device ecosystem that developed rapidly following the allocation of the band for unlicensed operation, with 668.4 million 6 GHz-enabled Wi-Fi chipsets forecast to ship this year, a greater than 10X expansion from 66.1 million in 2021. As Chart 9 illustrates, 6 GHz-enabled Wi-Fi chipset shipments are projected to continue growing Year-over-Year (YoY) throughout the decade, increasing at a CAGR of 32.8% between 2023 and 2029 to reach over 2.2 billion in 2029. This rapid shipment growth of 6 GHz-enabled Wi-Fi chipsets is considerably faster than the 7.4% CAGR expected for Wi-Fi chipsets in general. The breakneck buildout of the 6 GHz Wi-Fi ecosystem also contrasts starkly with the sluggish development of the 6 GHz IMT ecosystem, indicative of the relative lack of demand for additional IMT spectrum resources. Indeed, in the few markets where portions of 6 GHz have been reserved for IMT, the spectrum is currently being underutilized, a waste of a valuable spectrum asset that could have been leveraged today through Wi-Fi. This amounts to a lost opportunity.

Chart 9: Shipments of 6 GHz-Enabled Wi-Fi Chipsets
World Markets: 2020 to 2029

(Source: ABI Research)



CONCLUSIONS AND STRATEGIC RECOMMENDATIONS

The findings of this report highlight that as Wi-Fi continues to evolve and its penetration into everyday life deepens, the technology's demand for spectrum resources will only grow. The challenge will be further exacerbated by myriad factors, including an expanding installed base of Wi-Fi devices, rapidly growing 6 GHz traffic, spectrum-heavy Wi-Fi innovations, including Wi-Fi 7 and mesh networking, the introduction of Integrated Sensing and Communications, and the need for wider 320 Megahertz channels driven by the emergence of new high-throughput, low-latency demanding applications. At the same time, as investments in upgrading the U.S. fixed access DOCSIS and PON networks accelerate, expanded spectrum capacity will be invaluable in allowing Wi-Fi to transfer the speeds and latency improvements these improved fixed networks offer to the end consumer, as well as enabling strong ROI on these fixed assets. The report also revealed that Wi-Fi is the technology best positioned to extract the maximum value and deliver the greatest societal benefit from spectrum assets.

Regulators should begin exploring potential spectrum bands to meet Wi-Fi's growing demands as soon as possible. It is advised that the reactive approach taken with 6 GHz, when the band was only assigned once congestion on 5 GHz was already severe, should not be repeated. Instead, regulators should be proactive toward the next wave of unlicensed spectrum allocations and assign additional spectrum for Wi-Fi before congestion on 6 GHz becomes an issue. The 7 GHz band represents a sensible option, as its propagation properties are well suited for the needs of home networks, and it offers the unique ability to connect with the existing 6 GHz band to create more contiguous wide channels, while following similar rules and protocols to promote coexistence with existing wireless users. A further benefit of 7 GHz is that the lower 125 Megahertz can be accessed by existing 6 GHz-enabled chipsets, meaning that the existing Wi-Fi 6E and Wi-Fi 7 installed base can harness an additional 320 Megahertz channel immediately with no extra investment.

A proactive stance toward spectrum allocation will be vital for supporting the United States in maintaining and potentially even extending its leadership in developing competitive and innovative new services, particularly with respect to U.S. leadership in developing applications like VR and Augmented Reality (AR), for which the availability of very wide channels will be critical to support the operation of these use cases. Ultimately, spectrum will be key in enabling the U.S. Wi-Fi ecosystem to continue its unhindered development and position of leadership.

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