6 GHz Wi-Fi®: Connecting to the future

October 2022

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Executive summary

Internet connectivity is an essential socioeconomic function and Wi-Fi® is the primary means of delivering it to billions of users around the world. As with any wireless technology, Wi-Fi functionality depends on access to frequency spectrum. Recognizing that lack of spectrum access threatens Wi-Fi performance and functionality, policymakers are expanding spectrum access for Wi-Fi with a particular focus on the 6 Gigahertz (GHz) band (5.925 to 7.125 GHz).

Opening the 6 GHz band to Wi-Fi enables a wide range of new technologies and use cases, which aligns with growing broadband (e.g., fiber) deployments. Wi-Fi connectivity is versatile, extremely affordable, and compatible with existing networks, sharing security, management, and authentication implementations. This makes Wi-Fi an ideal "force multiplier." Importantly, Wi-Fi technology, built on IEEE 802.11 standards, has demonstrated its ability to coexist with and protect other spectrum users. Coexistence is inherent to Wi-Fi technology as it is essential to Wi-Fi's efficient operation.

Technical, operational, and regulatory solutions already adopted by various countries to ensure Wi-Fi coexistence with ongoing, incumbent operations in the 6 GHz band are also facilitating regulatory harmonization. This creates economies of scale and a robust ecosystem, benefitting businesses, consumers, and economies. But these benefits cannot be realized in the absence of Wi-Fi access to adequate spectrum capacity in the 6 GHz band.

Although several countries already authorized Wi-Fi access in the entire 6 GHz band, the upper portion of this spectrum (i.e., 6.425 to 7.125 GHz) will be under consideration at the upcoming 2023 World Radiocommunication Conference (WRC-23) for a potential International Mobile Telecommunications (IMT) designation to support licensed 5G networks, devices, and services (5G/IMT). The pending WRC-23 outcome has caused regulatory uncertainty that is impeding the introduction of advanced 6 GHz Wi-Fi technology and use cases. To rectify the situation and resolve this uncertainty in a timely manner, Wi-Fi Alliance calls on policymakers to consider that:

- **5G/IMT networks cannot coexist with incumbent services in the 6.425 to 7.125 GHz frequency band or deliver commercially viable services.** The arguments advanced by 5G/IMT proponents are flawed for several reasons, including unrealistic forecasts of demand, the existence of multiple alternative spectrum options, and lack of coexistence with incumbent users of 6 GHz, to name a few. In fact, much of the spectrum previously designated for 5G/IMT remains underutilized, including 4 to 5 GHz, 26/28 GHz, 39 GHz, and 42 GHz, as well as other frequency bands already earmarked for 5G/IMT use. Even if the WRC-23 were to identify the 6.425 to 7.125 GHz band for 5G/IMT in some countries, significant time (i.e., years) and investment would be required to develop, implement, deploy, and operate 5G/IMT networks in the upper 6 GHz band. It is unlikely that such 5G/IMT networks would be commercially viable given their limited market scale and harmonization. Importantly, proposed 5G/IMT implementations would lack the economies of scale necessary for a robust equipment ecosystem or commercial viability. In short, additional 6 GHz spectrum cannot address the underlying problems of 5G/IMT networks
- **The next generation of wireless connectivity (i.e., 6G) use cases cannot be delivered by wide area networks, as these use cases require computational resources and connectivity that is hundreds if not thousands of times faster than current 5G/IMT implementations.** These use cases will be predominated by immersive experiences such as virtual-, augmented-, and extended-reality (VR/AR/XR), wearables, telehealth, industrial automation, IoT, 3D-video, etc. Instead of wide area networks, the next generation of connectivity will rely on local area, short range communications, such as the next generation of Wi-Fi, which is designed for more data traffic, more devices, more applications, and much lower latencies
- **Wi-Fi significantly outperforms 5G/IMT in energy efficiency through low power, cognitive radio techniques.** Greater energy efficiency in conjunction with significantly lower equipment and deployment infrastructure costs make Wi-Fi one of the most eco-friendly and economical communications solutions

On all these grounds, it is imperative for policymakers to act now to secure Wi-Fi availability and performance by designating spectrum access to the entire 6 GHz band.

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Introduction

Wi-Fi is one of the most successful connectivity technologies and is used ubiquitously in homes, businesses, institutions, and countless other locations. Evolution of Wi-Fi is essential for the connected society and economic prosperity, which, in turn, depend on more data traffic, more devices, more services, and more applications. Wi-Fi technology will continue to support and drive this growth.

Recognizing Wi-Fi's essential role, policymakers are expanding Wi-Fi access to spectrum with a focus on the 5.925 to 7.125 GHz ("6 GHz") frequency band. These policy decisions are grounded in the fact that the 6 GHz band is uniquely suited to enable the Wi-Fi evolution needed to support ever more devices with increasing data rates and minimal latencies. These decisions also recognize that the 5G/IMT networks cannot coexist with important incumbent operations in the 6 GHz band.

Why Wi-Fi needs access to the 6 GHz band

Wi-Fi's need for additional spectrum access is well documented.[1] Over the last two decades, as global data traffic has experienced exponential growth, Wi-Fi has become indispensable to connecting billions of people and devices. Wi-Fi access to spectrum, however, has remained largely unchanged. As an integral component of telecommunications infrastructure, people rely on Wi-Fi to deliver ever-increasing data traffic volumes. For example, data traffic over Wi-Fi exceeds cellular traffic by orders of magnitude (see Figure 1). The looming spectrum shortfall threatens Wi-Fi performance, viability, and socioeconomic benefits. The 6 GHz band is the best and possibly only spectrum suited to accommodate this urgent need and a robust and fast-growing Wi-Fi device ecosystem already exists in the 6 GHz band.

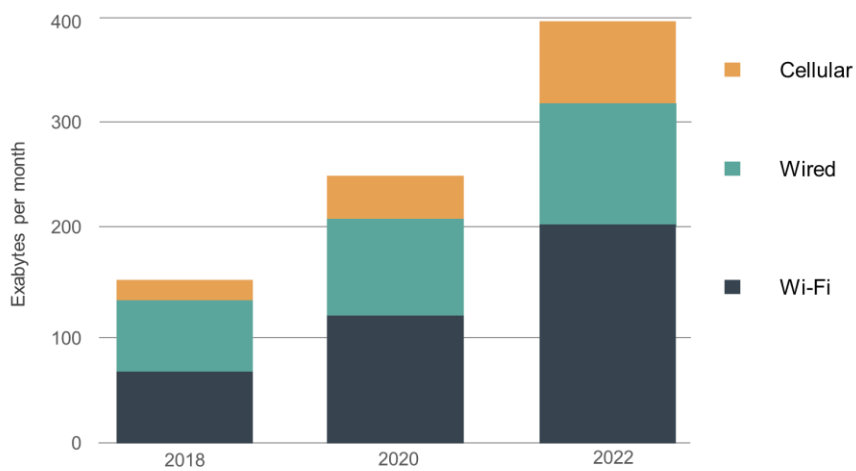

Figure 1: Global data traffic[2]

Wi-Fi connects people and devices and drives economic activity

Billions of people rely on Wi-Fi, which connects 18 billion devices.[3] Wi-Fi device shipments will increase to nearly four billion annually by 2024.[4] In many parts of the world, Wi-Fi devices are now the primary means by which both consumers and business users connect to the Internet,[5] cloud services, and enterprise networks. Wi-Fi devices also support a broad and growing array of Internet of Things (IoT) and smart home solutions.

[1] Quotient Associates, 2017
[2] Cisco VNI, 2017-2022
[3] IDC Research, 2022
[4] ABI Research, 2019
[5] Cisco, 2022

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Wi-Fi's ubiquity reflects its integral role in achieving governments' connectivity objectives. For instance, the European Commission's 2030 Digital Compass report underscores that gigabit connectivity is essential for realizing the benefits of wide-area broadband, and gigabit connectivity requires Wi-Fi functionality for the "last meter" of delivery to users.

Finally, the global economic value of Wi-Fi was $3.3 trillion in 2021, a number expected to grow to $4.9 trillion by 2025.[6]

In 2024, nearly four billion Wi-Fi devices will ship annually.

Wi-Fi's future depends on access to the 6 GHz spectrum

While Wi-Fi technology connects billions of people every day, insufficient spectrum access puts Wi-Fi's future — including its economic value and evolution — in jeopardy. Other frequency bands that support Wi-Fi lack necessary bandwidth and are often congested, especially in densely populated areas. Moreover, Wi-Fi shares access to these frequency bands with other license-exempt technologies (e.g., Bluetooth and Zigbee), conference audio-visual systems, and proprietary wireless devices such as remote-controlled toys, garage door openers, and others. Importantly, these bands cannot support the wider channels necessary for emerging use cases such as high-definition video, automation, XR, metaverse, etc.

The 1200 MHz of spectrum in the 6 GHz band enables major advances in Wi-Fi applications, infrastructure, and services. Increased data throughput rates, ultra-low and deterministic latencies, better mobility, and high densities of users/devices all become more achievable and practical with the 6 GHz spectrum.

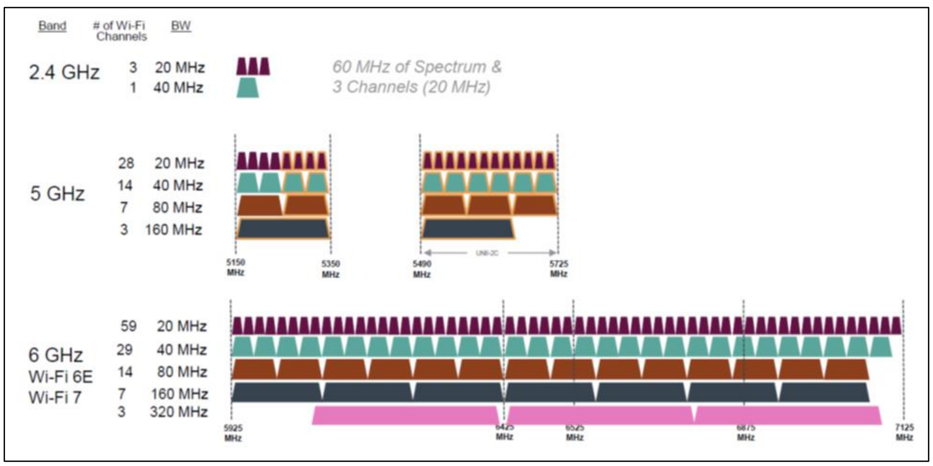

Figure 2: Wi-Fi channelization in mid-band

These benefits are being realized in several markets with 6 GHz Wi-Fi products already shipping in volume, and there is a roadmap for further Wi-Fi enhancements in 2023 and beyond. These benefits also match realistic business models and deployment preferences, such as consumers' reliance on fixed/fiber home broadband or enterprises' desire to own or control their own network assets.

Importantly, there is no alternative frequency range available to support expanding demand for Wi-Fi and the growing device ecosystem. Therefore, optimal performance of Wi-Fi 6E, Wi-Fi 7, and future Wi-Fi generations depends on access to the 6 GHz spectrum.

Wi-Fi is integral to broadband connectivity

Numerous techno-economic studies, including those by OECD, Capgemini, and others, consider the future importance of Industry 4.0 systems such as factory robotics, or the benefits of enhanced connectivity for healthcare, education, and connected-home applications. As the COVID-19 pandemic demonstrated, high-speed broadband

[6] Telecom Advisory Services, 2021

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connectivity is critical for billions of people working, learning, and staying connected. While high-speed broadband is delivered by either fiber, fixed-wireless, or satellite technologies, Wi-Fi is the primary means of distributing this connectivity to end users. Considering that high-speed broadband capabilities continue to increase, with many administrations targeting multi-gigabit capabilities, it is important to ensure that Wi-Fi spectrum bandwidth does not constrain broadband connectivity.

Wi-Fi is a transformative "force multiplier for other innovative technologies — including IoT, cloud, and edge computing."[7] Some of these important use cases include healthcare, location, advanced connectivity, automotive, wireless display casting, and AR/VR, with many applications still to be defined. Wi-Fi is ideal for all these use cases because it is easily deployed, integrates with existing networks, and shares security, management, and authentication models. In enterprise settings, professional installers can interpret floorplans and foot traffic estimates to ensure complete coverage and optimal performance. While in residential settings, broadband providers often supply consumer Wi-Fi access points, which can support mesh "extenders" and assistant apps on smartphones to cover the entire house.

Importantly, Wi-Fi, built on IEEE 802.11 standards, has demonstrated the ability to coexist with and protect other 6 GHz spectrum users, as evidenced by regulatory decisions in several countries. These protections are inherent to Wi-Fi technology and are critical to its efficient operation on a license-exempt basis worldwide. The Wi-Fi industry is committed to implementing technical, operational, and regulatory solutions that ensure coexistence with ongoing, incumbent operations in the 6 GHz band.

A thriving and growing 6 GHz Wi-Fi ecosystem

In 2021, Wi-Fi Alliance introduced the new Wi-Fi 6E brand to distinguish the latest generation of Wi-Fi 6 devices that are capable of 6 GHz operation. Wi-Fi 6E establishes a common industry name that allows Wi-Fi users to identify devices that offer the features and capabilities of Wi-Fi 6 — including higher performance, lower latency, and faster data rates — extended into the 5.925 to 7.125 GHz band. Wi-Fi 6E devices are quickly becoming available following regulatory approvals in several countries.

As the 6 GHz regulatory landscape evolves, Wi-Fi Alliance member companies continue to expand the Wi-Fi 6E ecosystem even further. Initial deployments in the band included Wi-Fi 6E consumer access points, smartphones, computers, and televisions, followed by enterprise-grade access points. Industrial environments are also expected to see strong adoption of Wi-Fi 6E to deliver applications including machine analytics, remote maintenance, and virtual employee training (see Wi-Fi Alliance 2022 Wi-Fi trends). Wi-Fi 6E utilizes the 6 GHz band to support the much anticipated immersive experience use cases (e.g., VR/AR/XR, industrial IoT, automotive, telepresence, 3D video, and other applications).

The list of Wi-Fi 6E certified products is growing. In 2021, over 300 million Wi-Fi 6E devices entered the market and over 350 million devices are expected to ship in 2022. Regulatory harmonization in the 6 GHz band will create economies of scale and produce a robust equipment market, benefitting businesses, consumers, and the economy. But these benefits cannot occur in the absence of Wi-Fi access to adequate spectrum.

Based on the developing IEEE 802.11be standard, Wi-Fi 7 will be the next major generational Wi-Fi technology evolution and will deliver unprecedented quality of service (QoS) benefits at higher data rates and lower latencies. Optimal performance of Wi-Fi 7 will depend on access to multiple wider (e.g., 320 MHz) channels in the 6 GHz band. Wi-Fi Alliance plans to complete development of a Wi-Fi 7 certification program by 2024, which typically serves as an inflection point for mass market adoption.

Without Wi-Fi access to 6.425 to 7.125 GHz — the frequency range that 5G/IMT proponents are targeting — consumers and enterprises will not realize the full benefits of Wi-Fi 6E, Wi-Fi 7, and future generations of Wi-Fi technologies. Access to less than the entire 6 GHz band (i.e., 5.925 to 6.425 GHz and 6.425 to 7.125 GHz) would

[7] Deloitte, 2020

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substantively increase Wi-Fi latency and reduce data throughput. Importantly, there are no alternative frequency bands that adequately address expanding Wi-Fi spectrum requirements.

Recognizing the importance and advantages of advanced Wi-Fi connectivity, several countries have already opened the entire 6 GHz band for Wi-Fi access. As a result, a range of low-cost, power-efficient Wi-Fi 6E equipment capable of high data speeds has become increasingly available.

The cellular industry's demands for 6 GHz are unreasonable

Cellular service providers assert that the upper portion of the 6 GHz (i.e., 6.425 to 7.125 GHz) band is needed for future 5G/IMT licensed deployments, ignoring the fact that much of the spectrum previously designated for 5G/IMT remains unavailable for use. For example, "spectrum assignment, an important precondition for the commercial launch of 5G, is still not complete: only 56% of the total 5G harmonized spectrum has been assigned, in the vast majority of Member States."[8]

The arguments advanced by 5G/IMT proponents for access to the 6 GHz band are flawed for a number of reasons:

- Forecasts of demand for 5G/IMT connectivity and implied spectrum requirements are unrealistic
- Multiple alternative spectrum options for 5G/IMT expansion exist besides 6 GHz
- 5G/IMT networks are unable to coexist with 6 GHz incumbent users
- Propagation characteristics of the 6 GHz spectrum limit wide-area (i.e., cellular) network coverage, negating its business models
- 5G/IMT equipment is lacking. Many countries already decided to designate the entire 6 GHz band for license-exempt deployments, negating possible 5G/IMT deployments in the band. It is therefore unlikely that 5G/IMT in the 6 GHz band can attain the sufficient market scale and harmonization necessary for a robust equipment ecosystem or commercial viability

Unrealistic forecast of demand for 5G/IMT

Recently published analyses that proponents use to rationalize 5G/IMT demands for the 6 GHz spectrum rely on a predetermined conclusion that 2 GHz of mid-band spectrum is necessary to meet projected demand, especially in urban areas.[9] Before accepting these demands, policymakers should consider the validity of the underlying assumptions, with particular attention to the following:

- The assumption that the full International Telecommunication Union (ITU) 5G requirements for continuous 100 Mbps downlink and 50 Mbps uplink, per concurrent active user, are reasonable to apply everywhere in mobile network operator (MNO) coverage.[7] These requirements were developed nearly a decade ago, dating back to 2014 or even earlier, and do not represent actual continual-use needs demonstrated by 5G/IMT applications/devices (e.g., battery capacity) in the real world. This arbitrary assertion does not appear to have been tested against interviews with device suppliers or mobile application developers
- The model's estimates are distorted by an "activity factor" multiplier, which represents the proportion of users simultaneously accessing the network. This parameter is not adequately explained or justified. The model assumes continued increase in the activity factor over time, with little supporting evidence or analysis. In fact, the activity factor may decline, not increase, as new use cases emerge. For instance, some device classes such as laptops, fixed-wireless access routers, in-vehicle systems, and other IoT products may be used only sporadically. As another example, 5G-connected security cameras may only transmit video data when they detect an anomalous event — few will stream 4K video to the network continually
- The demand model fails to distinguish indoor versus outdoor use cases. The 5G/IMT outdoor base stations cannot effectively service indoor users due to propagation characteristics of the 6 GHz band

[8] European Commission, 2022
[9] Coleago Consulting, 2020

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- Conversely, indoor 6 GHz small cells would incur development, production, installation, and operational costs that would render such deployments economically unfeasible for many locations, especially multi-operator coverage
- 5G/IMT proponents use past mobile data traffic statistics to forecast future demand for 5G/IMT. However, these top-down numbers combine multiple types of mobile usage, only some of which could be, theoretically, addressed by additional 6 GHz spectrum. A proper spectrum requirements analysis should separate indoor from outdoor traffic, smartphone mobile broadband from IoT or fixed wireless access, public versus private networks, and so on, and examine the growth in 5G/IMT demand of 6 GHz-addressable use cases specifically
- Demand forecasts include spurious claims about IoT traffic that are not representative of the real-world data usage by devices and applications. For instance, while a connected or autonomous car may generate 1 terabyte (TB) of data per hour from sensors and cameras, the vast bulk of this data will be processed in the vehicle itself. Only a small fraction of this data (i.e., perhaps 1 percent) would be transmitted outside the vehicle over the 5G/IMT network, and much of this will not be time or latency critical
- Correlation of 5G/IMT traffic to GDP growth is deeply flawed as well. There is no adequate analysis of what fraction of that projected growth is addressable with 4G (or Wi-Fi or even satellite connections). And there is no attempt at attributing a suitable percentage of the economic impact to the 5G mobile network rather than parallel advances in the necessary fiber backhaul, cloud platforms, semiconductors, software, cameras, or dozens of other system elements involved

> While connected cars may generate 1 TB of data per hour, the vehicle would send maybe 1 percent of this over the network.

Alternative bands for IMT/5G mobile broadband

The cellular industry has access to multiple alternative spectrum options for the use cases it has identified for the 6 GHz bands:

- Existing mid-band allocations are still underutilized by 5G/IMT. In Europe, for example, years after the "5G Pioneer Bands" designation, assignments stand at 60 percent:[10]
  - 700 MHz is assigned at less than 75 percent
  - 3.6 GHz is assigned at less than 80 percent
  - 26 GHz is assigned at less than 30 percent
- Existing 2G, 3G, and 4G frequency with sizeable allocations around 2.1 GHz and 2.5 to 2.7 GHz can be repurposed for 5G use
- The 4 to 5 GHz and 7 to 8 GHz frequency ranges are of increasing interest to the mobile industry. In fact, 5G/IMT proponents maintain that 4.4 to 4.9 GHz and 7.125 to 8.5 GHz are "well suited to meet the requirements both from a coverage and capacity perspective"[11]
- 5G/IMT proponents expressed significant interest in the 12 GHz band for 5G.[12] Interestingly, proponents use the same arguments and claims for both 6 GHz and 12 GHz. For dense "hotspot" and indoor use, 5G can use 26 GHz and 28 GHz mmWave cells, where a large ecosystem of devices, radios, and chipsets already exists. 39 GHz and 42 GHz options are also available[13]
- 5G deployments may also use unlicensed 6 GHz spectrum under appropriate sharing and coexistence conditions

[10] European 5G Observatory, 2021
[11] Ericsson, 2022
[12] 5G for 12 GHz Coalition, 2022
[13] Qualcomm, 2021

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In short, 5G/IMT proponents' claim that 6 GHz is essential appear to be exaggerations at best. There are ample other frequency options for addressing 5G/IMT spectrum needs.

Coexistence with 6 GHz incumbent users and commercial viability

The plans outlined by the 5G/IMT proponents for deployments in the 6 GHz band are clearly incompatible with ongoing incumbent operations in this frequency range. To maintain the necessary quality of service, 5G/IMT wide-area networks require priority access to the spectrum. Hence, licensed 5G/IMT networks cannot avoid interfering with or tolerate interference from incumbent operations in the 6 GHz band. In most countries, the 6 GHz band is used extensively for long distance and high-capacity fixed links. The 5G/IMT proponents have not offered any viable method for coexistence with fixed networks. Similarly, 5G/IMT coexistence with 6 GHz incumbent satellite services is not guaranteed. Importantly, countries are obligated by an international treaty to protect on-orbit fixed-satellite service (FSS) satellite receivers from interference that may be caused by the 5G/IMT network(s) deployed on their territories. Therefore, it is unrealistic to expect that 5G/IMT networks can avoid interfering with and tolerate interference from other incumbent operations in the 6.425 to 7.125 GHz band. 5G/IMT proponents' claim of achieving coexistence with the 6 GHz incumbents by limiting operations to dense urban-area "hotspots" are unrealistic. Not only does this approach not protect incumbent services from harmful interference, but it is also not commercially viable. 5G/IMT "hotspot" implementations simply lack the economies of scale necessary for a robust equipment ecosystem or commercial viability. Moreover, 5G/IMT already have access to previously designated mmWave bands, which are intended for the hotspot services and remain significantly underused.

Nonexistent 5G/IMT equipment ecosystem

Beyond one or two early proof-of-concept demonstrations, there is no existing 6 GHz 5G/IMT ecosystem or even any formal roadmaps. 3GPP has only recently concluded standardization of the band, now called n104, as part of its Release 17 specifications.[14]

If IMT achieves 6 GHz designation, it is highly unlikely that there will be an adequate equipment ecosystem for either networks or end-users, including chipsets and devices. Furthermore, questions over supply chain diversity will remain, especially because the number of 6 GHz macro radio access network (RAN) suppliers is likely to see constraints and be subject to ongoing geopolitical tensions. Moreover, considering ongoing license-exempt (e.g., Wi-Fi) deployments in several countries, including leading Open RAN vendors, such as in the US and South Korea, it is doubtful that potential 5G/IMT entrants will achieve sufficient scale to justify significant upfront investment for development of the 6 GHz equipment.

On the device side, it is unclear whether some major vendors will support 6 GHz for 5G/IMT given the huge range of other bands for consideration — especially 26/28 GHz mmWave options, which should see a renaissance in the coming years.

Therefore, it is far from clear that there will be a mature 6 GHz ecosystem for cellular infrastructure and devices in the next five years, even under favorable assumptions on spectrum availability.

Advancing environmental policy objectives

Wi-Fi Alliance enthusiastically supports administrations' efforts to leverage spectrum policy toward combating climate change and meeting environmental policy objectives. Wi-Fi technology excels in low-power, cognitive radio techniques including spectrum sensing, spectrum sharing, and adaptive transmission. These techniques enable Wi-Fi to significantly outperform 5G/IMT in energy efficiency, particularly in conjunction with fiber-to-home and cable broadband deployments. When deciding the best use of the 6 GHz band, policymakers should consider Wi-Fi versus 5G/IMT network energy consumption factors, such as:

[14] Telecom Review, 2022

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- **Efficiency:** Policymakers should reserve 6 GHz for efficient wireless connectivity, especially lower-powered, short-range connections that building structures or other obstacles do not wastefully reduce. In the future, eco-centric building construction will add more insulation to walls and windows, which will further reduce outdoor-to-indoor propagation of 6 GHz. Additionally, the power that devices use to uplink to a nearby access point is orders of magnitude less than that needed for a distant cell tower
- **Enablement:** The focus of 6 GHz wireless should be on use cases that have the most potential to combat climate change through enablement of low-emission activities. As discussed above, most broadband wireless connections occur indoors, from video calls (or metaverse experiences) replacing travel to smart building technology optimizing energy or water usage
- **Embodiment:** Policymakers should consider how 6 GHz wireless promotes low amounts of energy/CO_2 in the manufacture and installation of new network infrastructure and devices. The physical engineering of new 6 GHz outdoor macro cell sites requires considerable infrastructure (concrete, steel, copper cabling, and other CO_2-intensive elements). Conversely, 6 GHz Wi-Fi network deployments require minimal installation or infrastructure

On all three of these grounds, Wi-Fi is advantageous compared to MNO macro outdoor cellular deployments in the 6 GHz band.

Conclusion

The case for allowing Wi-Fi access to the entire 6 GHz band (i.e., 5.925 to 7.125 GHz) is clear and compelling. 6 GHz Wi-Fi is already delivering significant socioeconomic benefits in many countries. With a diverse and growing 6 GHz product ecosystem, Wi-Fi fits perfectly with market needs and customer preferences for broadband wireless connectivity without disrupting 6 GHz incumbent users. Wi-Fi operations in the 6 GHz band quickly and significantly enhance the value of the band when such Wi-Fi operation is allowed.

Conversely, 5G/IMT networks conflict with 6 GHz incumbents. The complete absence of a 5G/IMT equipment ecosystem, along with regulatory decisions already adopted in several countries, confirm that 5G/IMT deployments in the 6 GHz band are not feasible. The value and benefits from that spectrum will stall with the 5G/IMT designation, and such a designation will promote a connectivity divide in contrast to regions where Wi-Fi will operate in the full 6 GHz band. Furthermore, 5G/IMT proponents' claims of urgent need for access to the 6 GHz spectrum appear to be exaggerated. But even if such needs exist, they are addressable with other frequency bands without impeding introduction of advanced Wi-Fi technologies now or in the future.

About Wi-Fi Alliance®

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