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ITU-APT Foundation of India (IAFI)[1]

PROPOSAL FOR A NEW APT REPORT ON WIFI IN LOWER AND UPPER 6 GHZ BAND

1. Background

Remote working and work from home due to Covid-19 pandemic has led to an unprecedented increase in use of Wi-Fi during the last two years. In order to meet the severe shortage of Wi-Fi spectrum, many countries around the world have been considering opening of new frequency bands for Wi-Fi type of services.

The frequency band 5.925-7.125 GHz MHz (referred to in this document as “6 GHz band”) is currently being considered for unlicensed Wi-Fi services in many countries around the world. This band includes the UPPER 6 GHz band (6425-7125 MHz) and the LOWER 6 GHz band (5925-6425 MHz). It is also noted that the Band 7025-7125 MHz is currently being considered for IMT under WRC-23 agenda item 1.2 for all regions.

Countries including the United States, UK, Canada, Korea, Brazil, UAE, Saudi Arabia and the countries in the EU have already allocated parts of 6GHz band for Wi-Fi. The rationale for delicensing has been to enhance benefits to citizens while reaping the benefits of economic growth in their economies. Enclosed table summarizes the regulatory actions by countries around the world (Europe, United Kingdom, United States, Canada, Brazil, etc.) towards delicensing of WI-FI 6e

2. Discussions

6GHz band represents an immense opportunity for indoor Wi-Fi to fully adopt the promise of new high throughput Wi-Fi services,

3. Proposal

This contribution proposes the drafting of a new report on issues relating to sharing aspects of Wi-Fi spectrum in upper and lower 6 GHz band. It is understood that the completion of the draft APT reports will depend on further inputs from APT members as well as external organizations.

[1] ITU-APT Foundation of India (IAFI) is a new Affiliate member of APT. Details of IAFI can be seen at itu-apt.org

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WORKING DOCUMENT TOWARDS A DRAFT NEW APT REPORT ON SHARING OF NEW WIFI SPECTRUM IN UPPER AND LOWER 6 GHZ BAND

[Editor's Note: Further contributions are invited from APT members to further update this working document Presently this report is planned to be completed for AWG-31]

1. Scope

This new APT Report provides an overview of technology developments of Wi-Fi spectrum in upper and lower 6 GHz bands, in particular the band 5.925-7.025 GHz band which is currently being considered for Wi-Fi in a number countries

2. Introduction

Wi-Fi is often the most cost-effective way to get online, enabling extensive use of Internet-based applications and services without incurring the hefty connectivity charges associated with cellular contracts. Low-cost reliable connectivity makes citizens more productive. Wi-Fi has become a lifeline for connecting people, enhancing digital technology and the global proliferation of Wi-Fi access is important for both established and developing economies. The flexibility and benefits Wi-Fi brings to digital economies have proven to provide essential benefits during the COVID-19 pandemic and the increasing demand for Wi-Fi means that the regulators need to assign much larger unlicensed spectrum for Wi-Fi. Due to such expected growth, which is followed by the expectations of consumers that is ever increasing requirement being fueled by fast connectivity, low latency and maximization of connections in more and more devices. Wi-Fi networks congestion at the access point level is becoming an issue because access to license-exempt mid-band spectrum creates an artificial spectrum shortage; since the World Radiocommunication Conference in 2003 no new mid-band spectrum has been made available for Wi-Fi despite the exponential growth in data traffic. Furthermore, the current Wi-Fi spectrum doesn't offer sufficiently wide channels for newer applications and services.

Wi-Fi 6 or new spectrum for WIFI will enable new use cases for industrial IoT, smart homes and support for high-density deployments, to name a few, but access to wider channels is needed to support these new use cases. The new 6GHz Wi-Fi band will lead to opening up of up to seven new 160 MHz channels. The 6 GHz band could potentially serve as a multi-lane superhighway for the latest Wi-Fi devices. The 6 GHz band comprises frequencies from 5.925 to 7.125 GHz, and the V band from 57 to 71 GHz. The bands support new Wi-Fi versions, Wi-Fi 6E and WiGig, respectively, which offer much higher data speeds and shorter range than previous versions of Wi-Fi.

3. References

4. Abbreviations and acronyms

AP	Access Points
AR	Augmented reality
DFS	Dynamic Frequency Selection
LAN	Local Area Network

MU-MIMO	Multi-User Multiple-Input Multiple-Output
OFDMA	Orthogonal Frequency-Division Multiple Access
TWT	Target-Wake-Time
VR	Virtual reality

5. Application of new spectrum in upper and lower 6GHz band

Wi-Fi 6 in 2.4 GHz and 5 GHz and **Wi-Fi 6E** in 6 GHz is the successor of 802.11ac. It is also known as *High Efficiency* Wi-Fi, for the overall improvements to Wi-Fi 6 clients under dense environments. The main goal of this standard is to enhance access to spectrum which is critical to enable a better user experience and enable innovation.

Wi-Fi can be used in the 2.4 and 5GHz bands throughout most of the world. In the UK, 83MHz is available for Wi-Fi use at 2.4 GHz and 585MHz at 5GHZ. However, there are variations between countries in the supported frequencies and the ways in which devices can connect. For instance, in the 5.8 GHz band there is more available spectrum but this is because **it has been made available in the UK,** even though the bands are not available for similar Wi-Fi services and applications throughout Europe.

Figure 1: Wi-Fi channels in the 2.4 GHz band.

The higher number of connected devices within existing bands, and the limited number of Wi-Fi channels can lead to congestion when several devices attempt to use the same Wi-Fi channel.

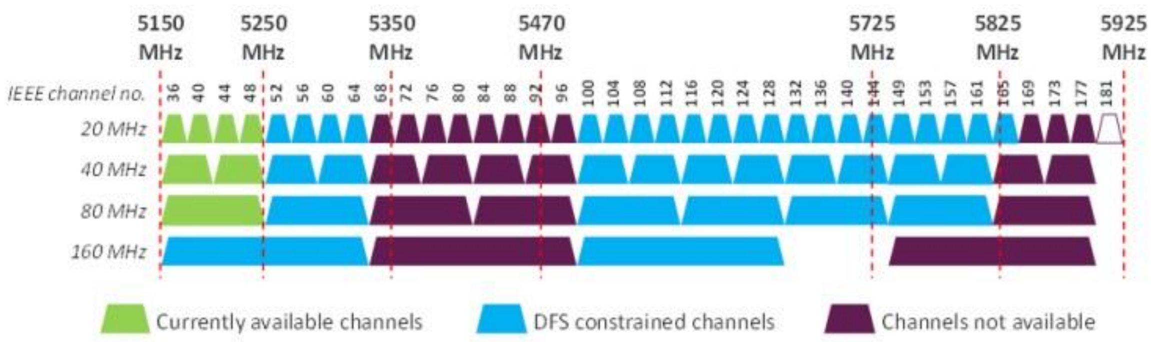


Figure 2: Example Wi-Fi channel plan used in the 5 GHz band

Therefore, it can be agreed that more than one Wi-Fi channel is needed for mesh technologies to provide different multimedia platforms throughout the home, and this demand for higher throughput mesh technologies in the home will increase in the future. Opening new Wi-Fi bands, and removing DFS requirements in the 5.8 GHz band, will offer a higher number of wider channels needed.

In order to see this in a growing demand the latest development in the Wi-Fi is the Wi-Fi 6 and other RLAN technologies. It is agreed that Wi-Fi 6 will improve battery life, allow a higher density of wireless devices.

The 5.8 GHz band (5725-5850 MHz) is very lightly used due to the requirement to implement DFS in this band. As a result, we have considered removing the DFS requirement in this band to enable more efficient use of it.

In light of increasing demand for wireless connectivity and the new Wi-Fi technologies being capable of providing the capacity needed for low latency multimedia applications, we proposed to open up access to new spectrum in the lower 6 GHz band (5925- 6425 MHz) and to remove the DFS requirements for the lower power indoor3 use of Wi-Fi in the 5.8 GHz band.

Enterprises users rely on W-Fi for most corporate connections, using mesh-based systems to coordinate fast internet access for a large number of users;

6.1 Technical improvements

The 802.11ax amendment brings several key improvements over 802.11ac. 802.11ax addresses frequency bands between 1 GHz and 6 GHz. Therefore, unlike 802.11ac, 802.11ax will also operate in the unlicensed 2.4 GHz band. To meet the goal of supporting dense 802.11 deployments, the following features have been approved.

In the previous amendment of 802.11 (namely 802.11ac), multi-user MIMO has been introduced, which is a *spatial* multiplexing technique. MU-MIMO allows the access point to form beams towards each client, while transmitting information simultaneously. By doing so, the interference between clients is reduced, and the overall throughput is increased, since multiple clients can receive data at the same time. With 802.11ax, a similar multiplexing is introduced in the *frequency domain*, namely OFDMA. With this technique, multiple clients are assigned with different Resource Units in the available spectrum. By doing so, an 80 MHz channel can be split into multiple Resource Units, so that multiple clients receive different types of data over the same spectrum, simultaneously. In order to have enough subcarriers to support the requirements of OFDMA, four times as many subcarriers are needed than by the 802.11ac standard. In other words, for 20, 40, 80 and 160 MHz channels, there are 64, 128, 256 and 512 subcarriers in the 802.11ac standard, but 256, 512, 1,024 and 2,048 subcarriers in the 802.11ax standard. Since the available bandwidths have not changed and the number of subcarriers increases by a factor of four, the subcarrier spacing is reduced by the same factor, which introduces four times longer OFDM symbols: for 802.11ac the duration of an OFDM symbol is 3.2 microseconds, and for 802.11ax it is 12.8 microseconds

6.1 Technical improvements in WIFI 6

Features	802.11ac	802.11ax	Usage/Application
OFDMA	Not Available	Centrally controlled medium access with dynamic assignment of 26, 52, 106, 242, 484 or 996 tones per station. Each tone consists	OFDMA segregates the spectrum in time frequency resource units (RUs). A central coordinating entity (the AP in 802.11ax)

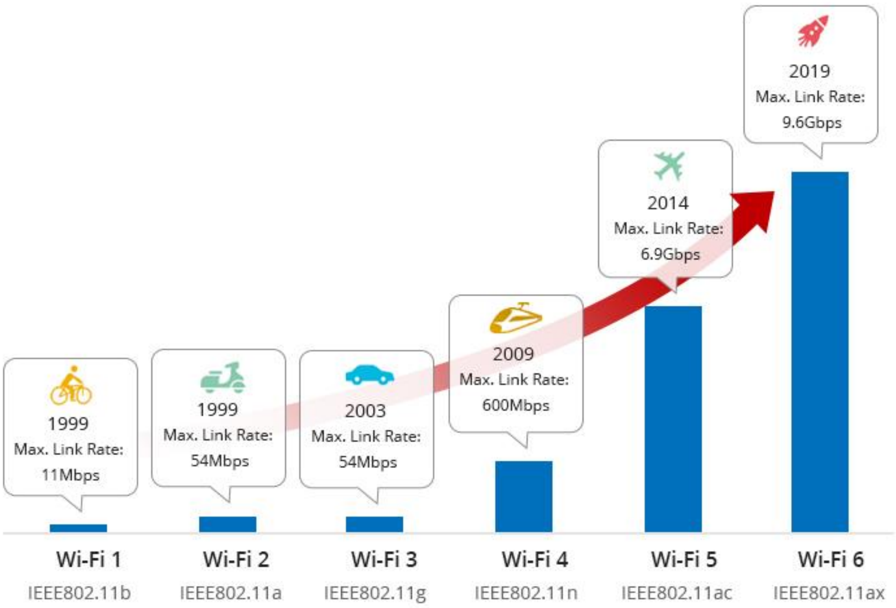
		of a single subcarrier of 78.125 kHz bandwidth. Therefore, bandwidth occupied by a single OFDMA transmission is between 2.03125 MHz and ca. 80 MHz bandwidth.	assigns RUs for reception or transmission to associated stations. Through the central scheduling stations of the Rus contention overhead can be avoided which increases efficiency in scenarios of dense deployments.
Multi-user MIMO (MU-MIMO)	Available in downlink direction	Available in uplink direction	With downlink MU-MIMO an AP may transmit concurrently to multiple stations and with uplink MU-MIMO an AP may simultaneously receive from multiple stations. Whereas OFDMA separates receivers to different RUs, with MU-MIMO the devices are separated to different spatial streams. In 802.11ax, MU-MIMO and OFDMA technologies can be used simultaneously. To enable uplink MU transmission, the AP transmits a new control frame (trigger) which contains scheduling information (Rus's allocation station, modulation and coding scheme (MCS) that shall be used for each station.
Trigger-based Random Access	Not available	Allows performing UL OFDMA transmissions by stations which are not allocated RUs directly.	In Trigger frame, the AP specifies scheduling information about subsequent UL MU transmission. However, several RUs can be assigned for random access. Stations which are not assigned RUs directly can perform transmissions within RUs assigned for random access. To reduce collision probability (i.e., situation when two or more

			stations select the same RU for transmission), the 802.11ax amendment specifies special OFDMA back-off procedure. Random access is favorable for transmitting buffer status reports when the AP has no information about pending UL traffic at a station

Two of the most significant changes involve how Access Points support a large number of devices in high density environments. Wi-Fi 6 incorporates features found in 4G LTE cellular networks by upgrading access points to Orthogonal Frequency Division Multiple Access (**OFDMA**) from the older OFDM (minus the Access). OFDMA divides the 802.11 channel (20, 40, 80, 160 MHz wide) into hundreds of sub-channels, also known as Resource Units (RU).

Wi-Fi 6 also enables each Access Point to add a unique color—referred to as "Basic Service Set (BSS) Color"—to each transmitting channel. With 63 different colors available, coloring ensures that neighboring APs can all be assigned unique colors. With each Access Points transmitting a locally-unique color, a device can easily distinguish transmissions coming from its Access Points from that of a neighboring Access Points. This distinction enables a device to ignore a neighboring Access Point's transmission when attempting to transmit. Coloring leads to increased capacity by enabling simultaneous transmissions between Access Points on the same channel.

Figure 3:



Optimize Efficiency with OFDMA Technology

Orthogonal Frequency-Division Multiple Access (OFDMA) divides available channel bandwidth into several mutual orthogonal subcarriers or resource units (RUs). Furthermore, by subdividing the channel, applications that use small frames can be transmitted to multiple endpoints simultaneously, which cuts down on overhead and congestion at layer two. When multiple connections transmit limited amounts of data, OFDMA will be leveraged at maximum.
Unlike the previous OFDM technology adopted by Wi-Fi 5, OFDMA is flexible to allocate the entire channel to a sub-divide depending on traffic, greatly improving efficiency and reducing latency. The following diagram will further illustrate the working principal differences via analogy. One truck can only send one kind of package to one house at a time previously (Wi-Fi 5 with OFDM), while the same truck is able to carry multiple packages to separate destinations now (Wi-Fi 6 with OFDMA).

Figure 4:

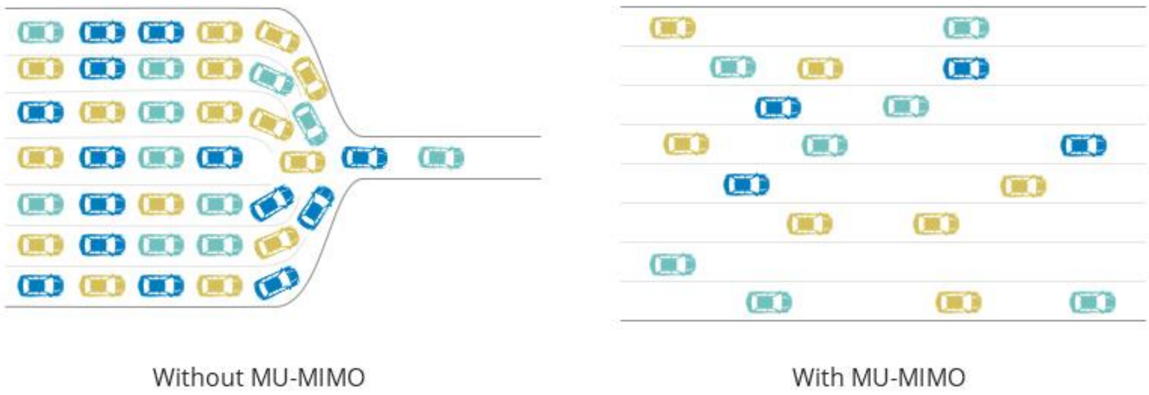
OFDMA is like an Access Point-centric methodology enabling an 802.11ax access point to simultaneously communicate with multiple devices by dividing each Wi-Fi channel into smaller sub-channels. That is to say, an AP can choose to allocate the whole channel (all sub-channels within a channel) to a single user in a given time frame, or it may partition the whole channel to serve multiple devices simultaneously. The adoption of this new technology moves Wi-Fi from a contention-based to a scheduled-based service, which helps to stabilize the Wi-Fi performance.

Increase Throughput With MU-MIMO Technology

MU-MIMO, short for "multi-user, multiple input, multiple output," allows routers to communicate with multiple devices at the same time rather than communicate successively. Wi-Fi 5 supports this MU-MIMO technology as well, but only working for downloads whereas Wi-Fi 6 works with both uploads and downloads. Wi-Fi 6 uses 8x8 uplink/downlink to provide 4x larger capacity than Wi-Fi 5 to handle more devices. The enhancement of this technology in Wi-Fi 6 will largely increasing the utilization of Wi-Fi network bandwidth. The following diagram indicates that MU-MIMO has enlarged the capacity for better efficiency. In Wi-Fi 6, MU-MIMO and OFDMA mechanisms form a unity of complementation.

Both focus on improving the efficiency of Wi-Fi networks and reducing latency for time-sensitive applications. MU-MIMO and OFDMA have their advantages and applications respectively: OFDMA is ideal for low-bandwidth, small-packet applications such as IoT sensors, whereas MU-MIMO increases capacity and efficiency in high-bandwidth applications like mission-critical voice calls or video streaming.

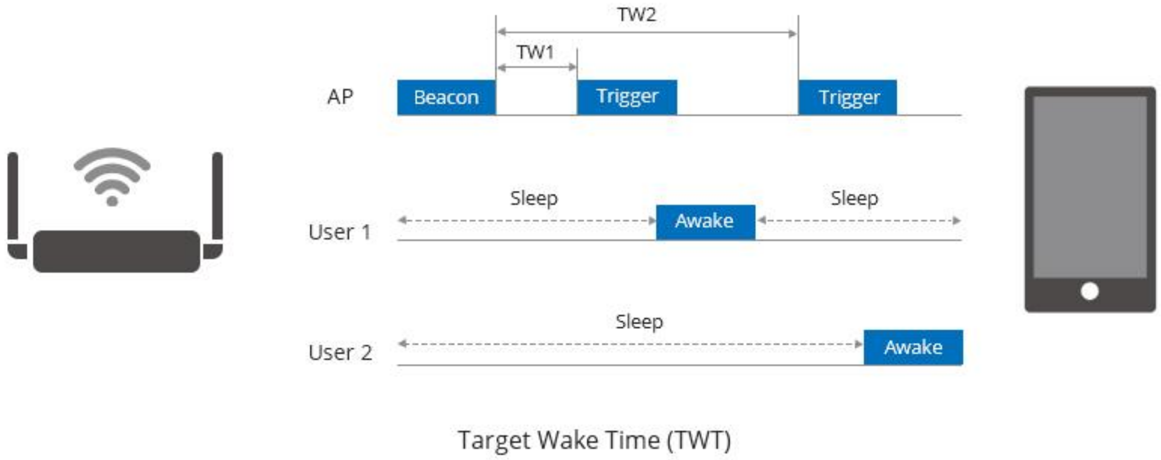
Figure 5:



Reduce Power Consumption with TWT Technology

Target Wake Time (TWT) allows devices to negotiate when and how often they will wake up to send or receive data, increasing the sleep time, and substantially improving battery life for devices. Introducing this new technology in Wi-Fi 6, devices will be planned out communications with a router, reducing the amount of time they need to keep their antennas powered on to transmit and search for signals. That is to say, the devices remain inactive until it's their turn to transmit data using a scheduling scheme negotiated with the APs. It's like parking a vehicle in the cell phone waiting area, rather than circling the airport for arrivals. Wi-Fi 6 Target Wake Time featuring less congestion and energy savings will create better experiences for the users.

Figure 6:



Use case application

1) Ensuring application assurance
2) Indoor wireless coverage
3) Enabling the intelligent edge
4) IoT convergence
5) Safer Wi-Fi

6.2 Making more efficient use of spectrum in the 5.8 GHz band

Wi-Fi use is currently accessing 580 MHz of unlicensed spectrum in the 5 GHz band. Some of the available channels have Dynamic Frequency Selection (DFS) requirements to protect military and meteorological radars in these frequencies.

It is believed that the removal of the DFS requirements from the 5.8 GHz band (5725-5850 MHz) for indoor Wi-Fi use on the basis that the risk of undue interference to radars from indoor Wi-Fi use is extremely low.

Furthermore, if the DFS requirements removed from the 5.8 Ghz band for indoor W-Fi use case use up to 200 mW EIRP. DFS is a means of protecting radars operating in the 5 GHz band. The system detects transmissions from the radars and requires Wi-Fi devices to switch to a different channel if they detect co-channel radar pulses.

The 5.8 GHz band is not widely available for low-power indoor Wi-Fi use in other European countries. It has, however, been made available for Wi-Fi use without a DFS requirement in a number of countries throughout the world – including US and Canada, where it is heavily used.

At the World Radio Conference 2019 (WRC-19), the Radio Regulations were amended to allow limited outdoor RLAN use in the 5150-5250 MHz band: up to 200mW with a proviso to extend up to 1W with controlled use and by implementing antenna masks that limit power in the direction of satellites.

6.3 Opening spectrum for Wi-Fi in the 6 GHz band

RLAN use, including Wi-Fi, is currently authorized in the 2.4 GHz and 5GHz bands. To improve coverage and capacity, lower latency and ease congestion, and view of future innovation, it is best to make the lower 6 GHz 5925-6425 MHz) available for Wi-Fi use.

That the 6 GHz band was suitable to address demand for additional Wi-Fi spectrum for three principal reasons:

a) The large amount of contiguous spectrum available would allow for wide, non-overlapping channels with the same technical conditions;

b) The adjacent 5 GHz band is already widely used for W-Fi, therefore similarities in the ranges achievable, router and antenna design of the two bands would enable manufactures to invest fewer resources and implement 6 GHz more rapidly in products. This would also mean similar deployment models for infrastructure and routers for operators

c) The 6 GHz band should be used by more efficient Wi-Fi technologies.
From the outset, Wi-Fi 6 has been designed to support large number of users in congested environment through new techniques which results in more efficient use of spectrum, improvement in throughput better latency and less congested environments for Wi-Fi and other RLAN use. This will provide notable benefits in comparison with usage in the 2.4 GHz and 5 GHz bands

6.4 Use case application

The new 6Ghz band mandates a new type of access point infrastructure (AP) whether it's a bookend-type of application (e.g., bridge or backhaul link) or if it's an access type of application (e.g., enabling 6GHz capable clients to connect).
In initial deployments, the WiFi6 MAC upgrades associated with MU-MIMO, MU-OFDMA and BSS coloring will not even need to be invoked to see immediate, massive performance gains; even at low power (250 mW EIRP), the constrained dimensions of an average indoor floorplan (~2600 sq ft) suggest accumulated link losses should not force the negotiated MCS to drop below midgrade levels at worst case. The upshot of this observation is that spectral efficiency should remain high over relatively massive Wi-Fi bandwidths (up to160 MHz)

Low Power use case
With legacy 802.11 indoor radiated power limits permitting more robust levels, it is reasonable to wonder why one might be interested at indoor performance achievable with a very modest 250 mW EIRP for the 6 GHz band. The answer lies in good neighbor coexistence (especially with extant outdoor 6 GHz infrastructure coupled with a desire to be conservatively biased with respect to interference) and the potential for the FCC to partition up the 6 GHz band into "standard-power" (presumably outdoor or outdoor/indoor uses) and "low-power" (indoor) bands in the first place. Of keen interest at the designated low power bands is the ability for indoor CPE to jettison intervention from cloud (or edge) -based interference arbitration schemes associated with the Automated Frequency Coordination (AFC) function (itself bearing some similarity to the CBRS band's Spectrum Access System -- SAS).

Band (MHz)	Primary Allocations	U-NII	Devices	Max Power	AFC
5.925-6.425	Fixed Service FSS	U-NII-5	Standard-Power AP	4W (36 dBm) 30 dbm/6 dBi ant gain (U-NII-1 & 3)	Yes
6.425-6.525	Mobile Service FSS	U-NII-6	Low-Power AP (indoor)	1W (30 dBm) 24 dbm/6 dBi ant gain (U-NII-2a)	No
6.525-6.875	Fixed Service FSS	U-NII-7	Standard-Power AP	4W (36 dBm) 30 dbm/6 dBi ant gain (U-NII-1 & 3)	Yes
6.875-7.125	Fixed Service Mobile Service FSS*	U-NII-8	Low-Power AP (indoor)	1W (30 dBm) 24 dbm/6 dBi ant gain (U-NII-2a)	No

6. Summary

The 6 GHz band provides a magnificent aperture for unlicensed wireless services to grow in a disciplined and future-proofed direction, providing instant relief for the capacity exhaustion and contention-based loss of efficiency occurring in the legacy 2.4 and 5 GHz bands while also delivering a self-installable, low-latency remedy which grants consumers an indoor-propagation-friendly wireless framework with massive, extensible bitrate support. In detached single-family dwellings, just the insertion of a dedicated 6 GHz / WiFi6 wireless trunk from WAN GW to middle-of-the-home extender promises multi-Gbps, interference-free whole-home WiFi coverage. MDU applications at 6 GHz, while more challenging due to the client and BSS densities implied by multiple overlaid networks operating in close proximity, nonetheless will greatly benefit from the 6 GHz spectrum access while barely invoking MU mechanisms in antenna directivity and the two-axes options for transmission data packing afforded by OFDMA. And the rather more friendly confines of single (onefloor) units in these structures mean additional low power backoff (perhaps to 100 mW, or less) can be implemented without concern for compromised services delivery.