6GHz WiFi - The Silver Bullet for Addressing the 1000x Data Challenge Using Unlicensed Spectrum

Introduction

With the explosive growth in data consumption, demand for high-speed WiFi is also growing, driven by new devices, applications and use cases. The rollout of WiFi 6 technology is happening at a very opportune time. However, WiFi 6 technology may not be able to address the challenge on its own and regulatory interventions are also required.

Widespread use of WiFi across the world has been made possible by the availability of unlicensed spectrum in 2.4GHz and 5GHz bands. However, this has also become its Achilles heel. By definition, unlicensed bands can be used by any device/technology as long these conform to the rules. As a result, in addition to WiFi, the 2.4GHz and 5GHz bands are also used by other systems such Bluetooth, ZigBee, unlicensed 4G/5G, wireless backhaul etc. While regulatory provisions ensure co-existence with non-WiFi systems, there can be significant impact on end user experience due to network congestion. Furthermore, high throughput applications require wider channels. While WiFi does support 80MHz and 160MHz channel bandwidth, given the relatively small amount of unlicensed spectrum coupled with restrictions on the use of so-called DFS channels, it is not feasible to use 80/160MHz channels, especially in high/medium density scenarios. Another challenge with current bands is the presence of legacy devices, i.e clients and APs that support older versions of WiFi. As a result, benefits of newer technologies such as WiFi 6 become more difficult to realise in the field since newer APs and clients have to be backward compatible with legacy devices. This adds overhead in the form of legacy headers and also reduces the advantages of new features such as Spatial Reuse, TWT, OFDMA, etc. Due to these reasons, there's an urgent need to allocate more bandwidth for unlicensed use. This will relieve congestion in existing bands and also enable the use of wider channel bandwidths, thus enabling WiFi technology to serve the ever-increasing demand for high-speed wireless connectivity.

The WiFi industry has been considering the 6GHz band as one of the options for future expansion. In fact, the IEEE802.11ax standard was designed to support operation in the 6GHz band. Regulatory bodies like the FCC and CEPT have also been actively discussing proposals to make this band available for unlicensed services. However, due to the presence of incumbent services in this band such as Fixed Satellite Services (FSS), regulations need to be put in place to protect existing users while allowing unlicensed operation.

6GHz Regulatory Framework

The 6GHz band encompasses frequencies between 5.925GHz and 7.125GHz, thereby providing 1200MHz spectrum. This is further sub-divided into 4 sub-bands as shown below.

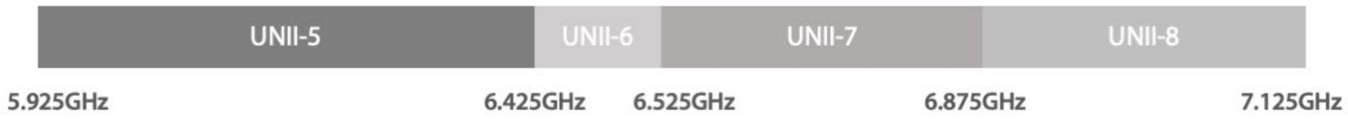

Figure 1: 6GHz Spectrum Band

In the United States, the 6GHz has several incumbent users, across all the 4 sub-bands, as listed in the table below.

Table 1: 6GHz Incumbent Services

Sub-band	Primary Service	Incumbents
UNII-5	Fixed, FSS	Fixed Microwave, FSS (uplinks)
UNII-6	Mobile, FSS	Broadcast, Cable TV Relay, FSS (uplinks)
UNII-7	Fixed, FSS	Fixed Microwave, FSS (uplinks/downlinks)
UNII-8	Fixed, Mobile, FSS	Broadcast, Fixed Microwave, Cable TV Relay, FSS (uplinks/ downlinks)

With the 6GHz band already in use by a variety of incumbent users, operating both fixed and mobile links, making it fully unlicensed like the 5GHz band was out of the question. A balance had to be struck so that unlicensed operation could be allowed while providing adequate protection to the incumbent links.

With these considerations in mind, in its 'Report and Order' (R&O) on April 2, 2020, the FCC allowed unlicensed operations in the 6GHz band, based on the following rules:

1. Unlicensed access points are allowed to operate across the entire 6GHz band at lower power and indoors only.
2. In the UNII-5 (5.925-6.425 GHz) and UNII-7 (6.525-6.875GHz) bands, access points are allowed to operate both indoor and outdoor, at standard power levels same as those currently permitted in the 5GHz band, under the control of an Automated Frequency Coordination (AFC) system.
3. Client devices are allowed to operate across the entire 6GHz band, only under the control of standard power indoor/outdoor or low power indoor access points.

[1] FCC Report and order and further notice of proposed rulemaking, https://docs.fcc.gov/public/attachments/FCC-20-51A1.pdf

[2] Automated frequency coordination: an established tool for modern spectrum management, http://dynamicspectrumalliance.org/wp-content/uploads/2019/03/DSA_DB-Report_Final_03122019.pdf

The table below summarizes the power restrictions for access points.

Table 2: AP Transmit Power Restrictions in 6GHz

Operating Band	Type of AP	Location	AFC	Maximum EIRP (dBm)	Maximum Power Spectral Density (dBm/MHz)
UNII-5	Standard Power	Indoor, Outdoor	Yes	36	23
	Low Power	Indoor	No	30	5
UNII-6	Standard Power	Not Allowed	-	-	-
	Low Power	Indoor	No	30	5
UNII-7	Standard Power	Indoor, Outdoor	Yes	36	23
	Low Power	Indoor	No	30	5
UNII-8	Standard Power	Not Allowed	-	-	-
	Low Power	Indoor	No	30	5

The rules for clients are summarized in the table below.

Table 3: Client Transmit Power Restrictions in 6GHz

Operating Band	Type of Client	Location	AFC	Maximum EIRP (dBm)	Maximum Power Spectral Density (dBm/MHz)
UNII-5	Connected to Standard Power AP	Indoor, Outdoor	No	30	17
	Connected to Low Power AP	Indoor	No	24	-1
UNII-6	Connected to Standard Power AP	Not Allowed	-	-	-
	Connected to Low Power AP	Indoor	No	24	-1
UNII-7	Connected to Standard Power AP	Indoor, Outdoor	No	30	17
	Connected to Low Power AP	Indoor	No	24	-1
UNII-8	Connected to Standard Power AP	Not Allowed	-	-	-
	Connected to Low Power AP	Indoor	No	24	-1

Exempting low power indoor operations from the AFC requirement enables the entire band to be used by WiFi access points, just like the 5GHz band today. Lower Tx power coupled with signal attenuation because of outer walls will provide adequate protection to incumbents from harmful interference.

In the UNII-5 and UNII-7 bands where P2P microwave links are used heavily, standard power APs are allowed to operate both indoor and outdoor under AFC. The purpose of the AFC system is to determine if access points can operate at a given location on a given set of frequencies, without causing harmful interference to existing users. FSS links are protected from interference due to outdoor APs by restricting antenna elevation angles of these devices.

Client devices are allowed to operate only under the control of low power indoor AP or standard power AP. This rules out other modes of operation such as WiFi Direct and ad-hoc connections. Portable access points such as dongles are allowed only as long as these devices are stationary, as mobile APs or clients can lead to unpredictable interference to incumbents.

While FCC has already notified the 6GHz rules, European regulators are focusing only on the UNII-5 band (5.925-6.425 GHz) for Wireless Access Systems (WAS) and Radio LAN (RLAN), as critical services operate in the remaining part of the 6 GHz band. As per the feasibility assessment done by the European Conference of Postal and Telecommunications Administrations (CEPT), WAS/RLAN can coexist with existing services and systems within and adjacent to the designated band under certain conditions. In particular, limiting the EIRP of indoor WAS/RLAN deployment in the range of 200-250 mW would suffice to ensure coexistence with FS and FSS. To protect Communication-based Train Control (CBTC) systems and Road-ITS, additional restrictions such as a guard-band and requirements on WAS/RLAN in-band and/or out-of-band emissions are needed. In light of these restrictions, the available spectrum for WAS/RLAN will be less than the entire UNII-5 band. A final decision is expected to be made towards the end of 2020 or the beginning of 2021.

The option of using LPI devices in the entire 1200MHz band will expedite the introduction of WiFi APs and clients in 6GHz since there is no need for AFC. However, these devices will still need to adhere to all other RF requirements from IEEE802.11 standard. Standard power APs will, in addition to, need to support AFC as well. In the subsequent sections, we discuss these two aspects.

Automated Frequency Coordination

The proposed AFC system will be used to determine the exclusion zones where the operation of standard power APs can cause harmful interference to incumbent links in the UNII-5 and UNII-7 bands. The exclusion zone calculations will use a set of interference protection parameters specified by the FCC, covering the following aspects:

- Propagation models
- Interference protection criterion
- Methodology for addressing adjacent channel operations

The AFC response to an AP query will not be simply Yes/No. Instead, the system will not only be able to inform the AP if standard power operation @36dBm is possible but also, in case operation at 36dBm is now allowed, suggest one or more lower power levels (in steps of 3dB) that can be used by the AP. This flexibility will enable more efficient spectrum utilization. To ensure that AFC spectrum grants take into account any changes in status of incumbent links, APs need to query the AFC system at least once every 24 hours.

The FCC has laid the following requirements for AFC:

- The AFC system will be based on a centralized model where each standard-power AP will query the system to get a list of available frequency ranges in which it is permitted to operate and the maximum permissible power in each frequency range.
- Standard-power APs will have to share geo-location data (AP coordinates and antenna height) with the AFC system which will use it for calculating the availability of frequencies and channels of operation.
- The AFC system will use FCC's Universal Licensing System (ULS) for fixed microwave links data to determine the exclusion zones. The AFC system will download ULS data at least once a day to keep its local database up-to-date.

As mentioned above, an AP will be required to provide its coordinates to AFC. If the AP does not have an internal geo-location function, it can use an external geo-location source. This situation may arise, for example, when AP is deployed at locations where internal geo-location capability is not operational. Note that a single geo-location source may provide location information to multiple APs.

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[3] CEPT Report 73: Assessment and study of compatibility and coexistence scenarios for WAS/RLANs in the band 5925-6425 MHz, https://www.ecodocdb.dk/download/0d0696a1-89ae/CEPT%20Report%2073.pdf

[4] REPORT AND ORDER AND FURTHER NOTICE OF PROPOSED RULEMAKING, https://docs.fcc.gov/public/attachments/FCC-20-51A1.pdf

6GHz Support in 802.11ax Standard

The IEEE802.11ax standard has incorporated support for 6GHz operation. An AP that supports 6GHz operation includes the HE 6 GHz Band Capabilities element in its Beacon, Probe Response and (Re) Association Response frames. A client that supports 6GHz mode includes the HE 6GHz Band Capabilities element in its Probe Request and (Re) Association Request frames. Devices operating in the 6GHz band include the 6 GHz Operation Information field in the HE Operation element to provide channel and bandwidth information related to 6 GHz operation.

Legacy protocols will not be supported in the 6GHz band. In other words, only 802.11ax capable devices can operate in the 6GHz band. Hence, a 6 GHz device shall not transmit an HT/VHT Capabilities element, HT/VHT Operation element, VHT Operation element or an HE Operation element that contains a VHT Operation Information field. Furthermore, transmission of legacy PPDUs (HT, VHT, DSSS etc) is not allowed in 6GHz. An AP is allowed to send only a Beacon frame in an HE SU PPDU when operating in the 6 GHz band. These rules enable greenfield 11ax deployment in the 6GHz band.

Deployment Scenarios

The availability of the 6GHz band for unlicensed use provides a tremendous opportunity for the WiFi industry. This will not only drive the use of WiFi for newer use cases but also help relieve issues in current deployments.

In Enterprise deployments, network administrators are averse to using 80MHz channels to avoid co-channel interference and DFS restrictions. However, with more and more enterprise applications moving to the cloud and the increasing usage of video-conference applications such as Zoom and Google Hangouts, the need for more WiFi bandwidth per user in the enterprise is also growing. The traditional approach to address this requirement has been to deploy more APs. However, with more bandwidth available, it is possible to add capacity by increasing the operating bandwidth to 80MHz. In addition, given that 6GHz can be used by 11ax clients only, WiFi 6E APs can initially be used as an overlay network to augment the capacity of existing networks. As the population of 11ax clients grows, the existing APs can be incrementally replaced with WiFi 6E capable APs.

WiFi networks deployed in high-density scenarios such as stadiums, conference and exhibition venues tend to use 20MHz channel bandwidth so as to maximise the number of available channels within the given bandwidth. This often leads to capacity issues when there's a spatio-temporal surge in data consumption. Dynamic bandwidth solutions can help in such a case, but when the number of APs is in the 100s and 1000s, dynamic optimization can be very challenging. The availability of more bandwidth in the 6GHz band will enable the use of wider channels such as 40MHz and 80MHz, even in high-density scenarios.

As the 6GHz-capable client population will be small to start with, the 6GHz radio can also be used for mesh backhaul. With standard power APs capable of operating both indoors and outdoors at powers up to 36dB, high-throughput mesh links can be leveraged to bring down the CAPEX for providing wired backhaul from every AP.

In home scenarios also, with an increasing number of devices per person and a growing number of high-bandwidth applications, 6GHz operation will allow users to enjoy the benefits of more capacity. In particular, with the COVID-19 pandemic resulting in the shifting of the WiFi workload from enterprise/university/school to home, QoS requirements for Home WiFi have become more stringent. In large apartment complexes, the simultaneous use of a large number of APs with saturated duty cycles, coupled with uncoordinated channel, bandwidth and power, can potentially result in significant performance issues. The availability of a larger number of channels can mitigate this problem to a large extent. Furthermore, in bigger homes, where multi-AP deployment is necessary, 6GHz radios can be used for creating a mesh of APs.

Newer applications such as AR/VR require significantly higher bandwidth and ultra-low latency. According to a Qualcomm study, immersive AR/VR will require bandwidths in the order of 10s to 100s of Mbps. Similarly industrial IoT applications such as Factory Automation will mean the deployment of a large number of sensors and remotely-operated machines, equipped with audio-visual capabilities, going beyond the typically low-bandwidth IoT sensors of today. 6GHz spectrum is uniquely placed to meet these requirements.

Implementation considerations

In addition to the wide spectrum available in the 6GHz band, a key benefit of 6GHz WiFi is the unburdening from backward compatibility. While peak data rates for WiFi have been increasing at a steady rate, the biggest hurdle to the real throughput of WiFi networks keeping pace with the peak rate increases is the maintenance of backward compatibility with earlier standards. 802.11ax is the only standard that is supported in the 6GHz band; this ensures that 6GHz WiFi does not have to share spectrum and be backward compatible with legacy 802.11 standards, increasing the spectral efficiency and hence guaranteeing higher real throughput.

Enterprises have traditionally been early adopters of new standards, with residential and personal use following once the price points become more economic. However, since 802.11ac Wave 2 and 802.11ax, personal and residential use have been in the forefront of technology adoption. As discussed earlier, home use scenarios with increasing device density, and increasing data hunger in applications like AR/VR and IoT coming to home appliances will drive the need for 6GHz in home and private networks.

Like with all other technology advancements, the 6GHz WiFi will be embedded initially only in high end devices; mass adoption will follow. On the infrastructure side, creating mesh links over 6GHz or 5GHz radios has been put forward as a way to address connectivity in large homes that require multi AP deployments; however, in cases where quality links cannot be established for mesh (because of building material or placement of APs), an upgrade to multiGig Ethernet (and in some cases even cabling) will be required to ensure that the promised throughput is achieved, especially between devices connected to different APs.

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Standard power indoor/outdoor APs also have the additional burden (and cost) of AFC. While AFC rules have been specified, AFC providers are just starting out and AFC will refine over time. Standardisation of the AFC-AP interface is being undertaken by the WiFi Alliance.

[5] VR and AR pushing connectivity limits, https://www.qualcomm.com/media/documents/files/vr-and-ar-pushing-connectivity-limits.pdf

Conclusions

FCC's recent decision on making the 6GHz band available for WIFi and other unlicensed technologies is a watershed moment in the history of WiFi. This is the biggest swathe of unlicensed spectrum made available in one go. With 1200 MHz available in the 6GHz band for Low Power Indoor devices, there's a tremendous opportunity for the WiFi ecosystem to deploy WiFi 6, without being encumbered by the presence of legacy devices. Other regulators around the world are also taking steps in the same direction and 6GHz band availability is expected to become more widespread around the world in the next couple of years. AFC-based standard power APs can also use parts of the 6GHz band, as per the rules specific by FCC. With both indoor and outdoor deployments allowed for these types of devices, AP vendors can leverage the 6GHz band to address a wide variety of use cases, ranging from ultra high-capacity, small cell scenarios such as stadiums to low-capacity, large cell scenarios such as rural WiFi

Arista's AP portfolio already includes a set of WiFi 6 APs, catering to all the typical use cases. Arista is also investing in expanding its portfolio to include APs capable of 6GHz operation as well. Watch this space for some exciting news in the coming months.

For more information about Arista WiFi, visit https://www.arista.com/en/products/cognitive-wifi.

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