Cambium Networks™

# Wi-Fi 6E: Extend High Efficiency Into a New Frequency

**IN APRIL 2020,** the US FCC voted to allow unlicensed wireless LANs to operate in the 6 GHz band, covering frequencies from 5925 MHz to 7125 MHz. Other regulatory domains have since announced their own plans or intention to adopt rules for their particular country or region. The resulting 1200 MHz is over double the best-case scenario for wireless LAN networks in the past 25 years. Make the most of this opportunity by designing optimal use of the available frequency. Understanding the details will help to get the design right the first time.

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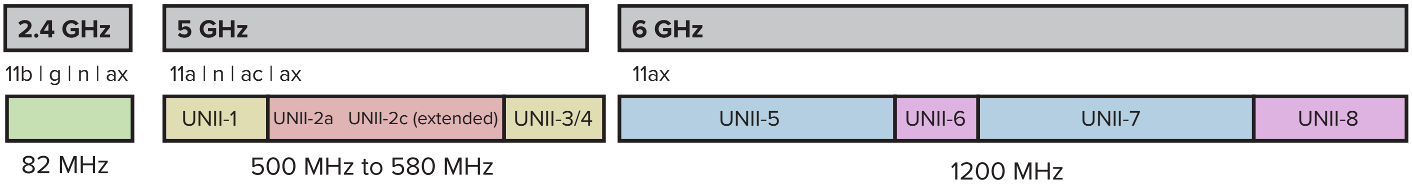
Not all spectrum is available in every domain and not at the same power levels. First, here are the key features of Wi-Fi 6E followed by the regulatory outlook.




## Up to 1200 MHz of New Spectrum

The newly available spectrum is the headline feature of the 6 GHz band. In contrast, the 5 GHz band has approximately 500 MHz (in most domains) of frequency, where over 300 MHz of it is locked up by Dynamic Frequency Selection (DFS) access rules. The existing spectrum in the 2.4 GHz and 5 GHz bands are shared with legacy devices and protocols that existed from the late 1990s. Continued backward compatibility is one of the barriers that prevents Wi-Fi capacity from reaching a new orbit.

### Wireless LAN Class

Three classes of a wireless LAN are defined. Each serves a particular purpose and has its own set of rules.

- **Low Power Indoor (LPI).** This is the most common category and likely the one that will be most commonly deployed. For most regulatory domains, LPI is allowed for indoor Wi-Fi networks without registration or license. LPI will have a maximum transmit power defined by the regulatory agency. For example, the US FCC will allow 30 dBm whereas the European Union will allow 23 dBm.

    - Access points are not allowed to be built into environmentally hardened enclosures or operate on battery power. The access point will only use internal antennas. These rules help to ensure that LPI access points remain indoors and abide by the regulatory EIRP limits.
    - Carrier-sense multiple access with collision avoidance (CSMA/CA) and Listen Before Talk (LBT) will be used to further ensure that the LPI access point will not interfere with a nearby licensed service.
    - Client-to-client networks are not allowed. Mobile client devices can be moved from indoors to outdoors where interference is more likely. Thus, ad hoc wireless LANs are not allowed under these rules. Mobile client devices will transmit at a lower EIRP than the access point, typically 6 dB lower than the access point.
    - Mesh nodes will support the same power level and rules as the LPI access point.
    - Power Spectral Density (PSD) is 5 dBm/MHz for the access point.
- **Standard Power (SP).** This category will allow up to 36 dBm of transmit power but will require authorization from a central service called Automatic Frequency Coordination (AFC). The AFC service for each regulatory domain will inform the standard-power AP or fixed client of its allowed frequency based on the incumbent users of the same frequency that may be in the same geographic area. Refer to the section on AFC for details on how this system will operate.
    - Access points or fixed clients can be built into environmentally hardened enclosures and may use external antennas.
    - AFC ensures that the SP access point or fixed client will not interfere with a nearby licensed service.
    - Mobile client devices will transmit at a lower EIRP than the access point, typically 6 dB lower than the access point.
    - Power Spectral Density (PSD) is 23 dBm/MHz for the access point and a fixed client connected to the access point.
- **Very Low Power (VLP).** Very low power is often defined at 14 dBm maximum transmit power. For many regulatory domains, this category will support wide channel widths for very high bandwidth applications such as wireless display controllers, augmented reality and virtual reality. At this time, US FCC rules do not include VLP. Other regulatory domains allow the VLP class to be used indoors or outdoors.

# Changes to the Way Maximum EIRP Is Applied

Effective isotropic radiated power (EIRP) is the maximum transmit power including all streams, antenna gain and less antenna cable loss. The access point power limit is the lower value of either the PSD or the regulatory domain's defined maximum EIRP. The following examples will apply to sub-bands in various regulatory domains around the globe. Not all regulatory domain limits are shown in these examples, so it is imperative to check local regulatory domain limits and adjust as needed.

**Standard Power (SP) Class 6 GHz Access Point or Fixed Client**

The SP class in the 6 GHz band has the same maximum allowed PSD and maximum EIRP as the Wi-Fi 6 standard running in 5 GHz band. The PSD is 23 dBm/MHz. We can calculate the SP class EIRP of a 20 MHz channel using the formula:

EIRP = [PSD limit in dBm/MHz] + 10log[channel bandwidth]

EIRP = 23 + 10log[20]

EIRP = 23 + 13

EIRP = 36 dBm on a 20 MHz channel

**Table of SP PSD and Maximum Allowed EIRP**

| Bandwidth (MHz) | 10log[BW] | SP PSD Limit (dBm/MHz) | Calculated PSD EIRP (dBm) | SP Max EIRP (dBm) |
|---|---|---|---|---|
| 20 | 13 | 23 | 36 | 36 |
| 40 | 16 | 23 | 39 | 36 |
| 80 | 19 | 23 | 42 | 36 |
| 160 | 22 | 23 | 45 | 36 |

When we calculate the PSD EIRP for all channel widths, the values increase by 3 dB at each step. However, in the 5 GHz band and the 6 GHz SP class, the maximum allowed by any regulatory domain is 36 dBm. Thus, even if the PSD EIRP increases, it is restricted by the regulatory domain to 36 dBm.

**Table of SP SNR With Common RSSI and Noise**

| BW (MHz) | RSSI (dB) | Noise Floor (dB) | Resulting SNR (dB) |
|---|---|---|---|
| 20 | -65 | -90 | 25 |
| 40 | -65 | -87 | 22 |
| 80 | -65 | -84 | 19 |
| 160 | -65 | -81 | 16 |

Another factor to consider is the impact on signal-to-noise ratio (SNR). As channel width doubles, the noise floor rises by 3 dB. Thus, the SNR starts out high but degrades as the channel width increases. Suppose there is a network with a measured received signal strength indicator (RSSI) of -65 dB and a noise floor of -90 dB. This chart shows how the SNR degrades as the channel width increases.



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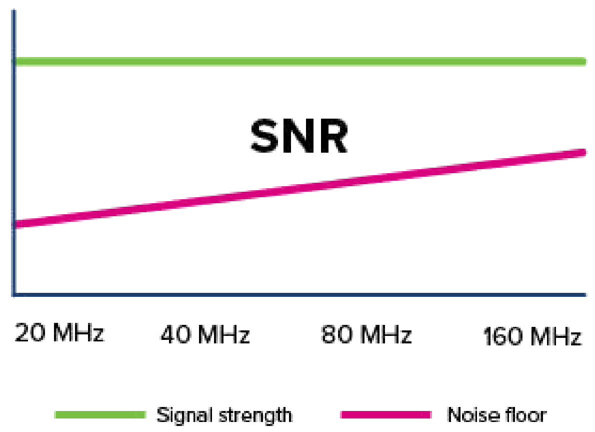
**SP SNR Degrades as the Channel Width Increases**




**Low Power Indoor (LPI) Class 6 GHz Access Point**

For the LPI class of wireless LAN, the PSD of 5 dBm/MHz is lower than previous generation of Wi-Fi and lower than the SP class.

We can calculate the LPI class EIRP of a 20 MHz channel using the formula:

EIRP = [PSD limit in dBm/MHz] + 10log[channel bandwidth]

EIRP = 5 + 10log[20]

EIRP = 5 + 13

EIRP = 18 dBm on a 20 MHz channel

When we calculate the PSD EIRP for all channel widths, the values increase by 3 dB at each step. Note how the PSD EIRP increases, starting from 18 dBm up to 27 dBm. LPI networks are limited by the PSD, not by the maximum allowed EIRP in the regulatory domain.

**Table of LPI PSD and Maximum Allowed EIRP**

| Bandwidth (MHz) | 10log[BW] | SP PSD Limit (dBm/MHz) | Calculated PSD EIRP (dBm) | SP Max EIRP (dBm) |
|---|---|---|---|---|
| 20 | 13 | 5 | 18 | 30 |
| 40 | 16 | 5 | 21 | 30 |
| 80 | 19 | 5 | 24 | 30 |
| 160 | 22 | 5 | 27 | 30 |

Following the same example as above, a 6 GHz LPI-class network has a measured RSSI of -65 dBm and a noise floor starting at -90 dB. Since the LPI-class PSD increases by 3 dB at each step, the resulting SNR remains constant.



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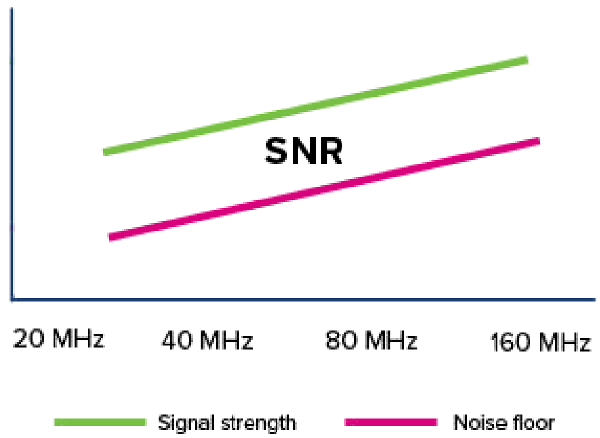
**Table of LPI SNR With Common RSSI and Noise**

| BW (MHz) | RSSI (dB) | Noise Floor (dB) | Resulting SNR (dB) |
|---|---|---|---|
| 20 | -65 | -90 | 25 |
| 40 | -62 | -87 | 25 |
| 80 | -59 | -84 | 25 |
| 160 | -56 | -81 | 25 |

**LPI SNR Remains Constant as the Channel Width Increases**




### Asymmetry in the Client EIRP

The maximum allowed EIRP for a client connected to the AP will be 6 dB lower. In practice, this asymmetry is already very common as physical space and power will limit or preclude the use of higher-transmit power.

| Class | AP EIRP* | Client EIRP* | Sub-Band* | Notes |
|---|---|---|---|---|
| **Standard Power (SP)** | 36 dBm | 30 dBm | UNII-5, 7 | Allowed frequency under AFC control |
| **Low Power (LP)** | 30 dBm | 24 dBm | UNII-5, 6, 7, 8 | |
| **Very Low Power (VLP)** | - | - | - | VLP not ruled by FCC |

** Values shown are from the US FCC rules. Each regulatory domain sets the rules to ensure compatibility with incumbent services sharing the same band. Check individual domain and country rules to see what is applied in other areas.*

## Protect Incumbent Users of 6 GHz Band

Incumbent users generally fall into one of three categories:

- Fixed Microwave Services
- Mobile Services
- Fixed Satellite Services

Each global regulatory agency is adopting rules that will allow both wireless LAN networks and incumbent users to share the same spectrum.

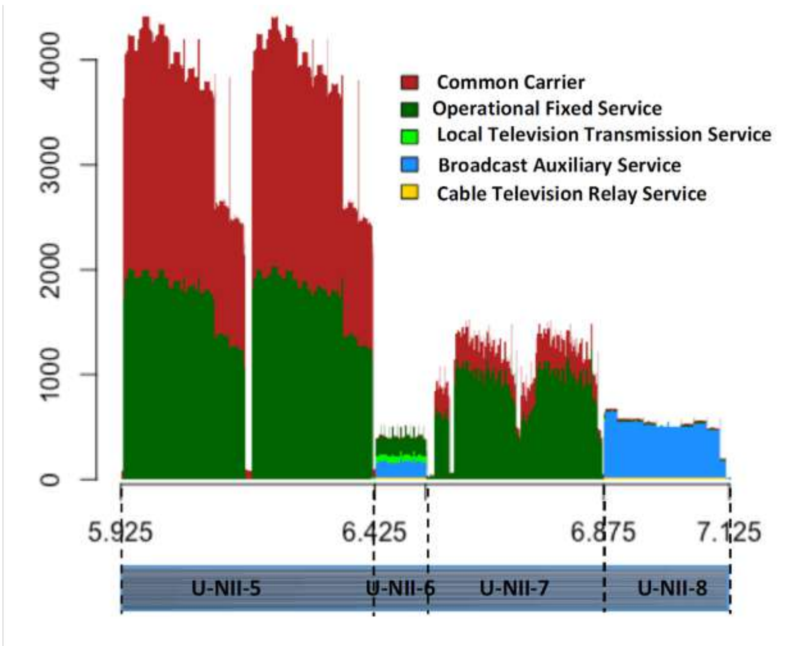



*Figure 1. Assignment Density*

Density of assignments per Hz, US FCC

https://docs.fcc.gov/public/attachments/FCC-18-147A1_Rcd.pdf

| UNI Sub-Band | Spectrum | Primarily Used For | Allowed Wireless LAN* |
|---|---|---|---|
| UNII-5<br>UNII-7 | 500 MHz<br>350 MHz | Fixed Service<br>Fixed Satellite Service | LPI<br>SP allowed under AFC control |
| UNII-6<br>UNII-8 | 100 MHz<br>250 MHz | Mobile Services<br>Mobile/Fixed Terrestrial Microwave Service | LPI<br>SP not allowed |

** Data shown is from the US FCC rules. Individual country and regulatory domain restrictions apply, e.g., Canada allows SP in UNII-6 and most of UNII-8, EU will not allow SP, and many domains will allow VLP while the US FCC has not ruled on VLP.*

### Thoughtful Use of 4 Sub-Bands

**UNII-5, UNII-7**

Combined, these sub-bands provide 850 MHz of spectrum predominantly used for Fixed Services and Fixed Satellite Service where the geographic location is known by the regulatory agency.

**Examples:** Carrier backhaul between cellular tower and central office, public/private utilities, railroad coordination and public safety.

**Mitigation and Sharing:** Most regulatory agencies will allow LPI and VLP without requiring coordination by an automated frequency control (AFC) system. SP wireless LANs will require authorization and control from a centralized AFC system. Essentially, the AFC system will allow the SP wireless LAN to transmit in frequencies that will not interfere with a known incumbent provider. In order for the AFC system to make the geographically specific frequency allocation, outdoor wireless LANs will include a GPS receiver to report the access point location.

**UNII-6, UNII-8**

Combined, these sub-bands provide 350 MHz of spectrum. However, in many regulatory domains these sub-bands are used by mobile Broadcast Auxiliary Service (BAS) and Cable TV Relay Service (CARS). In the UNII-6 band, these services are most often mobile, providing a temporary program uplink of news, sports or events. In UNII-8, these systems can be either fixed or mobile. In either case, these systems are not allowed to broadcast directly to the subscriber. Rather, they must relay the programming through an intermediary broadcast studio and transmission medium that is licensed for subscriber communication.

**Examples:** Local TV station broadcasting a newsworthy event. Fixed PTP microwave link from a professional sports arena to a local broadcast studio.

**Mitigation and Sharing:** Since the mobile services are moving around and often temporary, most regulatory domains will not allow SP wireless LANs to share this spectrum. LPI and VLP wireless LANs will be allowed to operate in these sub-bands.

## Automatic Frequency Control (AFC)

Due to the mobile nature of the incumbent services in the UNII-6 and UNII-8 sub-bands, they are particularly vulnerable to interference. For these sub-bands, regulatory domains will not allow an LPI or SP device to operate outdoors. Some regulatory domains will allow VLP class to operate indoors or outdoors in UNII-6 and UNII-8.

For the UNII-5 and UNII-7 sub-band, each regulatory domain will require that the SP-class access point or fixed client will be controlled by an AFC system. The sole purpose of the AFC is to protect the incumbent users of the 6 GHz sub-band. Commercial AFC operators are licensed by the regulatory domains with communications between the SP-class device and the AFC proxied by the wireless LAN vendor.

A mobile wireless client that connects to an SP-class Wi-Fi AP will transmit 6 dB lower than the EIRP of the AP. It will not be required to register with the AFC. The power asymmetry between the SP-class Wi-Fi AP and a mobile client will mitigate interference with incumbent 6 GHz microwave systems. A fixed wireless client that is part of a fixed wireless LAN broadband network will register with the AFC in the same way as an SP-class AP.

Using the US FCC as an example, the communication flow for an SP-class AP or fixed client under control of an AFC works like this:

- AFC system retrieves information about licensed services in UNII-5 and UNII-7 sub-bands from FCC ULS databases. AFC databases are synchronized on a daily basis.
- The SP access point or fixed client sends an Available Spectrum Inquiry Request with its FCC ID, serial number, GPS coordinates and antenna height to the AFC. The FCC ID and serial number will be useful in identifying the Wi-Fi vendor and product to enforce SP-class rules.
- The AFC queries a database of known licensed microwave systems (in the US FCC domain, this is the Universal Licensing System) and calculates an interference model for the location of the SP-class access point or fixed client.
- The AFC sends back the Available Spectrum Inquiry Response with a set of frequencies and maximum EIRP levels that are acceptable in that geographic location.
- Within the allowed spectrum, the SP-class access point or fixed client can select its channel and operate similarly to the 5 GHz band. Note that there is no spectrum coordination between unlicensed devices provided by the AFC.

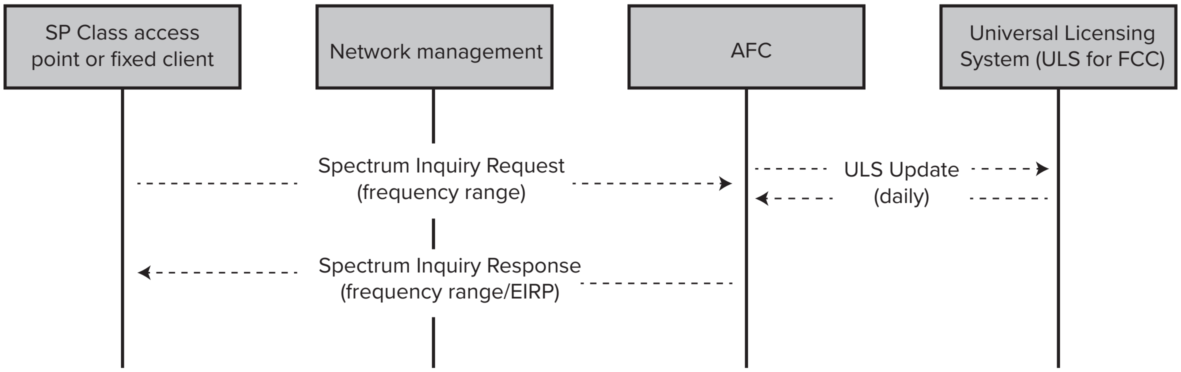
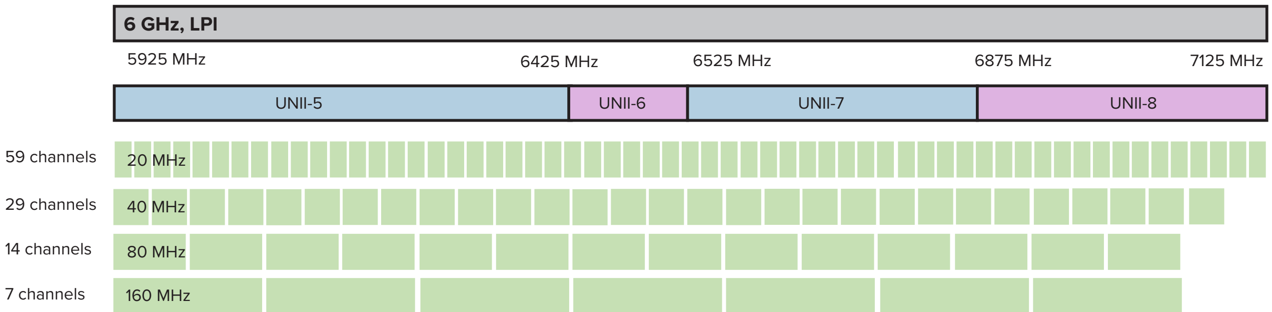



*Figure: Communication flow in an AFC controlled system*

# Network Design Considerations

### Channel Width

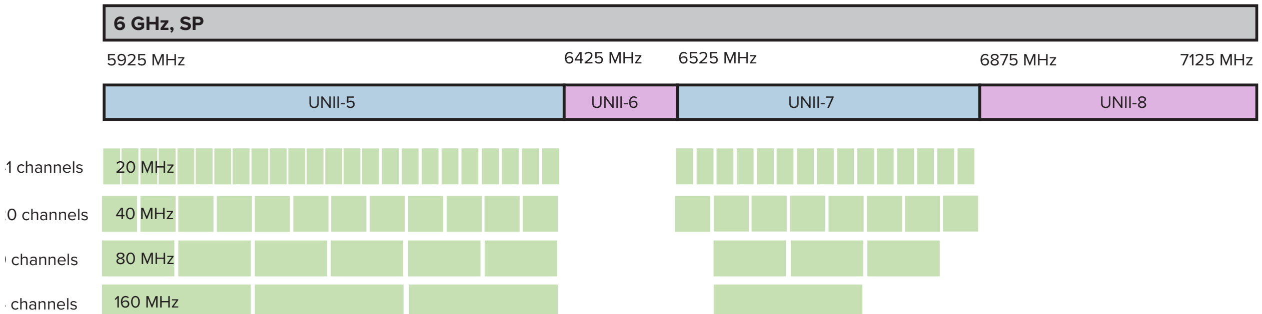
The 6 GHz band will be deployed using wider channels for two reasons. First, the 1200 MHz of contiguous frequency is shown in the graphic below. Second, the LPI rules reward using wider channels by increasing the EIRP as the channel width increases. Allocate channels according to the capabilities of the connected client. Note that 160 MHz is not often supported by client devices. The channel capacity of a single 80 MHz channel will be 600 Mbps per stream at MCS 11. A four-stream Wi-Fi 6E will have a maximum channel capacity of 2400 Mbps at 80 MHz. All things considered, 80 MHz and 160 MHz channel widths are likely to be very popular in the 6 GHz band.




As described above, the LPI class has a lower EIRP than the previous generation of Wi-Fi technology, and it is lower than the SP class. This will necessitate a change in the network architecture for larger Wi-Fi networks, requiring a higher density of LPI access points to propagate the same SNR to the wireless clients. The tradeoff is significantly higher throughput, greater client density and a better user experience.

Indoor SP follows the same PSD and current 5 GHz rules. Thus, most of the current network design processes will be the same, with two exceptions. The 6 GHz band will have an average of 2 dB greater path loss, and the SP class will require AFC control.

The outdoor SP class will also require AFC control and follows the same PSD as current 5 GHz rules. Outdoor is likely to use a 20 MHz or 40 MHz channel to get a balance of reduced co-channel interference and high SNR.




### Increased Path Loss

The RF path loss difference between 5150 MHz and 7125 MHz is 2.8 dB due to the higher frequency. As the channel delta gets closer, the RF path loss will decrease. For example, the delta between 5500 MHz and 6500 MHz is 1.45 dB. For safety, assume a link budget reduction of 2 dB versus a 5 GHz network.

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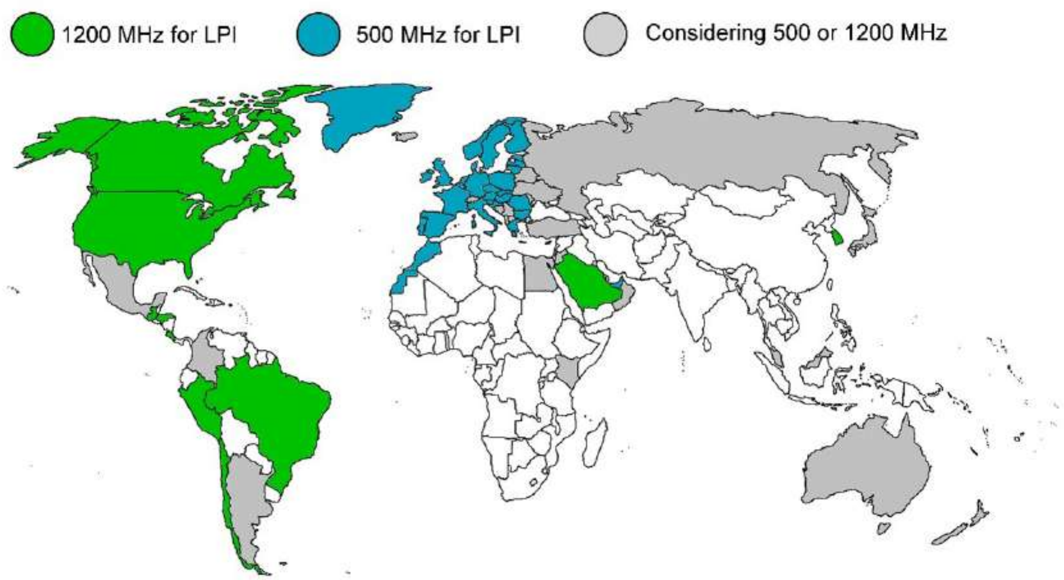
## Regulatory Status

Around the globe, regulatory domains are considering how to respond to the increased demand for high bitrate and high-quality Wi-Fi networks. The regulatory domains are considering three factors: how much spectrum to allocate, power level and access rules. This graph illustrates the current status of the allocated spectrum.




The following table shows the global status of power levels and access rules as of this writing. We expect updates to the global view and detailed table as 2022 progresses.

| | LPI (AP) | SP (AP) | VLP (AP) | Notes |
|---|---|---|---|---|
| Europe | 23 dBm | No plans | 14 dBm | 500 MHz UNII-6 |
| US | 30 dBm | 36 dBm | TBD | Commercial work is being done on an AFC-compliant system similar to CBRS |
| Canada | 30 dBm | 36 dBm | 14 dBm | 1200 MHz LPI, up to 30 dBm<br>900 MHz SP, up to 36 dBm |
| Brazil | 30 dBm | TBD | 17 dBm | Released Public Consultation 82 for industry input |
| Costa Rica | 30 dBm | TBD | 14 dBm | 1200 MHz for LPI |
| Mexico | 30 dBm | 36 dBm | 14 dBm | 1200 MHz for LPI, SP require AFC.<br>Tx power is still under consideration |
| Guatemala | 30 dBm | TBD | TBD | 1200 MHz for LPI |
| Honduras | TBD | N/A | TBD | 1200 MHz for LPI, Tx power TBD |
| Peru | 30 dBm | 36 dBm | 14 dBm | 1200 MHz for LPI, SP require AFC |
| Morocco | 23 dBm | No plans | 14 dBm | 500 MHz UNII-6 for LPI and VLP |
| Norway | 23 dBm | No plans | 14 dBm | 500 MHz UNII-6 |
| South Korea | 30 dBm | 36 dBm | 14 dBm | 1200 MHz for LPI |
| UK | 24 dBm | No plans | 14 dBm | 500 MHz UNII-6 |
| Saudi Arabia | 23 dBm | No plans | 14 dBm | 1200 MHz UNII-6 |
| United Arab Emirates | 24 dBm | No plans | 14 dBm | 500 MHz UNII-6 |





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## Conclusion

Wi-Fi 6E opens up new opportunities in every market and addresses the demand for high-quality Wi-Fi. It does this by expanding the available spectrum up to an additional 500 MHz or 1200 MHz, by restricting use to the 802.11ax protocol and by simplifying the access mechanism with AFC. At the same time, Wi-Fi 6E rules protect existing services that are using the 6 GHz band, thus enabling a wider range of uses for this important upper mid-band frequency.



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