Best Practices for Wi-Fi 6E (Tri-Band) including Voice, with Aruba WLAN Infrastructure

ZEBRA

Best Practices Guide

MN-004733-01EN Rev B

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Introduction

This Guide is designed to provide recommendations of deployment best practices of 6GHz radio band with co-located AP Infrastructure and the following Zebra mobile computers:

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Wi-Fi 6E is an extension of Wi-Fi 6 (also known as 802.11ax), which enables the operation of features in the 6GHz band, in addition to the existing 2.4GHz and 5GHz bands. The 6GHz frequency band provides additional spectrum to increase the efficiency and performance for the growing density needs of Wi-Fi devices.

The 6 GHz radio band provides greater capacity and better performance with higher data rates and low delays for a better overall user experience. In addition to the existing features available under Wi-Fi 6 standard, such as Uplink/Downlink MU-MIMO, OFDMA and TWT, Wi-Fi 6E supports Multiple BSSID functionality, Reduced Neighbor Report, greater number of channels, and wider Channel Widths.

The combined benefits of the Wi-Fi 6E features, utilized in the 1200MHz additional spectrum, enable boosting applications performance and quality in enterprise use-cases, while the connected device is roaming around in the ever-dynamic Wi-Fi environment, such as Retail, Healthcare, Education, Manufacturing and Warehousing.

Device Settings

This section lists the default, supported, recommended settings, and configuration information a user needs for deploying a 6GHz network with Zebra devices.

Table 1 Default, Supported, and Recommended Device Settings for a 6GHz Deployment

Feature	Default Configuration	Supported Configuration	Recommended for 6GHz Deployment
ChannelMask_2.4GHz	1-11	1-11	As default
ChannelMask_5.0GHz	(36-48), (52-64), (100-144), (149-165)	(36-48), (52-64), (100-144), (149-165)	As default
ChannelMask_6.0GHz	(1-93), (97-113), (117-181), (185), (189-233)	(1-93), (97-113), (117-181), (185), (189-233)	As per country-specific allowed PSC Channels
Band Selection	Auto/all channels	• Auto/all channels • 2.4GHz • 5GHz • 6GHz • 2.4GHz and 5GHz • 2.4GHz and 6GHz • 5GHz and 6GHz	• Auto/all channels OR • 2.4GHz and 6GHz OR • 5GHz and 6GHz
Band Preference	Prefer 6GHz or 5GHz	• Prefer 5GHz • Prefer 2.4GHz • Prefer 6GHz or 5GHz • Prefer 5GHz band over 6GHz • Disable	As default
Power Save	TWT for Wi-Fi6	• Always active (CAM) • WMM-PS • Null Data Power Save (NDP) • PS-POLL • TWT for Wi-Fi6	As default

Table 1 Default, Supported, and Recommended Device Settings for a 6GHz Deployment (Continued)

Feature	Default Configuration	Supported Configuration	Recommended for 6GHz Deployment
11k	Enable 802.11k Lite	• Disable • Enable 802.11k Lite • Enable 802.11k Full	As default
11w	Capable	• Required • Optional (Capable) • Disable	As default
11v	Enabled	• Enable • Disable	As default
PMKID	Disabled	• Enable • Disable	As default
FT	Enabled	• Enable • Disable	As default
FT Over DS	Enabled	• Enable • Disable	As default
Channel Width	20/40/80/160	20/40/80/160	As default
Call Admission Control	Enabled	• Enable • Disable	As default

Target Wake Time

The Target Wake Time (TWT) feature provides the solution for dense environments by minimizing contention between STA's and optimizing the power consumption by reducing the STAs awake time.

Zebra devices use certain traffic conditions to negotiate the TWT sessions dynamically with APs and optimize the awake time of a device, thus improving the device's battery life. By default, TWT is enabled on the Zebra device. If your infrastructure is configured for TWT, the Zebra device uses TWT or will revert to the legacy power save method Null Data Packet (NDP).

11k Lite

11k Lite configuration allows the disabling of the 11k measurement features (Link Measurement and Beacon Measurement and others), while keeping only the Neighbor Report feature enabled. Zebra devices advertise only Neighbor Report during initial connection and while roaming across the APs

11k Full

11k Full configuration allows the enabling of all the 11k features supported by a Zebra device.

Zebra devices support the following 11k features which are used by APs to identify traffic/environment conditions of a client device.

- Link Measurement
- Neighbor Report
- Beacon Passive Measurement
- Beacon Active Measurement
- Beacon Table Measurement

Channel Width

- Zebra devices support all channel widths, including 20//40/80/160MHz.
- 6GHz band provides 59 additional 20MHz channels, 29 additional 40MHz channels, 15 additional 80MHz channels, and seven additional 160MHz channels.
- Wider channel widths, preferably 80MHz, are recommended to provide an advantageous user experience.

Band Preference

When operating in a co-located environment, Zebra devices intelligently select and move between available band/channels based on Received Signal Strength Indicator (RSSI), channel utilization, and other factors. By default, Zebra devices use Prefer 6GHz or 5GHz configuration. For example, Zebra devices prefer to stay on a 6GHz configuration when operating in a co-located environment, provided it meets certain RSSI, channel load, conditions, and other factors.

Country-Specific Allowed Preferred Scanning Channels (PSC)

The channels configuration on the device (also known as channel mask) should match the channel deployment at the customer site.

For the 6GHz band, it is recommended that you only deploy PSC channels. The number of available PSC channels depends on the country of operation.

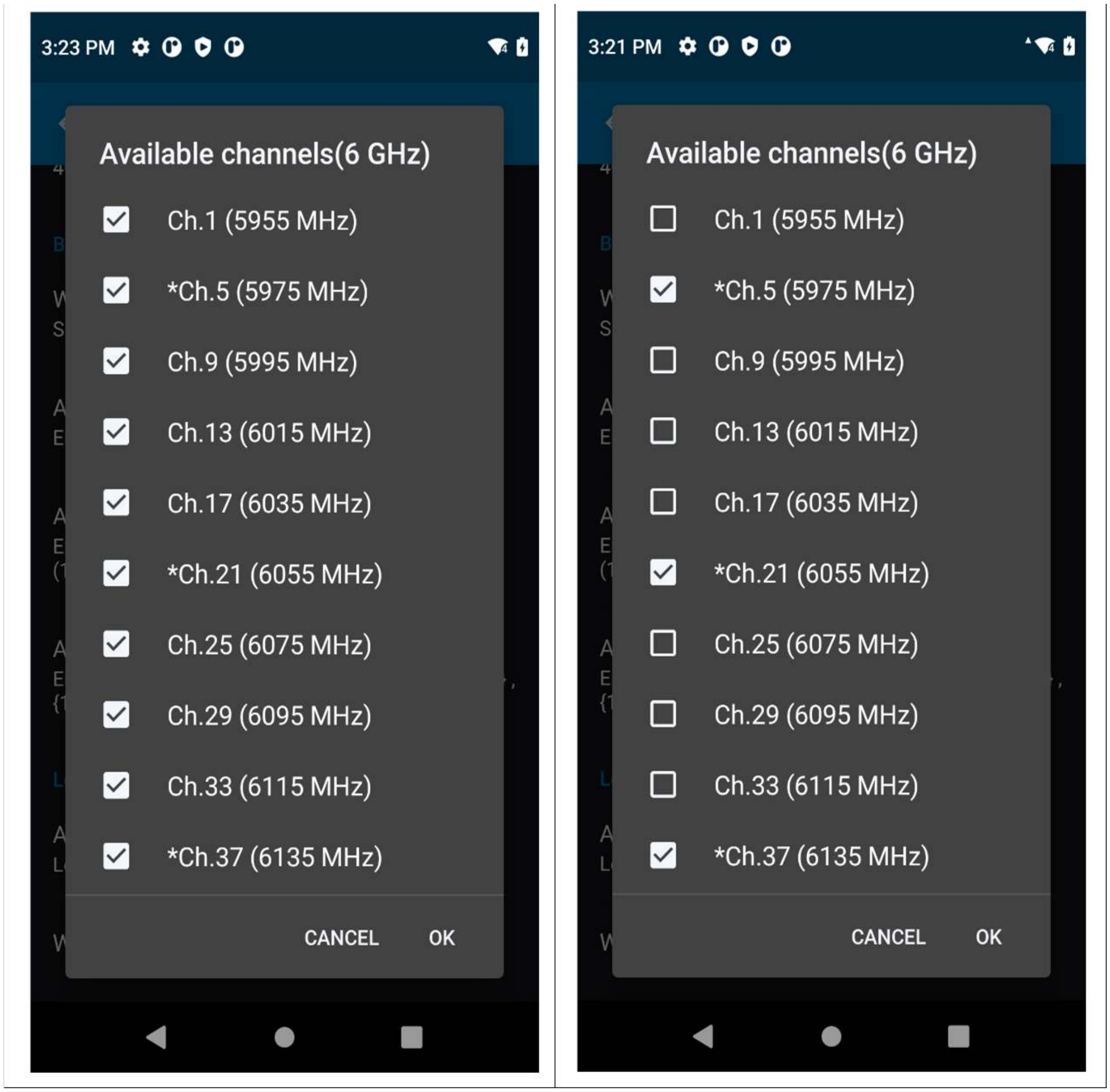
In any case, if PSC-only or also non-PSC channels are deployed, the device uses a standard mechanism of Reduced Neighbor Report (RNR) to discover the 6GHz channels.

Please refer to List of Channels for the complete list of PSC channels available in each sub-band.

Please refer to the following website for the list of countries that have enabled the 6GHz band and the specifically approved sub-bands: wi-fi.org/countries-enabling-wi-fi-6e

If the configuration of the device channels needs to be verified in the Android UI, use Android Settings to navigate to Network > Wi-Fi > Preferences > Advanced > Additional Settings > Band and Channel Selection > Available Channels (6 GHz). The PSC-listed channels are marked with an asterisk next to the channel number for ease of identification, while the non-PSC are not marked with an asterisk. For example, channel 5 is a PSC channel, so it is shown as *Ch.5 (5975 MHz) to indicate that it is a PSC channel.

Figure 1 6GHz Default and Recommended Channel Selection



Common Infrastructure Setting Recommendations

This section lists a Zebra device's recommended common infrastructure settings and configuration.

Table 2 Common Infrastructure Settings and Configuration

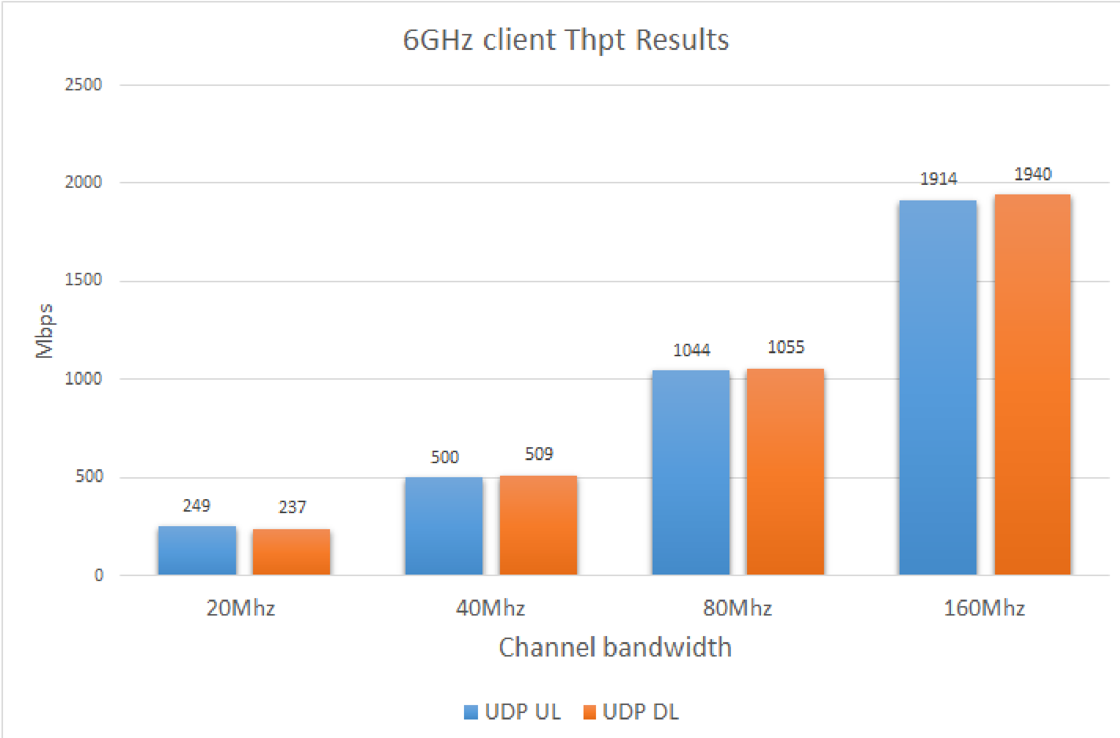
Configuration Parameter	Recommended Settings for Co-Located AP
Channel Width	80MHz
Target Wake Time (TWT)	Enable
Broadcast Target Waketime	Enable
Multiple BSSID	Enable
11k	#
RNR	#
11v	#
Data Rates (Mbps) (for Data Only Deployment)	6GHz Supported Rates: 6(B), 9, 12(B), 18, 24(B), 36, 48, 54 MCS 0-11
Data Rates (Mbps) (for Voice Deployment)	6GHz Supported Rates: 12(B), 18, 24(B), 36, 48, 54 MCS 0-11

Channel Width Settings

The 6GHz band allows network administrators to deploy 14 non-overlapping channels of 80MHz. This number of channels enables flexibility of AP Layout coverage design without the legacy-bands practices which must make compromises on the channel width. This enables the 6GHz WLAN environment to maintain less network congestion, thus yielding better application performance and overall user experience. For this reason, it is recommended to use 80MHz channel widths.

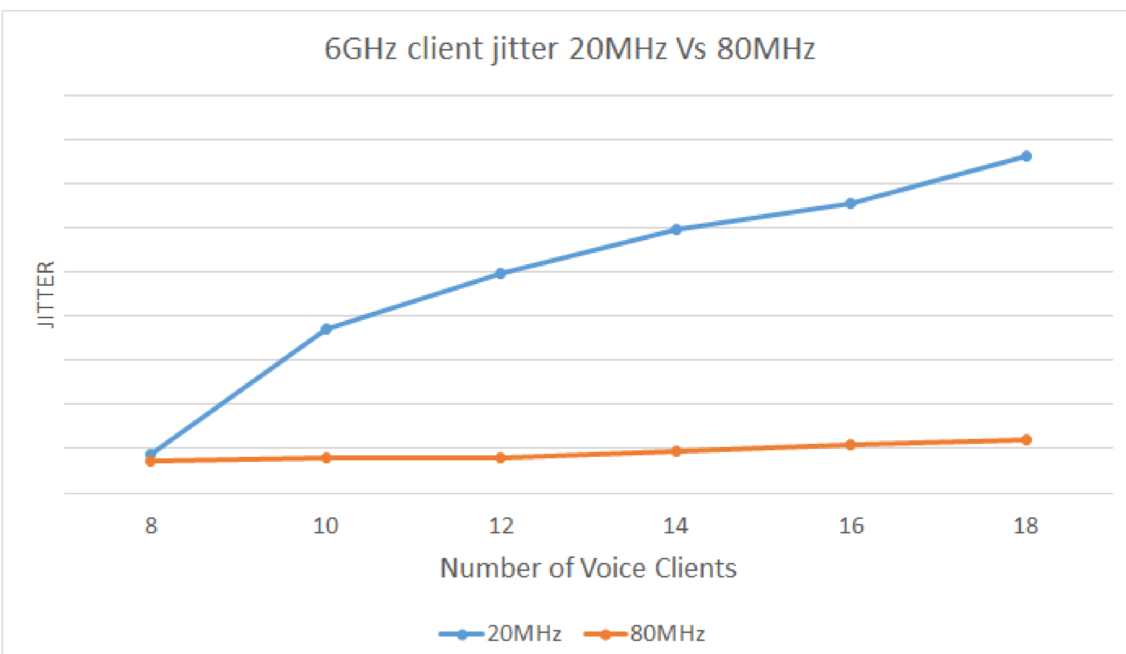
The chart below depicts how the throughput of the 80MHz recommended setting is four times higher than the 20MHz.

Figure 2 6GHz Throughput in Different Channel Width Settings



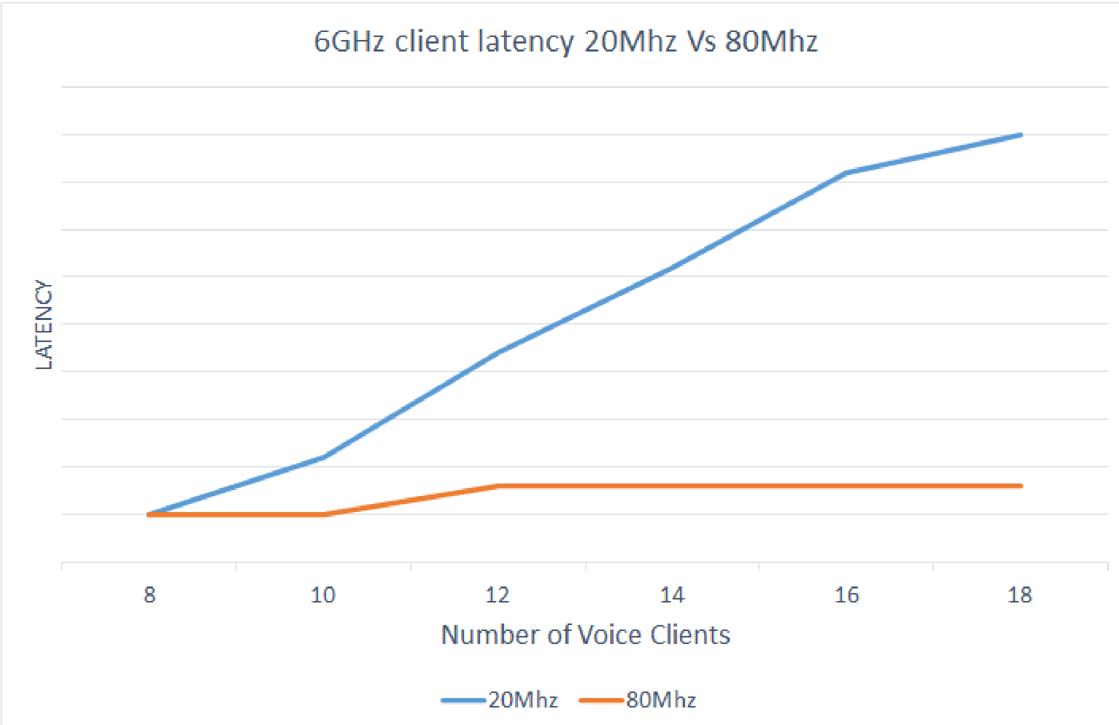
The chart below depicts 80MHz width with packet jitter (in milliseconds) remaining consistently low with an increasing amount of voice clients.

Figure 3 Voice Client Packet Jitter in 20MHz vs. 80MHz



Similarly, the chart below illustrates 80MHz width with packet latency (in milliseconds) remaining consistently low with an increasing amount of voice clients.

Figure 4 Voice Client Packet Latency in 20MHz vs. 80MHz



Target Wake Time

802.11ax (Wi-Fi 6) introduced a new power-saving mechanism called Target Wake Time (TWT). This feature improves the battery life of client devices in dense environments by minimizing contention between STAs, which in turn minimizes packet retries and optimizes power consumption by increasing the STA's sleep time. This is a distinct advantage over legacy power-saving techniques.

In TWT, STA and Access Points negotiate a STA's wake-up time to send and receive data in a negotiated wake interval and remain in a sleep state at other times. The device negotiates specific service periods to communicate with Access Points.

By default, Zebra devices use TWT if the network is configured for TWT. A device sets up a TWT session and switches in and out of TWT mode automatically, based on Tx/Rx traffic conditions.

Multiple BSSID

Multiple BSSID (MBSSID) was originally specified in the IEEE 802.11v and is a mandatory 802.11ax feature for Wi-Fi 6E-capable APs, which supports multiple SSIDs of an AP radio without broadcasting complete beacons for each single SSID configured on an AP.

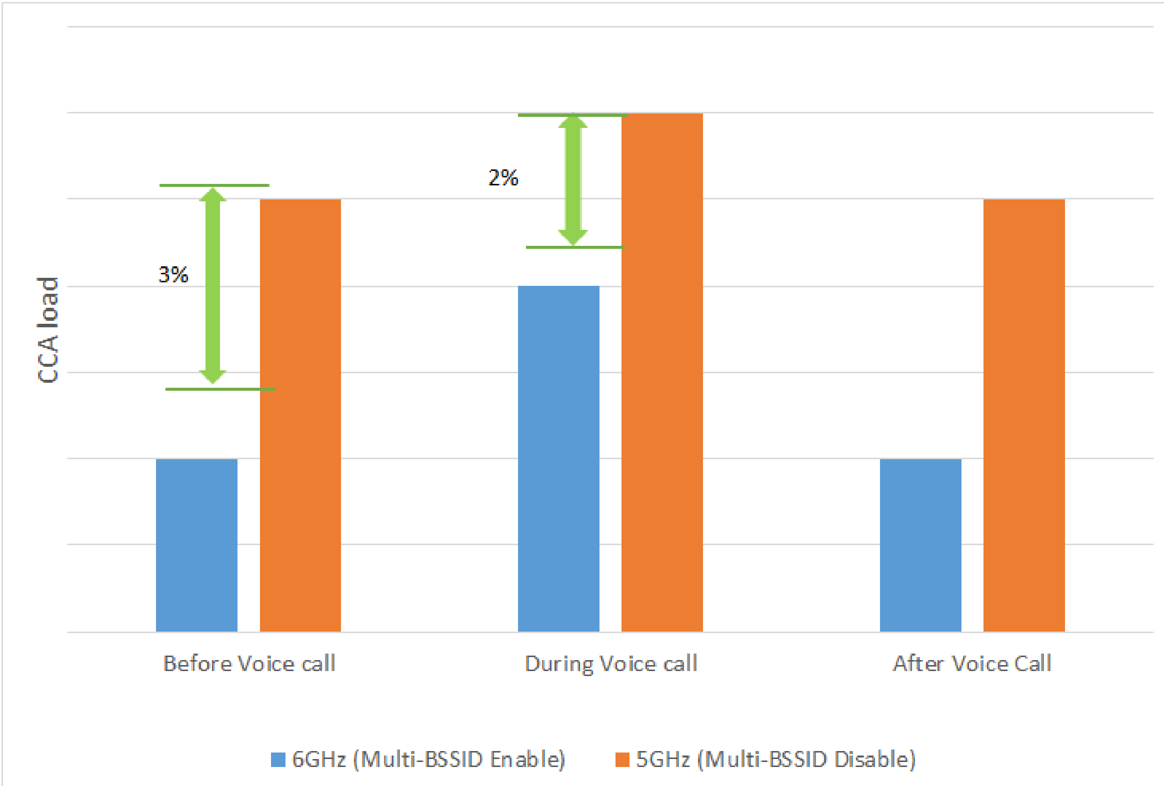
This feature broadcasts information for multiple BSSIDs within a single beacon or probe response frame, instead of multiple beacons or probe response frames, for each corresponding single BSSID. This reduces the RF interference and overhead on air as the APs broadcast lesser numbers of beacons and probe responses.

Clear Channel Assessment (CCA) is a physical carrier-sensing technique used in wireless networks for channel sensing as part of their medium access mechanism. When a Wi-Fi station performs a physical carrier sense, it will listen to the channel to identify whether the channel is occupied with any other RF transmissions.

While CCA itself is implemented at the PHY layer, the primary impact of its performance is on MAC metrics such as throughput, latency, and power efficiency. Higher CCA increases Wi-Fi clients channel contention time to send and receive data on the negotiated channels which affects Wi-Fi Clients performance, for example, lower throughput, high latency, packet loss, and more power consumption etc.. Hence Zebra recommends using multiple BSSIDs.

The chart below depicts the Air Medium Consumption Level measured by CCA load and affected by Multi-BSSID Beacons that are enabled in the 6GHz network compared to the 5GHz network (which does not support this feature). Furthermore, it compares the levels in different traffic scenarios of before, during, and after voice calls. In the following example, the 6GHz and 5GHz networks are configured with 6 BSSIDs.

Figure 5 CCA Load Level Multi-BSSID Enable vs. Disable in Different Traffic Scenarios



Data Rates

To provide reliable coverage, Wi-Fi networks are configured to deliver adequate signal strength in all areas where the Wi-Fi stations will be used.

The required minimum signal strength for all Zebra Devices depends on the frequency band in which it is operating, the data rates enabled on the AP, and the data rate used by the Zebra device while operational.

Zebra devices use automatic rate-switching capabilities so that the Wi-Fi radio adapts and uses lower rates for data transmissions as the device moves away from the AP. This results in increased range when operating at lower transmission data rates.

6 GHz Supported Rates are 6(B), 9, 12(B), 18, 24(B), 36, 48, 54, and MCS 0-11. Based on business use cases such as Retail, Healthcare, Education, Manufacturing, and Warehousing, Zebra recommends adjusting the data rates to help reduce the overhead on the wireless network and improve client performance. For better voice experience, Zebra recommends using 12 Mbps as the minimum bitrate for voice networks.

NOTE: Rate settings may need to change per environmental characteristics to accomplish balanced AP Minimum Coverage.

Aruba Infrastructure Setting Recommendations

This section details the applicable configuration parameters and associated recommended settings specific to the Aruba infrastructure.

Table 3 Parameters and Recommended Settings for Aruba Infrastructure

Configuration Parameter	Recommended Settings for Co-Located AP
Regulatory Domain	Enable
QBSS IE	Enable
HE UL MU-MIMO (disabled by default in Aruba infrastructure)	# (as default)
Downlink OFDMA	# (as default)
Uplink OFDMA	# (as default)
Downlink MU-MIMO	# (if supported by AP Model)
Band Steering (Client Match)	# (as default)

PSC Enforcement

Zebra recommends enabling, if possible, the Preferred Scanning Channels (PSC) Enforcement on the WLAN Controller.

NOTE: Zebra recommends enabling the PSC Enforcement feature, which is disabled by default on the controller. This expedites the controller's ability to find (scan), connect, and roam in the network.

In countries where UNII-5, 6, 7, 8 frequency ranges are enabled, the 6 GHz band provides 59 additional 20 MHz channels. Within those 59 channels, 15 are PSC channels. A Zebra device scanning on all the 59 channels will take 60% more time to complete the scan and find the best available network, compared to scanning on only the 15 PSC channels. Also, the device must scan on legacy bands (both 2.4 GHz and 5 GHz) in an environment where the WLAN supports all bands.

For faster network discovery during initial connection, as well as while roaming, Zebra recommends enabling “PSC Enforcement” option on the controller so the 6 GHz network will utilize 15 PSC channels to optimize the discovery and connection to a network.

In countries where only UNII-5 frequency is allowed, such as countries in the European Union, the WLAN can be operational on up to 24 6GHz channels of 20 MHz width. Within those 24 channels, six are PSC channels. If the WLAN deployment prefers not to enable “PSC Enforcement” such that more channels are operational (due to the UNII limitation), Zebra then recommends that 11k be enabled on the WLAN for optimal network discovery. The RNR discovery mechanism is used under the hood to facilitate the discovery of all the 6GHz channels, PSC and non-PSC alike.

Security Recommendations While Deploying Zebra Clients in 6GHz Network

This section details the various security combinations used in a 6GHz network that are supported by Zebra.

6GHz does not allow open security and WPA2 security combinations. To provide more robust security, 6GHz enforces the use of WPA3 Enterprise, WPA3 Personal, and Enhanced Open security combinations, but does not support backward compatibility for legacy clients. WPA3 Personal is mandatory to be supported by clients operating in a 6GHz network, while Enhanced Open and WPA3 enterprise support is optional.

WPA3 default uses PMF (802.11w) and it is a mandatory requirement for both client and APs, which helps to prevent deauthentication attacks. Zebra Clients supports all three security combinations; WPA3 Enterprise, WPA3 Personal and Enhanced Open, which are described in more detail in this guide.

WPA3 Enterprise

WPA3-Enterprise security is based on WPA2-Enterprise with the additional requirement of using Protected Management Frames (PMF) for WPA3 connections. CCMP-128 and GCMP 256 cipher suites are used for data encryption, and BIP (GMAC-256) cipher suite is used to protect Group Management frames. WPA3 Enterprise 192-bit mode is an optional mode of operation that offers increased security in enterprise networks, and it uses EAP-TLS (certificate-based authentication) and strong cryptographic algorithms. WPA3-Enterprise 192-bit Mode requires support of GCMP-256 for encryption and Signature hash algorithm ECDSA_SHA384 for key derivation.

Radius server and Certificate requirements for WPA3 192-bit mode:

- WPA3 Enterprise 192-bit Mode requires a supported EAP server such as Cisco Identify Service Engine (ISE) and Aruba Clearpass Policy Manager (CPPM), which require 802.1X Authentication type as TLS EAP (EAP-TLS)
- Supported 192-bit cipher suites: TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384; TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384
- The current certificate generation mechanisms (Windows 2019 CA) support RSA key sizes of 512, 1024, 2048, 4096, 8192, and 16384. The 192-bit Mode mandates the use of RSA certificates with the key size >/= 3072 bits. Therefore, while generating the certs, be sure to use 4096 key size certs.

WPA3 Personal

WPA3 Personal uses the Simultaneous Authentication of Equals (SAE) protocol with PMF required, replacing WPA2 Personal with Pre-shared Key (PSK). WPA3 SAE provides more reliable password-based authentication and is resistant to offline dictionary attacks. SAE authentication uses both H2E and HnP methods to obtain the Password Element (PWE) from passwords. Zebra clients supports both H2E and

HnP, however, in 6GHz networks, HnP is disallowed and only H2E is allowed. H2E is mandatory for WPA3 certification in the 6 GHz band. SAE and SAE FT AKMs are supported by Zebra client.

Enhanced Open

Prior to the introduction of the Enhanced Open (EO) security method, network ecosystems that had challenges supporting Passphrase Management architecture, such as Captive-Portal systems, had to choose between either staying Open and completely unsecure, or minimally enabling WPA2-PSK, which could de-stabilize the system. With the introduction of EO based on the Opportunistic Wireless Encryption (OWE) standard, those systems can choose to use EO, which is more robust security than the WPA2-PSK, and with a better fit to the no-Passphrase-Management architecture. This mode uses OWE protocol, which is defined in the IETF document RFC 8110. OWE provides AES(CCMP128) encryption for data privacy, and PMF is required.

Supported WPA3 Combinations in Order of Priority

This section details supported WPA3 combinations and lists them in order of priority in the table below.

Table 4 Supported WPA3 Combinations in Order of Priority

Protocol	Encryption	AKM	Default Config	Supported Config	Recommended for Co-located Environment
WPA3 Enterprise	GCMP 256	SuiteB-192 FT	Enabled	FT	FT
WPA3 Enterprise	AES-CCMP 128	FT 802.1X	Enabled	FT	FT
WPA3 Personal	AES-CCMP 128	SAE FT	Enabled	SAE H2E	SAE H2E
WPA3 Enterprise	GCMP 256	SuiteB-192	Enabled	PMKID	PMKID
WPA3 Enterprise	AES-CCMP 128	802.1X-SHA256	Enabled	OKC	OKC
WPA3 Personal	AES-CCMP 128	SAE	Enabled	SAE H2E	SAE H2E
Enhanced Open	AES-CCMP 128	OWE	Enabled	OWE	As default

Zebra-Recommended WLC and AP Models by Vendor

The following list shows the Zebra-recommended WLC and AP of Aruba models supporting Wi-Fi6E / 6GHz capabilities.

- WLC 7008 and 72xx Series (Software versions 8.9.x, 8.10.x, and 8.11.x)
- AP models 635 and AP655
- IAP model AP635 (Software versions 8.8.x, 8.9.x, and 8.10.x)

Channel and Regulatory Information

This section details the channel and regulatory information for the 6GHz band, including a list of channels, a breakdown of sub-bands, channel width and power spectral density, standard power, low power indoor, and Tx power per channel for 5GHz versus 6GHz.

List of Channels

The 6GHz band covers 1200MHz from 5.925GHz to 7.125GHz.

In the 1200MHz spectrum there are:

- 59 x 20MHz channels
- 29 x 40 MHz channels
- 14 x 80 MHz channels
- 7 x 160 MHz channels

The channels are numbered from 1 to 233. Of the total 59 channels, 15 are designated as PSC channels:

Table 5 PSC Channels

Count	1	2	3	4	5	6
PSC Channel Number	5	21	37	53	69	85
Central Frequency (MHz)	5975	6055	6135	6215	6295	6375

7	8	9	10	11	12	13	14	15
101	117	133	149	165	181	197	213	229
6455	6535	6615	6695	6775	6855	6935	7015	7095

The PSC channels play an important role in discovering the Access Points in the 6 GHz band. When scanning the 6 GHz band, to optimize for scan time a client device usually scans first the PSC channels and if no APs are found, then it scans all the channels. Deploying the APs on the PSC channels improves the probability for the AP to be discovered faster. However, note that the collocated APs use the Reduced Neighbor Report to assist with being discovered while the client device scans the 2.4 GHz or the 5 GHz bands. Please refer to the RNR section below.

Sub-Bands

Table 6 6GHZ Sub-Bands

Name of Band	Frequency (GHz)	Channels	PSC Channel Numbers
U-NII-5	5.925-6.425	1-93	5, 21, 37, 53, 69, 85
U-NII-6	6.425-6.525	97-113	101
U-NII-7	6.525-6.875	117-185*	117, 133, 149, 165, 181
U-NII-8	6.875-7.125	185*-233	197, 213, 229

(*) Channel 185 (6875MHz) overlaps both U-NII-7 and U-NII-8 bands.

North America and a few other countries have adopted the entire band from 5.925 GHz to 7.125 GHz. The European countries have adopted only the U-NII-5 band.

For a list of countries that have enabled the 6GHz band and the specific approved sub-bands, go to: wi-fi.org/countries-enabling-wi-fi-6e

Regulatory Information

There are different regulatory rules regarding the allowed transmit power limits based on the device operating category.

Table 7 Allowed Transmit Power Limits Per Operating Category

Device Classification	Applications	Max EIRP	Max Power Spectral Density (PSD)	Zebra Device
Standard Power (SP)	Outdoor and indoor under control of Automated Frequency Coordination System (AFC)	FCC: AP: 36 dBm STA" 30 dBm (*) (*) The client max TX power must always be 6 db less than the AP max TX power	FCC: AP: 23 dBm/MHz STA: 17 dBm/MHz	Supported (*) (*) Follow the SP AP max TX power
Low Power Indoor Only (LPI)	Indoor only	FCC: AP:30 dBm STA: 24 dBm	FCC: AP: 5 dBm/MHz STA: -1 dBm/MHz	Supported
Very Low Power (VLP)	Outdoor and Indoor for short range applications	FCC: not approved Other countries: 14 dBm	FCC: not approved Other countries: -8 dBm/MHz	Supported

Standard Power (SP) access points must access an AFC system before transmitting. The AFC system provides information about the permissible frequencies (channels) and maximum transmit powers to SP access points based on their geographic location. The client devices operating under an SP access point must set their maximum transmit power to 6 dB below the maximum transmit power of the access point.

Standard power access points may be used outdoors as they have higher transmit power limits, but they may be used indoors as well as long as they are connected to an AFC system.

Channel Width and Power Spectral Density

The following section describes the relationship between Power Spectral Density (PSD) and Equivalent Isotropically Radiated Power (EIRP), and the channel width.

EIRP = PSD + 10 log (channel width)

For example, with a PSD of 5 dBm/MHz and a channel width of 20MHz, the EIRP is:

EIRP = 5 dBm/MHz = 10 log (20MHz) = 5 = 13 =18 dBm

NOTE: 320MHz channel width is not supported for Wi-Fi 6E devices and is added in the following diagrams for illustration purposes only. 320MHz channels will be added in Wi-Fi 7.

Standard Power

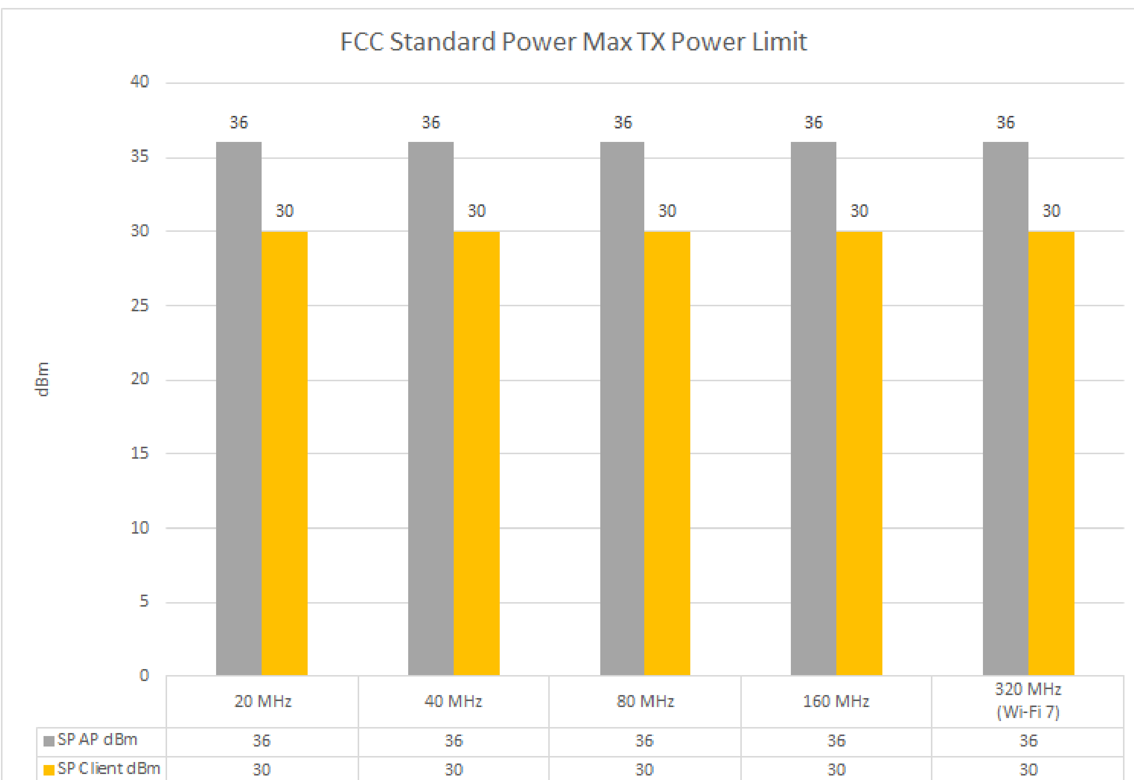
Go to the table in the Regulatory Information section for Standard Power AP and client power limits.

For the FCC regulatory power limits, refer to:

SP AP: ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-E#p-15.407(a)(4)

Client under SP AP: ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-E#p-15.407(a)(7)

Figure 6 FCC Standard Power Max TX Power Limit

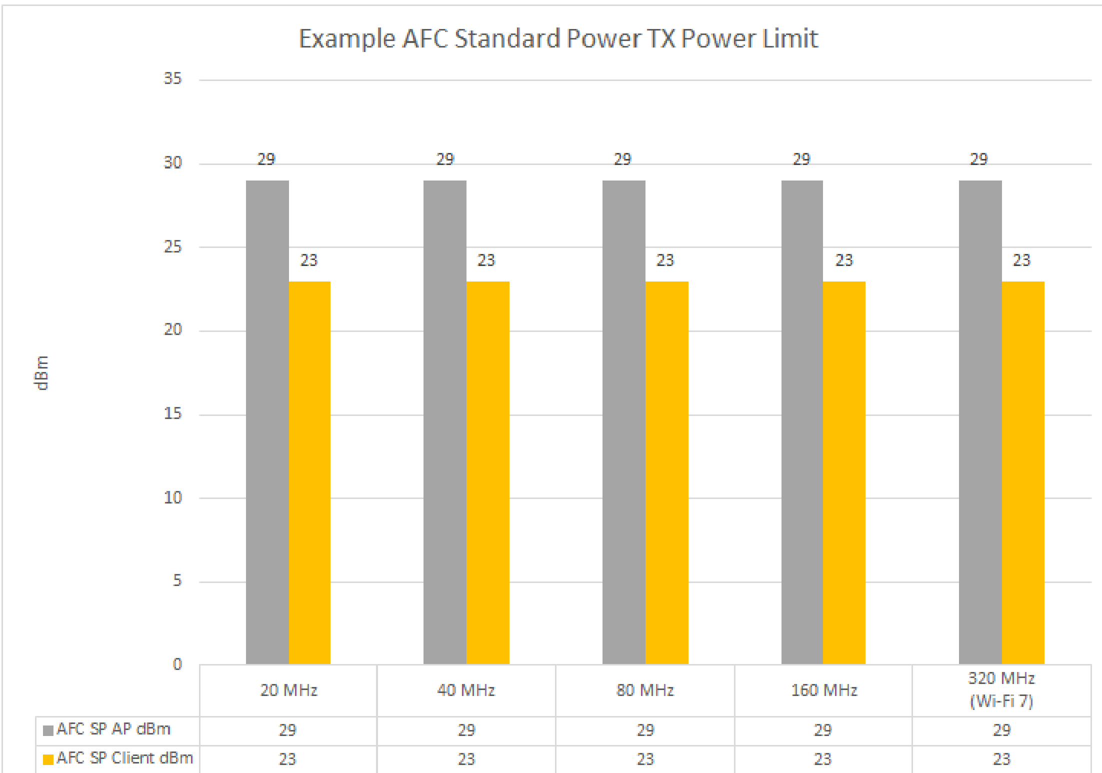


The previous diagram shows the FCC maximum transmit power limit for Standard Power Access Points and client devices. As mentioned in the Regulatory Information section, the Standard Power Access Points get the allowed power limit and the channels available at their specific geographic location from the AFC system. It is possible for the maximum power limit at that location to be less than the 36 dBm for AP and implicitly 30 dBm for client. Also, the SP client device must always set its maximum transmit power 6 dB below the maximum transmit power of the SP AP.

For example, if we assume that the AFC database indicates the maximum power limit for the Standard Power AP is 29 dBm, then the client maximum transmit power is 23 dBm.

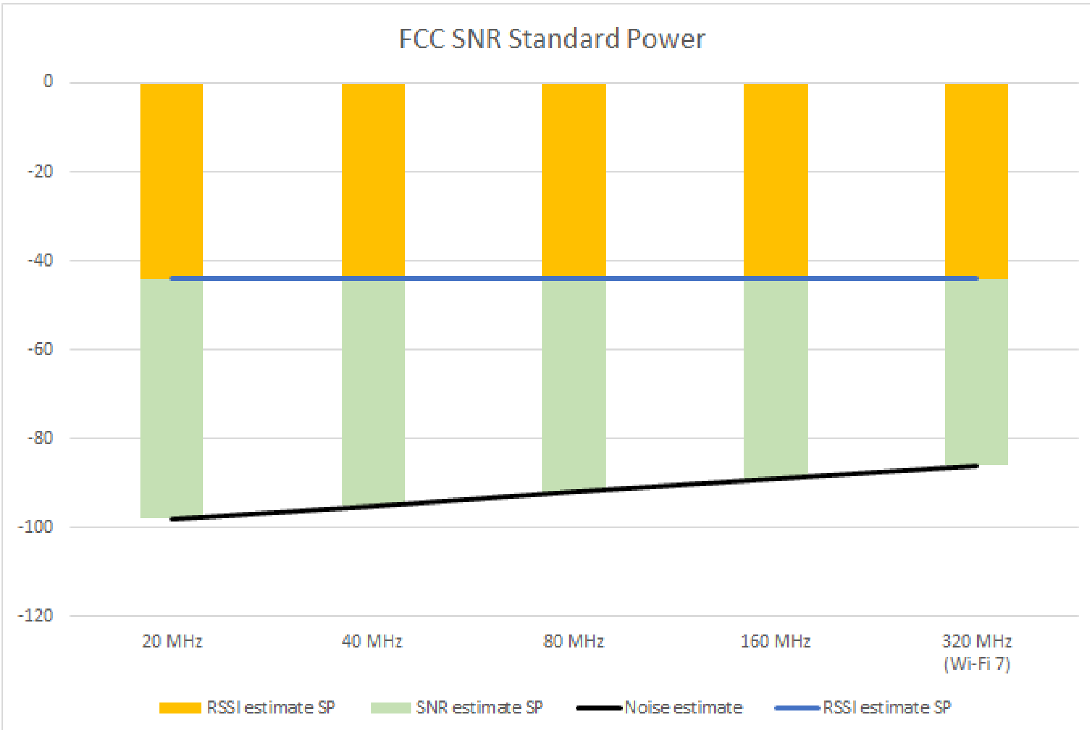
Another point to consider is that mobile devices would limit the maximum power to values lower than regulatory limit to be more effective due to various physical and design constraints.

Figure 7 AFC Standard Power TX Power Limit



For Standard Power the SNR (Signal to Noise Ratio) decreases with channel width increase because the noise floor doubles (adds 3 dB) with each doubling of the channel width. This is illustrated in the next diagram

Figure 8 FCC SNR Standard Power



Low Power Indoor

The following section details Low Power Indoor in relation to RSSI, SNR, and Noise estimates.

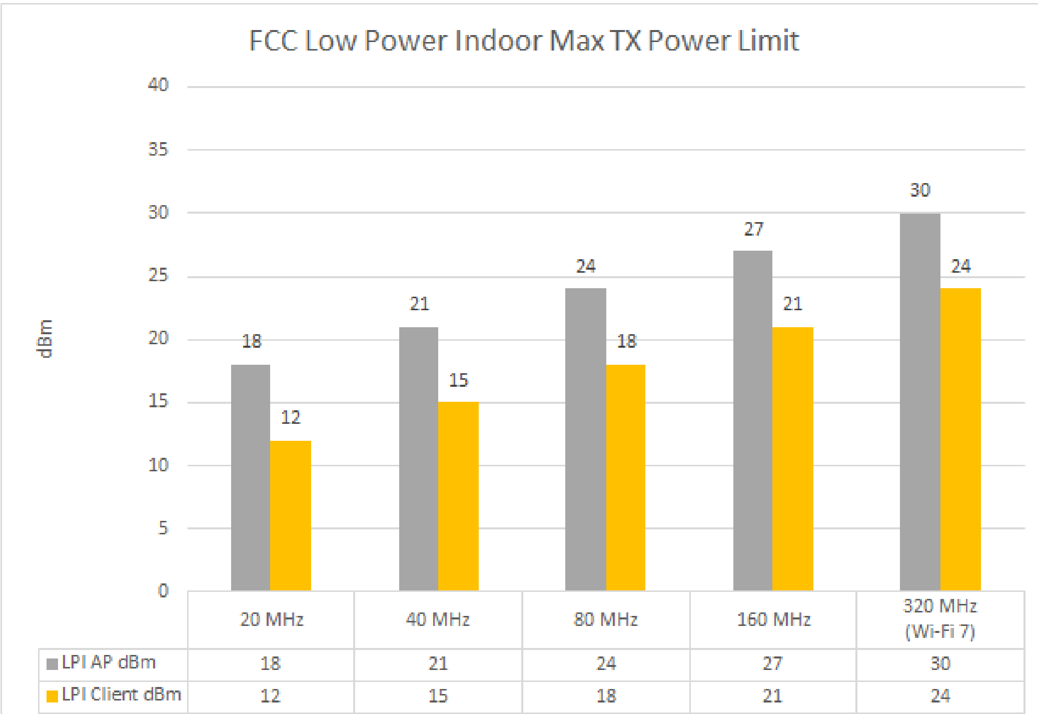
For Low Power Indoor AP and client power limits please refer to the table in Regulatory Information.

For the FCC regulatory power limits, please refer to:

LPI AP: ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-E#p-15.407(a)(5)

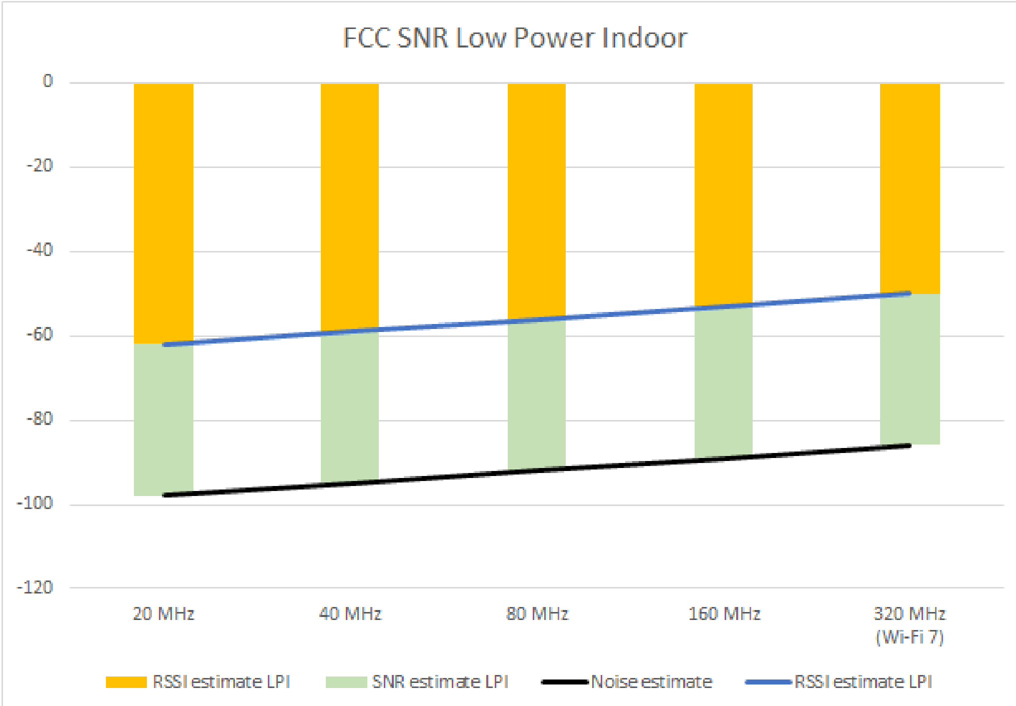
Client under LPI AP: ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15/subpart-E#p-15.407(a)(8)

Figure 9 FCC Low Power Indoor Max TX Power Limit



For Low Power Indoor, the SNR remains constant with channel width increase because the power limit is allowed to increase by 3 dB which compensate for the noise floor increase. However, for a device positioned at the same distance from an AP, the SNR is still lower for a Low Power Indoor AP at 160 MHz channel width compared with a Standard Power AP 160 MHz channel.

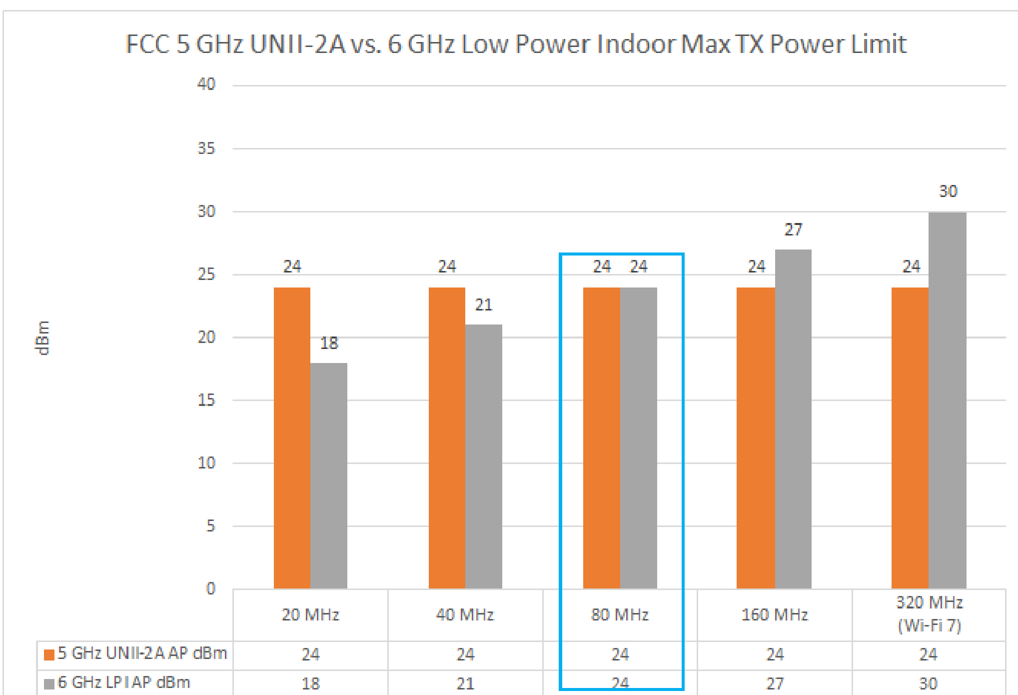
Figure 10 FCC SNR Low Power Indoor



Tx Power Per Channel 5GHz Versus 6 GHz

For 5GHz DFS sub bands U-NII-2A and U-NII-2C, the AP power limit is 24 dBm (250 mW) for all channel widths. For a 6 GHz Low Power Indoor AP this is equivalent to 80 MHz channel width as illustrated in the following diagram. This is one reason why in the 6 GHz band it is recommended to deploy wider channels to maintain similar coverage area for both bands.

Figure 11 FCC 5GHz UNII-2A vs. 6GHz Low Power Indoor Max TX Power Limit



Band Preference

This section describes how the Zebra device's band-connectivity preferences interoperate within the Wi-Fi 6E ecosystem.

In co-located multiband deployments, a 5GHz network might show better RSSI compared to 6GHz band in some places due to factors such as differences in transmit power. RSSI for 6GHz network might appear lower compared to 5GHz network as AP in 6GHz may be transmitting Beacons and Probe responses in a lower transmit power in 20MHz bandwidth.

Even in that case, 6GHz-supported client devices should ideally prefer 6GHz band since it will have cleaner channels and it can support higher bandwidth for enhanced performance. By default, Zebra devices will prefer 6GHz over 5GHz up to a certain coverage level.

When a device moves from one area to another, signal strength for the connection degrades and the device will have to search for a better AP to roam to. In some cases, legacy band APs may show better RSSI than 6GHz band AP due to frequency and Transmit power differences.

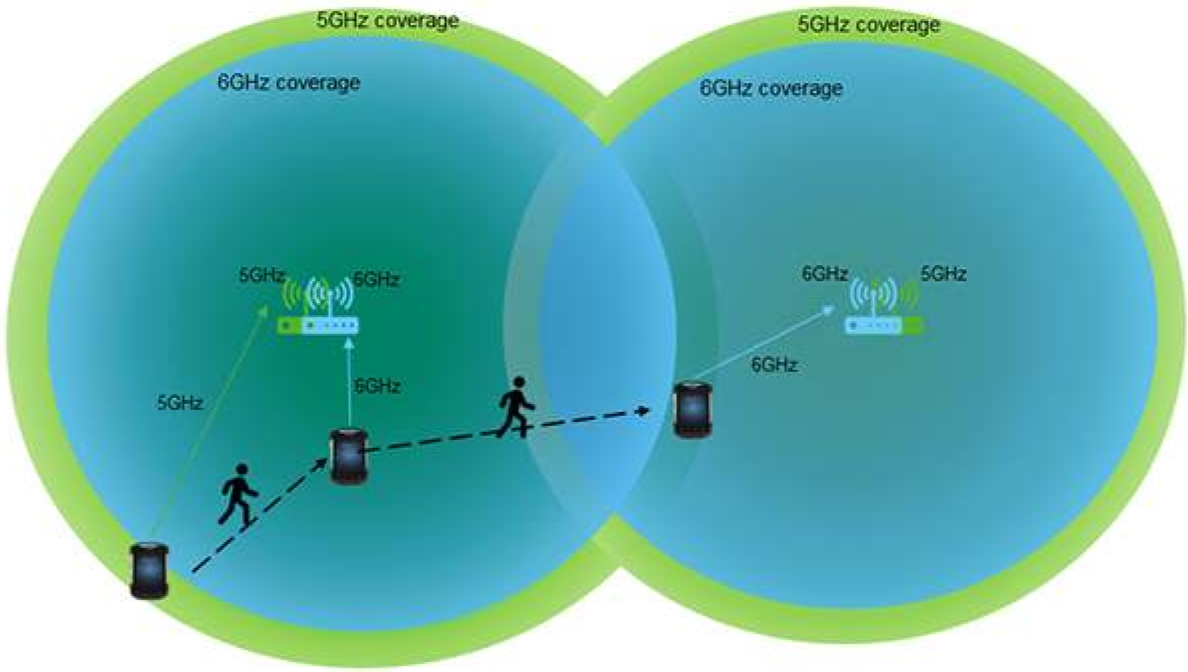
Even if the 6GHz AP RSSI is slightly lower than legacy band APs, it can still be a better candidate for roam if all parameters for a stable connection are considered. Zebra devices evaluate the candidate APs based on RSSI and other parameters so that the device always stays in 6GHz band.

With the arrival of Wi-Fi 6E, the expectation is that enterprises will modify network layout such that corporate networks will be present in both 5GHz and 6GHz bands. Legacy clients will use 5GHz band for connectivity and Wi-Fi 6E clients can utilize the 6GHz band for improved connectivity experience.

When a client device enters a coverage area, band preference capability of Zebra devices makes sure that 6GHz-capable devices are getting connected in 6GHz band and continue to stay in the same band when the device is moving within the coverage area.

The below graphic shows a device entering the coverage area of a 5GHz/6GHz network, and then roaming to another AP. This illustrates the 6GHz band preference feature. In real deployments, the actual coverage area might not be circular.

Figure 12 Band Connectivity Within the Wi-Fi 6E Ecosystem



Reduced Neighbor Report and 802.11kv

This section describes how Zebra devices use Reduced Neighbor Report, 802.11k, and 802.11v for connecting to a network faster and maintaining connectivity without impacting application traffic.

Co-located multiband APs include a Reduced Neighbor Report (RNR) Information Element in Probe responses and Beacons for assisting out of band discovery of 6GHz networks. APs in 2.4GHz and 5GHz include this RNR element which has information such as SSID, BSSID and the channel of operation of the 6GHz band AP.

6GHz networks also support 802.11k Neighbor Report and 802.11v BSS Transition Management features. 802.11k Neighbor Report provides information regarding neighboring APs, including channel information. 802.11v BSS Transition Management feature provides information regarding neighboring APs and the order of preference from AP perspective. Zebra devices utilize both these features to discover best AP quickly and roam faster. Using RNR, 802.11k and 802.11v, Zebra devices can improve time taken to discover the best AP by up to 78%.

Zebra devices use RNR, 802.11k and 802.11v for connecting to a network faster and maintaining connectivity without impacting application traffic such as voice when the device is moved from one place to another. Zebra recommends keeping both the 802.11k and 802.11v features enabled in the network, so that Zebra devices can take advantage of these features as explained above.

Voice Calls, Video Streaming, and Conferencing

This section details how connectivity over the 6GHz band benefits Enterprise Wi-Fi serving any kind of Latency-Sensitive Applications.

Enterprise Wi-Fi that is serving any kind of Latency-Sensitive Applications benefit greatly from devices' connectivity over the 6GHz Band. Using the 6GHz improves the user experience in any scenario where quality and reliability of the network are paramount to the real-time experience, especially in ecosystems that include higher density and a larger number of users and application sessions.

Latency-Sensitive traffic takes advantage of the OFDMA Uplink and Downlink technologies of the 802.11ax. In most deployments of 6GHz, the channel serving the connected devices is using 80MHz channel width. Given that streaming traffic uses a relatively small Resource Unit (RU) Tones of the OFDMA, there is a likelihood that many separate subcarriers are utilized in accessing the medium without any contention and are able to efficiently fill vacancies of the spectrum.

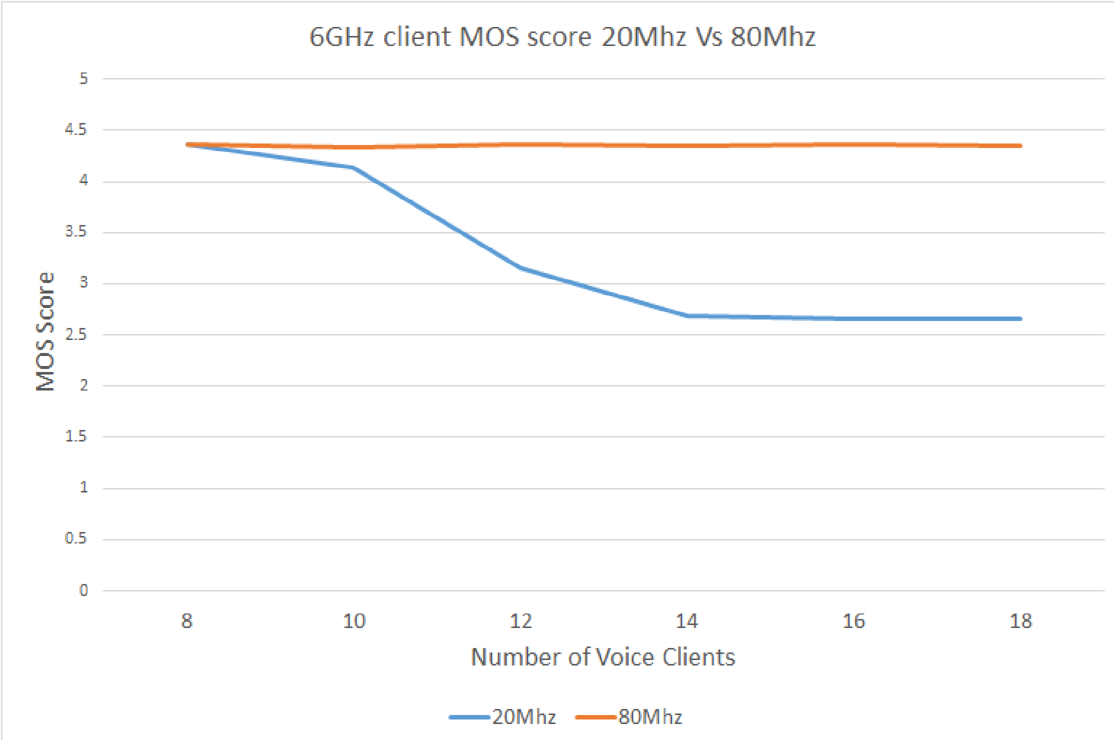
The efficiency of the OFDMA allows the ecosystem to support a much larger capacity of such applications while keeping the traffic performance intact and maintaining the stable performance with lower jitter, latency, and packet loss for all the connected devices. Without OFDMA, a lower density of connected devices can maintain good quality.

Consider the following real-world scenarios of Voice deployments, which apply to other media apps. Note that the Voice examples given here use a standard metric of Mean Opinion Score (MOS), in which, in most Voice Applications scales, a value of 4.3 and above is “Excellent”, between 4 and 4.3 is “Good”, and anything below the value of 4 yields noticeable impact to the User Experience (a.k.a. “Fair”, “Poor” or “Bad”).

In one scenario, multiple Zebra Wi-Fi 6E-capable devices are connected to 6GHz channel, and while most of those devices handle ongoing Voice Calls, some others handle background traffic of data Applications. In this situation, the advantage of the default deployment of 6GHz using 80MHz bandwidth allows for significantly more ongoing Voice Calls to maintain the same high level of MOS value without degradation across all devices, compared to a bandwidth of 20MHz.

The following chart shows a test result example of the above scenario: the chart depicts a MOS value of increasing number of the devices handling Voice Calls at the same time, each facilitating a call with a remote peer, while several other devices handle background traffic (not shown). As shown, in the 80MHz plot the average MOS value for each given number of Voice Calls remains consistently “Excellent” as the number of Calls is increasing. Conversely, in the 20MHz plot, the Average MOS value is Excellent in up to 8 Calls, then decreasing to Good in 10 Calls, and further degrading to Poor and Bad when increasing the number of Calls to beyond 10.

Figure 13 6GHz Client MOS Score 20MHz vs. 80MHz



In another deployment scenario, a Voice Solution is deployed on a mixed fleet of device types at the same venue. Some are Zebra's Wi-Fi 6E-capable devices and others are Wi-Fi5-capable or older, which don't support Wi-Fi6/6E altogether, thus are not OFDMA-capable.

In 'some' of the times and places in the venue where the 6GHz coverage is either insufficient or not supported by the WLAN at all, Zebra's Wi-Fi 6E-capable devices are connected to the 5GHz coverage that is also used by the Wi-Fi5 devices, and those Wi-Fi5 device are either also run Voice Calls at the same time or any data application. In all, the entire traffic over the 5GHz of all connected devices with same AP is utilized over a 20MHz width of the channel.

20MHz channel width is the common and recommended practice in Enterprise 5GHz WLANs for Voice, due to 5GHz being limited by smaller overall spectrum and under Regulations of Dynamic Frequency Selection (DFS) imposed on big portions of the spectrum. In all, the 5GHz needs to be sliced to narrower width of channels.

In 'other' times and places in the venue, if 6GHz is supported by the WLAN and its coverage is sufficient, the Zebra's Wi-Fi 6E-capable devices are connected to the 6GHz coverage. In this situation the Wi-Fi 6E-capable devices facilitate their Voice Calls on the 6GHz/80MHz while the Wi-Fi5-capable devices facilitate their Voice Calls or data applications on the 5GHz/20MHz.

In this mixed fleet scenario, it is expected that if and where 6GHz WLAN is supported, the Zebra's Wi-Fi 6E-capable devices will maintain the MOS values as depicted in the previous chart's 80MHz orange plot.

Multiuser MIMO

This section describes how Multiuser (MU) MIMO allows an AP to transmit and receive traffic with multiple connected devices simultaneously.

The technology started in the 802.11ac/Wi-Fi5 standard for MU “Downlink” traffic operations and extended in 802.11ax to support also MU “Uplink”. MU-MIMO lets the AP manage the Multiuser traffic in separate simultaneous ‘lanes’, where each lane is dedicated to a connected device at given time, not logically separated to traffic timing and sizes.

Unlike OFDMA, the MU-MIMO does not ‘split’ the given channel into independent-subcarriers of the spectrum in which each does not contend with others, thus able to ‘fill’ unused vacancies in the spectrum. Instead, MU-MIMO is very effective in scenarios where multiple Users/Devices all need to receive and transmit full-buffers of traffic with all connected devices without any time gaps in between, such as during high-throughput applications by all the participating users.

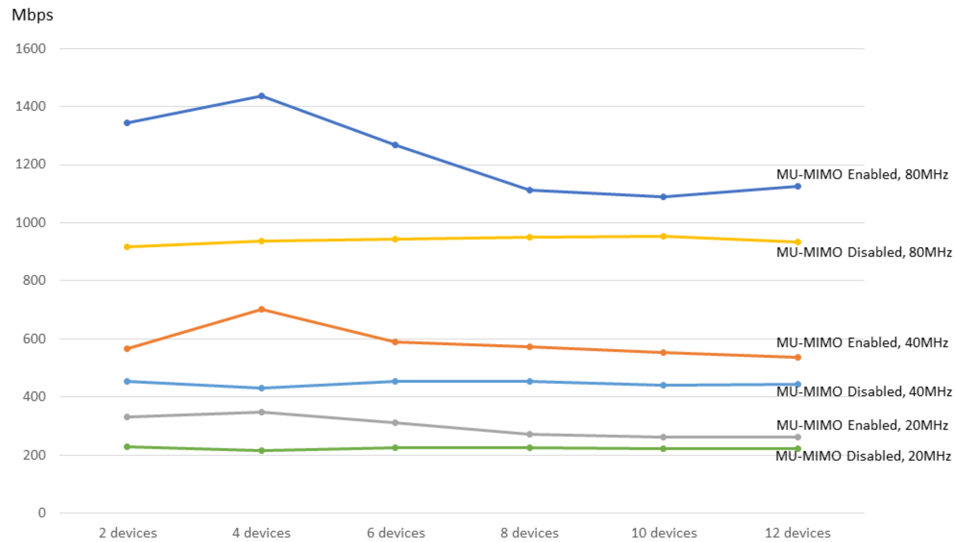
The MU-MIMO’s gain and effectiveness during high-throughput of Multiuser traffic, compared to without MU-MIMO, largely depends on the following factors:

- The Width of the channel. The wider the width, the faster the ongoing full buffers can be crammed into each of the given number of connected devices.
- The AP execution of the Multiuser connections. This is a combination of APs hardware dependencies, such as MIMO capabilities (2x2, 4x4, 8x8), and the APs concurrency of the connections over the MIMO. It is expected that as long as the AP can manage the full-buffers for a number of devices of less than or equal to the physical MIMO capabilities, then the relative gain of the MU-MIMO speed for all of those devices is the highest. Whereas if larger number of devices participate in full-buffers scenario, the AP needs to multiplex its MIMO operations and that can reduce the relative gain.

MU-MIMO in an ecosystem of 6GHz connections greatly benefits from the default channel widths of 80MHz, in the sense that the 80MHz is efficient for both the MU-MIMO type of applications as well as traffic and OFDMA type of applications. Thus, the connection of 6GHz serves all the application types mostly automatically, compared to ecosystems of 2.4GHz band which typically is 20MHz only for all applications, and 5GHz band which typically is 20MHz if it needs to support latency-sensitive applications.

The following chart depicts six test results of Multiuser aggregated downlink speed in Mbps unit, for each given number of participating devices. The six tests are performed in combinations of MU-MIMO Enabled vs Disabled for each of the three AP channel widths settings: 20MHz, 40MHz, and 80MHz.

Figure 14 Aggregated Throughput Results of MU-MIMO Enabled vs. Disabled



The chart illustrates the following points:

- The wider the channel, the higher the result is of the Multiuser aggregated speed.
- Within the context of each width (20, 40, or 80MHz), the speed gain of the MU-MIMO in all three is relatively high in up to four to six participating devices, averaging ~50% relative gain, whereas once the number of participating devices is higher, the relative gain in all widths is diminishing to average of 20%. This test example of diminishing to a 20% gain in the larger amount of devices is subjected to specific AP's model. This can vary greatly to higher or lower gains, depending on the AP model and its number of antennas.

Zebra Devices Operating with Standard Power

This section describes how information elements advertised by an Access Point dictates how a device realizes the AP mode of operation.

The device determines the Access Point mode of operation (LPI, SP or VLP) from the information elements advertised by the AP in beacons. These information elements are examined by the device to determine the operating transmit power:

- Country Element (ID 7)
- Power Constraint Element (ID 32)
- Transmit Power Envelope Element (ID 195)

The device calculates the minimum allowed transmit power from the above information elements as well as its internal regulatory power tables.

When connected to a Low Power Indoor AP, the device operates at or below the power levels advertised by the LPI AP.

When connected to a Standard Power AP the device operates at 6 dB lower than the SP AP's authorized power level established by the AFC system. More about the Standard Power operation is explained in the Standard Power section, along with the 6dB reduction requirement.

Glossary of Abbreviations

This section identifies the acronyms used in this guide for easy reference.

AFC	Automated Frequency Coordination
AP	Access Point
BSS	Basic Service Set
CCA	Clear Channel Assessment
DFS	Dynamic Frequency Selection
EIRP	Equivalent Isotropically Radiated Power
FCC	Federal Communications Commission
HE	High Efficiency
H2E	Hash to Element (SAE)
HnP	Hunting and Pecking (SAE)
LPI	Low Power Indoor
MIMO	Multiple Input Multiple Output
MU-MIMO	Multiuser MIMO
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
OWE	Opportunistic Wireless Encryption
PSC	Preferred Scan Channel
PSD	Power Spectral Density

QBSS	QoS BSS
RNR	Reduced Neighbor Report
SAE	Simultaneous Authentication of Equals
SNR	Signal to Noise Ratio
SP	Standard Power
STA	Station (client device)
TWT	Target Wake Time
U-NII	Unlicensed National Information Infrastructure
VLP	Very Low Power
WPA	Wi-Fi Protected Access
WPA3	WPA version 3