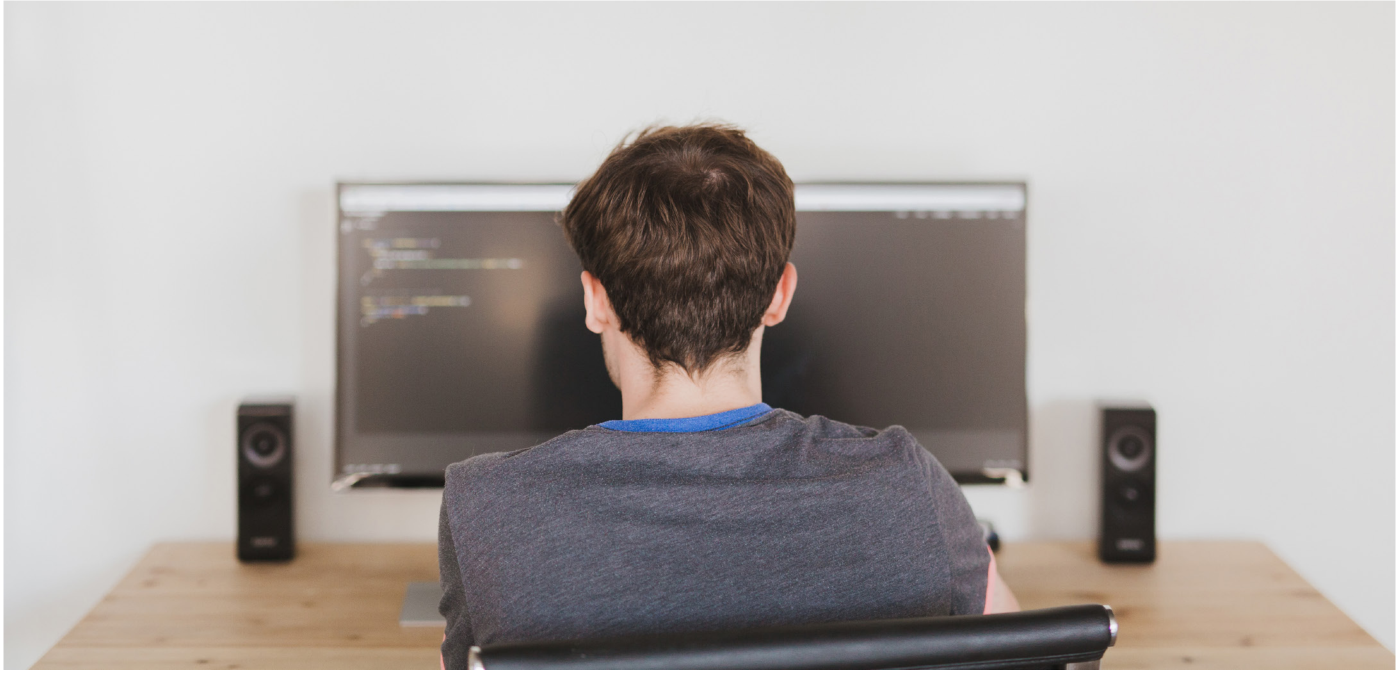
Wi-Fi 6E WLAN Deployment Findings and Recommendations

Introduction

This document details the Wi-Fi 6E client discovery process with Arista access points (APs), providing practical insights through examples and packet captures. Additionally, we will outline a comprehensive list of recommendations for network administrators while upgrading from legacy 802.11ac (hereafter referred to as 11ac) access points to 802.11ax (hereafter referred to as 11ax) access points, specifically those supporting the 6 GHz frequency band, all within the same location. This document offers a detailed examination of both client discovery mechanisms and deployment considerations for a seamless transition to a modern, Wi-Fi 6E-enabled wireless networking infrastructure.



The Experiment

Figure 1: Floor plan of HQ location wherein 17 APs were replaced with C360 11ax

Arista conducted a series of experiments involving the latest Wi-Fi 6E capable client devices including Apple iPad Pro, Samsung S22, Google Pixel 7, and Dell Laptops equipped with the Intel AX 210 card. These experiments were conducted at Arista HQ wherein the 11 ac access points were replaced with tri-band Wi-Fi 6E-based 11ax access points at the same locations. For this experiment, the flagship C-360 access points were used.

In the floor plan shown in Figure 1, we observed the presence of approximately seventeen 11ac-capable access points. Subsequently, we adopted the rip-and-replace method, replacing the existing 11ac access points with an equal number of 11ax access points in the same physical locations. Throughout this deployment, we employed the aforementioned client devices to validate the seamless discovery of Arista APs by clients and their consistent connection to the 6 GHz radios.

This document elaborates our findings and recommendations based on our field deployments and internal testing experience, offering valuable insights for the successful deployment of 6 GHz networks. All environments are different, therefore, a POC or a pilot implementation is recommended before pervasive implementation of recommendations offered in this solutions document.

AP Discovery - Traditional vs. 6 GHz Discovery

Before diving into the Wi-Fi 6E client behavior, it's essential to have a solid understanding of the legacy discovery methods, including how pre-6 GHz clients join the network. This understanding will help you appreciate the differences when it comes to the 6 GHz band.

Traditional Client Discovery

Wi-Fi clients have traditionally used an active hunt & seek method to scan for APs. Clients usually send out probe requests across 2.4 and 5 GHz channels to discover APs. The APs respond with a probe response frame containing the required information for a client device to learn about the parameters of the BSS / WLAN.

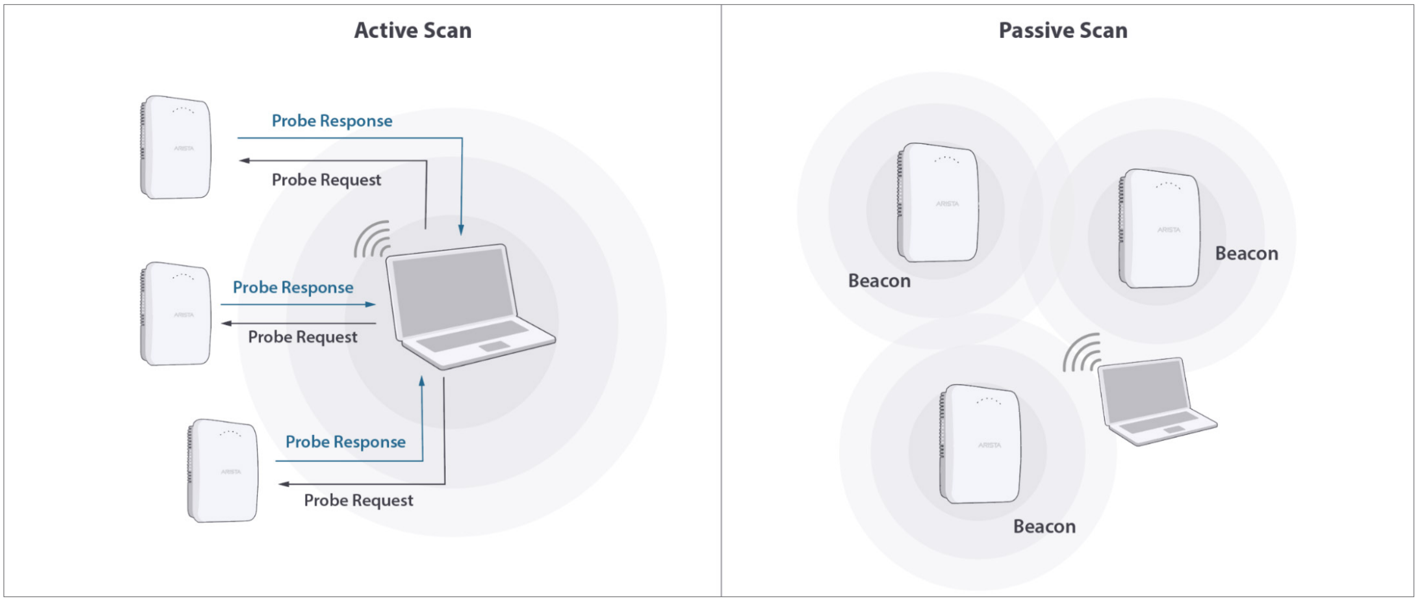


Figure 2: Passive Scanning vs. Active Scanning

Wi-Fi clients employ an active scanning method by transmitting probe request frames across all channels. When a client receives probe responses from multiple APs, it typically relies on factors like RSSI (Received Signal Strength Indication) or SNR (Signal-to-Noise Ratio) to determine which AP offers the strongest signal, guiding its decision on which AP to connect to.

6 GHz Client Discovery

The traditional active scanning method is no longer efficient for initial AP discovery in the 6 GHz band, and it's even less effective for roaming between APs. Probing is discouraged in the 6 GHz band due to the large number of channels — 59 channels of 20MHz each. Scanning each channel would consume a significant time and adversely impact the client connectivity and roaming.

In the 6 GHz band, new probe restrictions have been introduced. Clients are prohibited from blind probing and must wait approximately 20 milliseconds from the start of probing (the wait time is called probe deferral interval). There's a minimum spacing of 20ms for Fast Initial Link Setup (FILS) and unsolicited probe responses, which clients are expected to listen to before initiating a probe. Additionally, AP probe responses are always a broadcast.

Wi-Fi 6E clients have the option to discover APs using either the in-band or out-of-band AP discovery mechanisms.

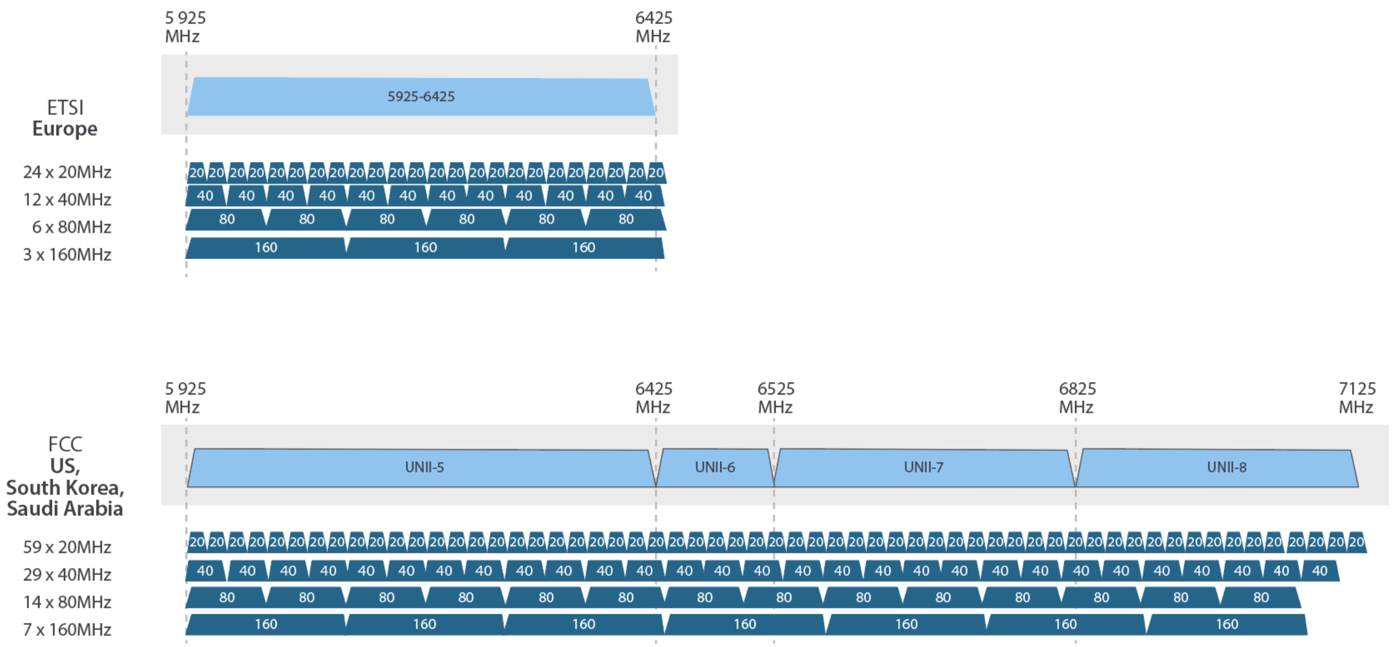


Figure 3: *6 GHz channel representation for US and Europe regulatory domain*

Within In-Band discovery, there are passive methods such as FILS (Fast Initial Link Setup) and Unsolicited Probe Response frames, as well as an active method known as PSC (Preferred Scanning Channel). In this document, we will place a greater emphasis on the PSC (Preferred Scanning Channel) method, as either FILS or Unsolicited Probe Response cannot be employed simultaneously, and these methods cease as soon as an SSID is broadcast in the 2.4 GHz or 5 GHz bands. These methods are purely intended for 6 GHz-only deployment, which would not be the case in a typical campus-like deployment. It's worth noting that modern Wi-Fi clients typically conduct probing exclusively on PSC channels.

Active: Preferred Scanning Channels (PSC)

According to the new standards, clients are limited to probing on 15 preferred scanning channels known as PSC channels. Instead of scanning across all 59 available channels in the 6 GHz band, clients can now focus their scanning efforts on these 15 channels. Starting from Channel 5, every fourth 20MHz channel is specifically designated for active probing by Wi-Fi 6E clients. PSC channels play a crucial role as primary channels for channel bonding in 80MHz.

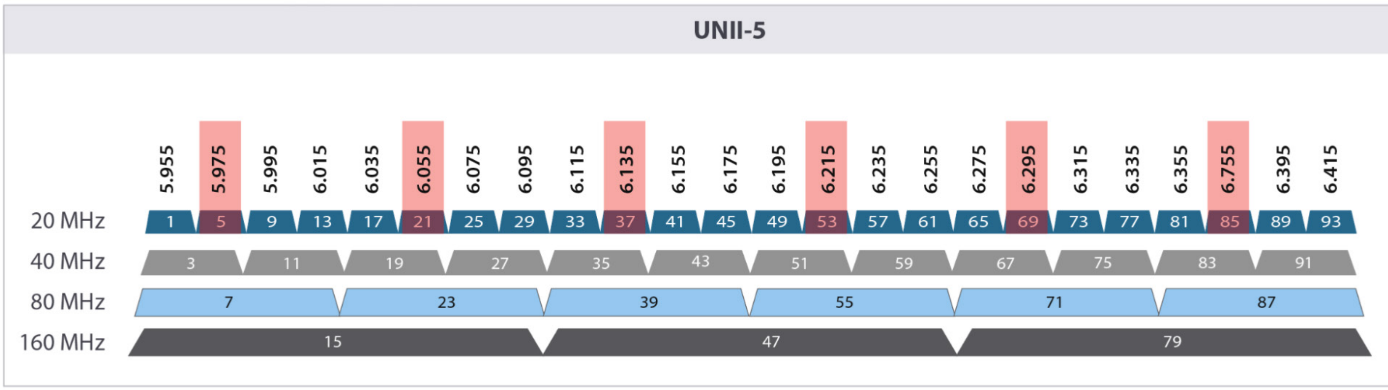


Figure 4: *UNII-6 Channel distribution across channel bandwidth*

The PSC channel list includes the following channels: 5, 21, 37, 53, 59, 69, 85, 101, 117, 133, 149, 165, 181, 197, 213, and 229. Wireless clients probe only the PSC channels; they consider probing Non-PSC channels only if they detect a need to do so through the RNR (Reduced Neighbor Report) mechanism.

Wi-Fi 6E Client Behavior

Major client vendors have recently begun to support Wi-Fi 6E, but their AP discovery mechanisms differ. Arista conducted various experiments to understand how each client's AP discovery mechanism works. The experiments started by enabling only a single SSID in the 6 GHz band and attempting to connect each of the aforementioned clients to comprehend their association behavior. With the SSID exclusively available in the 6 GHz band, 6 GHz-capable clients typically discover this network through In-Band discovery, as the name suggests. Subsequently, the experiment involved enabling the SSID across all three bands and observing the client connectivity behavior using the out-of-band mechanism. The result of the experiment is listed in the following table:

6 GHz Client model	OS	In-band Discovery	Out-band Discovery	Comments
iPad Pro	iOS	Not supported	Supported	Supports only Out-of-Band discovery method
Samsung S22	Andriod	Supported	Supported	
Google Pixel 7	Andriod	Supported	Supported	
Intel AX 210	Windows	Supported	Supported	
Apple M2 Macbook Pro	MACOS	Not supported	Supported	Supports only Out-of-Band discovery method

The majority of client devices support both In-Band and Out-Of-Band discovery mechanisms. However, Apple devices, including iPad Pro and Macbook Pros, exclusively support Out-Of-Band discovery.

Out-of-Band discovery means that a client device looks into the beacons of either the 2.4 GHz or 5 GHz band to understand the RNR IE (Reduced Neighbor Report Information Element). This information helps the client identify its co-located 6 GHz band channel and initiate the association process.

Insight from the Experiment: Apple M2 Pro

When the SSID is enabled on all three radios—2.4 GHz, 5 GHz, and 6 GHz bands—the beacon captures the presence of its co-located 6 GHz BSSID in the RNR IE (Reduced Neighbor Report Information Element) within the beacon frame. (Refer to the following screenshot , where the Reduced Neighbor Report, a component of the beacon frame, is highlighted.) In this Figure 5 it is seen that the operating class is of 80MHz channel width, whether this BSSID is co-located or not, along with BSSID and channel information. It's worth noting that the packet capture in the image was taken on channel 44, wherein beacons advertise about the 6 GHz network as a co-located AP to enable Apple devices to join the 6 GHz network.

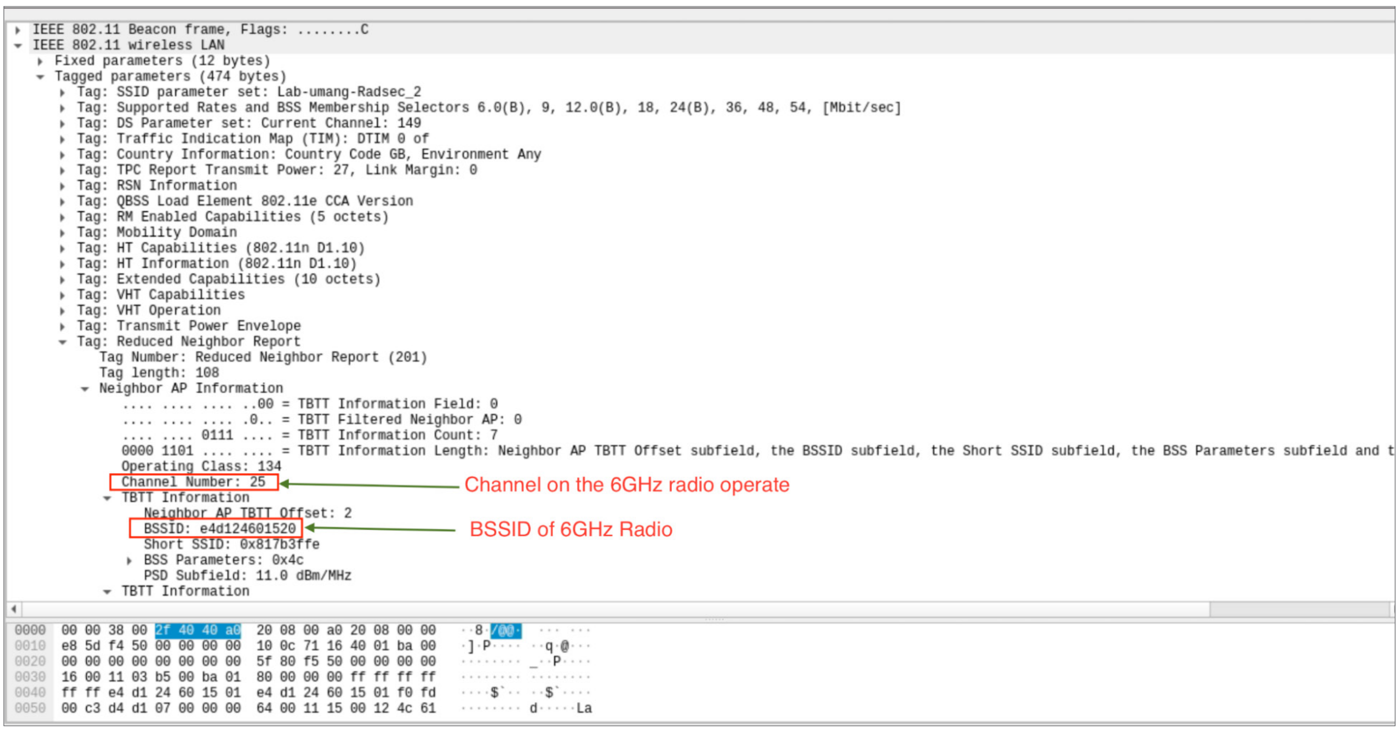


***Figure 5:** Beacon frame containing RNR information*

When the Apple M2 client encounters the RNR IE (Reduced Neighbor Report Information Element) within the beacon frame, it learns about the 6 GHz co-located band information. As illustrated in the image below, the Apple M2 client proceeds to send an Authentication Request frame directly on the 6 GHz band, specifically on channel 37. Subsequently, the access point responds with an Authentication frame and continues with the subsequent association and key management phases. In this particular case, the Apple device did not probe the 6 GHz band directly; instead, it utilized the RNR IE and sent the authentication frame directly to the 6 GHz band. This method of discovery is often referred to as the "Out-of-Band" discovery method.

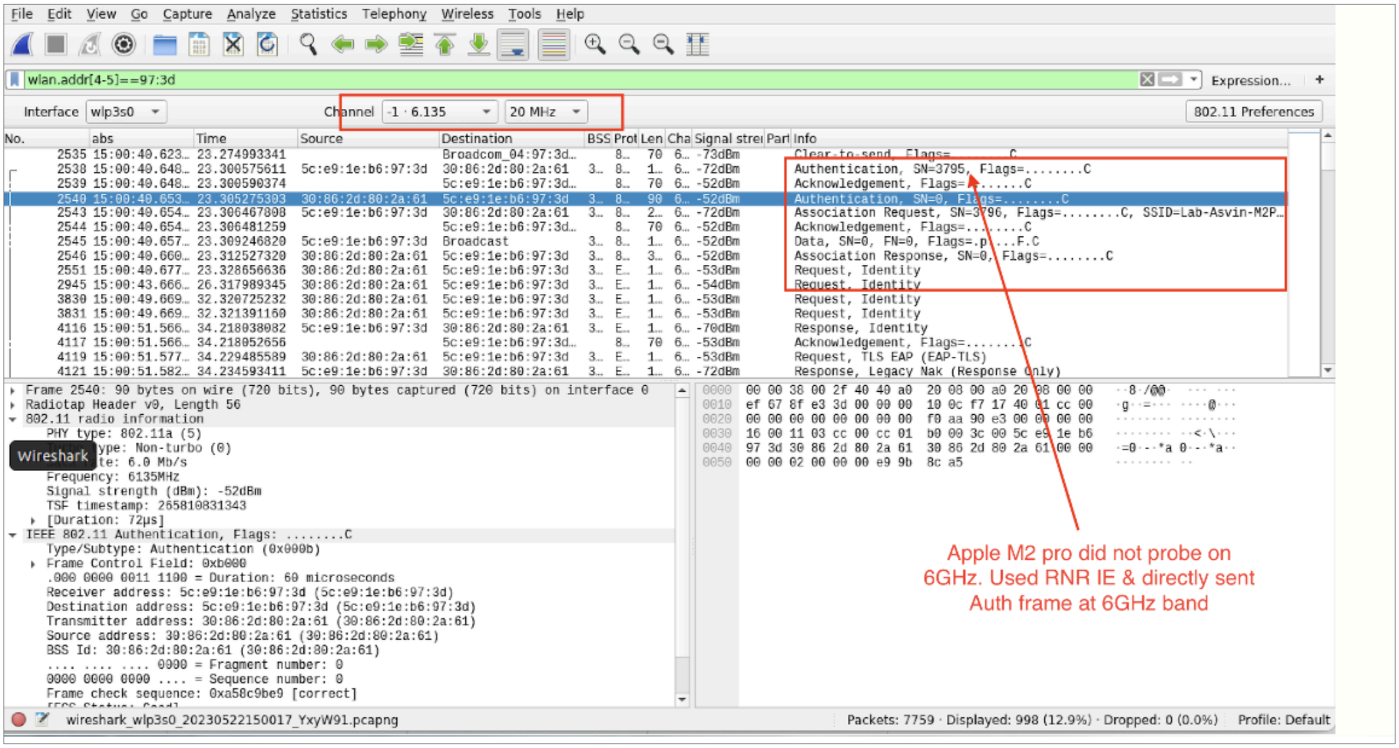


Figure 6: *Capture representing Apple M2 associating directly to 6 GHz*

Practical Insight from the Experiment: Google Pixel 7

The Google Pixel supports both In-Band and Out-of-Band AP discovery. In the case of In-Band discovery, as previously mentioned, the user configures the SSID exclusively on the 6 GHz band, with no 2.4 GHz or 5 GHz SSIDs enabled. For the Google Pixel to discover the SSID in the 6 GHz band, it must scan the 6 GHz channel.

The Reduced Neighbor Report (RNR), which typically relies on 2.4 GHz or 5 GHz beacons to inform the client about 6 GHz SSIDs, is not available in this scenario because there are no 2.4 GHz or 5 GHz SSIDs on the air.

In the packet capture shown in Figure 8, an 80MHz wide 6 GHz channel 39, with a primary channel of 37 is used for the experiment. This channel is designated as a preferred scanning channel (PSC), meaning that clients should scan this channel, as well as all of the other preferred channels, to receive AP beacons over the air.It is always preferable to enable the PSC channel, as these devices prioritize scanning these channels when seeking to discover 6 GHz band networks. Once successful discovery occurs, the Google Pixel adds the 6 GHz network to its client scan list.

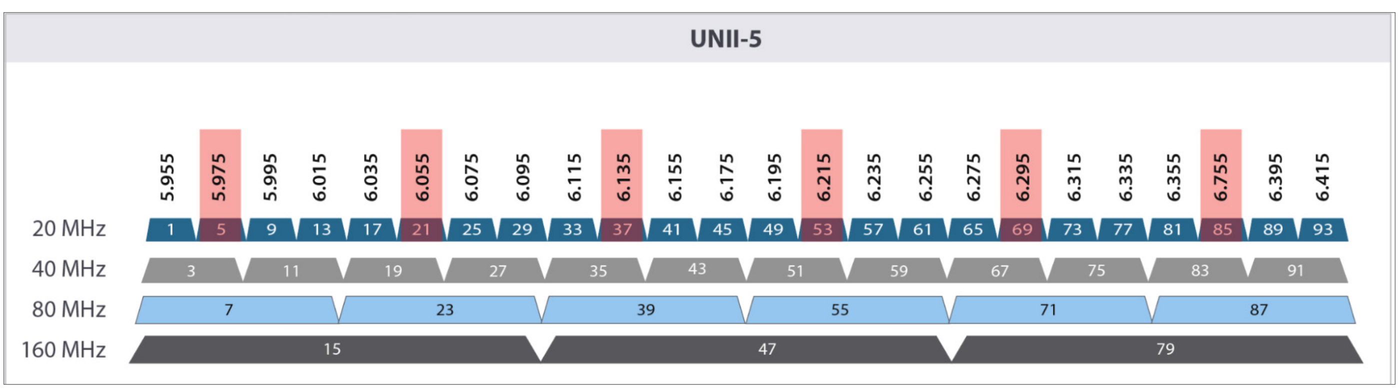


Figure 7: *PSC channel spaced every 80MHz*

Here is what happened on the 6 GHz channel when only the 6 GHz SSID (without 2.4 GHz or 5 GHz) was enabled on the AP. The AP automatically initiated the broadcasting of FILS frames to aid the client in discovering the 6 GHz SSIDs. FILS action frames are sent by AP every 20ms making the devices discover and associate the 6 GHz network a bit faster.

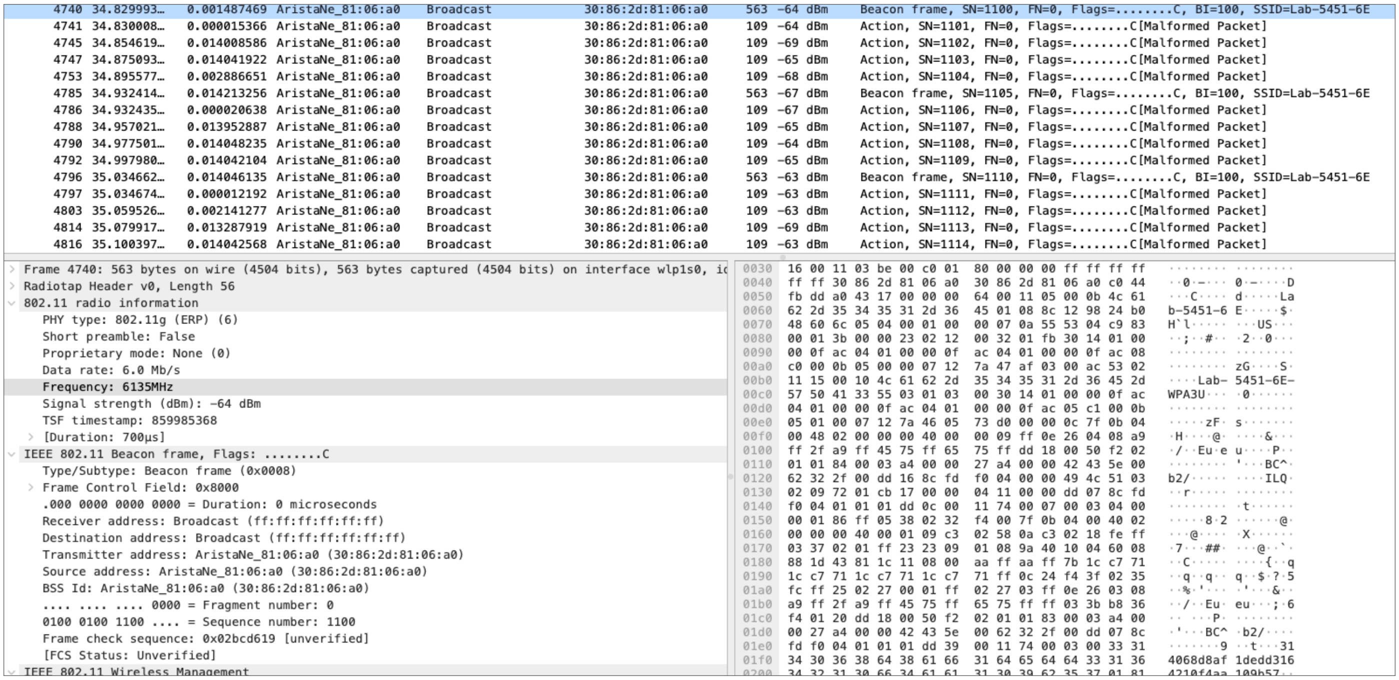


***Figure 8:** Capture representing FILS discovery as part of Action frame*

Let's re-emphasize this point: having just one 6 GHz band SSID in a campus deployment scenario is not practical. Therefore, Out-of-Band discovery is poised to become the default standard or the preferred approach moving forward. With the two examples provided, the Apple M2 Pro and Google Pixel 7, you must have received a fair understanding of the client discovery patterns.

Key Takeaway

During the In-Band discovery experiment, in which the SSID was applied only to the 6 GHz radio of an access point, Apple clients did not discover SSIDs in their scan list. This is primarily because Apple devices do not support the In-Band discovery method. The key takeaway here is that, in real-life deployment, if there are any Apple devices at a customer site, it is not recommended to have the SSID exclusively in the 6 GHz band. You must have at least one SSID in either the 2.4 GHz or 5 GHz band to allow the clients to examine the beacon of the RNR IE and appropriately discover its 6 GHz BSSID / WLAN.

Wi-Fi Roaming: Client Behavior

In the Wi-Fi 6E client roaming behavior experiment, the clients (listed previously in this document) were added to a roaming cart. We simultaneously connected all of these clients to assess their ability to successfully join the network in the 6 GHz band. Once they had successfully connected to the 6 GHz band, we moved the roaming cart within the Arista HQ office along a predetermined path. We monitored whether these clients consistently maintained their connection to the 6 GHz band throughout the test. In both cases, the clients listed above joined the network and roamed seamlessly to another AP within the 6 GHz band

Clients	6 GHz capable (Yes/No)	Initial association to 6 GHz AP (Yes/No)	Roam to Target AP successful in 6 GHz (Yes/No)
Apple iPad Pro	Yes	Yes	Roaming to 6 GHz is successful.
Samsung S22	Yes	Yes	Roaming to 6 GHz is successful.
Google Pixel 7	Yes	Yes	Roaming to 6 GHz is successful.
Intel 11ax 210 chipset	Yes	Yes	Roaming to 6 GHz is successful.
Apple M2 Pro	Yes	Yes	Roaming to 6 GHz is successful.

Note: *Roaming is driven by the client, and results may vary depending on the software driver version.*

Deployment Recommendations

The key to a successful 6 GHz deployment result is to have well-defined deployment tactics. This includes

- Implementing effective SSID strategies
- Optimizing transmit power in compliance with the new Power Spectral Density (PSD) rules of the 6 GHz band
- Adhering to recommendation for deployment to ensure seamless client roaming.

Let's examine each of the tactics in detail.

SSID Recommendation

With the availability of the additional 6 GHz spectrum, creative band planning becomes feasible for various Wi-Fi use cases.

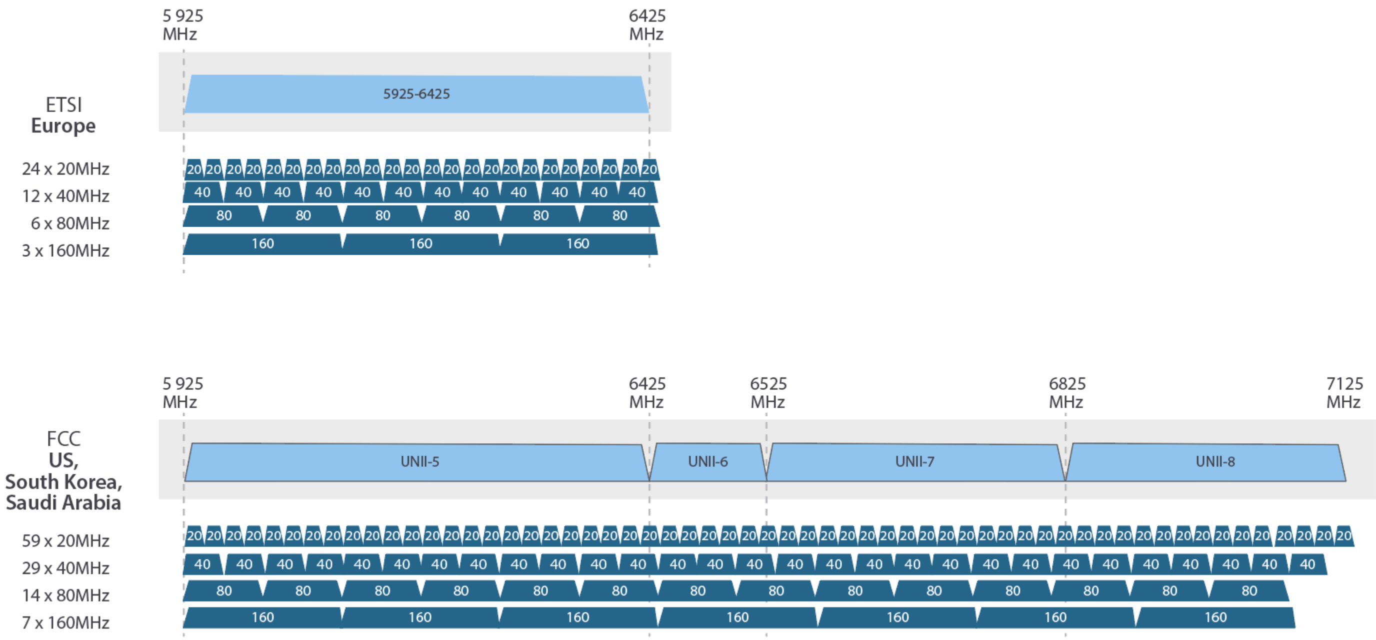


Figure 9: *Wi-Fi 6E Channelization*

As the AP C-360, C-330, and W-318 support all three Wi-Fi frequency bands, it is crucial to thoroughly understand and clearly define the requirements of the business use case, application needs, and client capabilities. Each Wi-Fi frequency band comes with its own set of advantages and disadvantages, affecting factors such as throughput, range, and latency.

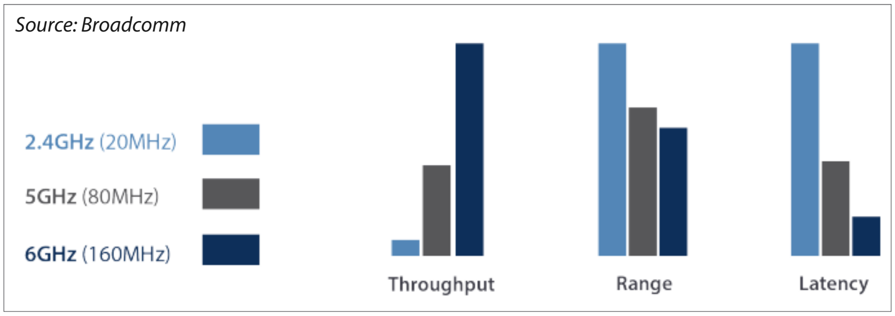


Figure 10: *Throughput, Range, and Latency improvement with 6 GHz*

Security Modes

WPA3 and OWE security modes are mandatory and no legacy security modes (WPA2, Open) are allowed in the 6 GHz band. There are significant consequences of this requirement, especially in the tri-band operation mode.

There may be interoperability issues with the new 6 GHz capable clients. To provide the convenience of a single SSID and password that can be configured across all WPA3 and WPA2 clients, the WPA3 Transition mode was introduced, which caters to both WPA3-Personal or Enterprise, and WPA2-Personal or enterprise clients.

	WPA	WPA2	WPA/WPA2 Mixed Mode	WPA3	WPA3 Transition Mode	Open	OWE (Enhanced Open)	OWE Transition Mode
2.4 GHz	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5 GHz	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6 GHz	No	No	No	Yes	No	No	Yes	No

The transition mode is only supported in 2.4 GHz and 5 GHz bands. Again, 6 GHz clients must use OWE and/or WPA3 Personal/Enterprise modes.

Homogeneous and Heterogeneous Environments in the Enterprise

- **Heterogeneous environment** is an environment where both WPA2 and WPA3 clients are present and a single SSID is needed. It is recommended to configure a single SSID for each of the 2.4 GHz, 5 GHz, and 6 GHz bands with security mode as WPA3 personal/ Enterprise with the Transition mode when using CV-CUE to configure APs. CV-CUE will automatically configure the WPA3 Transition mode for 2.4 & 5 GHz radios and configure the WPA3-only mode for 6 GHz radios when an SSID with WPA3 security is created and applied to the radios. Similar configuration behavior is followed for OWE transition mode, i.e. CV-CUE will automatically apply the OWE Transition mode to 2.4 & 5 GHz bands and Enhanced Open mode for the 6 GHz band when an SSID with OWE is created and applied to the radios.

- **Homogeneous Environment** is an environment where all the clients support WPA3 Personal/Enterprise. A single SSID with Security mode as WPA3-Personal/Enterprise can be configured for all the bands, i.e. 2.4/5/6 GHz.

SSID	Security Mode	Type	Channel Width	Radios Configured	Application	Device
Corporate SSID	WPA2/WPA3 Mixed Mode	WPA3 Enterprise	20/40/80MHz	2.4/5/6 GHz	High throughput and seamless roaming. Most clients connected to 5/6 GHz band	Employee laptops, tablets, handheld devices
Guest SSID	OWE	Transition Mode	20/40/80MHz	2.4/5/6 GHz	No high throughput demands. No domain credentials required	Visitors or contractors devices like phones, laptop, etc
IOT SSID	WPA2/WPA3 Mixed Mode	WPA3 Personal	20MHz	2.4 GHz	Low bandwidth requirements. Devices only support PSK onboarding	IoT devices like sensors, printers, etc.

Based on the various use cases, define SSID using the above security mode parameters and values.

NAC Engagements
Start engagement with NAC solution vendors like Clearpass, ISE, or AGNI to check on the security type as in enterprise environments we rely on the above provisioning tools to push configuration profiles to devices.

Usually, the NAC solution pushes configuration profiles to devices with security type as WPA2-Enterprise. Even though the client is capable of operating on WPA3, it would still work on WPA2-Enterprise. We can initiate the engagement with mobile device management (MDM) vendors to set the appropriate configuration based on the deployment use cases.

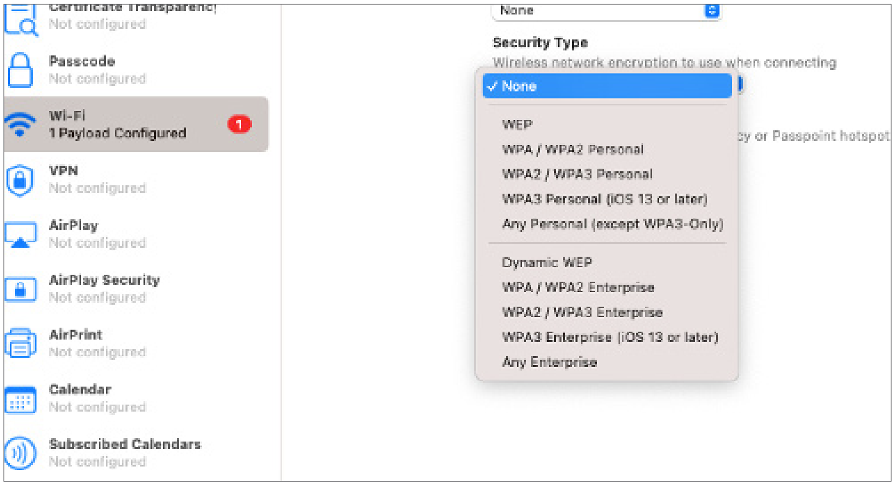


Figure 11: *Apple configuration utility represent various security type option for the user*

Transmit Power Recommendation
Let's deep dive into design considerations.

Even today, the 20/40MHz reuse plan still dominates the 5 GHz spectrum compared to the 80MHz.

40MHz channels are created by bonding two 20MHz channels together. Channel bonding effectively doubles the frequency bandwidth, which in turn doubles the data rates and throughput.

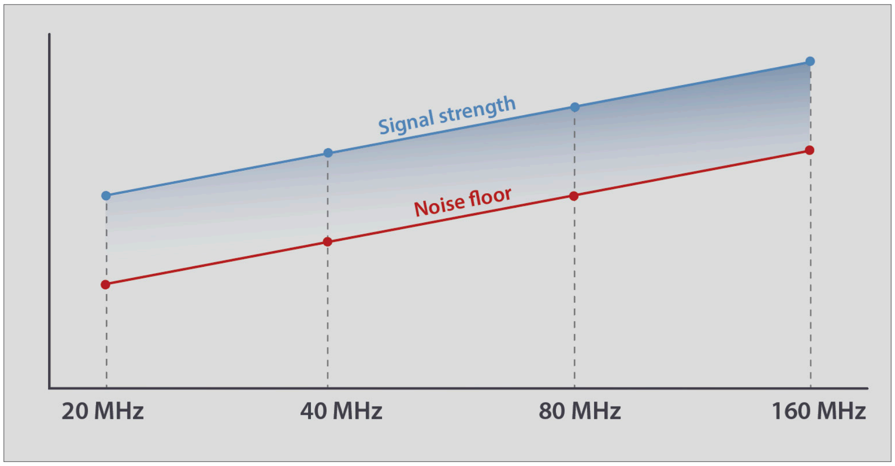


Figure 12: *SNR remains constant during channel width doubling*

80MHz channels are created by bonding four 20MHz channels together. However, deploying 80MHz channels does not scale well in the 5 GHz band due to limited available channels. This can lead to co-channel interference. If 80MHz channels are deployed on multiple 5 GHz APs in an enterprise, performance is likely to suffer significantly.

With the 5 GHz band, SNR degrades as the channel width increases and this would be the primary reason for administrators not to deploy 80MHz channels in the 5 GHz band. Whereas, for 6 GHz, SNR remains constant as the channel width increases. Thanks to new transmit power rules, which favor the use of larger bandwidth channels. With new power transmit rules, administrators can comfortably deploy 80MHz channels in the 6 GHz band.

Comparing 6 GHz to 5 GHz

- Path Loss - The signal in the 6 GHz band won't propagate as far as 5 GHz.
- Cell size - The coverage area of the 6 GHz band is smaller compared to the 5 GHz band.
- Obstacles - Signal loss due to obstacles is relatively higher in the 6 GHz band compared to the 5 GHz band.

These differences are worth accounting for while planning the deployment; to compensate for the shorter range and signal loss, consider increasing the power level of APs by 3dB.

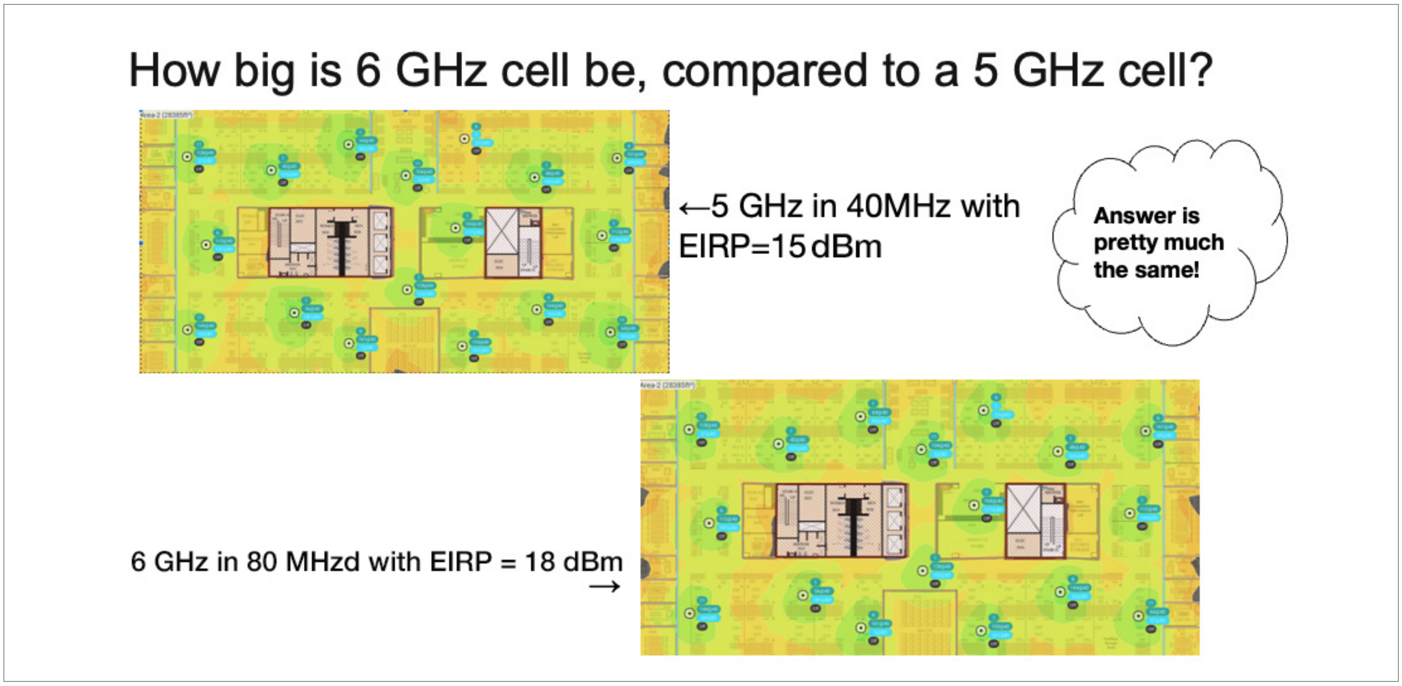


***Figure 13:** 6 GHz cell size is comparable with 5 GHz when the user increases the Tx power*

In Figure 13, in the top left corner we have 5 GHz 40MHz with EIRP set to 15 dBm; to match the same coverage floor plan. We bumped up the EIRP power by 3dBm to 18 dBm for 80MHz for the 6 GHz band.

6 GHz Design Recommendations

- If you already have a capacity-based 5 GHz design plan and the network is meeting the capacity and coverage requirements, then
  - one-for-one replacement with Wi-Fi 6E access points should continue to meet coverage requirements while more than doubling the capacity capabilities.
- In case of a new deployment, consider undertaking a thorough and detailed RF design for the 6 GHz band.

Optimizing 6 GHz Deployment: Your Connectivity Approach Matters

Here is the quick summary of what we have discussed in the solutions document. To optimize 6 GHz deployments, follow the recommendations summarized below.

SSID Recommendations

- Enable WPA3 in your current set-up first and observe, and then adopt 6GHz.
- Engage and configure MDM for WPA3 support.
- Enable WPA3/OWE transition modes on 6 GHz multiband SSIDs (This eliminates the need to create 2 SSIDs)

Transmit Power Recommendation

- Configure 3dB higher power on 6 GHz radios compared to 5 GHz radios. If using auto-transmit power, set the operating range for 6 GHz radios at least 3 dBm higher than the range for 5 GHz radios.

Client Association Behavior

- Enable PSC channels and avoid 6 GHz-only SSIDs.
- Configure 80MHz in 6 GHz.

Roaming Across the 6 GHz Band

- Enable WPA3 or WPA3 transition mode along with enabling 11r and Opportunistic Key Caching (OKC). Most modern clients support both 11r and OKC. If some clients don't support 11r, they would fall to the OKC-based method of roaming. By this method, you can eliminate full 802.1x packet exchanges, thereby improving the overall roaming air-time efficiency.

Santa Clara—Corporate Headquarters
5453 Great America Parkway,
Santa Clara, CA 95054

Phone: +1-408-547-5500
Fax: +1-408-538-8920
Email: info@arista.com

Ireland—International Headquarters
3130 Atlantic Avenue
Westpark Business Campus
Shannon, Co. Clare
Ireland

Vancouver—R&D Office
9200 Glenlyon Pkwy, Unit 300
Burnaby, British Columbia
Canada V5J 5J8

San Francisco—R&D and Sales Office 1390
Market Street, Suite 800
San Francisco, CA 94102

India—R&D Office
Global Tech Park, Tower A & B, 11th Floor
Marathahalli Outer Ring Road
Devarabeesanahalli Village, Varthur Hobli
Bangalore, India 560103

Singapore—APAC Administrative Office
9 Temasek Boulevard
#29-01, Suntec Tower Two
Singapore 038989

Nashua—R&D Office
10 Tara Boulevard
Nashua, NH 03062