ARISTA

Campus WLAN Design and Deployment Guide

Version 3.0

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Introduction

The purpose of this guide is to provide an overview of the Arista WLAN solution and to offer guidance for network design, configuration and deployment best practices for campus environments.

This guide covers the following topics:

- Arista Networks WLAN Solution Overview
- Channel Capacity Planning
- Site Preparation
- Deployment Best Practices
- AP Placement and Channel Planning
- Campus Use Cases

Arista Networks Solution Overview

With Arista Networks, all services such as WiFi, WIPS, monitoring, troubleshooting, and guest management are integrated into a single cloud platform, providing a cost-effective, easy to manage, highly scalable, secure and reliable cloud WiFi solution.

Arista Networks also offers an on-premise, appliance or VM management solution available for those organizations that are not able or ready to adopt the cloud management solution. It should be noted that the on-premise offering does not include Arista Guest Manager.

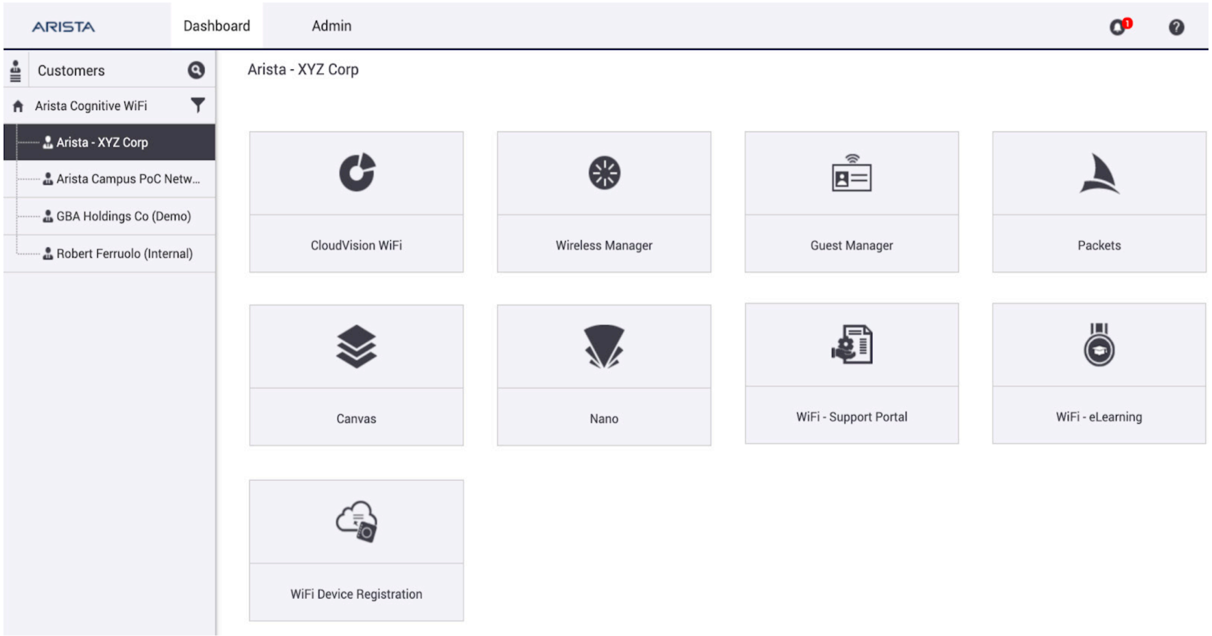


Figure 1: Cloud Dashboard

The Arista Networks WLAN solution is built on a controller-less architecture and only encrypted management traffic is sent to the cloud. Customer data traffic is never sent to the cloud.

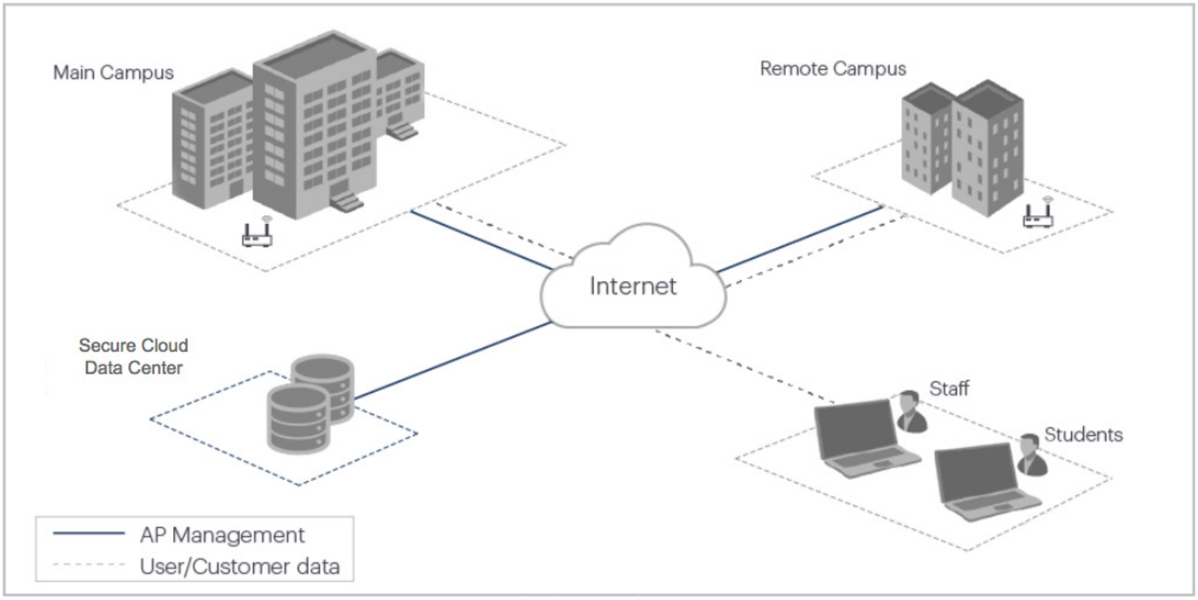


Figure 2: Cloud Managed Campus WLAN

Arista Access Points (APs) are cloud-managed, but provide full functionality even when internet access is unavailable. When an Arista AP reboots without access to the internet, the AP will activate using its locally stored configuration and will operate normally. Because Arista Networks APs operate without a controller, features and functionality, such as those listed below, are performed at the AP:

- QoS
- Radio Resource Manager (RRM)
- Application visibility and control (AVC)
- WIPS
- Traffic shaping
- Service Set Identifier (SSID) scheduling
- Service assurance
- Application QoE
- Band steering
- Smart client steering
- Client load balancing
- Auto packet capture

CloudVision WiFi

CloudVision WiFi greatly simplifies WLAN management, performance optimization and troubleshooting. Cognitive WiFi, built on Arista's deep domain expertise, transforms ~300 continuously monitored Key Performance Indicators (KPIs) into essential, actionable insights. Arista's Cognitive WiFi establishes a basis for a self-healing/self-optimizing WLAN using machine learning, artificial intelligence, and cognitive computing.

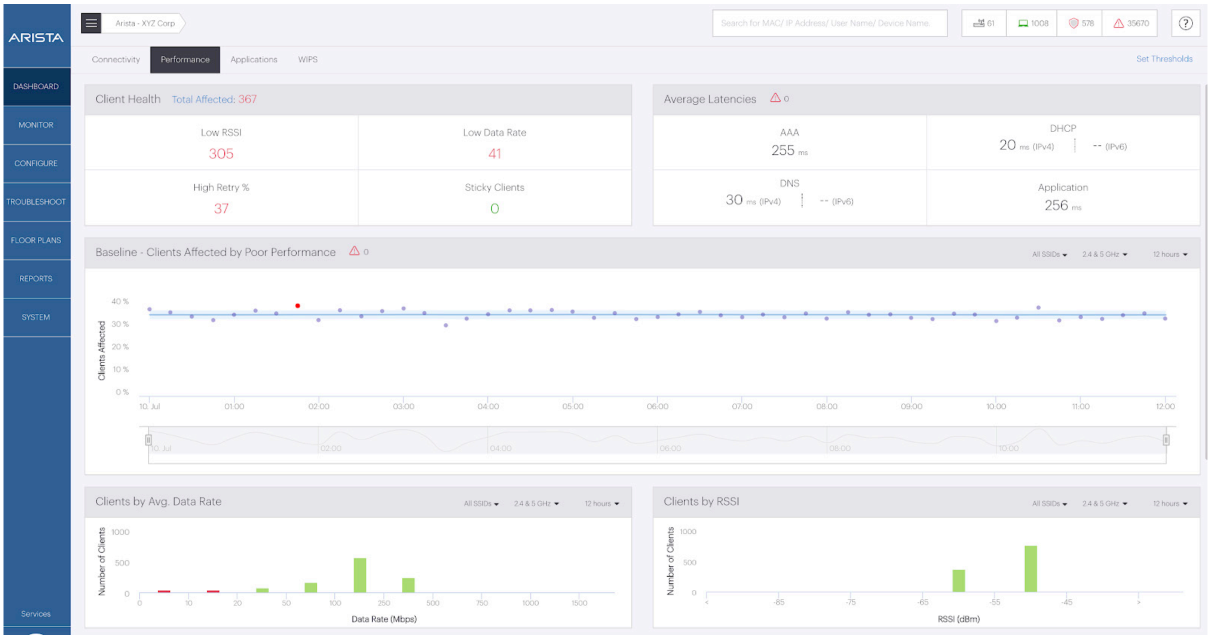


Figure 3: Performance Dashboard

Client Journey

CloudVision WiFi provides direct and real-time insight into the experience of WiFi clients as they journey on the network. Client Journey tracks when and why clients fail to connect to the network, reporting latencies of network services such as AAA, DHCP, and DNS. Administrators can drill down and access live and historical client connection logs to aid troubleshooting.

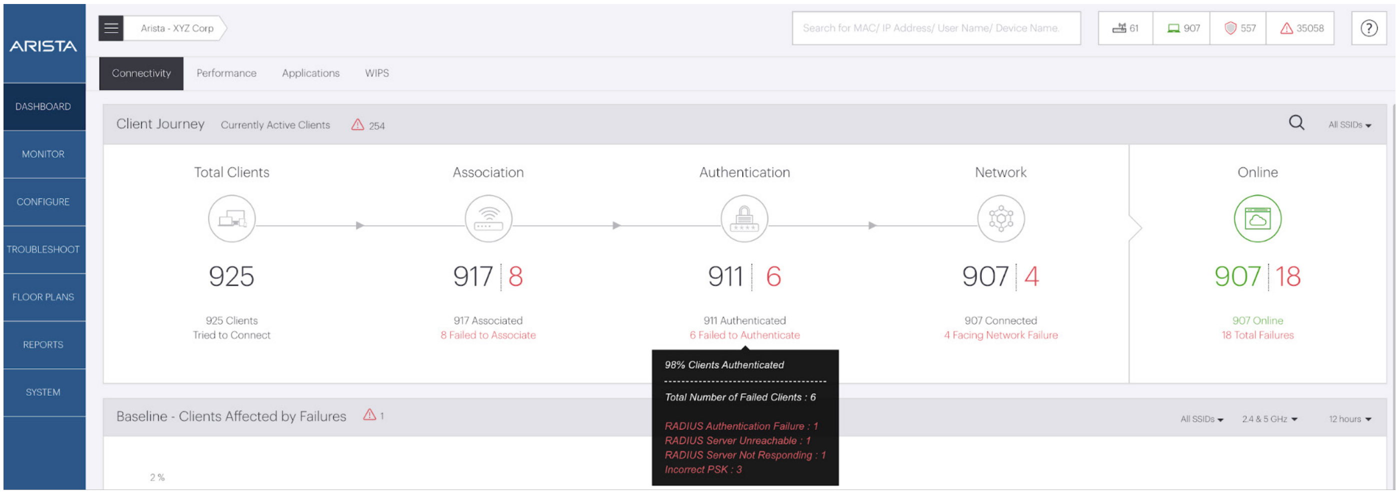


Figure 4: Client Journey

Network Baselining

Using machine-learning algorithms on the telemetry it collects, CloudVision WiFi baselines network traffic and automatically detects and highlights anomalies.

Figure 5: Baselines

Root Cause Analysis / Inference Engine

CloudVision WiFi employs in-built domain expertise and protocol-level intelligence to help administrators maintain the network. In real time, it automatically detects and classifies WiFi clients connection failures and pinpoints the root cause—if it is related to WiFi or to a network service such as DHCP or DNS, a client device or an application.

Similarly, it automates root cause analysis of poor performance, such as poor coverage, high retry rate and sticky clients and it then can recommend remediation steps.

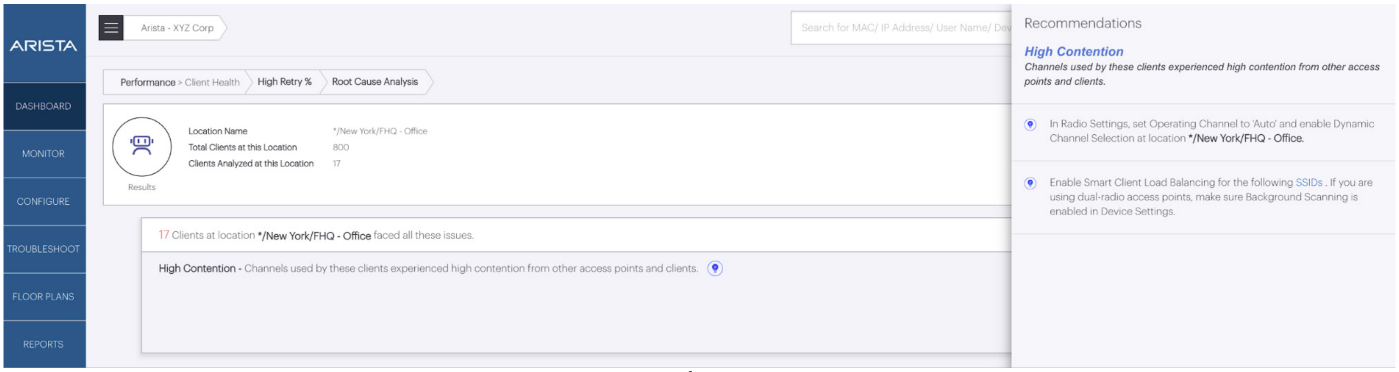


Figure 6: Inference Engine

Automatic Packet Capture / Visual Packet Capture Analysis

With real-time, inline packet capture, CloudVision WiFi preemptively captures packet traces to help capture problems. The traces are stored alongside related failures or symptoms to simplify troubleshooting at a later time. Packet traces can be downloaded or directly visualized in Arista Packets, the cloud-based, visual WiFi packet analyzer.

Figure 7: Auto Packet Capture / Visual Packet Capture Analysis

Network Assurance Testing

CloudVision WiFi employs a multi-function 3rd radio, turning it into a client to run tests and proactively identify problems before users do. Scheduled automated end-to-end performance tests help validate the network's readiness for supporting business-critical applications.

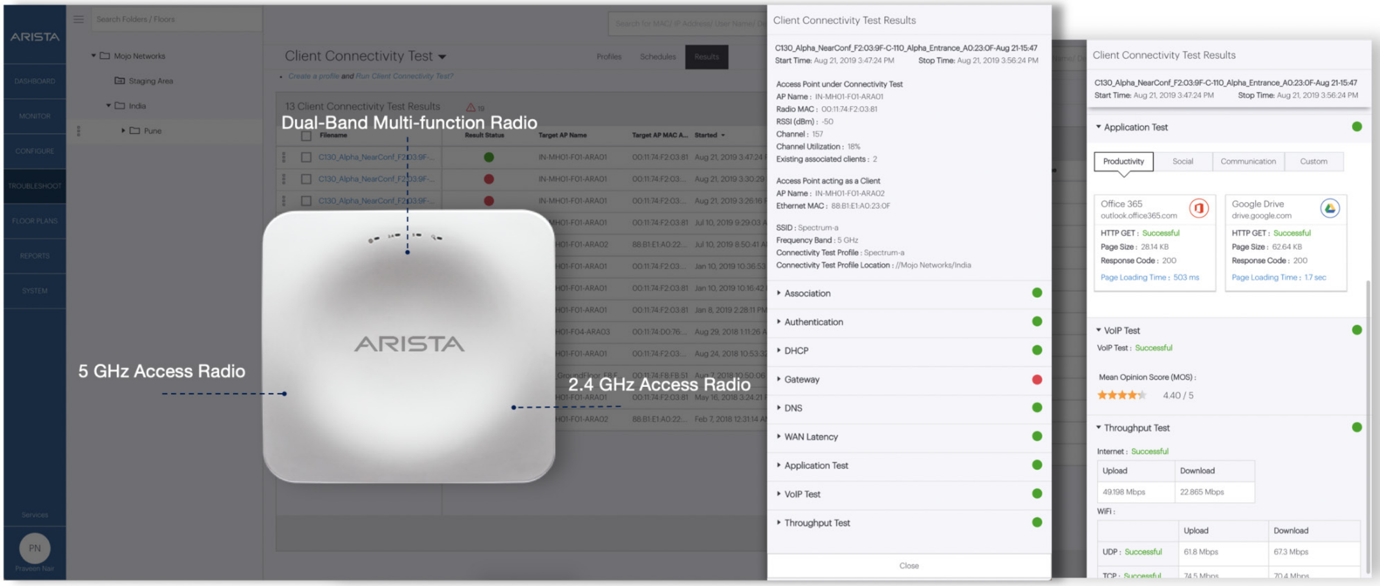


Figure 8: Network Assurance Testing

Intelligent RF Optimizations

Arista's 3-radio APs provide unparalleled visibility in both 2.4 GHz and 5 GHz bands which enables automatic RF optimizations such as band steering, smart steering, auto channel selection or auto transmit power control to maximize WiFi capacity. Real-time application performance is further enhanced with multicast-to-unicast conversion and smart blocking, pruning and optimization of broadcast and multicast traffic.

Application QoE / Single Client Inferencing

Know whether or not your users are happy with their experience of running VoIP and video conferencing applications on your network. In the event that users are experiencing poor application performance the system can do automatic root cause analysis and offer remediation recommendations.

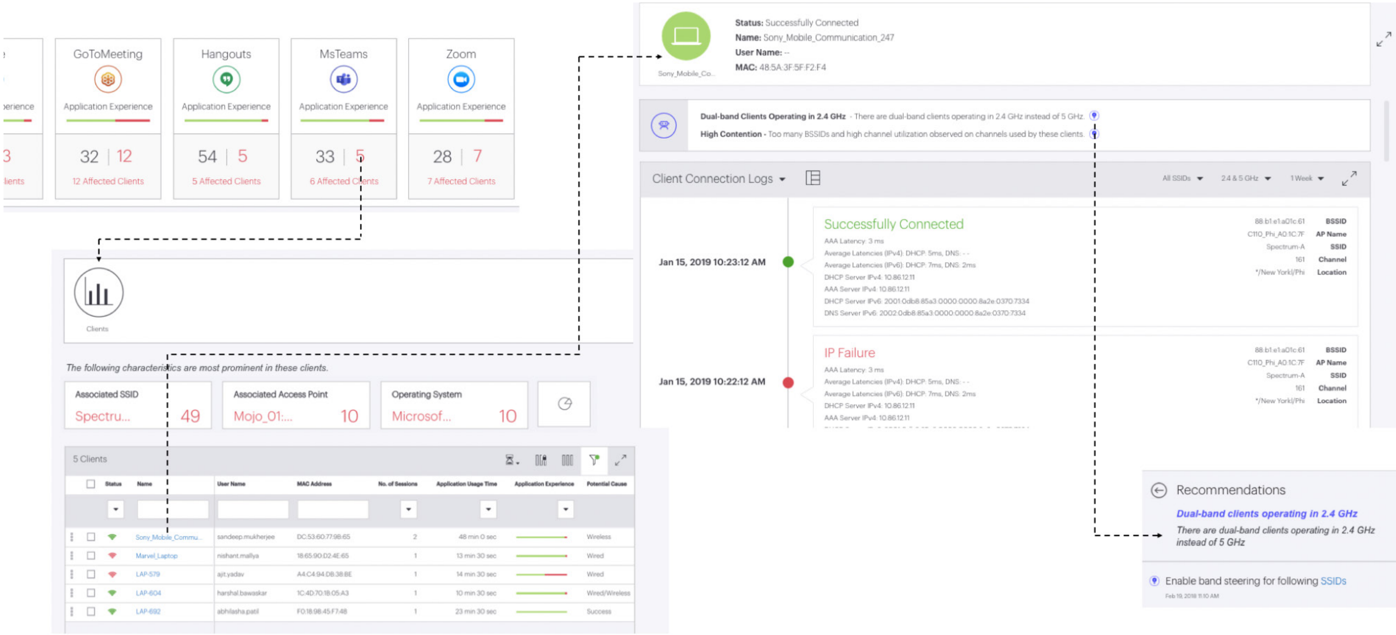


Figure 9: Application QoE / Single Client Inferencing

WIPS

Arista provides the best-in-class Wireless Intrusion Prevention System (WIPS), it is powered by several patents and ranked at the top by Gartner in all six Marketscope reports on WIPS. The system provides comprehensive protection from all types of wireless threats such as rogue APs, soft Rogue APs, ad-hoc networks, client mis-associations, honeypots, WiFi Denial of Service (DoS) attacks, and Bring Your Own Device (BYOD) risks such as mobile hotspots.

With the 3rd radio acting as a dedicated wireless intrusion prevention (WIPS) sensor, wireless threats are detected and blocked almost instantly. CloudVision WiFi works with the APs powered by patented techniques such as Marker Packets to enable surgical over-the-air prevention, automatically and accurately creating alerts and classifying wireless threats.

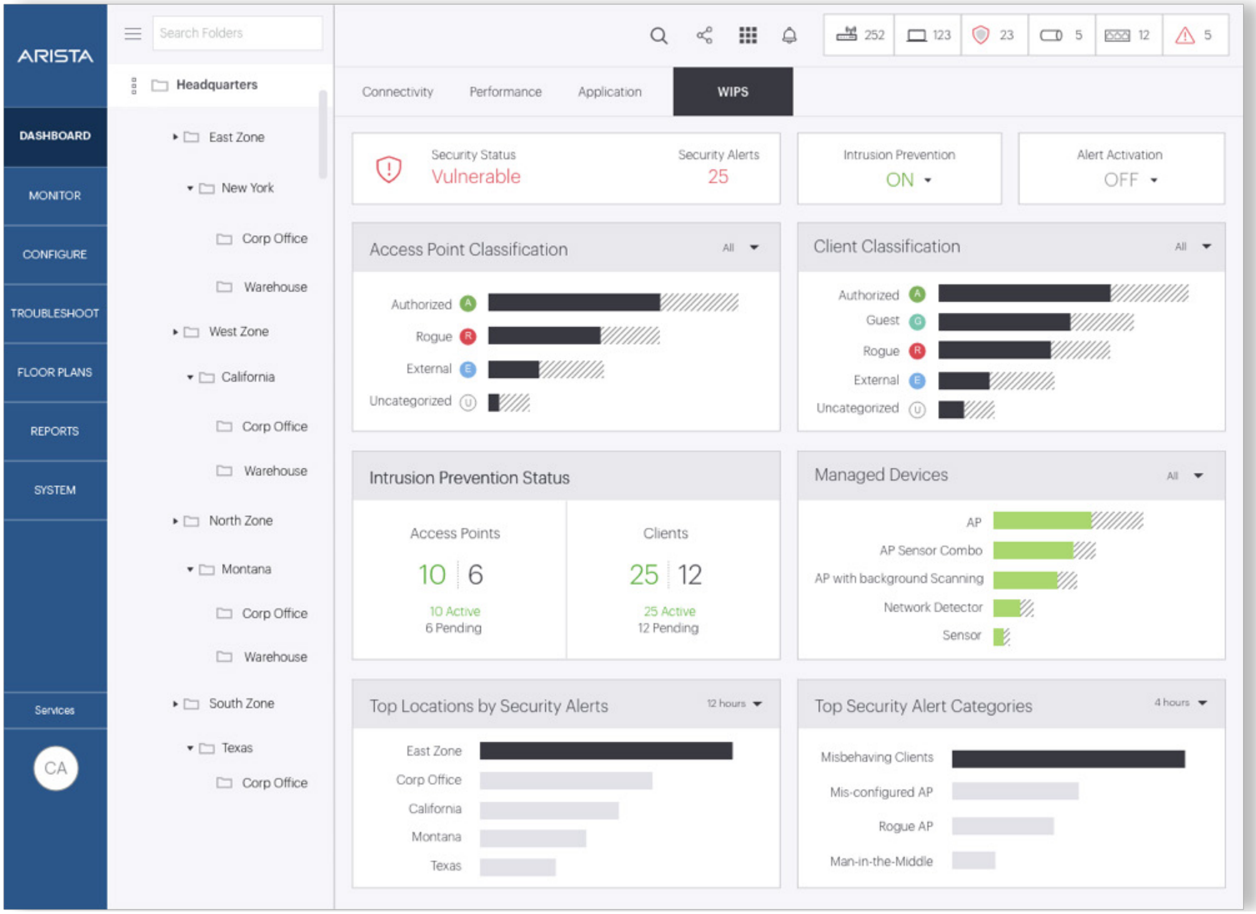


Figure 10: WIPS Dashboard

Packets

Packets is a graphical cloud-based collaborative packet analysis/WLAN troubleshooting tool. Arista APs can automatically perform packet captures while still servicing WiFi clients, and the captures can be saved directly to the cloud, enabling remote troubleshooting. Issues can be discovered quickly using the graphical interface, where patterns are readily visible, as opposed to traditional packet analysis tools which require sifting through thousands of packets.

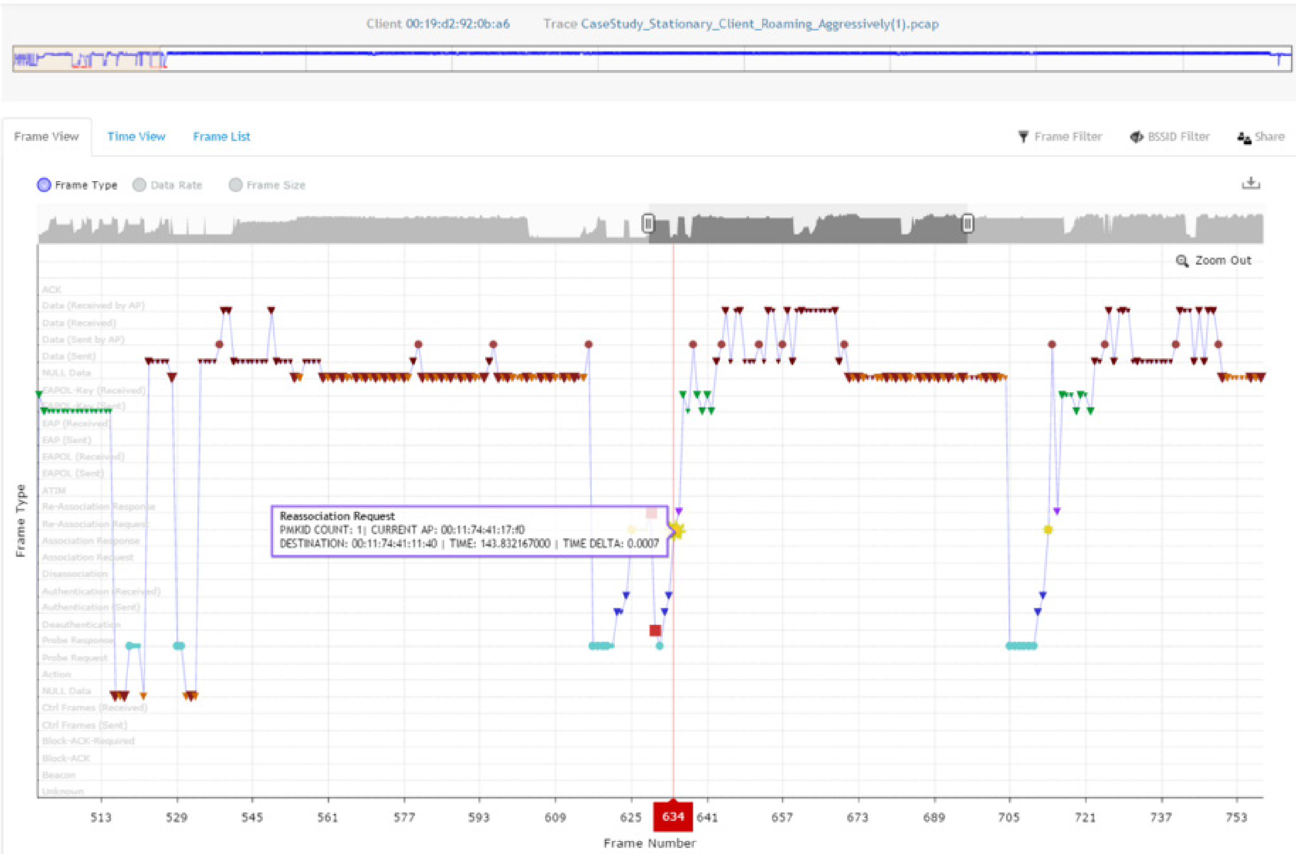


Figure 11: Packets

Guest Manager

Guest Manager provides enhanced guest management functionality by enabling guests to access WiFi using social media, SMS, Guest Book, and Web Form plugins. During social login, guest WiFi users can also opt to share their public profile information, which can be used to foster user engagement.

Figure 12: Analytics

Regulatory Compliance

Arista Networks enables organizations to meet wireless security requirements defined by their respective regulatory compliance standards. The audit process is simplified with predefined Health Insurance Portability and Accountability Act (HIPAA) and Payment Card Industry (PCI) compliance reports which map wireless vulnerabilities and threats to specific requirements. Reports can be generated across many locations from a single management console. Reports can be generated on-demand, scheduled for automatic generation, archived, and/or delivered by email.

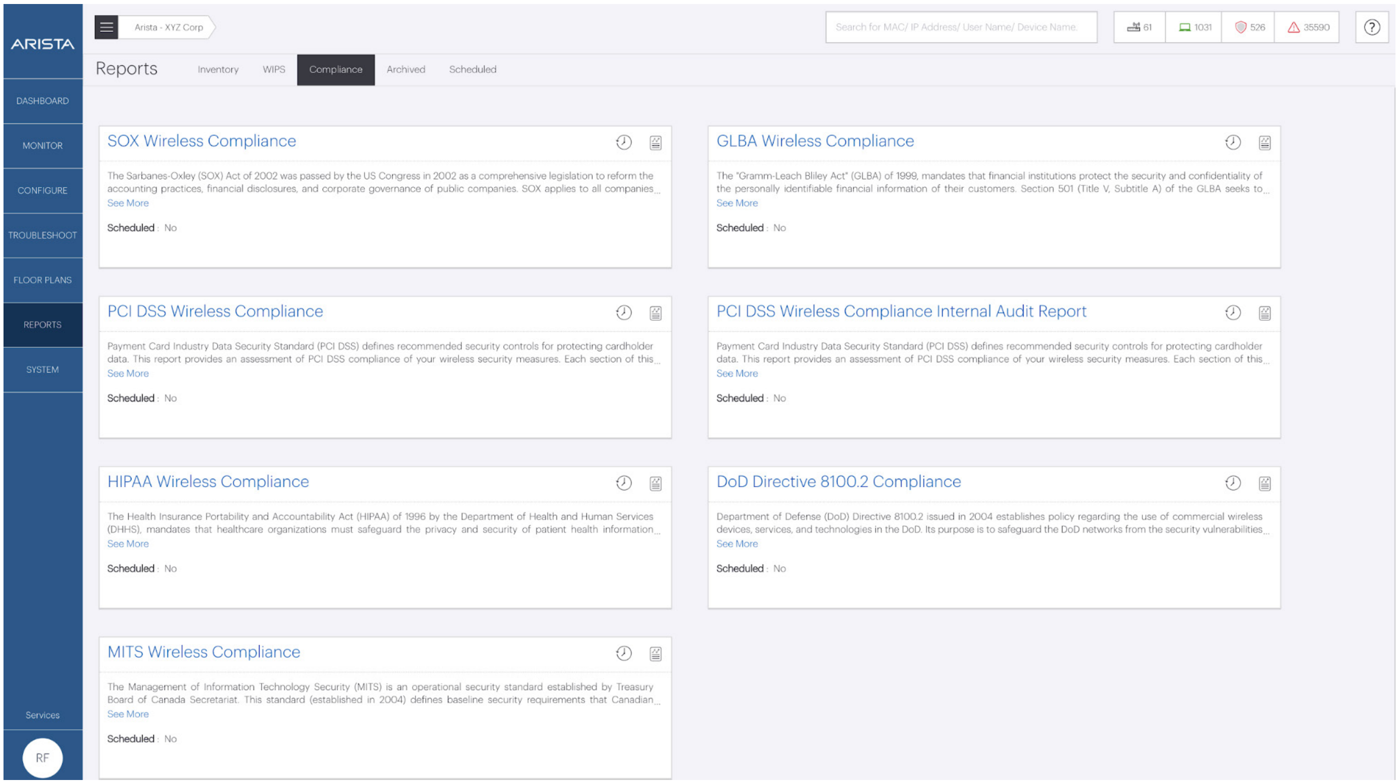


Figure 13: Predefined Compliance Reports

Massively Scalable, Secure Multi-Tenant, Elastic Cloud Architecture

Powered by a mature, elastic cloud technology in development since 2008, the Arista cloud can scale to any number of locations. Built-in multi-tenancy allows account information, configurations and data to be completely segmented, even for customers served from a common server instance.

The Arista cloud management platform is SSAE-18 SOC 2 Type 1 and Type 2 certified and offers 99.95% uptime with local and WAN-based high availability as well as disaster recovery.

Arista APs are managed from the cloud over a secure AES-encrypted tunnel. They are capable of standalone operation and provide uninterrupted service with full functionality even if the connectivity to cloud is lost (e.g. if the WAN link at a remote site goes down).

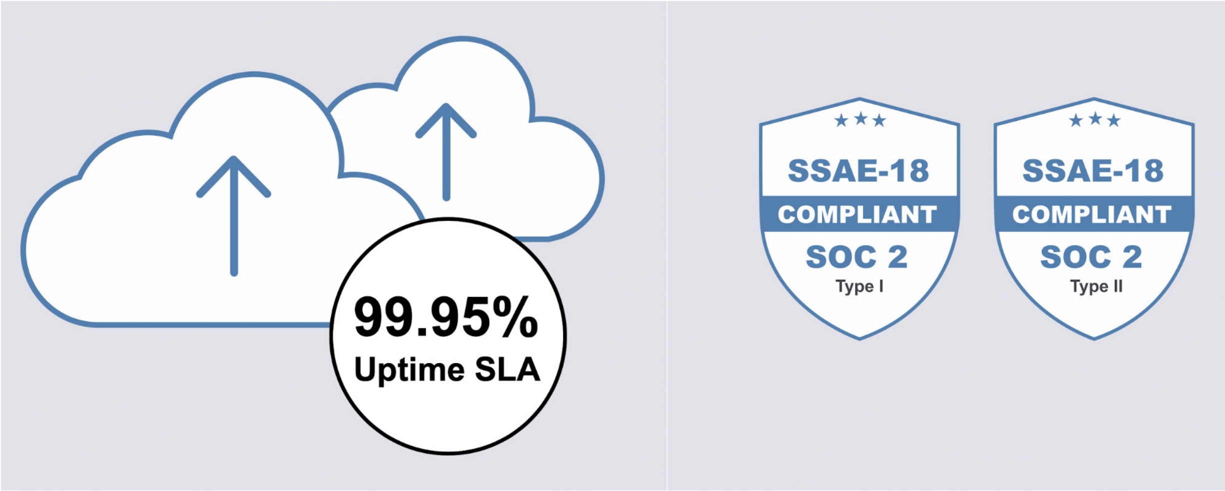


Figure 14: Reliable, Scalable and Secure Public Cloud

Navigator

Navigator is a unique hierarchical location-based policy management architecture that simplifies management of multiple locations from a single console. Everything from role-based administration, WiFi configurations and WIPS policies to compliance reporting and alerting can be defined in a logical context and tied to specific locations.

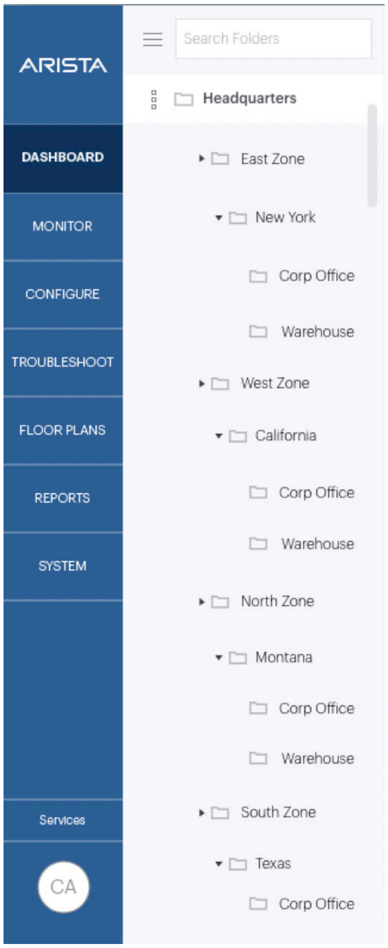


Figure 15: Hierarchical Navigator

Zero Touch Deployment

Arista APs come programmed out of the box to automatically discover and connect to the Arista Cloud as soon as they are powered up and get Internet access. This simplifies the rollout even at remote sites without IT staff. Once the AP is moved to its respective location folder in Navigator, the policies and configurations assigned to that location are automatically pushed to the device, so the AP is up and running in a matter of minutes.

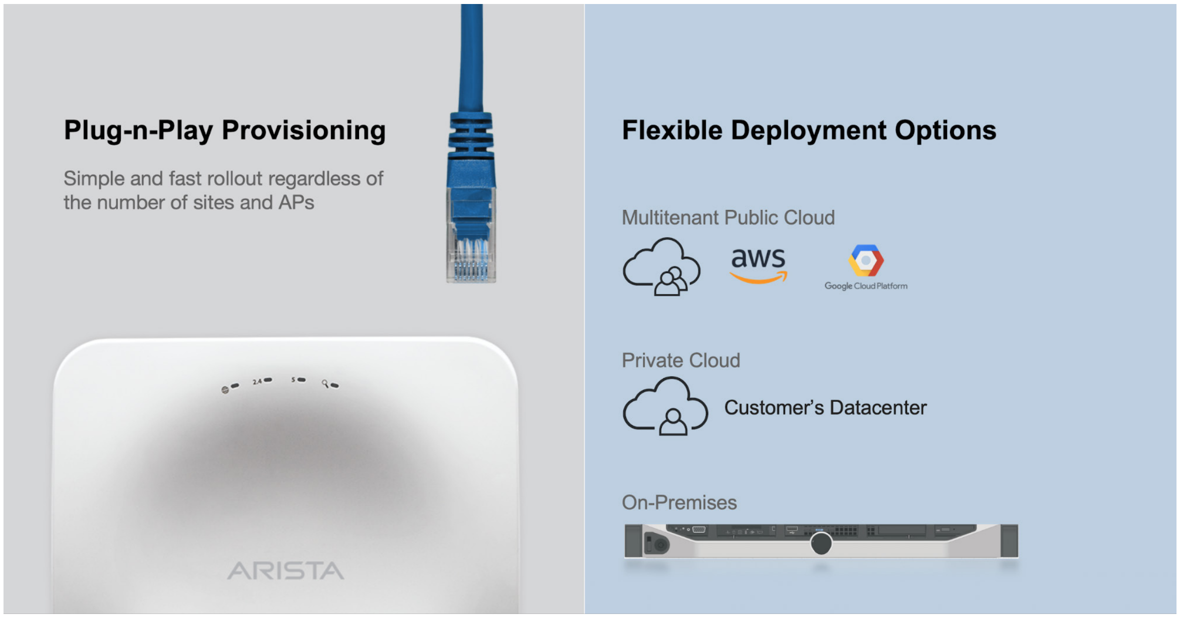


Figure 16: Zero Touch Deployment

Architecture - Management, Control and Data Plane

CloudVision WiFi's cognitive management plane simplifies provisioning, configuration, troubleshooting and reporting. A centralized management plane simplifies policy management and provisioning of WiFi networks. A flexible data plane enables customizable data traffic flow per SSID. A distributed control plane enables enterprise features without the scalability issues of legacy controller-based architectures. The Arista innovative cognition plane, with streaming telemetry, automates WiFi network monitoring and troubleshooting to optimize the WiFi user experience, minimizing the mean time to resolution (MTTR) for network access and performance issues.

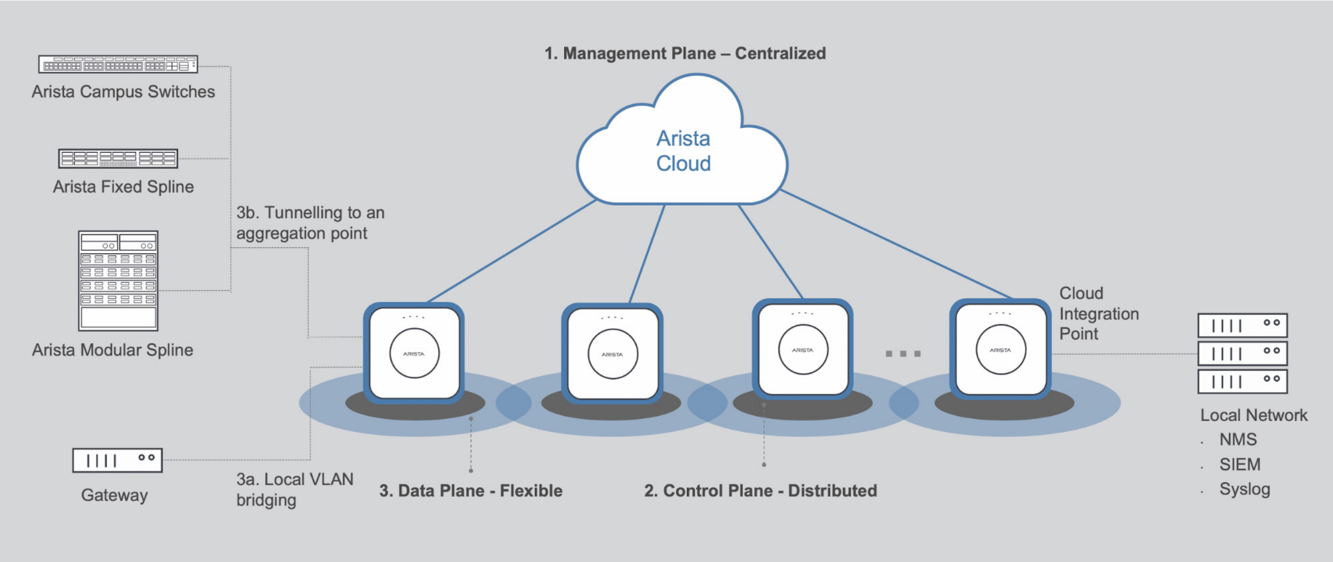


Figure 17: Management, Control and Data Plane

Software-defined, Programmable WiFi

Build your own applications on top of the extensible Arista Cloud using push and pull APIs. Alternatively, implement your own management system for a multi-vendor network with the built-in support for OpenConfig.

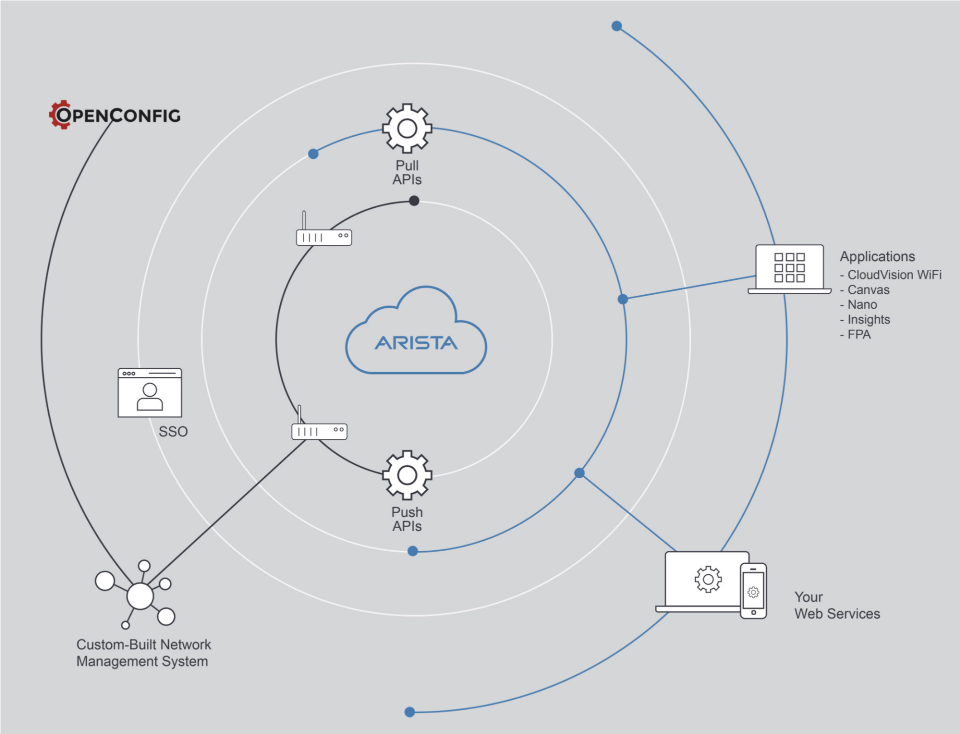


Figure 18: Programmable WiFI

Channel Capacity Planning

Most WiFi networks are designed for capacity rather than coverage these days, where high client densities and high bit rate applications (e.g. HD video streaming) are the norm. To design networks for capacity, the first step is a discovery of the requirements such as client density, types of clients in use, applications in use, use case, and per client throughput Service Level Assurance (SLA). Other information needed to ensure a successful design is related to the environment, such as WiFi spectrum availability, building layouts, building materials used, and neighbor WiFi channel usage.

WiFi 6 Impact on Channel Capacity

Generally speaking, WiFi 6 / 11ax has the same coverage characteristics as WiFi 5 / 11ac. One benefit that WiFi 6 offers is higher capacity or better performance for the same number users for a given coverage area. That said, until we all have more WiFi 6 performance testing lab results (e.g. MU-MIMO and OFDMA efficacy) and production deployments to inform our capacity design models the general recommendation is to use existing capacity planning estimates, which were derived from years of testing of 11b/a/g/n/ac performance.

Designing WLANs for Capacity

The design process presented in this guide is outlined below. The goal of this process is to determine how many APs are required throughout each area of the deployment. The methodology presented can be broken down to the following three steps.

1. Requirements Discovery
2. Environment Discovery
3. Channel Capacity Planning

Requirements Discovery

WiFi 6 Impact on Channel Capacity

In this step we discover the number and types of devices as well as where they are located on the network. Channel capacity and overall network capacity are as much a function of the client population as the types of APs and switches deployed. While it is not always possible to know the exact breakdown of client capabilities for a given area of the network, the more details that are known, the more accurate the channel capacity planning will be. Monitoring and client fingerprinting tools of the current WiFi system can provide details about the clients being used on the network.

The image below shows maximum data rates for different client types operating with different channel widths. Comparing the maximum data rate of the 1x1 Acer F15 (i.e. 200 Mbps) to that of the 3x3 MacBook Pro (i.e. 600 Mbps), using 40 MHz channels, reveals that the MacBook Pro has three times the maximum data rate of the Acer F15. For a network that only has MacBook Pro clients, a WLAN could have as much as three times the capacity than a network with only Acer F15 clients (assuming that the WLAN has deployed an AP that supports 3 or more spatial streams like the Arista Networks C-130 or the C-260).

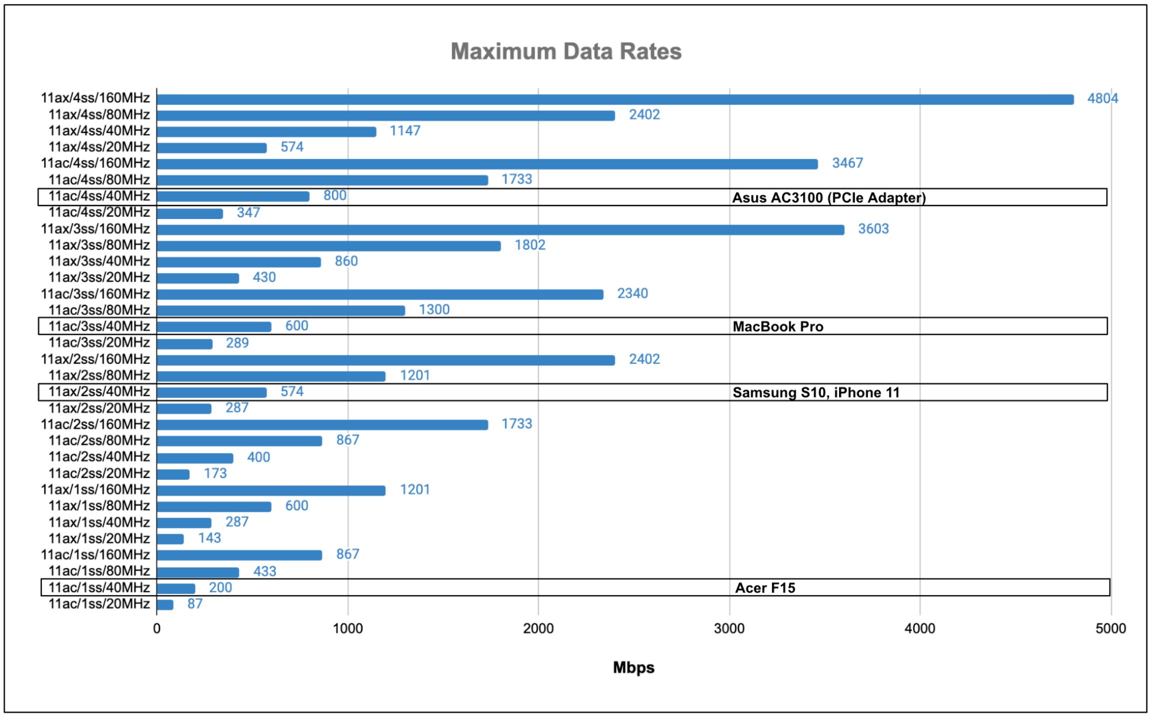


Figure 19: Maximum Data Rates for Clients

Applications

An application's bitrate is one of the factors used to determine capacity planning requirements, so the applications that are, or will be, running on WiFi devices must be identified. To estimate a per-client Mbps SLA for a given area of a deployment, the application with the highest bitrate should be used. For example, in a classroom the highest bit rate application may be HD video streaming at 5 Mbps, so a per-client SLA of 5 Mbps would be recommended. Application visibility tools of the current WLAN system can help determine which applications are currently in use.

It is also important to design for applications that will be used in the future. Querying IT personnel about proposed future application usage is recommended.

The table below provides approximate bit rates for common applications. These values can be used as references for calculating capacity requirements.

Application	Approximate Average Bitrate
Audio	.100 - 1 Mbps
File Backups	20 - 60 Mbps
File Sharing	5 Mbps
Online Testing	2 - 4 Mbps
Printing	1 - 3 Mbps
Video Conferencing: Standard Definition	.5 - 1 Mbps

Video Conferencing: High Definition	2 - 3 Mbps
Video Gaming	*Need to measure
Video Streaming: Standard Definition	1 Mbps
Video Streaming: High Definition 720p	3 - 5 Mbps
Video Streaming: High Definition 1080p	8 - 12 Mbps
Video Streaming: UHD (4K)	18 - 25 Mbps
Webinars	1 Mbps
Web Browsing	750 Kbps

Table 1: Estimated Application Data Rates

*No value is provided for Video Gaming (e.g. Xbox One X console that is WiFi connected playing a game online). As new applications will continually be introduced, Arista recommends performing an over-the-air packet capture or use the application visibility feature in the current WLAN system to measure an application's bitrate.

Use Cases

In this step, unique use cases found throughout the deployment will be discovered. In this context a use case is defined as:

Use Case = number of devices + types of devices + set of applications + usage patterns + for a given area

To learn about use cases for a particular deployment, a thorough site walk-through with IT personnel familiar with the current network usage is recommended. In later sections of this guide solutions for various campus uses cases are presented.

Environment Discovery

Building(s)

Understanding both building dimensions and construction materials used throughout the site is critical for estimating the number and location of APs. To gather this information, a thorough walk-through of the site is recommended.

Regulatory Domain

The number of channels potentially available for a deployment depends on the regulatory domain where the deployment is located. Some regulatory domains have more spectrum capacity compared to others. The amount of spectrum available for a given deployment has a direct impact on the types of uses cases that can be supported.

Radio Frequency (RF) Environment

In this step the RF environment is characterized, where local sources of WiFi and non-WiFi interference are identified. Deployments located in dense urban areas will generally have more potential interference than for deployments located in rural areas. A spectrum analyzer and WLAN discovery tools can be used to learn about the RF environment.

Spectrum Availability in 5 GHz

Before capacity planning, a review of spectrum availability helps guide the planning process. The graphic below shows the current 5 GHz spectrum for the regulatory regions covered by the Federal Communications Committee (FCC). Even with the use of all of the channels currently available, which include Dynamic Frequency Selection (DFS) channels, there are some high density/high throughput use cases where meeting the capacity requirements can be challenging.

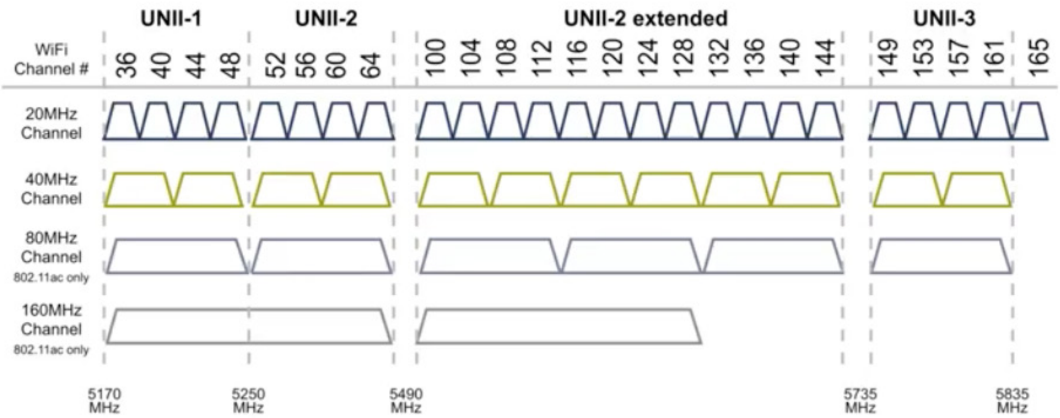


Figure 20: US 5 GHz Spectrum
Source: VeEX Inc.

Channel Availability in the US

Channel availability in the US is shown in the table below. Most campus networks will deploy 20 MHz channels for 2.4 GHz and 40 MHz channels for 5 GHz. Some notable exceptions are high density auditorium or stadium/arena deployments where 20 MHz channels are often preferred due to the requirement for efficient channel reuse. The use of 80 MHz channel plans should only be considered if all or most DFS channels are available, as without DFS channels there are only two non-overlapping 80 MHz channels available. Utilizing DFS channels allows for up to six non-overlapping DFS channels in the US, as shown in the table below.

Channel Width	Without DFS	With DFS
20 MHz	9	25
40 MHz	4	12
80 MHz	2	6
160 or 80+80 MHz	1	3

Table 2: US 5 GHz Channel Availability

Channel Width Selection

Ultimately, channel width selection depends on a number of factors including use case requirements, spectrum availability, RF environment, AP budget, etc.

In a deployment in which DFS channels cannot be used (thus forcing the use of 40 MHz or 20 MHz channels), requirements may need to be reconsidered. For example, by lowering the bitrate at which video is streamed.

When designing a WLAN for maximum capacity while also minimizing AP count, deploying 80 MHz channels is often the best option. If DFS channels are used, many regulatory regions around the globe make enough spectrum available to support 80 MHz deployments. If all or most DFS channels cannot be used, 40 MHz channels are recommended for most regions, including the US.

Using DFS Channels

In the past, WLAN designers were reluctant to deploy DFS channels due to concerns about lack of client support and network instability from radar event detection. However, many networks today rely on DFS channels to meet their increasing capacity requirements. Because radar events are not as common as once thought (for most deployments), and newer WiFi devices support DFS channels, DFS-enabled WLANs have become much more common.

Arista recommends enabling DFS channels if they are available. In addition, it is recommended to provision both 5 GHz and 2.4 GHz pervasively. Deploying 2.4 GHz coverage throughout the deployment is a best practice, as it is needed to provide access for 2.4 GHz-only clients and for the odd dual band clients that do not support DFS channels. Deploying 2.4 GHz pervasively will also provide some additional capacity (which is modest compared to 5 GHz).

Estimating Channel Capacity

Tools like Ekahau Site Survey can automate much of the capacity planning process; however, there are many network designers who prefer a manual approach. This section covers a manual method of estimating channel capacity requirements.

As mentioned previously, proper capacity planning needs to be use case specific and must consider factors such as:

- Total active devices
- Types of devices
- Usage patterns
- Applications in use
- Area of coverage

Estimated throughput capacities for different channel widths and spatial streams are provided in this guide. The table below shows the maximum data rates supported by different channel widths and spatial streams. Channel capacity planning will start with the values below as points of reference only.

Note: This guide currently uses 11ac (WiFi 5) data rates for channel capacity planning as the percentage of 11ax clients in use remains low. A future version of this guide will use 11ax (WiFi 6) data rates.

Maximum Data Rates				
	20 MHz	40 MHz	80 MHz	160 MHz
1 Spatial Stream	87 Mbps	200 Mbps	433 Mbps	867 Mbps
2 Spatial Streams	173 Mbps	400 Mbps	867 Mbps	1.73 Gbps
3 Spatial Streams	289 Mbps	600 Mbps	1.33 Gbps	2.34 Gbps
4 Spatial Streams	347 Mbps	800 Mbps	1.73 Gbps	3.47 Gbps

Table 3: Maximum Data Rates

The rates listed above are maximum data rates and not throughput capacity rates. Throughput capacity rates will be much less due to factors such as protocol overhead, contention loss, and loss due to signal strength degradation, etc. Appendix A provides a series of tables that list estimated channel capacities for different rates of contention loss and loss due to signal strength degradation for different channel widths and spatial streams. These tables may be referenced to simplify the channel capacity planning process.

Note: The estimated channel capacity tables in the guide do not factor in the effects of MU-MIMO or OFDMA as more testing and real world feedback is needed to truly understand the impact that these two enhancements will have on channel capacity. A future version of this guide will factor in the spectrum efficiency gains of MU-MIMO and OFDMA.

Channel Capacity Estimate Considerations

The channel throughput capacity estimates below, and in Appendix A, are derived from single AP and multi-AP competitive performance testing. The estimations factor is contention loss seen in tests for 5, 10, 20, 30, 40, 50 and 60 clients per radio, where all clients are placed within 20 feet (6.096 meters) of the AP under test. To estimate loss caused by rate adaptation due to lower signal strength, clients are placed from 10 to 60 feet (3.048 – 15.24 meters) away from an AP.

Note: While capacity loss from WiFi interference such as Co-Channel Interference (CCI) and Adjacent Channel Interference (ACI) can be substantial, these causes for capacity loss are not factored in, nor is non-WiFi interference capacity loss.

The table below lists maximum throughput rates for different channel widths and spatial streams, which is estimated to be 60% of maximum data rate. This is a conservative number as under the right circumstances a 3 spatial stream client (e.g. MacBook Pro) connected to 3 spatial stream AP configured for 80 MHz is capable of achieving throughput of 850 Mbps, as compared to the listed value of 798 Mbps.

Estimated Max Throughput Capacity - 60 % Max Data Rate				
1 Client Active	20 MHz	40 MHz	80 MHz	160 MHz
1 Spatial Stream	52 Mbps	120 Mbps	260 Mbps	520 Mbps
2 Spatial Streams	104 Mbps	240 Mbps	520 Mbps	1.04 Gbps
3 Spatial Streams	173 Mbps	360 Mbps	798 Mbps	1.40 Gbps
4 Spatial Streams	208 Mbps	480 Mbps	1.04 Gbps	2.08 Gbps

Table 4: Estimated Maximum Throughput Capacity

Actual use cases are unlikely to be with a single client active so the table above is only useful as a benchmark for throughput capacity. When factoring for higher client densities common to campus deployments, throughput capacity declines significantly. The tables in Appendix A will be referenced for the channel capacity planning example below, as well as for the campus use cases presented later in this guide.

Channel Capacity Calculations

This section provides a method to calculate channel capacity manually.

Step one is to determine the percentage of airtime or channel utilization that an individual client requires to meet a per client throughput SLA for a particular use case.

Step two is to determine the total channel capacity needed to accommodate all clients in the use case.

In step one below, a library use case has 150 MacBook Pros (or other 11ac 3x3 clients) active concurrently and each of them need a per client throughput SLA of 2 Mbps. DFS channels are not available so a 40 MHz channel plan will be used.

Before starting calculations, the estimated channel capacity per radio must be known and an estimated density per radio is needed to find the estimated channel capacity in Appendix A. This use case will likely fall into the very high client density category as there will be 150 clients active concurrently.

Step 1: Determine Per Device Airtime / Channel Capacity

Use Case	Device Type	Number of Active Devices / Density	App or SLA Bitrate	Channel Capacity	Per Device Airtime / Channel Capacity
Library	MacBook Pro 3ss	150 / Very High	SLA = 2 Mbps	120 Mbps / 40 MHz	1.67%

Table 5: Estimating Per Client Airtime - Library

The very high client density table in Appendix A shows that for 11ac 3x3 clients with a 40 MHz channel, the estimated throughput capacity is 120 Mbps. To determine the percentage of airtime or channel utilizations an individual client requires to meet a per-client throughput SLA, divide the SLA by estimated channel capacity and multiply by 100, as shown below.
(App Bitrate or SLA/Channel Capacity) X 100 = Per Device Airtime

(2 Mbps / 120 Mbps) x 100 = 1.67%

Per Device Airtime = 1.67%

The second step is to determine the total channels/radios required to meet the requirements of this use case.

Step 2: Determine Total Channels / Radios Required

Use Case	Device Type	Number of Active Devices / Density	Per Device Airtime	Total Airtime	Estimated Channels / Radios Required
Library	MacBook Pro 3ss	150 / Very High	1.67%	250%	3

Table 6: Estimating Radios Required - Library

To estimate the total channels/radios needed to meet the requirements of the use case, multiply the per-client airtime required and the total number of clients active concurrently, as shown below.

Number of Active Devices x per Device Airtime = Channels/Radios Required

150 Active Devices x 1.67% per Device Airtime = 250%

Channels/Radios Required = 3 (Rounding up)

This method will be used later in the guide to find solutions for additional use cases.

Maximum Clients per AP

WLAN vendors are often asked how many clients are recommended per AP, which is not to be confused with that maximum number of associations that an AP model can support. For the maximum number of associations that AP models can support, please refer to their respective AP datasheets, which can be found on the Arista website.
As discussed in the Channel Capacity Planning section of this guide, the answer to the question about how many clients an AP can support depends on the specific requirements of a use case. However, providing maximum client counts per AP model can still be helpful for choosing the right AP for the use case.
The table below lists some general guidelines for the recommended maximum clients for various Arista AP models.

Model	Description	Recommended Usage	Maximum Clients Recommended per AP	5 GHz / 2.4 GHz
C-100	Dual radio 11ac 2x2 Wave 2 Indoor	Low or moderate client density / throughput areas	70	40 / 30
C-110	Tri radio 11ac 2x2 Wave 2 Indoor	Low or moderate client density / throughput areas	70	40 / 30
C-130 / C-130E	Tri radio 11ac 4x4 Wave 2 Indoor	High client density / throughput areas	100	70 / 30
C-230 / C-230E	Tri radio 11ax 4x4 5 GHz 11ax 2x2 2.4 GHz Indoor	High client density / throughput areas	100	70 / 30
C-250 / C-260	Tri radio 11ax 8x8 5 GHz 11ax 4x4 2.4 GHz Indoor	Very high client density / throughput areas	120	80 / 40

W-118	Tri radio 11ac 2x2 Wave 2 Indoor Wall Plate	Low or moderate client density / throughput areas Hotel / dorm rooms	70	40 / 30
O-105 / 0-105E	Dual radio 11ac 2x2 Wave 2 Outdoor	Low or moderate client density / throughput areas / Outdoors / harsh environments	70	40 / 30
O-235 / O-235E	Tri radio 11ax 4x4 5 GHz 11ax 2x2 2.4 GHz Outdoor	High client density / throughput areas / Outdoors / harsh environments	100	70 / 30

Table 7: Recommended Max Client Per AP

Summary of Channel Capacity Planning Recommendations

Channel capacity planning recommendations for a campus WLANs are provided in the table below.

Recommendations	Notes
Design WLAN for capacity.	
Focus design on specific use cases.	Use Case = Number of devices + types of devices + set of applications + usage patterns + for a given area
Use most demanding application (per use case) for SLA.	Alternatively, if application information is unknown, design for a per client throughput SLA of 5 Mbps.
Use the current WLAN management system to determine the type and number of devices per use case.	
Use the current WLAN management system to determine application bitrates.	Alternatively, packet capture tools can be used to determine application bitrate.
Right size the AP for the use case.	Refer to Table 7: Recommended Max Client Per AP for AP selection.
Use predictive planning tools like Ekahau Site Survey to estimate the number of APs required to meet use case SLAs.	

Design for 5 GHz capacity.	Deploy both 2.4 GHz and 5 GHz pervasively.
Use DFS channels.	Discover if any DFS channels are causing interference with local radar and remove those channels from the channel candidate list.
Use 20 MHz channels for 2.4 GHz. Use 40 MHz channels for 5 GHz for most use cases. Use 20 MHz channels for very high client and AP density use cases. Consider using 80 MHz channels for high throughput use cases and DFS channels are available.	If a number of DFS channels cannot be used, opt for 40 MHz channels.

Table 8: Channel Capacity Planning Recommendations

Site Preparation

To ensure a successful deployment, the installation site must be prepared properly. This section provides a checklist to assist the implementation team with site preparation.

Checklist for Site Preparation

Installation Preparation	Notes
POE or AC power	See Table 13: AP Power Requirements for AP power requirements.
Cable plant (CAT5e or >)	See Table 14: Cable Category Reference for more information.
Ladder/Scissor Lift	
Special AP mounting requirements	AP mounting instructions are available in AP Installation Guides.
Internet availability	
Tools (for mounting APs)	

Implementation Preparation	Notes
Switch ports	
DHCP Service	

RADIUS Service	
DNS IPs	
VLAN IDs	
Firewall rules: • Port 3851 (UDP) outbound • Port 3852 (UDO) outbound • Port 80 (TCP) outbound • Port 443 (TCP) outbound	Port 3851 (UDP) AP-to-cloud comms Port 3852 (UDO) CIP Port 80 (TCP) AP upgrade /backup Port 443 (TCP) AP upgrade / primary
Proxy bypass rule for AP management traffic	Bypass rule is for management traffic from AP IP address to Arista cloud instance
Verification Preparation	**Notes**
WiFi clients	These clients are needed for acceptance testing.
Acceptance test plan	The acceptance test plan should verify proper client and application functionality throughout the deployment.

Table 9: Site Preparation Recommendations

Deployment Best Practices

In this section, deployment best practices are presented for the following:

- WLAN
- LAN
- Network Services
- AP Placement and Channel Plan

The recommendations in this section are based on successful WiFi deployments. However, as there are no two identical WiFi networks, the recommendations presented here are guidelines only.

WLAN Best Practices

This section offers suggestions for deploying a WLAN capable of supporting a variety of campus WiFi use cases.

Setting a Minimum Unicast Rate

The default minimum unicast rate for 2.4 GHz 11n and 5 GHz 11ac is more suitable for networks designed for coverage as opposed to client and/or throughput capacity. As mentioned previously, Arista recommends that campus WLANs should be designed for capacity whereas the goal is to improve the throughput and client capacity of each cell, and to reduce cell sizes so that channels may be reused more frequently. This results in an increase in the overall capacity of the network (given a fixed amount of spectrum).

One technique that can help reduce cell size is to increase the data rate at which clients can associate to a WLAN. Arista recommends that the minimum unicast/association data rate be set to 24 Mbps. This setting can be managed in the Configuration / WiFi / SSID Profile / Traffic Shaping & QoS section of CloudVision WiFi.

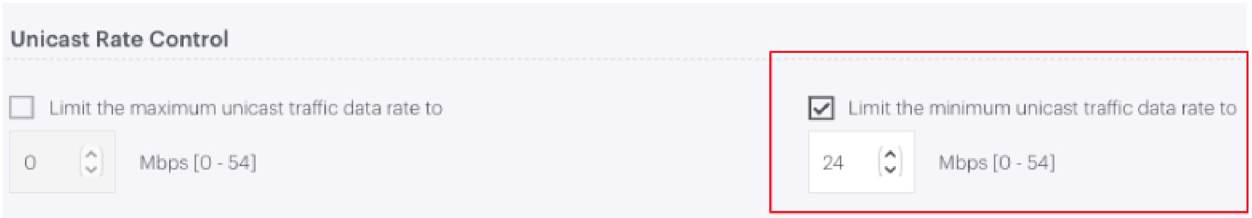


Figure 21: Setting Minimum Unicast/Association Rate

Signal Strength, Channel Width and Quadrature Amplitude Modulation (QAM)

The table below lists approximate signal strengths required to support various Modulation and Coding Scheme (MCS) rates for various channel widths. MCS rates that use 256-QAM require higher signal strengths than MCS rates that use 64-QAM due to the greater constellation density required to support 256-QAM. In addition, wider channels also require higher levels of Received Signal Strength Indicator (RSSI) compared to narrower channels to support a given modulation scheme.
For example, 64-QAM/MCS-7 requires -62 dBm for 40 MHz channels, but the requirement jumps to -58 dBm for 80 MHz channels. To design a network that supports 256-QAM/MCS-9, using 80 MHz channels pervasively, a signal strength of -52 dBm or greater throughout the deployment is required. This means that APs should be placed every 30 - 50 feet, depending on the environment, client and AP capabilities, etc. While there may be high density/throughput use cases (e.g. an auditorium) where designing for 256-QAM or even 1024-QAM is recommended, most campus deployments will be designed to support 64-QAM or greater pervasively.

Modulation Scheme	20 MHz	40 MHz	80 MHz	80+80 MHz	160 MHz
11ac 64-QAM/MCS-7	-64 dBm	-62 dBm	-58 dBm	-55 dBm	-55 dBm
11ac 256-QAM/MCS-8	-59 dBm	-56 dBm	-53 dBm	-50 dBm	-50 dBm
11ac 256-QAM/MCS-9	-58 dBm	-54 dBm	-52 dBm	-49 dBm	-49 dBm

Table 10: Modulation Scheme Signal Strength Requirements

Higher density modulation requires higher levels of signal strength and wider channels require higher signal strength compared to narrower channels. Support for 256-QAM is a fraction of the cell size compared to 64-QAM, as depicted in the simplified image below.

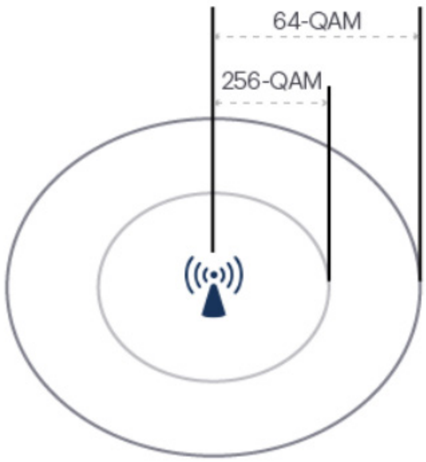


Figure 22: Modulation Scheme Coverage Compared

Signal Strength, Channel Width and Quadrature Amplitude Modulation (QAM)

In the past, network engineers would manually build a channel and power plan. While there are still environments where manual channel and power plans are used (e.g. stadiums), manual plans are not always the preferred choice. RF environments are dynamic, and reliable WLAN systems need to adapt real-time, at the RF layer, to ensure high quality service throughout an entire deployment. Arista Networks Auto Channel Selection (ACS) and Dynamic Channel Selection (DCS) enable Arista APs to adapt to RF conditions in real-time. If an interfering device (non-WiFi or WiFi), such as a microwave oven or a neighbor AP is sensed by an Arista AP, APs in the vicinity of the interference source can dynamically change channels to avoid interference.

Reducing AP Transmit (Tx) Power

Reducing AP Tx power is another way to help decrease cell size. As mentioned previously, smaller cells allow network designers to maximize channel reuse, which can increase aggregate throughput/capacity for a WLAN. AP Tx power guidelines are provided below.

Office Space (Mix of cubes and offices) / Moderate Client Density:

5 GHz: 8 - 16 dBm
2.4 GHz: 5 - 10 dBm

Open Space (Large conference room or auditorium) / High Client Density:

5 GHz: 5 - 12 dBm
2.4 GHz: 4 - 10 dBm

Arista recommends using AP Tx power levels for 2.4 GHz that are lower than those for 5 GHz. This is to compensate for better propagation of 2.4 GHz signals, as compared to 5 GHz. This setting can be managed in the Configuration / WiFi / Radio Settings section of CloudVision WiFi. The image below shows AP transmit power set to Auto with Minimum Tx Power Range set to 4 dBm and the Maximum Tx Power Range set to 10 dBm.

Figure 23: Limiting AP Transmit Power Range

Fast Roaming (802.11r)

Arista APs support 802.11r fast roaming. The 11r standard significantly improves roaming times and when enabled can significantly improve call quality while roaming. The 11r feature is enabled per SSID. Arista recommends enabling 11r with mixed mode support (as shown below) so the SSIDs will support 11r clients as well as clients that do not yet support 11r. This setting can be managed in the Configuration / WiFi / SSID / Security section of CloudVision WiFi.

Figure 24: Enabling 802.11r

Radio Resource Measurement (802.11k) and Wireless Network Management (802.11v)

WLAN infrastructures can influence client roaming decisions with features like Smart Steering; however, roaming decisions are still left up to client devices. Two relatively newer IEEE amendments, Radio Resource Measurement / 802.11k and Wireless Network Management / 802.11v use enhanced information exchanges that enable clients to make better-informed roaming decisions.

The 802.11k standard provides WiFi clients with nearby AP information, which helps them make faster, more efficient roaming decisions. And 802.11v enables an AP to inform an associated client that there are better APs to connect and that it's about to be disassociated from its current AP. Arista recommends enabling both 802.11k and 802.11v. This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

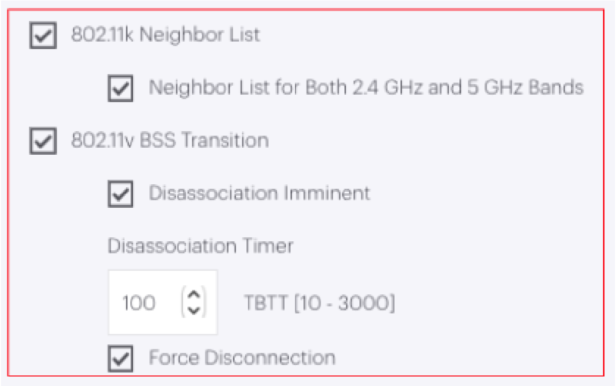


Figure 25: Enabling 802.11k and 802.11v

SSID Bridge vs. NAT vs. Tunneled Mode

Arista APs can operate in Bridged mode, Network Address Translation (NAT) mode or Tunneled mode. For most campus use cases, with perhaps the exception of single AP remote sites, Bridged mode and/or Tunneled mode are recommended. With bridge mode, traffic is simply bridged between the wireless interface and the wired interface. With NAT mode the AP supplies clients with IP addresses from the AP's built in DHCP service and the AP performs NAT for traffic between the wireless interface and the wired interface. Tunneled mode is useful for networks that do not bring VLANs to the edge of the network. Configuration of Bridged, NAT or Tunneled mode is done at the SSID/WiFi Profile level in the Network section, as shown below. This setting can be managed in the Configuration / WiFi / SSID / Network section of CloudVision WiFi.

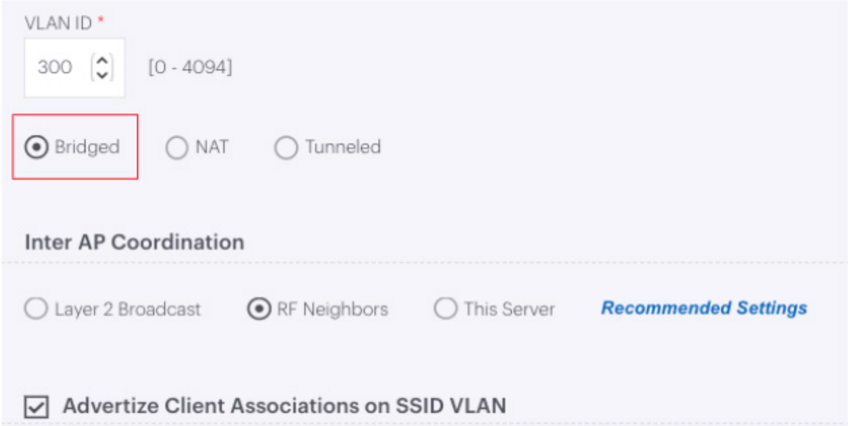


Figure 26: SSID in Bridge Mode

Broadcast/Multicast Control

A large VLAN creates a large broadcast domain. To limit unnecessary broadcast and multicast traffic from consuming valuable airtime, Arista recommends configuring the broadcast/multicast control. If there is an application that needs to be allowed an exemption can be configured by providing the EtherType, Destination MAC and Protocol details.

Alternatively, VLAN size can be limited. Arista Networks' controller-less architecture, which does not require tunneling all traffic back to a controller located in the core of the network, enables bringing VLANs out to the access switches. With VLANs at the edge of the network, the size of the VLANs can be limited per building or per floor, for example. Limiting VLAN size will also help with controlling broadcast and multicast bandwidth consumption.

Bonjour is an Apple protocol designed to make Bonjour-enabled devices and services easy to use and configure over the network. If the network needs to support Bonjour services a checkbox is provided to automatically apply an exemption. This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

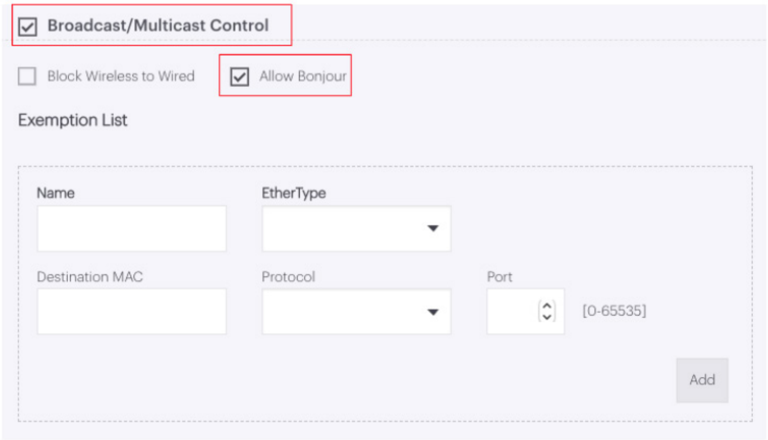


Figure 27: Controlling Broadcast and Multicast Traffic

Smart Steering

Sticky clients, or clients that would prefer to remain connected to far away APs rather than roam to nearby APs, are still a problem. Sticky clients not only experience poor performance but by operating at low data rates, they lower the capacity of the cell that they are in.

Smart Steering is a standards-based client-to-AP association optimization technology that gives the WLAN infrastructure more influence over client roaming decisions. Smart Steering monitors clients and automatically steers them to their optimal AP, improving the performance for the client that was steered, improving the performance for the AP from which the client disconnected, and improving performance for the overall WLAN. Smart Steering works with all types of clients, across all client operating systems.

Smart Steering is enabled per SSID/WiFi Profile as shown below. Arista recommends enabling Smart Steering only if there are known sticky clients in the environment. This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

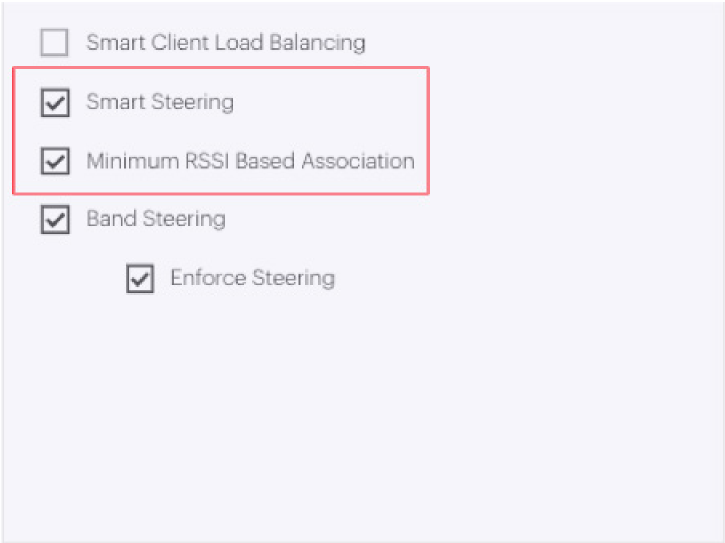


Figure 28: Enabling Smart Steering

Arista recommends using the default settings, as shown below. This setting can be managed in the Configuration / WiFi / Radio Settings section of CloudVision WiFi.

Figure 29: Tuning Smart Steering

Smart Client Load Balancing

In high-density environments like auditoriums, large conference rooms and libraries, APs are typically deployed relatively close to each other to support the large number of devices in a relatively small space. Because the APs are close to each other, a client device at any given location in the area will be able to see multiple APs with good signal strengths. In this type of environment, it is typical to see some APs over utilized while the others have capacity to spare. Distributing the clients across APs and across bands within an AP (w/Band Steering) can help with meeting per-client throughput SLAs, improve application performance and increase the overall capacity of the WLAN.

Note: The balancing mechanism may deny immediate access to the AP when a client roams. Clients that are roaming while using real-time applications such as video and voice may be impacted. It is recommended that Smart Client Load Balancing be enabled in areas with high AP density where mobility between APs is minimal, for example in a large conference room.

This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

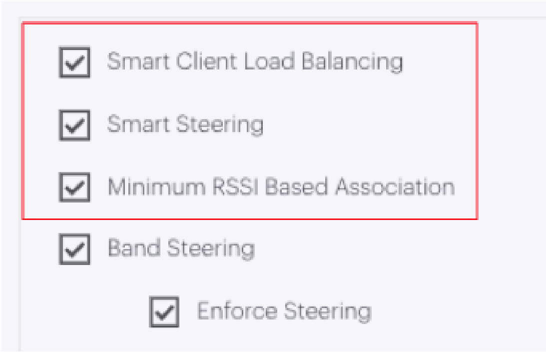


Figure 30: Enabling Smart Client Load Balancing

Tuning Smart Client Load Balancing can be managed in the Configuration / WiFi / Radio Settings section of CloudVision WiFi. Proposed values for high client density / high AP density environments are shown below.

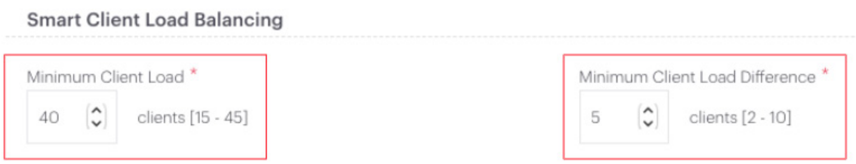


Figure 31: Tuning Smart Client Load Balancing

Band Steering

In the channel capacity planning section of this guide the recommendation was made to design WLANs for 5 GHz, and while most devices will tend to associate to 5 GHz radios, there are some clients that need to be directed towards the 5 GHz band. Arista Networks' band steering feature allows network designers to not only steer clients towards the 5 GHz, but also to distribute the clients across both bands so that the channel capacity, albeit limited, in 2.4 GHz can be used.

Band Steering is enabled per SSID. This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

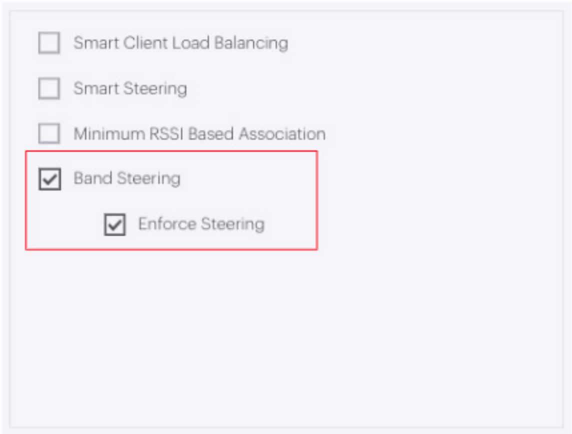


Figure 32: Enabling Band Steering

In the image below Band Steering is tuned with a threshold of 20, which means that clients will continue to be directed towards the 5 GHz radio until the 5 GHz radio has 20 clients more than the 2.4 GHz radio. This setting can be managed in the Configuration / WiFi / Radio Settings section of CloudVision WiFi.

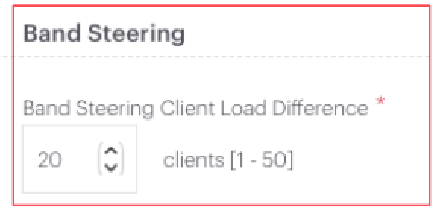


Figure 33: Tuning Band Steering

Client Steering Common Parameters

There are a number of client steering parameters that are common, or shared, by Smart Steering, Smart Client Load Balancing and Band Steering. The image below shows the default settings for these common steering parameters. This setting can be managed in the Configuration / WiFi / Radio Settings / Client Steering Common Parameters section of CloudVision WiFi.

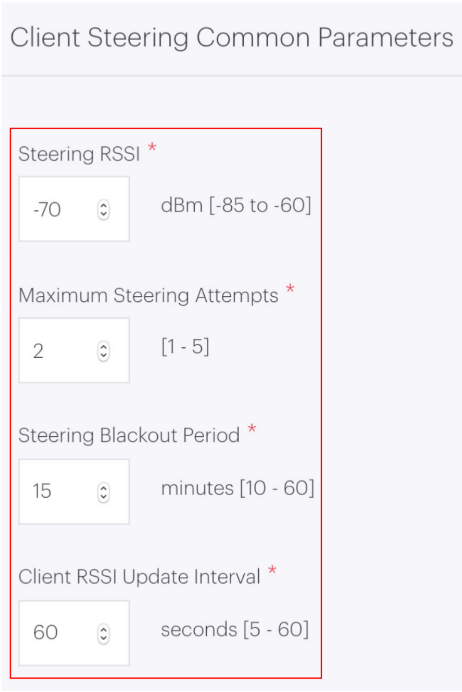


Figure 34: Client Steering Common Parameters

Bonjour Gateway

In many environments, multicast-based services like Bonjour are common. In order to enable Bonjour service advertisements (which use non-routable multicast addresses) to be seen across VLANs, a Bonjour gateway is required. Arista Networks APs have built in Bonjour Gateways that enable access to Bonjour services, such as Apple TVs and printers, across VLANs. This setting can be managed in the Configuration / WiFi / SSID / Access Control section of CloudVision WiFi.

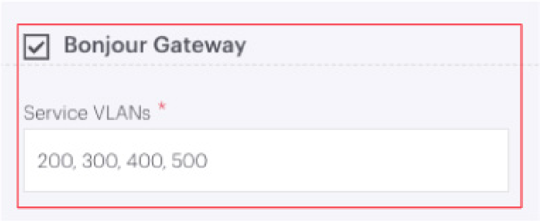


Figure 35: Enabling Bonjour Gateway

Reliable Multicast Delivery

Many campuses have multicast video streams running in their network for entertainment and educational purposes. Streaming multicast video over WiFi is inherently challenging, as multicast traffic over WiFi is not acknowledged by the receiving client. Since there are no acknowledgments for multicast packets, multicast over WiFi is essentially unreliable. Unicast packets, on the other hand, must be acknowledged by the receiving client. If unicast packets are not acknowledged by the receiver, the sender will resend the original packet. This feature enables unicast traffic to be more reliable than multicast traffic.

In order to ensure reliable delivery of multicast video, Arista APs can convert multicast video traffic to unicast traffic at the 802.11 layer. Traffic is still sent to the multicast address at the IP layer. If these unicast packets are not acknowledged by the receiver (i.e. a client that has joined the multicast group) the AP will resend the packet. In addition to the reliable delivery feature of unicast packets there is the added benefit of the packets being sent at unicast data rates, which are typically much higher than multicast data rates, even when multicast rate optimization is enabled.

Multicast to unicast conversion is only part of the solution. Internet Group Management Protocol (IGMP) snooping also needs to be enabled for multicast video to be delivered optimally. IGMP enables Arista APs to listen for multicast group join messages that are sent by WiFi clients. The IGMP feature then builds multicast group forwarding tables at the APs so that multicast traffic is transmitted to only those clients that have joined multicast groups. Arista recommends enabling the multicast to unicast feature if support for multicast video is required. This setting can be managed in the Configuration / WiFi / SSID / RF Optimization section of CloudVision WiFi.

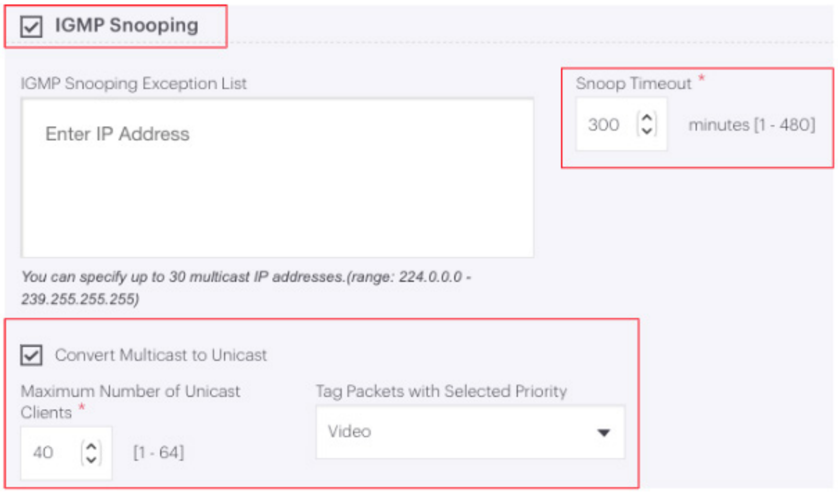


Figure 36: Configuring Multicast to Unicast Conversion

Multicast, Broadcast and Management Rate Optimization

The Multicast, Broadcast and Management Rate optimization feature allows the network engineer to configure the rate at which broadcast, multicast and management packets are transmitted by the AP. Increasing the data rate for multicast, broadcast and management traffic can improve WLAN performance by reducing the channel utilization consumed by these types of packets. This feature can also help reduce the effective cell size, allowing for greater channel reuse.

Additionally, management rate optimization, in combination with limiting the number of SSIDs configured, can significantly reduce the total airtime consumed by management traffic.

In the screenshot below, that rate has been set to 24 Mbps.

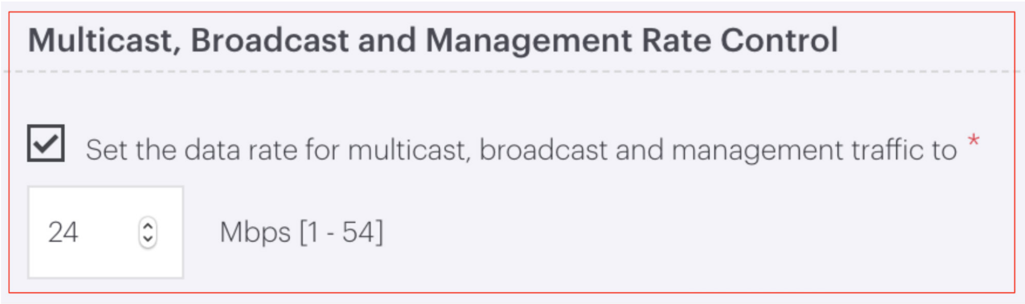


Figure 37: Setting Minimum Multicast, Broadcast and Management Data Rates

The feature is configured per SSID/WiFi Profile. The Multicast, Broadcast and Management rate should be configured for a data rate that is equal to or greater than the Minimum Unicast Data Rate. This setting can be managed in the Configuration / WiFi / SSID / Traffic Shaping & QoS section of CloudVision WiFi.

Multi-User MIMO (MU-MIMO)

MU-MIMO may help improve performance in a number of campus use cases due to its ability to enable simultaneous AP-to-client transmissions. In normal 802.11 communications, AP-to-client transmissions happen serially. With Multi-User MIMO, up to 8 AP-to-client transmissions can happen simultaneously, when using an 8x8 AP like the Arista C-260, which has the potential to significantly improve performance and capacity in many campus use cases.

The boost in performance and capacity depends on a number of factors such as channel conditions, client density, client capability, and client mix (i.e. 11ac to 11ax). Early MU-MIMO performance testing has shown that when conditions are right, there have been improvements in aggregate throughput performance of up to 50%.

Where MU-MIMO will likely help in campus deployments is in high-density areas such as large conference rooms and classrooms where aggregate throughput demands can be high. Both of these use cases will see mostly 1x1 and 2x2 clients used. These types of clients are well suited to take advantage of MU-MIMO. Of course, both APs and clients must be 11ac Wave 2 or 11ax to realize the benefits of MU-MIMO.

Orthogonal Frequency Division Multiple Access (OFDMA)

OFDMA is considered by many to be one of the most talked promising enhancements that WiFi has seen in many years. It has the potential of solving one of the main deficiencies that WiFi has had since its inception, which has been the lack of deterministic performance. That said, much more OFDMA efficacy testing is needed to determine the impact that OFDMA will have on normalizing WiFi performance KPIs (e.g. latency, throughput, jitter, etc.).

BSS Coloring

BSS coloring, another new feature of 11ax, is a technique used to get more out of the available spectrum by allowing simultaneous transmissions on the same channel when the transmitters are on different BSSs or WLANs. This is accomplished in part by using an adaptive clear channel assessment, where radios that are on different WLANs will be able to ignore each other's transmissions (when conditions are right).

Arista generally recommends enabling all 11ax enhancements; however, as these are all new features, compatibility with 11ax clients is not a given. Therefore, it is recommended that a small pilot program be followed before enabling 11ax enhancements throughout the production network. Settings for 11ax enhancements can be managed in the Configuration / WiFi / Radio Settings of CloudVision WiFi.

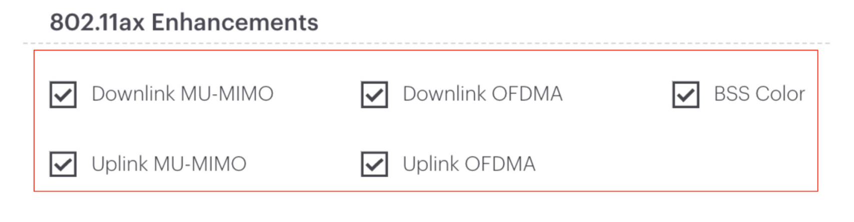


Figure 38: Enabling 11ax Enhancements

Traffic Shaping

A typical feature of a campus WiFi is to offer guest access. The guest SSID may be available in limited areas of the deployment or it may be pervasive. If guest WiFi is offered, steps may be taken to prevent guest traffic from consuming too much bandwidth. With the Arista Networks solution, rate limiting can be configured at the SSID level, as well as the individual client level. In the screenshot below the throughput rate for guest SSID users has been limited to 1 Mbps upstream and 3 Mbps downstream per user. This setting can be managed in the Configuration / WiFi / SSID / Traffic Shaping & QoS section of CloudVision WiFi.

Figure 39: Rate Limiting Guest Users' Bandwidth

Tunneling Traffic

There are use cases where Arista recommends tunneling traffic to a tunnel aggregation point located in the network, for example tunneling guest traffic to the DMZ from within a campus network or from a remote office. There are also times when regular user traffic needs to be tunneled back to the core of the network, as would be typical in a controller-based WLAN deployment.

Use Case 1: Tunneling Guest Traffic

In many campus networks there is a strict requirement to ensure that the guest network/VLAN is exposed only in the DMZ, therefore guest WiFi traffic needs to be tunneled from the AP to the DMZ. All network services including DHCP, DNS, Firewall, Routing, and NAT for the guest network are deployed at the DMZ.

Use Case 2: Tunneling Remote User Traffic

This use case is very similar to use case 1, except that the APs are deployed at remote sites. The remote site can be either a single AP or multi AP deployment. The guest networks at these remote sites typically utilize the network services deployed in the central DMZ, as with use case 1. APs from the remote sites will create tunnels to the tunnel endpoint deployed at the DMZ.

Use Case 3: Tunneling Regular User Traffic

As mentioned previously, this type of user data flow is typical with WLANs that were built using controllers. And while the Arista cloud-based WLAN solution does not have this requirement it is something that Arista supports. This capability allows migration from controller-based WLANs to the Arista solution without requiring redesigning of the underlying L2/L3 LAN.

WiFi Multimedia and Quality of Service

Even with the introduction of MU-MIMO WiFi is still a shared medium. With this in mind, care must be taken to ensure that mission critical applications and/or latency sensitive applications like voice are always given priority over other applications.

Quality of Service (QoS) is a combination of identifying, tagging and queuing mechanisms that prioritize different classes of traffic throughout the network. WiFi Multimedia (WMM) is a system for tagging different types of traffic and mapping them to different queues that have different WMM parameters such as Contention Window Minimum (CW_Min), Contention Window Max (CW_Max), Transmit Opportunity (TXOP) and Arbitration Inter-frame Spacing (AIFS). The different WMM Access Categories, along with their corresponding identifying values are shown in the table below.

Binary	Decimal	802.1p Priority	WMM Access Category	Traffic Type
001 (000)	8	1	AC_BK	Background
010 (000)	16	2	AC_BK	Background
000 (000)	0	0	AC_BE	Best Effort
011 (000)	24	3	AC_BE	Best Effort
100 (000)	32	4	AC_VI	Video
101 (000)	40	5	AC_VI	Video
110 (000)	48	6	AC_VO	Voice
111 (000)	56	7	AC_VO	Voice

Table 11: WMM Access Categories

While some applications/devices will properly tag packets so they are properly prioritized as they travel throughout the network, most traffic is transmitted as best effort (AC_BE). If there were an overabundance of capacity then this would not be a problem; however, there are many use cases where AP radios will operate at high levels of utilization and proper prioritization of latency-sensitive applications like voice and real-time video will be required to ensure solid application performance and high-quality user experience. In addition, traffic coming in from the Internet will be best effort, even if it originally was tagged as voice (AC_VO), before traversing the Internet. Therefore, APs need to be able to identify, tag and prioritize traffic.

End-to-End QoS

For QoS to work optimally, it must be implemented end-to-end throughout the entire network. All components along the path must at a minimum honor packet tagging.

Arista APs use WMM on the wireless side and DiffServ Code Point (DSCP) and 802.1p tagging for traffic destined for upstream on the wired side. DSCP/802.1p tagging ensures appropriate delivery on the wired side of the network. This setting can be managed in the Configuration / WiFi / SSID / Traffic Shaping & QoS section of CloudVision WiFi.

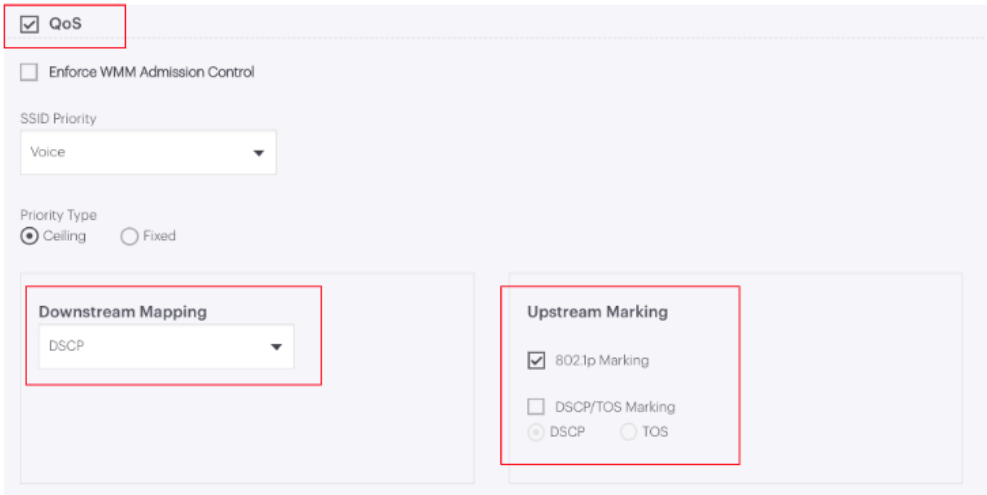


Figure 40: Enabling QoS

Application Visibility and Control

Arista Networks Application Visibility and Control (AVC) uses next-generation Deep Packet Inspection (DPI) technology, which provides real-time, Layer-7 application classification and metadata extraction for network traffic. Arista AVC uses a combination of application classification and DPI techniques to deliver industry leading scope and accuracy of network traffic. Arista AVC supports automation of classification for thousands of applications, such as:

- VoIP
- Video streaming
- Peer-to-peer
- Software updates
- File sharing
- File backups
- Video gaming
- Social

- Music streaming
- Email
- Video conferencing

Arista AVC provides visibility into which applications are being used by each user as well as providing a global view of which applications are running on the network.

AVC is enabled on a per SSID basis. Arista recommends enabling AVC on all SSIDs that may have voice or video traffic as this will help with application performance and can enhance the quality of experience for end users. The Application Visibility setting can be managed in the Configuration / WiFi / SSID / Analytics section of CloudVision WiFi.

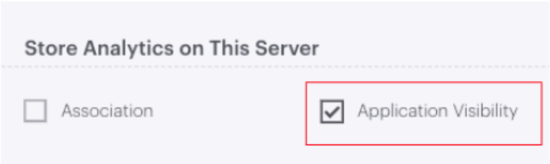


Figure 41: Enabling Application Visibility DPI Engine

With AVC enabled application traffic will be properly identified. Once the traffic is identified it can be Allowed, Blocked or Allowed and Marked. For real-time traffic the recommendation is that Application Firewall Rules be created for them with the setting of Allow and Mark so that the traffic flows for those applications get properly prioritized.

The screen grab below shows a rule being created for Skype for Business. This rule will tag Skype for Business traffic as DSCP value 56 or WMM 111 (AC_VO). As the rule is bidirectional, the traffic will be tagged for both downstream (i.e. AP to WiFi client) and upstream (i.e. AP to switch port) directions. Tagging the traffic on the downstream ensures that Skype for Business traffic uses the voice transmit queue on the AP. The voice transmit queue on the AP has the highest priority so traffic that uses that queue will take precedence over traffic in other AP transmit queues.

Tagging the traffic upstream tells the switch to use voice (i.e. high priority) queues for these flows as well. On the switch side DSCP 56 should be configured to map to the voice queue. This is part of the end-to-end QoS recommendation for real-time applications. This setting can be managed in the Configuration / WiFi / SSID / Access Control section of CloudVision WiFi.

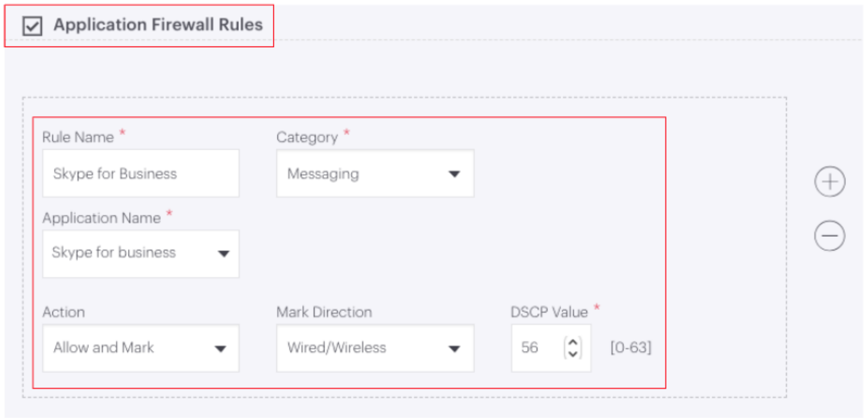


Figure 42: Configuring Application Firewall Rule

RF Interference

Interference caused by WiFi and/or non-WiFi devices can greatly reduce the performance of WLANs. Therefore, it is critical that a high performing WLAN system have the ability to identify, locate and avoid sources of interference, whether they are WiFi or non-WiFi. While conducting a one-time spectrum analysis during pre-installation will help identify sources of interference at the time of the deployment, a full-time / deployment-wide spectrum analysis solution is recommended.

Dynamic Channel Selection

Arista Networks' DCS feature detects and identifies interference sources, both WiFi and non-WiFi. The interference data is collected by Arista Networks' DCS algorithm so that AP channel changes can be better informed, resulting in better user experience and better overall network performance.

Some known WiFi interference sources are listed below.

WiFi Interference

- Personal hotspots (MiFi)
- Muni WiFi
- Malfunctioning clients
- Poorly designed WLAN
- Neighbor clients
- Neighbor APs

Some known non-WiFi interference sources are listed below.

Non-WiFi Interference

- Video game controllers
- Microwave ovens
- Security cameras

- ZigBee
- Cordless phones
- Bluetooth devices

This setting can be managed in the Configuration / WiFi / Radio Settings section of CloudVision WiFi.

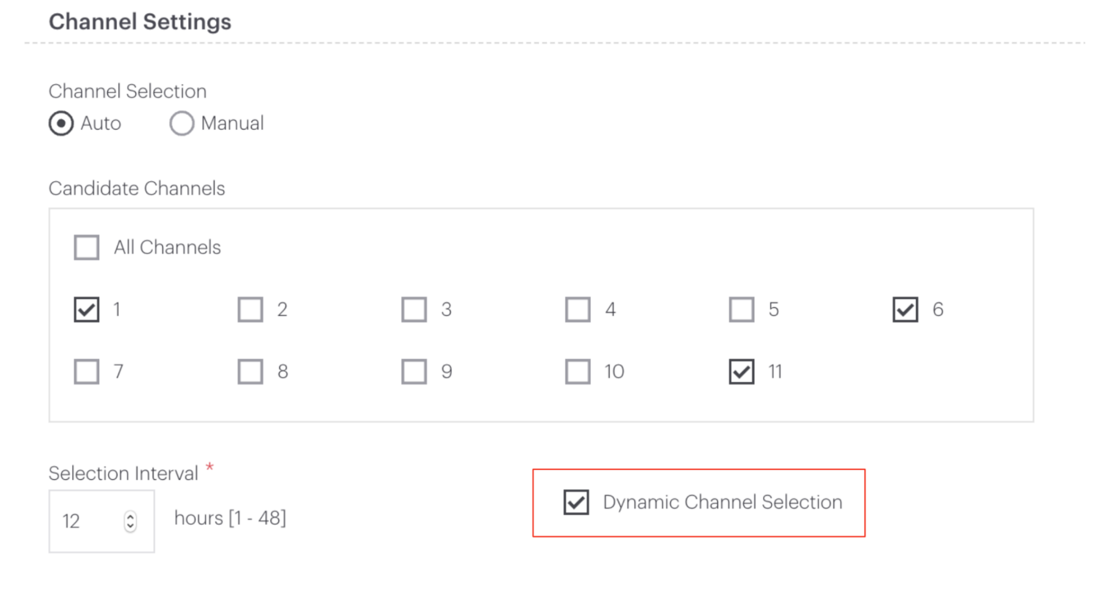


Figure 43: Enabling DCS

Dynamic Frequency Selection Channels

As mentioned previously Arista recommends enabling DFS channels. The image below shows all DFS channels being enabled. If radar events are detected regularly on a specific channel or channels, those channels can be removed from the channel candidate list. This setting can be managed in the Configuration / WiFi / Radio Settings / 5 GHz section of CloudVision WiFi.

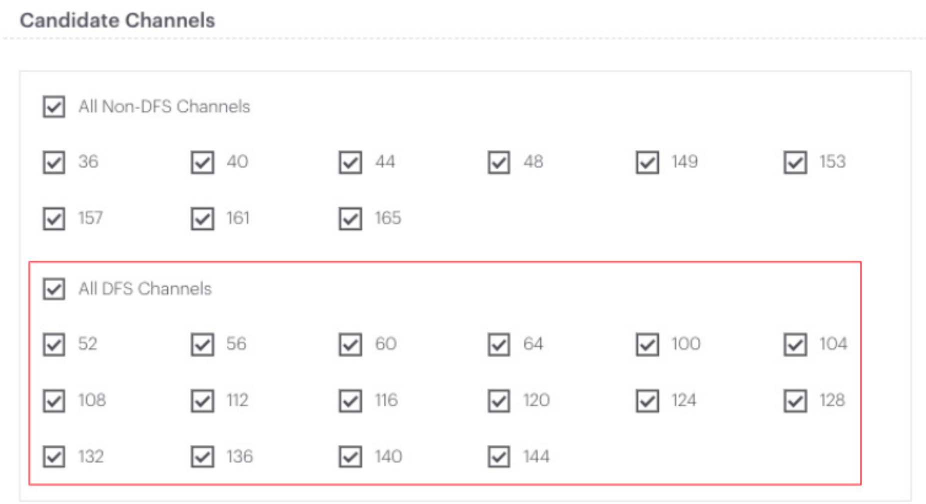


Figure 44: Enabling DFS Channels

Campus Spectrum Policy

As mentioned previously, Arista Networks DCS, when enabled, will auto select channels to avoid both WiFi and non-WiFi interference; however, it is preferable that WLANs not routinely change their channel plan, as channel plan changes can be disruptive to WiFi service.

Unwanted sources of interference from devices like rogue APs, cordless phones and non-WiFi cameras, can have a detrimental impact on WiFi performance. Having a campus spectrum policy, that informs all users about the types of devices that are not permitted on campus can help mitigate this problem.

Extra sources of interference are even more of a problem for campuses that use static channel plans, (i.e. where auto channel is disabled), as manual intervention is often required to locate and remove the source interference or to change the channel plan to avoid the source of interference.

Arista recommends having a campus spectrum policy to help minimize WLAN disruptions due to non-campus sanctioned sources of interference.

Cloud Integration Point (CIP)

The Arista CIP enables integration between the Arista Cloud and on-premise Enterprise Security Management (ESM) servers. With the CIP events and audit logs from the Arista Cloud can be sent securely to local SNMP and Syslog servers.

WIPS

For new deployments where real-time applications and WIPS must both be supported the recommendation is to deploy 3-radio APs. Arista 3-radio APs like the C-230, C-260 and W-118 have a multifunction third radio that performs WIPS scanning and over the air prevention. Having a third radio that deals with WiFi threat enables the two access radios to be dedicated to servicing WiFi clients. With 3-radio APs there is no tradeoff between supporting real-time applications (e.g. Zoom) and having a full featured robust WIPS.

Arista 2-radio APs operate in the four following modes:

- WiFi only (No Scanning)
- WiFi/WIPS with VoIP Aware Scanning
- WiFi/WIPS with Background Scanning
- WIPS only (Full-time Sensor)

Some customers have opted to deploy their APs in WiFi/WIPS mode where the access radios periodically perform background scanning. This option provides protection for many types of WiFi threats and it enables a deployment with fewer APs than opting for a mixed deployment of APs plus sensors.

However, for comprehensive threat detection and protection a mixed deployment is recommended if 2-radio AP models are deployed. For instance, if there is a requirement to prevent authorized user devices from connecting to a personal hotspot, a WIPS-only device is required as over the air prevention techniques would be required to effectively neutralize this type of threat. Access radios are not effective at performing over the air prevention as they would need to sacrifice WiFi performance to achieve effective threat prevention.

Another important consideration is video and voice application performance. APs that have background scanning enabled will need to periodically scan all channels, which means that they have to temporarily leave the channel where they are servicing clients. For typical data traffic, like web browsing or email, the latency induced by channel scanning does not present a problem. For real-time applications, like video and voice, that cannot tolerate latency, this is a problem.

In environments where 2-radio APs are deployed and real-time applications as well as WIPS must be supported the recommendation is to deploy a mixed mode model where a single WIPS only unit is added for every 3 - 5 WiFi only APs.

An alternative, and less preferable solution, would be to enable VoIP Aware Scanning mode on 2-radio APs. The VoIP Aware Scan feature spends less time doing background scanning to minimize the adverse effects on real-time traffic. This ensures high quality VoIP performance; however, it does not solve the over the air prevention challenge, as mentioned above.

Figure 45: Full Time WIPS Deployment with 2-Radio APs

Summary of WLAN Recommendations

Recommendations for a campus WLANs are provided in the table below.

Feature	Default	Recommended	Notes
Min Unicast (Association) Data Rate	2.4 GHz - 1 Mbps 5 GHz - 6 Mbps	24 Mbps	Removing supported data rates could cause client interop issues.
Min Broadcast, Multicast and Management Data Rate	2.4 GHz - 1 Mbps 5 GHz - 6 Mbps	24 Mbps	This rate should be equal to or greater than Min Unicast (Association) Data Rate.
SSIDs	0	Limit number of SSIDs to 3.	Use of RBAC to allow for the fewest number of SSIDs deployed will limit the amount of airtime consumed by management traffic.
Band Steering	Enabled Load Difference = 25	Enabled Load Difference = 25	
5 GHz Channel Width	20/40/80 MHz	20/40 MHz	Consider 20/40/80 MHz if most or all DFS channels are available and maximum capacity is needed and the AP budget is restricted. Consider 20 MHz for high density use cases.
Background Scanning (2 radio APs only)	VoIP-Aware WiFi Scanning	VoIP-Aware WiFi Scanning	For 2-radio AP deployments use 3-5 APs to 1 sensor for effective over the air threat prevention. Use 3-radio APs for best results in WLAN that require WIPS and must support real-time applications.
SSID Network Mode	Bridged	Bridged	Consider NAT only for single AP remote site deployments.

Smart Steering	Disabled	Disabled	Consider enabling Smart Steering if environments have known sticky clients.
11r Fast Roaming	Disabled	Enabled	With mixed mode support
11k Neighbor List	Disabled	Enabled	
11v BSS Transition	Disabled	Enabled	
Traffic Shaping	Disabled	Enable for Guest WLAN	
Proxy ARP	Disabled	Enabled	
DCS	Disabled	Enabled or Disabled w/Static Channel Plan	Depends on the environment and personal preference of WLAN engineers.
AP Transmit Power	Auto Power	Auto Power or Static Power Plan Office Space / Moderate Client Density: 5 GHz: 8 - 16 dBm 2.4 GHz: 5 - 10 dBm Open Space / High Client Density: 5 GHz: 5 - 12 dBm 2.4 GHz: 4 - 10 dBm	Depends on the environment and personal preference of WLAN engineers.
Broadcast and Multicast Control	Disabled	Enabled	With exception for Bonjour if required.
Bonjour Gateway	Disabled	Enabled	If required.
IGMP Snooping	Enabled	Enabled	
Multicast to Unicast Conversion	Disabled	Enabled	Enabled if the network needs to support multicast video streaming.
Smart Load Balancing	Disabled	Enabled	Enable in high client density areas (e.g. auditorium).

AVC	Enabled	Enabled	Enable QoS end-to-end switching infrastructure.
DFS	Disabled	Enabled	Remove channels with regular radar events from the channel candidate list.
Tunneling	Disabled	Enabled	Tunnel user traffic back to the network core if VLANs are not provisioned at the edge. Tunnel guest traffic back to the DMZ.
CIP	Disabled	Enabled	For integration with local NSM and Syslog servers
MU-MIMO	Disabled	Enabled	Test performance before deploying in production to ferret out potential client interop issues.
OFDMA	Disabled	Enabled	Test performance before deploying in production to ferret out potential client interop issues.
BSS Coloring	Disabled	Enabled	Test performance before deploying in production to ferret out potential client interop issues.

Table 12: WLAN Recommendations

LAN Best Practices

This section offers suggestions for deploying a wired network infrastructure capable of supporting a high-performance WLAN deployment suitable for campus environments.

AP Power Requirements

The table below lists Arista AP models along with their respective power requirements. The C-100 is fully functional with standard PoE (802.3af). Many of the other APs listed can operate when powered by PoE but with limited functionality. The C-250 can operate using 802.3at but with reduced functionality (i.e., 4x4 on 5 GHz and USB port is disabled). For AP specific limitations when operating on PoE power please refer to AP datasheets.

Summary of AP Power Requirements

Arista AP power recommendations are provided in the table below.

Model	Description	Recommended Use	Power Required
C-100	Dual radio 11ac 2x2 Wave 2 Indoor	Low or moderate client density / throughput areas	802.3af
C-110	Tri radio 11ac 2x2 Wave 2 Indoor	Low or moderate client density / throughput areas	802.3af*/at
C-130 / C-130E	Tri radio 11ac 4x4 Wave 2 Indoor	High client density / throughput areas	802.3af*/at
C-230 / C-230E	Tri radio 11ax 4x4 5 GHz 11ax 2x2 2.4 GHz Indoor	High client density / throughput areas	802.3af*/at
C-250 / C-260	Tri radio 11ax 8x8 5 GHz 11ax 4x4 2.4 GHz Indoor	Very high client density / throughput areas	802.3at*/bt
W-118	Tri radio 11ac 2x2 Wave 2 Indoor Wall Plate	Low or moderate client density / throughput areas Hotel / dorm rooms	802.3af*/at
O-105 / 0-105E	Dual radio 11ac 2x2 Wave 2 Outdoor	Low or moderate client density / throughput areas / Outdoors / harsh environments	802.3at
O-235 / O-235E	Tri radio 11ax 4x4 5 GHz 11ax 2x2 2.4 GHz Outdoor	High client density / throughput areas / Outdoors / harsh environments	802.3af*/at

Table 13: AP Power Requirements

* Indicates that the AP will operate, but with reduced functionality. For more detail please refer to AP datasheets.

AP Uplink Capacity

In lab tests, dual band throughput of 802.11ac Wave 1 APs can exceed 1Gbps, as the maximum theoretical data rate in 5 GHz is 1.3 Gbps (802.11ac 3x3) and in 2.4 GHz (802.11n 3x3) is 450 Mbps. With those data rates it is possible to associate a single MacBook Pro to each radio and run throughput tests to each client simultaneously to push past 1 Gbps of aggregate throughput. In production, on the other hand, breaking the 1 Gbps barrier does not happen often. With Wave 2 AP, such as the Arista C-130, which supports 4 spatial streams and has a combined maximum data rate of 2.3 Gbps (1.7 Mbps for 5 GHz and 600 Mbps for 2.4 GHz) it is still unlikely that C-130s in production will break the 1 Gbps throughput barrier. However, the C-130 supports link aggregation so the traffic destined upstream can be load balanced across an aggregated 2 Gbps pipe for the rarest use case where a single 1 Gbps may become oversubscribed.

New 11ax models, like the C-260, have 5 Gbps uplink, which will be more than enough capacity to handle all use cases.

AP Cabling

At the minimum, 11ac APs require Cat5e cables. For Greenfield deployments, Arista recommends deploying Cat6a cables, as many future APs will have Ethernet ports that will support rates greater than 1 Gbps. Installing Cat6a cables will future proof your investment. The table below is provided for reference.

Cable Category	Max Data Rate	Bandwidth	Max Distance Meters	Max Distance Feet
Cat 5	100 Mbps	100 MHz	100 Meters	328 Feet
Cat 5e	1 Gbps	100 MHz	100 Meters	328 Feet
Cat 5e	2.5 Gbps	100 MHz	100 Meters	328 Feet
Cat 6	5 Gbs	250 MHz	100 Meters	328 Feet
Cat 6	10 Gbps	250 MHz	50 Meters	164 Feet
Cat 6a	5 Gbs	500 MHz	100 Meters	328 Feet
Cat 6a	10 Gbps	500 MHz	100 Meters	328 Feet
Cat 7	10 Gbps	600 MHz	100 Meters	328 Feet

Table 14: Cable Category Reference

Access Network Uplink

The switching infrastructure should be designed properly to take full advantage of increased throughput capacity of 11ac and 11ax APs. Right sizing the network from the access switches to the distribution switches, and to the core is necessary to ensure that there are no Ethernet bottlenecks along the way.

Here is a summary of the recommended uplink capacities for 11ac and 11ax WLAN networks:

- Minimum 1 Gbps for AP ports on access switches.
- Consider mGig (IEEE 802.3bz) for AP ports on access switches for greenfield deployments.
- Minimum of dual-homed/redundant 100 Gbps uplink for PoE switches.

VLAN Design

If the network was designed for a WLAN controller to be centrally located, where all WLAN traffic gets tunneled back to the core of the network, the Arista solution supports that topology with native tunneling capabilities built into Arista APs and Arista switches. This is an option supported by Arista's flexible data plane architecture.

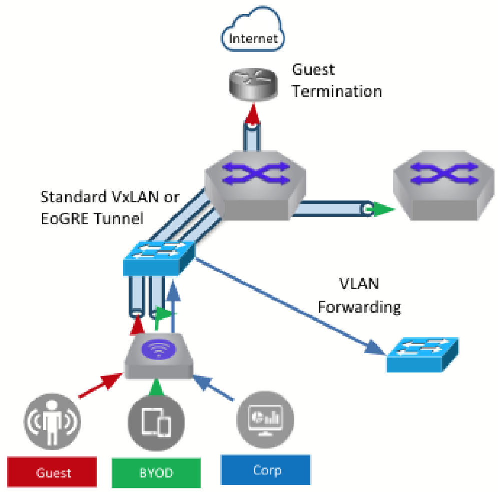


Figure 46: Flexible VLAN Design

With Arista's controller-less architecture, tunneling traffic back to a controller located in the core of the network is not required. This allows network designers to configure VLANs at the access switch layer of the network.

Deploying rightsized VLANs at the edge of the network has advantages. The image below shows that for each building there is a unique VLAN configured for SSID-1. Limiting a VLAN to a single building reduces the amount of broadcast and multicast traffic in a VLAN, while enabling seamless roaming within a building.

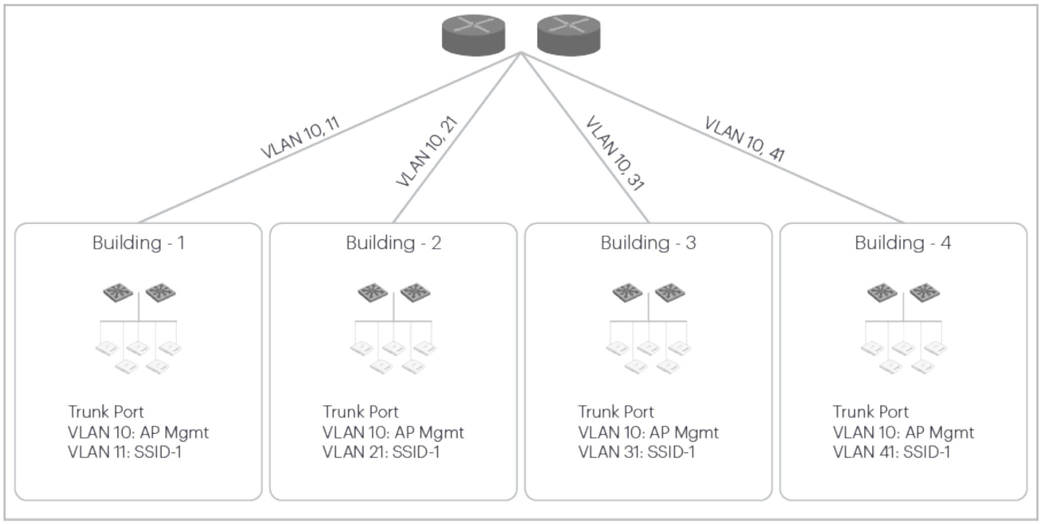


Figure 47: VLANs Extended to the Access Layer

Jumbo Frames

With the enhanced frame aggregation capabilities that are part of the 802.11ac standard, the switching network must support jumbo frames in order to realize the benefits of frame aggregation. If Jumbo Frame support is not enabled end-to-end, there will be fragmentation along the way, which will adversely affect performance.

It is also recommended that Jumbo Frames be supported end-to-end when implementing VxLAN tunneling between Arista APs and Arista switches.

Summary of LAN Recommendations

LAN recommendations for a campus WLANs are provided in the table below.

Requirement	Minimum	Recommended	Notes
AP Power	PoE / 802.3af	PoE+ / 802.3at	Most 802.11ac Wave 2 platforms require PoE+ for full functionality. Some 802.11ax platforms (e.g. C-260) require, at a minimum, PoE+ / 803.at.
AP Uplink Capacity	1 Gbps	mGig for greenfield deployments	It is unlikely that 802.11ac platforms will be able to oversubscribe a 1 Gbps link in typical use cases; however, some 802.11ax platforms are capable of oversubscribing 1 Gbps.

Ethernet Cabling	Cat5e	Cat6a	
Access Network Uplink Capacity	40 Gbps	2 x 100 Gbps	Multi-homed / Fault Tolerant
VLAN Design	No Preference	No Preference	VLANs may be brought to the edge of the network either by configuring them on the access layer switches or by extending L2 to the edge via an overlay network, using standards-based tunneling like VxLAN.
Jumbo Frames	A-MPDU and A-MSDU frame aggregation enabled on APs	Enable support for Jumbo Frames throughout entire switching infrastructure.	
QoS	All switches, from access to core, honor QoS tags	All switches, from access to core, honor QoS tags	

Table 15: LAN Recommendations

Network Services Best Practices

This section offers suggestions that will help with configuring network services to support an Arista Networks WLAN deployment that is suitable for campus environments.

Summary of Network Services Recommendations

Network Services recommendations for a campus WLANs are provided in the table below.

Service	Recommended	Notes
DHCP	Use the campus DHCP servers.	
DNS	Use the campus DNS solution.	

Proxy	Configure proxy bypass rules for AP to cloud management traffic.	All management traffic from the APs to the Arista cloud instance will need to be configured on proxy bypass. This will allow management traffic from the APs to the Arista cloud instance and does not allow user access unfiltered to the internet.
Campus Firewall	Firewall rules: • Port UDP 3851 outbound • Port TCP 443 outbound • Port TCP 80 outbound • Port UDP 3852 outbound	UDP 3851: AP-to-cloud comms TCP 443: AP upgrade (primary) TCP 80: AP upgrade (backup) UDP 3852: CIP
NAT	Use the campus NAT solution.	Consider enabling NAT at the AP for small, single AP, remote sites.
AVC	Use the campus AVC appliance at core to apply QoS for traffic inbound from the Internet.	
Content Filtering	Use the campus content filter solution.	Consider DNS-based content filtering at the AP for small remote sites.
RADIUS	Use the campus RADIUS solution.	

Table 16: Network Services Recommendations

AP Placement and Channel Plan Best Practices

In the channel capacity planning section of this guide, methodologies and best practices for determining how many APs would be required for specific use cases were discussed. In this section, methodologies for creating AP placement plans are offered.

Predictive Site Survey

A predictive site survey is recommended. A number of tools are available for this task, such as Ekahau Survey, Tamosoft Site Survey and iBwave Design.

Predictive site surveys are a convenient way to develop an AP placement plan that can estimate coverage and capacity; however, a post AP deployment physical site survey to validate the coverage and capacity is also recommended.

Predictive Survey Recommendations

- Input client types and quantity (currently in use and planned/anticipated)
- Input applications (currently in use and planned)
- Design for capacity

- Use high-quality floor maps
- Be very precise when setting the scale for the floor plan
- Consider RF leakage between floors

Indoor Attenuation Reference

Table 17 below, which provides estimated attenuation values for common obstructions, is provided as a guide only. To ensure an accurate predictive site survey, actual attenuation values for obstructions present at the deployment site should be measured. Once attenuation values are known, they can be used in the planning process to generate a more informed AP placement plan. To measure attenuation values, an AP and a smartphone running an application like WiFi Analyzer is needed.

To perform the measurement, check the signal level that the client sees at the AP when the client and AP are 5 meters with a clear Line of Sight (LoS). Then, check the signal level again at the same distance but this time with the smartphone behind the obstruction.

The difference between the LoS reading at the second reading is the attenuation level for the obstruction. Using attenuation values obtained this way will improve the accuracy of the predictive site survey.

Example:

Measurement 1: 5 Meters / LoS = - 57 dBm

Measurement 2: 5 Meters / Behind obstruction = - 53 dBm

Obstruction Attenuation = 4 dB

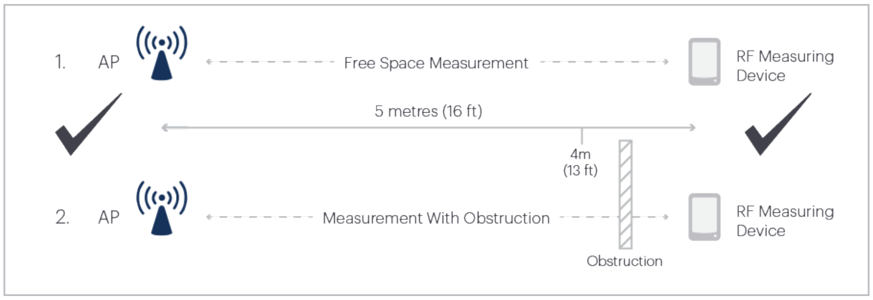


Figure 48: Measuring Attenuation
Source: Ekahau

Indoor Attenuation Reference

The table below lists some estimated values of attenuation for common materials found typical deployments. Note the variability in attenuation for a given type of material (e.g. concrete/brick wall +/- 10 dB). More precise attenuation values will produce a more precise predictive site survey.

RF Attenuators	Estimated Attenuation in 2.4 GHz	Estimated Attenuation in 5 GHz
Steel door	16 dB (+/- 3 dB)	28 dB (+/- 3 dB)
Concrete/brick wall	12 dB (+/- 6 dB)	20 dB (+/- 10 dB)
Coated or double-pane	12 dB (+/- 1 dB)	20 dB (+/- 1 dB)
Cubicle wall	4 dB (+/- 1 dB)	6 dB (+/- 2 dB)
Wood Door	4 dB (+/- 1 dB)	6 dB (+/- 1 dB)
Glass/window (not tinted)	3 dB (+/- 1 dB)	7 dB (+/- 1 dB)
Drywall (interior)	3 dB (+/- 1 dB)	4 dB (+/- 1 dB)
Ceiling tiles, curtains, blinds	1 dB (+/- .5 dB)	2 dB (+/- 1 dB)

Table 17: Attenuation Estimations

One-for-One AP Replacement

Before opting for a one-for-one AP replacement approach, make sure the following conditions are true:

- The current WLAN provides good coverage everywhere (e.g. -62 dBm).
- All clients are able to see 2 - 3 APs in all locations.
- The current network was designed for capacity.
- All applications are performing well in all locations.
- The current network is designed for 5 GHz.
- All clients are roaming well.
- The environment has remained the same (e.g. no building renovations) since the existing AP placement plan was created.

Avoiding Self Induced CCI in 2.4 GHz

Even if DFS channels are not used, 5 GHz channels outnumber 2.4 GHz channels by a wide margin. This means that if both radios are active on all APs the probability of creating harmful CCI in the 2.4 GHz band is likely high for networks designed for 5 GHz and capacity. Another contributing factor is that 2.4 GHz frequencies provide greater coverage range compared to 5 GHz frequencies. Therefore, Arista recommends disabling 2.4 GHz radios on a percentage of the APs deployed to minimize the amount of self-induced CCI in the 2.4 GHz band.

40 MHz Channel Plan

An example of a 40 MHz channel plan that does not use DFS channels is shown below. In the US, as well as in a number of other regions, there are only four non-overlapping 40 MHz channels available if DFS channels are not used. The example plan below accomplishes the goal of minimizing CCI by not deploying adjacent APs that operate on the same frequencies.

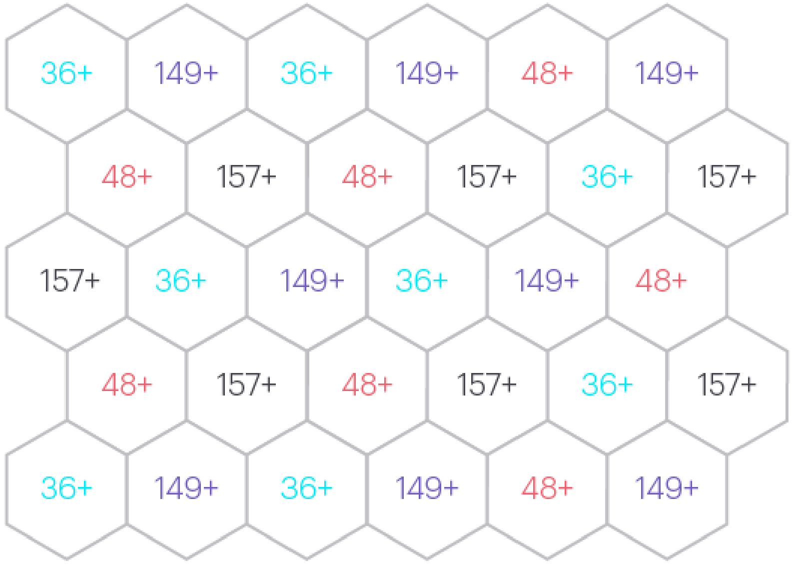


Figure 49: Example 40 MHz Channel Plan

80 MHz Channel Plan

An example of an 80 MHz channel plan that does use DFS channels is shown below. In the US, as well as in a number of other regions, there are six non-overlapping 80 MHz channels available if all DFS channels are used. As with the 40 MHz plan above, the example plan below accomplishes the goal of minimizing CCI by not deploying adjacent APs that operate on the same frequencies.

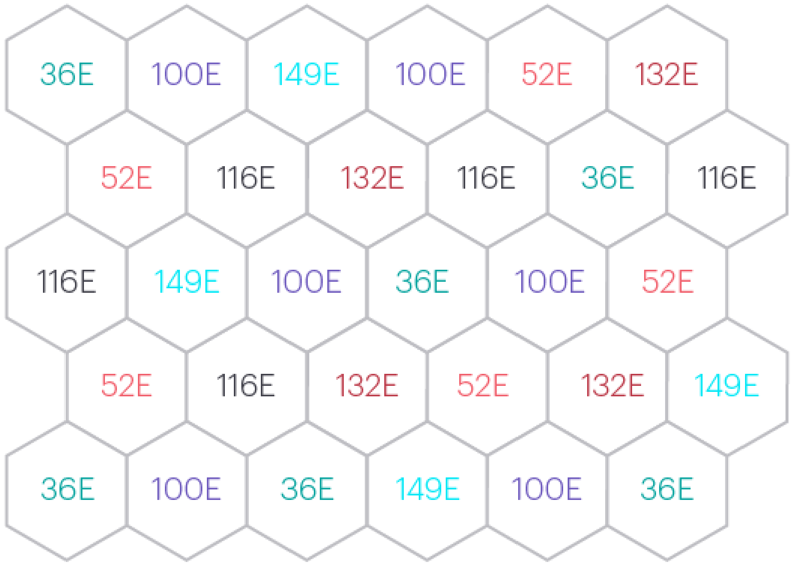


Figure 50: Example 80 MHz Channel Plan

AP Mounting Recommendations

Arista Networks Indoor APs are typically mounted on walls or ceilings. Arista Networks outdoor APs are typically mounted on walls, poles and cable strands.

Wall Mount

While not as commons ceiling mounts, wall mounted APs are typical to dormitory rooms. Wall mounted APs may also be found in large rooms like auditoriums where ceiling mounting is not practical due to factors such as ceiling height or accessibility. When opting for wall mounting consideration needs to be made for the antenna radiation patterns, including back lobe patterns, of the AP model being deployed.

Ceiling Mount

Most WLAN deployments use ceiling mounting. When mounting APs to a ceiling, in most cases, it is preferable to mount APs below the ceiling. It is not recommended to hide APs above a dropped ceiling for aesthetic or AP physical security purposes. The space may include metallic structures such as pipes or AC ducts that can attenuate RF transmissions.

Structural Proximity / Electrical Interference

As mentioned previously, there are many factors that can affect the reliability and performance of the WLAN, including the following:

Physical obstacles that can impede radio transmissions

Radio frequency interference (RFI) from electronic devices and other radio sources

Electromagnetic interference (EMI) from fluorescent bulbs, motors, and appliances

Incorrect AP antenna placement

Improper antenna selection

Distances between access points and clients

It is not recommended to place an AP in corners or near other obstacles that can block line-of-sight coverage.

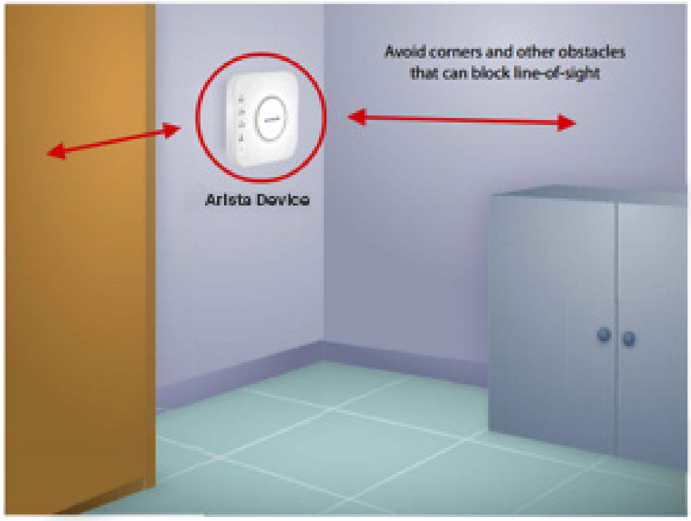


Figure 51: Avoid Corners

APs should not be placed within 3 feet of other building systems, such as heating, ventilation, and air conditioning (HVAC), plumbing, lighting, electrical, sprinkler systems, ventilation fans, motors, high voltage lines, electrical conduit, and electronic devices that can emit EMI and RFI.

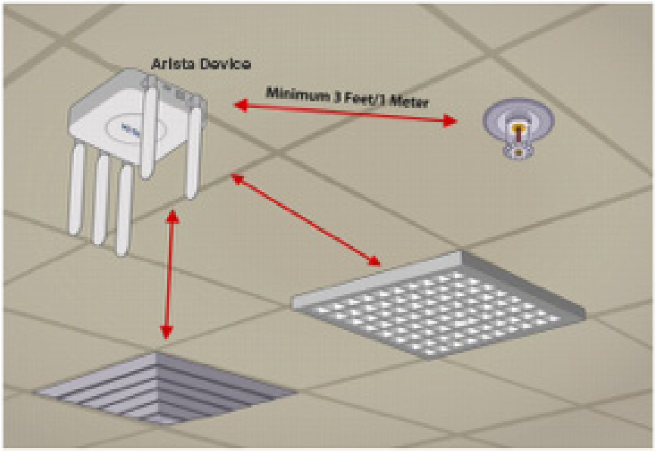


Figure 52: Minimum distance of 3ft/1m

Post Deployment Validation Survey

There are many post deployment site survey tools available. The Ekahau Survey is perhaps the most widely used. Like most site survey tools Ekahau Survey supports both passive and active site surveys. An active survey measures sent packets and received packets. This mode is used to determine metrics like packet loss and packet delay. A passive survey listens to probes and beacons passively and is useful to coverage and Signal-to-Noise Ratio (SNR) maps. Ekahau Survey also supports a hybrid survey mode that simultaneously performs a passive and active survey. Arista recommends using the hybrid mode.

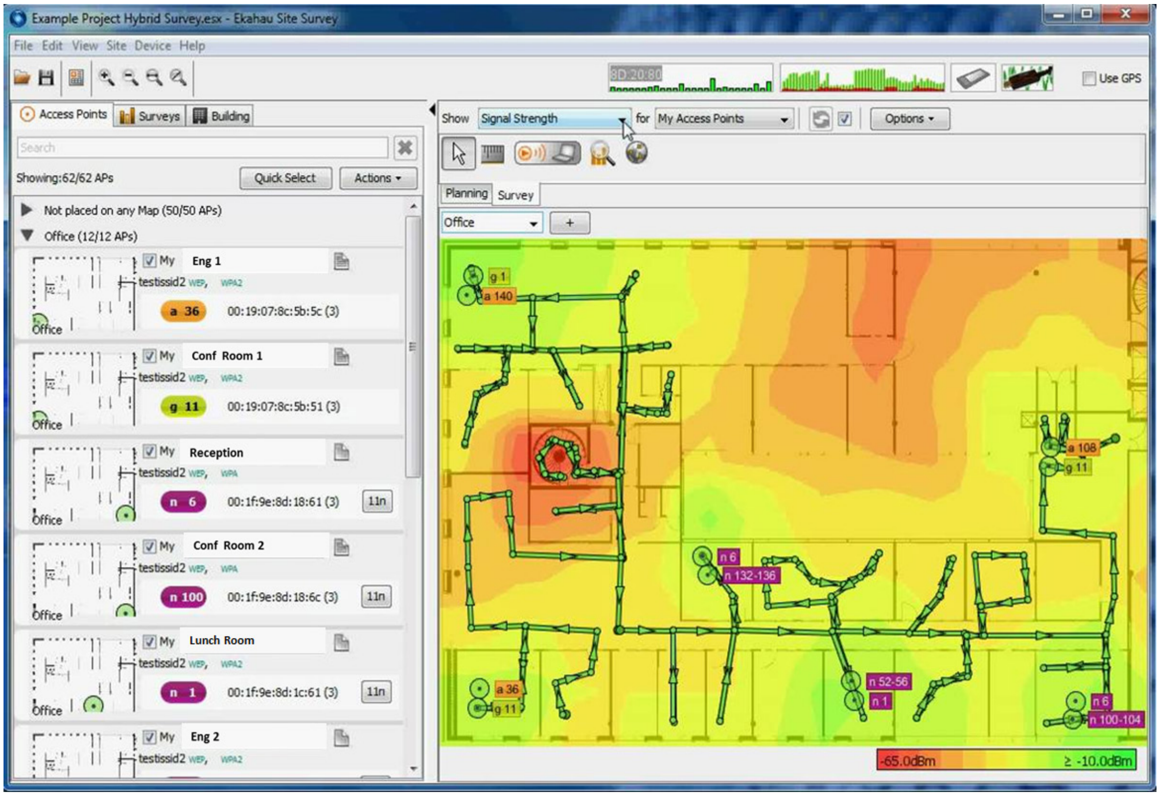


Figure 53: Ekahau Hybrid Mode Site Survey
Source: Ekahau

An in-depth discussion of post-deployment validation surveys is beyond the scope of this guide; however, some general guidelines are offered below.

- Uses Hybrid survey mode, if using ESS (or Passive mode and Active mode is using another tool)
- Survey both the 2.4 GHz and 5 GHz bands
- Disable/suspend auto channel (DCS)
- Remove all SSIDs from client supplicant excluding SSID being surveyed
- Gather sufficient number of data points (e.g. 1 data point for every 10 - 20 feet)
- Perform survey with doors closed

Summary of Recommendations for AP Placement and Channel Plan

AP placement and channel plan recommendations for a campus WLANs are provided in the table below.

Recommendations	Notes
Use a 3rd party planning tool like Ekahau Survey to perform a predictive site survey.	Ekahau Survey, and similar tools, can automate the AP placement and channel capacity planning process.

Consider 1-for-1 AP replacement.	Only implement 1-for-1 replacement if conditions are true as outlined in the One-for-One AP Replacement section of this guide.
SNR should be 25 dB or > throughout the coverage area.	
Minimum RSSI should be -62 dBm throughout the coverage area.	If designing for 256 QAM rates everywhere the minimum RSSI should be -52 dBm (w/ 80MHz channels).
Clients should see 2 - 3 APs (on different channels) at RSSI of -70 dBm or >.	
Consider deploying 1 full-time WIPS sensor for every 3 - 5 APs when deploying 2-radio APs.	Depending on security requirements
Distance between two APs should be approximately 30 to 70 feet.	
Set limits on AP Tx power.	Office Space / Moderate Client Density: 5 GHz: 8 - 16 dBm 2.4 GHz: 5 - 10 dBm Open Space / High Client Density: 5 GHz: 5 - 12 dBm 2.4 GHz: 4 - 10 dBm
APs may be ceiling or wall mounted.	Consider back lobe radiation of antenna when wall mounting.
Disable 2.4 GHz radios on a percentage of APs.	Percentage of APs with disabled 2.4 GHz radios depends mainly on how densely APs are deployed.
AP placement/channel plan should use channels to minimize CCI and ACI.	
Stagger APs across floors.	
Consider directional antennas for very high client density deployments.	
For high ceilings (e.g. > 35 feet / 10.7 meters), high gain (6-9 dB) patch antennas are recommended.	
Adjust AP output power in relation to antenna gain.	

Know the antenna radiation patterns and focus gain towards clients.	
Do not place APs (w/ internal antennas) or external antennas near lighting fixtures or conductive material.	
Do not place APs (w/ internal antennas) or external antennas above ceiling tiles.	
Perform a thorough post AP deployment site survey.	

Table 18: AP Placement and Channel Plan Recommendations

Campus Use Cases

This section provides solutions for three common use cases in campus environments. The channel capacity calculation methodology presented earlier in this guide will be used to estimate the number of APs required to meet each of the use case specifications. Simplified AP placement and channel plans are presented for each use case.

Classroom

A classroom environment can be a challenging use case to solve due to the combination of moderate to high client density, a relatively high per-client throughput SLA, and the close proximity of multiple classrooms. Video-based learning has become more prevalent, and is the main driver for the high per-client SLA in classrooms. The following solution is for a classroom video use case. Requirements are listed below.

Requirements

- 30 devices active concurrently in each classroom
- Tablets 11ac 1x1
- 4 Mbps per device SLA

Environment

- All DFS channels are available.
- Interior walls have moderate attenuation.

Channel Capacity Planning

For this use case there will be 30 tablets that are 11ac 1x1 active concurrently in each classroom. In order to support HD video, each client is provided with an SLA of 4 Mbps. DFS channels are available so an 80 MHz channel plan will be used.

This channel capacity estimation is for a single classroom. The proposed solution is scaled up to accommodate the total number of classrooms.

Step 1: Determine Per Device Airtime / Channel Capacity

Before starting calculations, the estimated channel capacity per radio is required. That information can be found in Appendix A. When referencing the estimated channel capacity tables in Appendix A an estimated number of clients per radio is required. This use case will fall into the moderate client density category, as 30 clients will be active concurrently.

Use Case	Device Type	Number of Active Devices / Density	App / SLA Bitrate	Channel Capacity	Per Device Airtime / Channel Capacity
Classroom	Tablets 11ac 1x1	30 / Moderate	HD Video (720p) / 4 Mbps	139 Mbps / 80 MHz	2.88%

Table 19: Estimating Per Client Airtime - Classroom

The moderate client density table in Appendix A shows that for 11ac 1x1 clients with an 80 MHz channel the estimated throughput capacity is 139 Mbps. To determine the percentage of airtime or channel utilizations an individual client requires to meet a per-client throughput SLA, divide the SLA by estimated channel capacity and multiply by 100, as shown below.

(App Bitrate or SLA / Channel Capacity) X 100 = Per Device Airtime

(4 Mbps / 139 Mbps) x 100 = 2.88%

Per Device Airtime = 2.88%

Step 2: Determine Total Channels / Radios Required

The purpose of the second step is to determine the total channels / radios required to deliver the SLA to all clients simultaneously.

Use Case	Device Type	Number of Active Devices / Density	Per Device Airtime	Total Airtime	Estimated Channels / Radios Required
Classroom	Tablets 11ac 1x1	30 / Moderate	2.88 %	86 %	1

Table 20: Estimating the Number of Radios Required - Classroom

Estimation of total channels / radios needed is found by multiplying the per client airtime required times the total number of clients active concurrently, as shown below.

Number of Active Devices x per Device Airtime = Channels/Radios Required

30 Active Devices x 2.88% per Device Airtime = 86.3%

Channels/Radios Required = 1 (Rounding up)

Solution

The image below shows the floorplan for a wing of a school building.

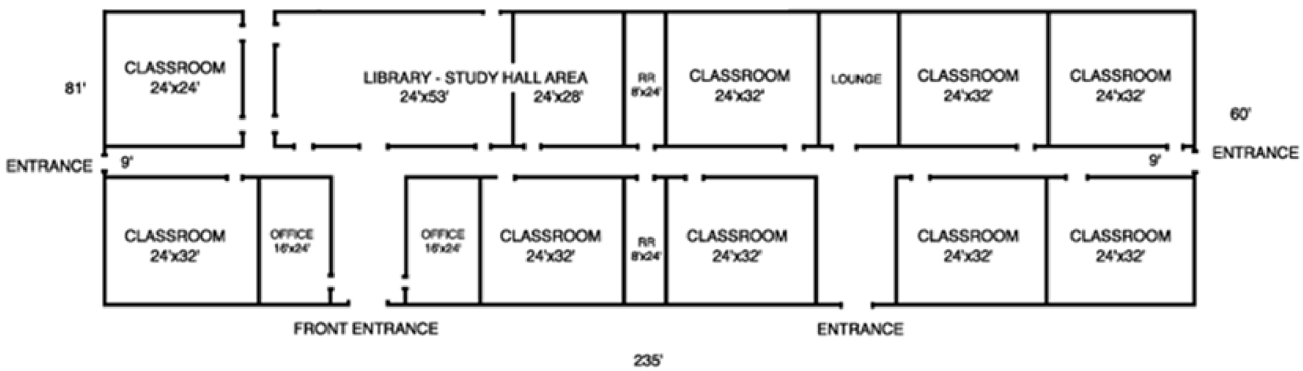


Figure 54: Classroom Floorplan

5 GHz Plan

The image below shows the AP placement and 5 GHz channel plan for a wing of a school building. Arista recommends using the C-130 for this use case. There are 12 C-130s used for this wing of the building, each with an 11ac radio active (80 MHz). The APs are ceiling mounted.

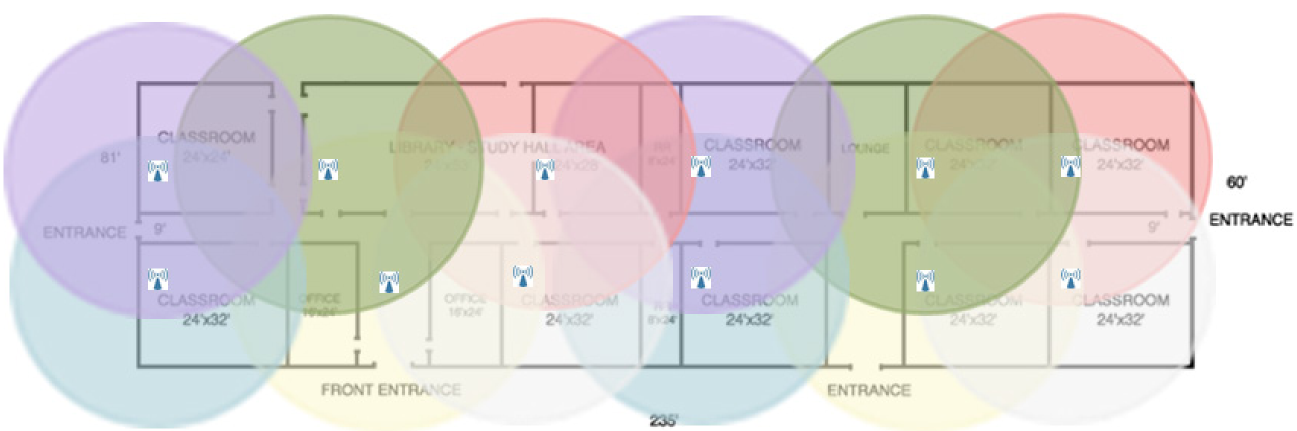


Figure 55: Classroom AP Placement Plan and 5 GHz Channel Plan

Color	Channels
	36E
	52E
	100E
	116E
	132E
	149E

Table 21: 5 GHz Channel Color Legend - Classroom

2.4 GHz Plan

The image below shows the AP placement and 2.4 GHz channel plan for a wing of school building. While there are 12 C-130s used for this wing of the building, only 7 of them have their 2.4 GHz radios enabled to reduce the level of CCI in the 2.4 GHz band.

Figure 56: Classroom AP Placement Plan and 2.4 GHz Channel Plan

Note: Same number of APs are installed as in 5 GHz AP placement / channel plan but those APs that have their 2.4 GHz radios disabled are not shown in the diagram above.

Color	Channels
[light blue circle]	1
[pink circle]	6
[light green circle]	11

Table 22: 2.4 GHz Color Legend - Classroom

Lecture Hall

Supporting a very high number of devices in a relatively confined space, such as in a campus lecture hall or large conference room, can be challenging. Such use cases are common in campus environments. For this sample use case it was determined that at peak times there can be as many as 200 devices using the WiFi simultaneously. The device population is made up of an even mix of 11ac 1x1, 2x2 or 3x3 clients. The exact ratio of clients will vary from day to day but for planning purposes, using 2x2 clients is recommended to simplify the process. If there were a larger proportion of 1x1 clients compared to 2x2 and 3x3, planning for 1x1 clients would be recommended. Client fingerprinting capabilities in the current WLAN is typically the easiest way to determine a client mix for a use case. The requirements for this use case are listed below.

Requirements

- 200 devices active concurrently in the lecture hall
- Mix of 11ac devices (1x1, 2x2 and 3x3)
- 3 Mbps per device SLA

Environment

- All DFS channels excluding channel 100 are available.
- All APs in the lecture hall will be within line of sight of each other.

Channel Capacity Planning

For this use case, there will be 200 devices that are a mix of 11ac laptops, tablets and smartphones that will be active concurrently. The per client throughput SLA is 3 Mbps. All DFS channels are available, excluding channel 100 as the currently installed WLAN system has detected radar activity on channel 100 on several occasions. An 80 MHz channel plan will be used. If auto channel is used the channel 100 should be excluded from the auto channel candidate list, as shown below. This setting can be managed in the Configuration / WiFi / Radio Settings / 5 GHz section of CloudVision WiFi.

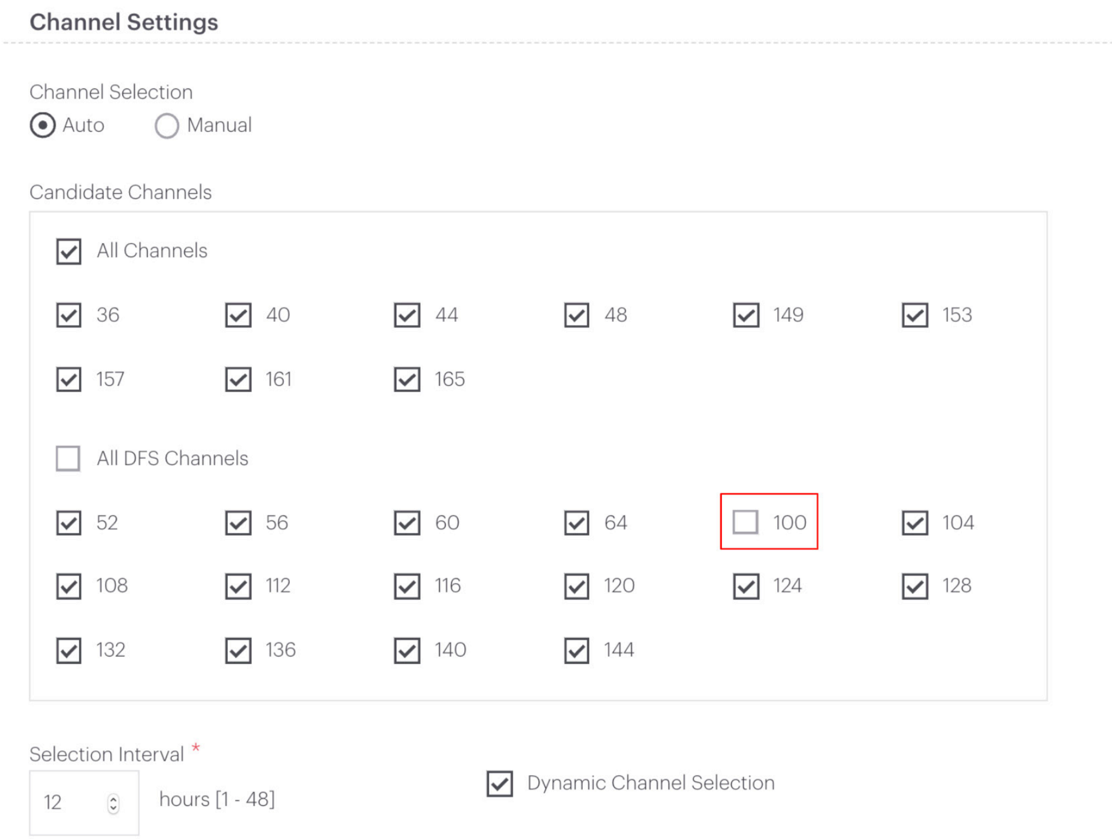


Figure 57: Configuring Candidate Channel List

Step 1: Determine Per Device Airtime / Channel Capacity

Again, the tables in Appendix A will be referenced to determine the estimated channel capacity. The estimated clients per radio for this use case will likely be very high as the requirement is to accommodate 200 active clients in a confined area. As mentioned above 2x2 clients will be used to simplify the design process.

Use Case	Device Type	Number of Active Devices / Density	App / SLA Bitrate	Channel Capacity	Per Device Airtime / Channel Capacity
Lecture Hall	Design for 11ac 2x2	200 / Very High	SLA = 3 Mbps	173 Mbps / 80 MHz	1.73%

Table 23: Estimating Per Client Airtime - Auditorium

The very high client density table in Appendix A shows that for 11ac 2x2 clients, with an 80 MHz channel, the estimated throughput capacity is 173 Mbps. To determine the percentage of airtime or channel utilizations an individual client requires to meet a per client throughput SLA, divide the SLA by estimated channel capacity and multiply by 100, as shown below.

(App Bitrate or SLA / Channel Capacity) X 100 = Per Device Airtime

(3 Mbps / 173 Mbps) x 100 = 1.73%

Per Device Airtime = 1.73%

Step 2: Determine Total Channels / Radios Required

The purpose of the second step is to determine the total channels / radios required to deliver the SLA to all clients simultaneously.

Use Case	Device Type	Number of Active Devices / Density	Per Device Airtime	Total Airtime	Estimated Channels / Radios Required
Lecture Hall	Design for 11ac 2x2	200 / Very High	1.73%	347%	4

Table 24: Estimating the Number of Radios Required - Auditorium

To estimate the total channels / radios needed multiply the per client airtime required times the total number of clients active concurrently, as shown below.

Number of Active Devices x per Device Airtime = Channels/Radios Required

200 Active Devices x 1.73% per Device Airtime = 347%

Channels/Radios Required = 4 (Rounding up)

Solution

The image below shows the lecture hall floorplan.

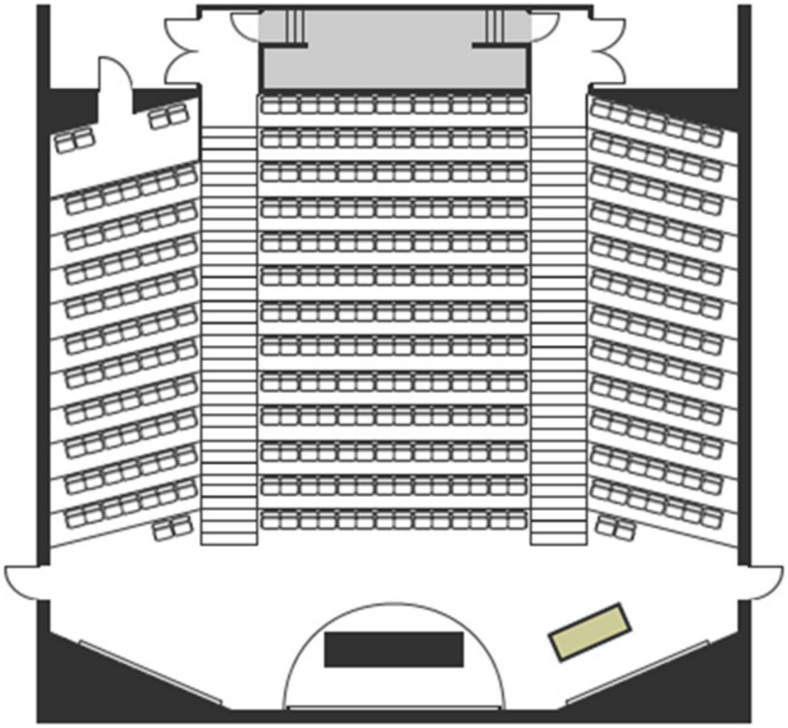


Figure 58: Auditorium Floorplan

5 GHz Plan

The image below shows the AP placement and 5 GHz channel plan for the lecture hall. Arista recommends using the C-130 for this use case. A total of 4 C-130s are used for the lecture hall, each with an 11ac radio active (80 MHz). The APs are ceiling mounted.

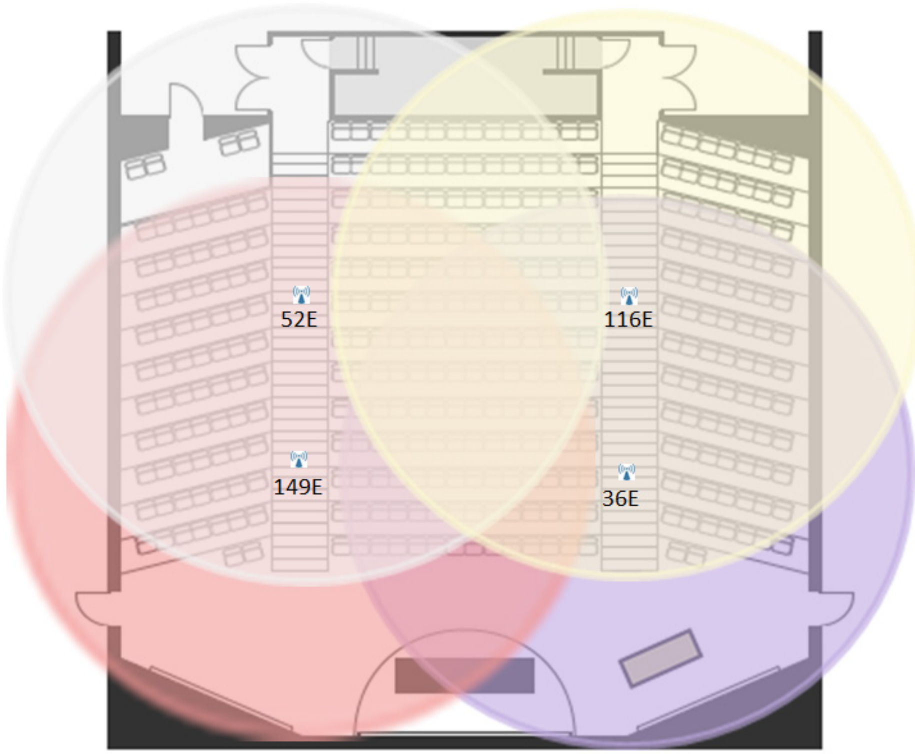


Figure 59: Auditorium AP Placement Plan and 5 GHz Channel Plan

2.4 GHz Plan

The image below shows the AP placement and 2.4 GHz channel plan for the lecture hall. While there are 4 C-130s used for the lecture hall, only 3 of them have their 2.4 GHz radios enabled to reduce the level of CCI in the 2.4 GHz band.

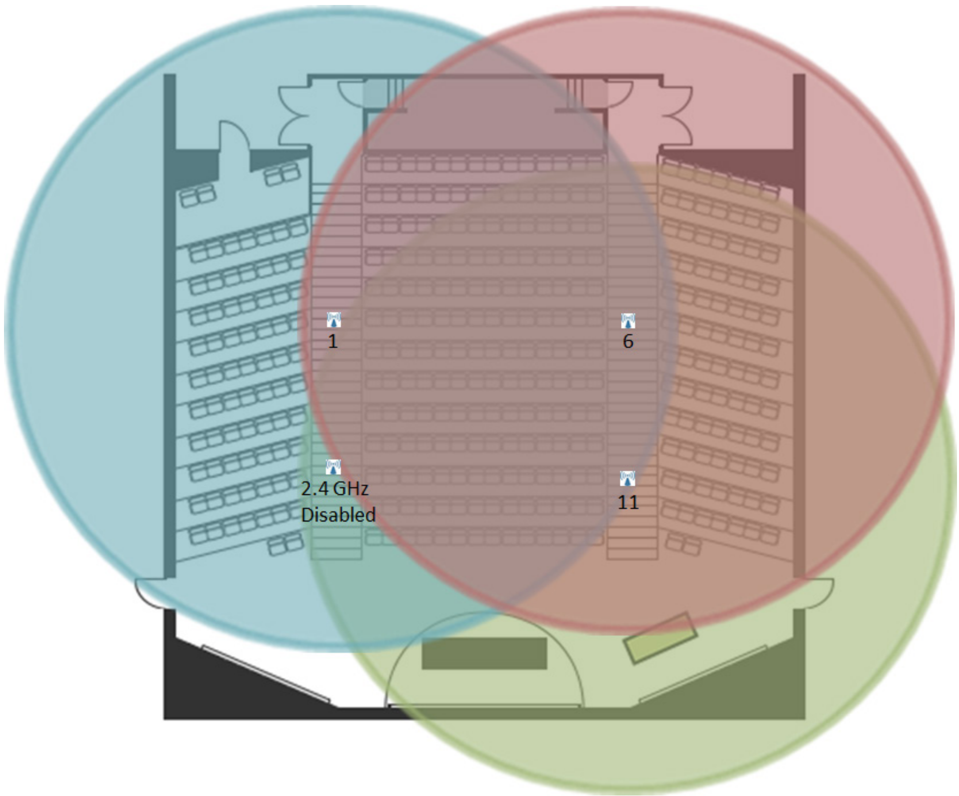


Figure 60: Auditorium AP Placement Plan and 2.4 GHz Channel Plan

Note: The AP in the lower left of the above image has its 2.4 GHz disabled.

Dormitories

Students in dorm rooms depend on solid connectivity and performance to get their work done as well as to stream movies, play video games, etc. Dorm room walls often have very high levels of RF attenuation. When this is the case, the best practice is to place APs in the dorm rooms to ensure high signal strength (e.g. -62 dBm or >) throughout the rooms. The requirements for this use case are listed below.

Requirements

- 10 devices active concurrently in each dorm room
- Mix of 11n and 11ac devices (1x1, 2x2 and 3x3)
- 5 Mbps per device SLA

Environment

- Only DFS channels are 100+ and 132+ are available.
- Dorm room walls have very high levels of attenuation.

Channel Capacity Planning

For this use case there will be 10 devices, which are a mix of 11n and 11ac devices (1x1, 2x2 and 3x3), active concurrently in each dorm room. The requirement is to provide each client with a per client throughput SLA of 5 Mbps. As all DFS channels are not available a 40 MHz channel plan will be used.

This channel capacity estimation is for a single dorm room. The proposed solution will be scaled up to accommodate the total number of dorm rooms.

Step 1: Determine Per Device Airtime / Channel Capacity

For this use case the clients per radio density is low. The low client density table in Appendix A is referenced to get an estimated throughput capacity. As there is a mix of 11n and 11ac, Arista recommends designing for 11ac 1x1, or average, clients.

Use Case	Device Type	Number of Active Devices / Density	App / SLA Bitrate	Channel Capacity	Per Device Airtime / Channel Capacity
Dorm Room	Design for 11ac 1x1	10 / Low	SLA = 5 Mbps	70 Mbps / 40 MHz	7.14%

Table 25: Estimating Per Client Airtime - Dormitory

The low client density table in Appendix A shows for 11ac 1x1 clients with a 40 MHz channel the estimated throughput capacity is 70 Mbps. As with the previous use cases the calculation below is performed to determine the percentage of airtime or channel utilizations an individual client requires to meet a per client throughput SLA.

(App Bitrate or SLA / Channel Capacity) X 100 = Per Device Airtime

(5 Mbps / 70 Mbps) x 100 = 7.14%

Per Device Airtime = 7.14%

Step 2: Determine Total Channels / Radios Required

The purpose of the second step is to determine the total channels / radios required to deliver the SLA to all clients simultaneously.

Use Case	Device Type	Number of Active Devices / Density	Per Device Airtime	Total Airtime	Estimated Channels / Radios Required
Dorm Room	Design for 11ac 1x1	10 / Low	7.14%	71.4%	1

Table 26: Estimating the Number of Radios Required - Dormitory

Estimate total channels/radios needed by multiplying the per client airtime required times the total number of clients active concurrently, as shown below.

Number of Active Devices x per Device Airtime = Channels/Radios Required

10 Active Devices x 7.14% per Device Airtime = 71.4%

Channels/Radios Required = 1 (Rounding up)

Solution

The image below shows the floorplan for a wing of the dormitory.

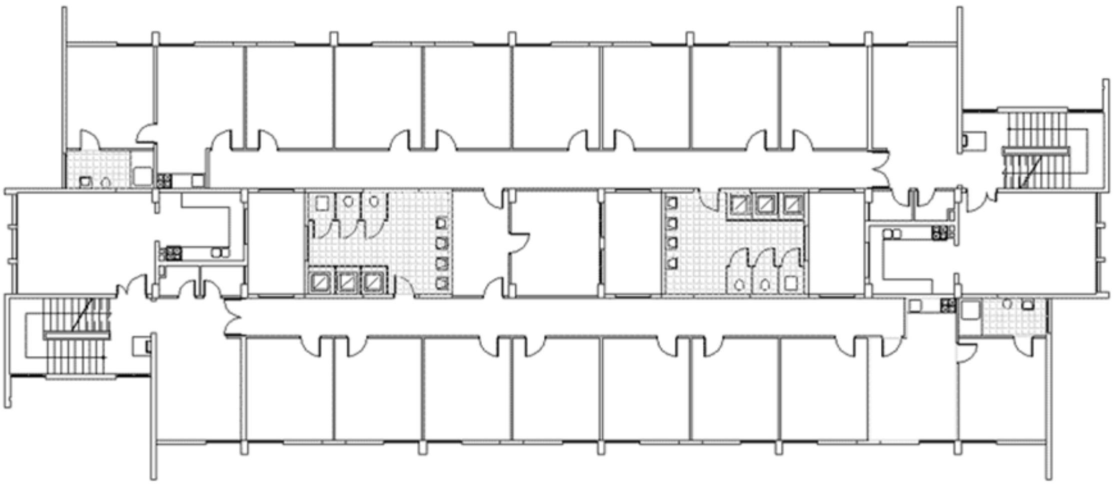


Figure 61: Wing of Dormitory Floorplan

The image below shows the AP placement/channel plan for the dormitory. The solution was to place 1 AP per room due to the very high attenuation properties of the material used in the wall construction. For dorms with walls that have less attenuation, 1 AP per 2 rooms would be preferable. Also, note that the proposed solution is using a 40 MHz channel. For a 1 AP per 2-room plan an 80 MHz plan could be used to support the 5 Mbps per device SLA as the number of devices per AP would double but so would the approximate throughput capacity of each AP. Arista recommends using the wall plate mounted W-118 for this use case.

5 GHz Plan

The image below shows the AP placement and 5 GHz channel plan for the dormitory. A total of 25 W-118s are used for the dormitory, each with an 11ac radio active (40 MHz). The W-118s are wall mounted.

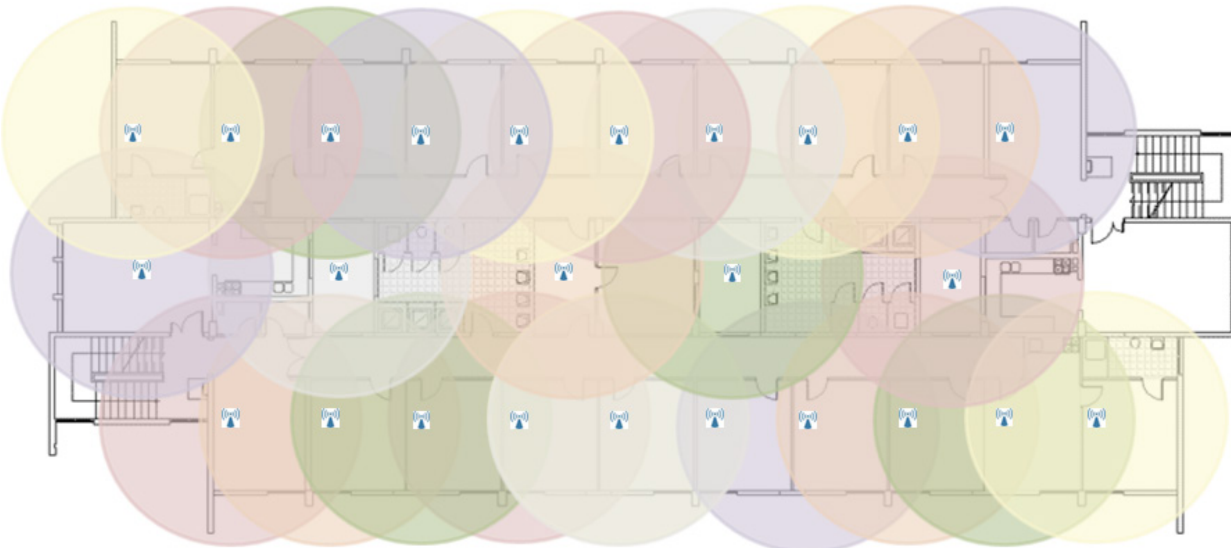


Figure 62: Dormitory AP Placement Plan and 5 GHz Channel Plan

Color	Channels
	36+
	44+
	100+
	132+
	149+
	157+

Table 27: 5 GHz Channel Color Legend - Dormitory

2.4 GHz Plan

The image below shows the AP placement and 2.4 GHz channel plan for the dormitory. While there are 25 W-118s used for the dormitory, only 16 of them have their 2.4 GHz radios enabled. As with the previous two use cases, a percentage of 2.4 GHz radios are disabled to reduce the level of CCI in the 2.4 GHz band.

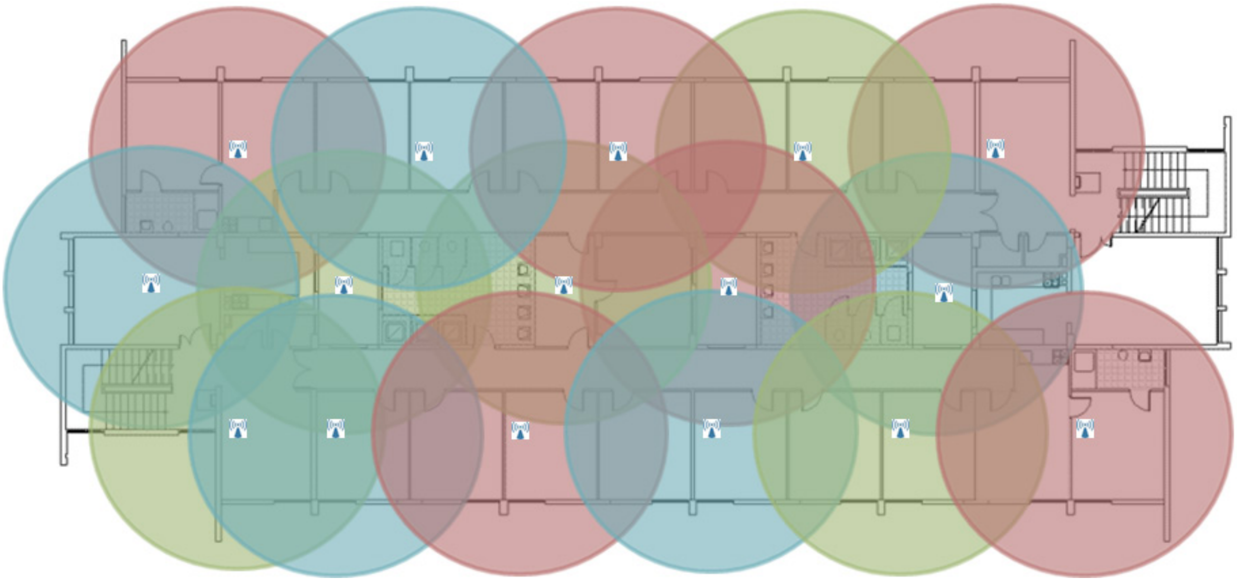


Figure 63: Dormitory AP Placement Plan and 2.4 GHz Channel Plan

Note: Same number of APs are installed as in 5 GHz AP placement / channel plan but those APs that have their 2.4 GHz radios disabled are not shown in the diagram above.

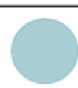
Color	Channels
	1
	6
	11

Table 28: 2.4 GHz Color Legend - Dormitory

Conclusion

As mentioned previously, this guide offers many configuration recommendations that are known to improve performance and/or scalability and/or reliability in campus networks; however, as RF environments, client sets, applications in use, etc. will be unique to each deployment, all of the recommendations offered in this guide may not be applicable to every campus network. With that in mind Arista recommends following best practices of performing PoC testing, followed by a pilot for a subsection of the network, before deploying the new WLAN solution pervasively.

Appendix A

Channel Capacity Estimates

All of the following capacity estimation tables are for reference only. Actual capacity depends on environmental conditions, levels of CCI and ACI, client behavior, and quality of WLAN design. As mentioned previously, predictive survey tools like RF Planner can automate capacity planning. The capacity estimations presented in this section are for a manual method of capacity planning.

The tables below only consider 5 GHz capacity. As most WLANs also include capacity in 2.4 GHz using the capacity planning approach described in this guide, will result in a built-in capacity buffer provided by the 2.4 GHz band, which in most cases is a small fraction of the capacity in 5 GHz. The size of the 2.4 GHz capacity buffer depends on how clients are distributed across bands and the ratio of 5 GHz spectrum to 2.4 GHz spectrum in use.

As mentioned previously the channel throughput capacity estimates below are derived from single AP and multi-AP competitive performance testing. The estimations factor is contention loss seen in tests for 5, 10, 20, 30, 40, 50 and 60 clients per radio, where all clients are placed within 20 feet (6.096 meters) of the AP under test. To estimate loss caused by rate adaptation due to lower signal strength, clients are placed from 10 to 60 feet (3.048 – 15.24 meters) away from an AP.

Note: While capacity loss from WiFi interference such as CCI and ACI can be substantial, it is not factored in, nor is non-WiFi interference loss.

This table below can be used as a reference for max single client throughput.

Estimated Max Throughput Capacity - 60 % Max Data Rate				
1 Client Active	**20 MHz**	**40 MHz**	**80 MHz**	**160 MHz**
1 Spatial Stream	52 Mbps	120 Mbps	260 Mbps	520 Mbps
2 Spatial Streams	104 Mbps	240 Mbps	520 Mbps	1.04 Gbps
3 Spatial Streams	173 Mbps	360 Mbps	798 Mbps	1.04 Gbps
4 Spatial Streams	208 Mbps	480 Mbps	1.04 Gbps	2.08 Gbps

Table 29: Estimated Maximum Throughput Capacity

This next table can be used as a reference for low-density use cases, where there is minimal loss (~ 5%) due to contention and the loss due to signal strength degradation/rate adaptation is estimated to be 20%.

Estimated Low Density Throughput Capacity - 35 % Max Data Rate				
1-15 Clients Active	**20 MHz**	**40 MHz**	**80 MHz**	**160 MHz**
1 Spatial Stream	30 Mbps	70 Mbps	151 Mbps	303 Mbps

2 Spatial Streams	61 Mbps	140 Mbps	303 Mbps	607 Mbps
3 Spatial Streams	101 Mbps	210 Mbps	465 Mbps	821 Mbps
4 Spatial Streams	121 Mbps	280 Mbps	607 Mbps	1.21 Gbps

Table 30: Estimated Low Density Throughput Capacity

The following table can be used as a reference for moderate density use cases, where there is moderate loss (~ 8%) due to contention and the loss due to signal strength degradation/rate adaptation is estimated to be 20%.

Estimated Moderate Density Throughput Capacity - 32 % Max Data Rate				
16 - 30 Clients Active	20 MHz	40 MHz	80 MHz	160 MHz
1 Spatial Stream	28 Mbps	64 Mbps	139 Mbps	277 Mbps
2 Spatial Streams	55 Mbps	128 Mbps	277 Mbps	555 Mbps
3 Spatial Streams	92 Mbps	192 Mbps	426 Mbps	750 Mbps
4 Spatial Streams	111 Mbps	256 Mbps	555 Mbps	1.11 Gbps

Table 31: Estimated Moderate Density Throughput Capacity

The table below can be used as a reference for high-density use cases, where there is high loss (~ 13%) due to contention and the loss due to signal strength degradation/rate adaptation is estimated to be 20%.

Estimated High Density Throughput Capacity - 27 % Max Data Rate				
31 - 45 Clients Active	20 MHz	40 MHz	80 MHz	160 MHz
1 Spatial Stream	23 Mbps	54 Mbps	117 Mbps	234 Mbps
2 Spatial Streams	47 Mbps	108 Mbps	234 Mbps	468 Mbps
3 Spatial Streams	78 Mbps	162 Mbps	359 Mbps	633 Mbps
4 Spatial Streams	94 Mbps	216 Mbps	468 Mbps	938 Mbps

Table 32: Estimated High Density Throughput Capacity

This next table can be used as a reference for very high-density use cases, where there is very high loss (~20%) due to contention and the loss due to signal strength degradation/rate adaptation is estimated to be 20%.

Estimated Very High-Density Throughput Capacity - 20 % Max Data Rate				
46 - 60 Clients Active	**20 MHz**	**40 MHz**	**80 MHz**	**160 MHz**
1 Spatial Stream	17 Mbps	40 Mbps	87 Mbps	173 Mbps
2 Spatial Streams	35 Mbps	80 Mbps	173 Mbps	347 Mbps
3 Spatial Streams	58 Mbps	120 Mbps	266 Mbps	469 Mbps
4 Spatial Streams	69 Mbps	160 Mbps	347 Mbps	695 Mbps

Table 33: Estimated Very High-Density Throughput Capacity

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