Reducing mean time to resolution using Root Cause Analysis

Enterprise Wi-Fi has evolved vastly in recent years, with ever-increasing reliance on wireless connectivity to support a wide range of data hungry, latency sensitive applications such as real-time audio-video communications e.g., Google Meet, Microsoft Teams, GoToMeeting, Skype, and the like. Managing enterprise-wide Wi-Fi networks for delivering high quality end user experience is often a challenging task, given the unpredictable radio environment and diverse client capabilities. A sub-optimally maintained network eventually leads to a poor quality of experience for the end users. Unless the enterprise can reap the best out of the existing network infrastructure, decisions on future investments in scaling up remain abstruse.Arista's Cloud Vision Cognitive Unified Edge (CV-CUE) is powered by a machine learning based root cause analysis (RCA) engine that greatly eases the task of network administrator in identifying and mitigating a wide range of performance issues.

The RCA engine periodically collects run-time metrics (viz., average data rate, retry rate, received signal strength indicator (RSSI), Wi-Fi/non-Wi-Fi interference, network latencies, etc.,) about clients and access points (APs). CV-CUE maintains a weighted moving average baseline for these metrics[1]. This baseline serves as a benchmark for the network performance, and any deviations from the baseline are flagged as anomalies, the root causes for which are determined with the help of machine learning algorithms built into the RCA engine. Further, with knowledge of system configuration parameters, the RCA engine suggests appropriate recommendations to mitigate the performance issues. The network administrator also gets access to rich visual analytics of the client/AP telemetry which helps in corroborating the root causes.

This application note outlines the capabilities of the RCA engine and demonstrates its utility in resolving network issues through well-defined use cases. It serves as a guide for network administrators in resolving issues encountered during various stages of client connectivity (association, authentication, network connectivity), fixing performance issues of low signal strength, high retry rate, low data rate, and poor application experience. In conjunction with CV-CUE's floor plan visualization, the RCA engine eases solving location specific issues, saving network administrator's valuable time and effort. All the use cases presented are accompanied with examples.

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1. Introduction

The challenges inherent to the wireless medium viz., contention for sparse radio resources, interference, and dynamic channel conditions affect the quality of any Wi-Fi deployment and complicate troubleshooting for network faults. For example, setting the RSSI and SNR thresholds too high could result in the clients failing frequently in associating with the APs, manifested as high retry rate.

Arista Cloud Vision Cognitive Unified Edge (CV-CUE) eliminates the need to manually troubleshoot commonly occurring network faults and performance issues such as the following:

Connectivity

- Association failures
- Authentication failures
- Network connectivity failures

Performance

- Low RSSI
- Low data rate
- High retry rate
- High latency (AAA, DHCP, DNS, Application latencies)

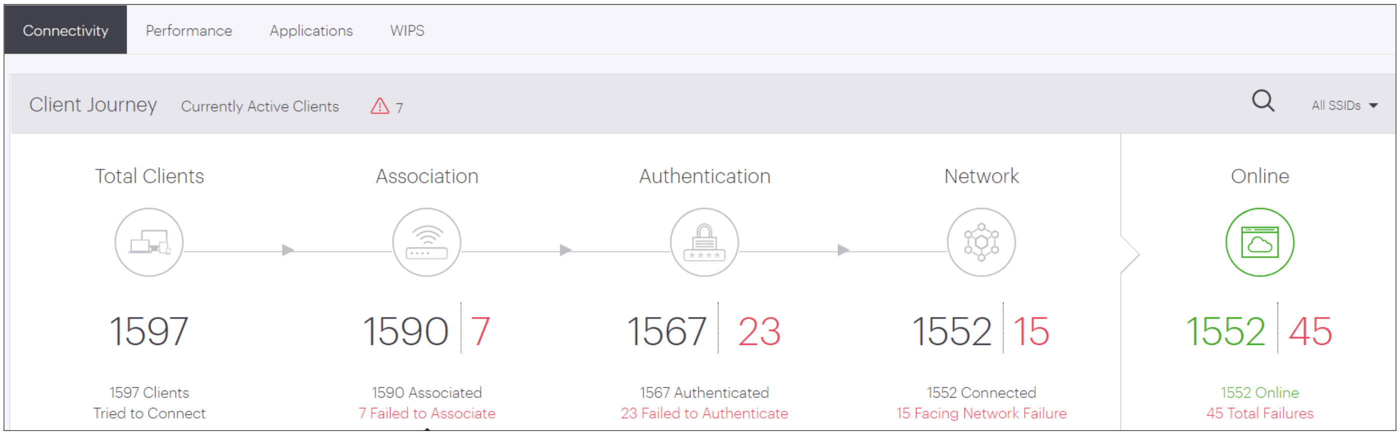

Figure 1.1: Connectivity dashboard - Client Journey

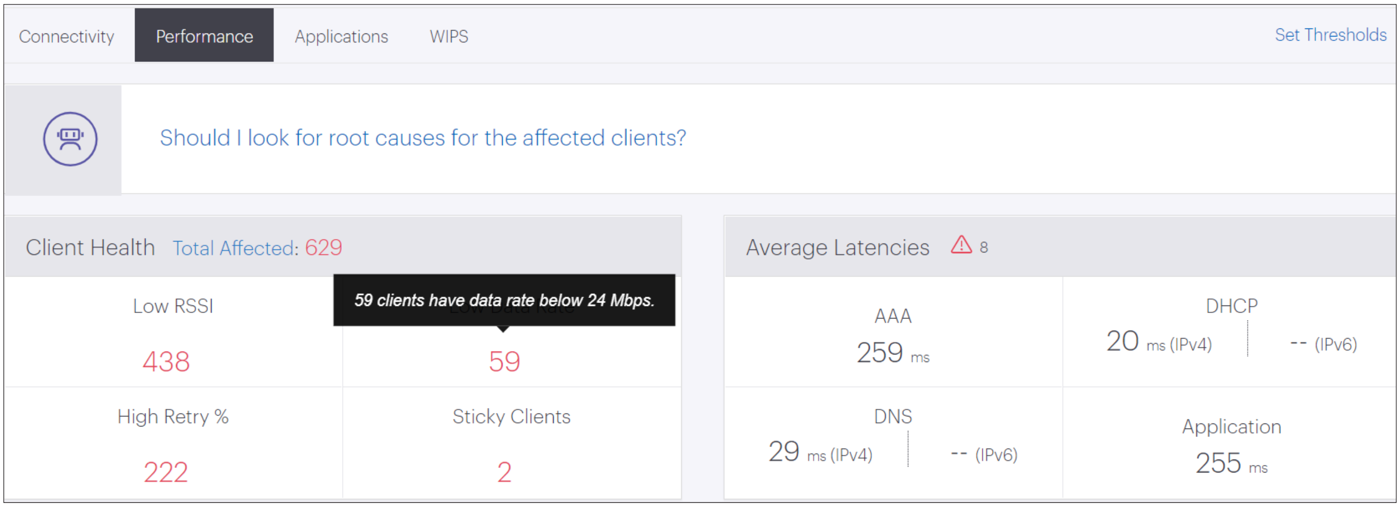

Figure 1.2: Performance dashboard - Client Health

2. The RCA Engine

Arista's CV-CUE records run-time network metrics at the granularity of a few minutes and network events within a few seconds of their occurrence to deliver fast turnaround time for fault diagnosis. The root cause analysis (RCA) RCA engine is designed to exploit the feature rich network data set gathered by CV-CUE to detect and analyze common problems encountered in customers' wireless environments.

Determining the root cause(s) of issues in a network is seldom a linear process. An interplay of multiple underlying parameters often manifests as a failure or an observable symptom of poor performance. Arista's RCA engine is designed using Mmachine learning and rule mining techniques to arrive at the root causes for client/network issues accurately as well as recommend the appropriate remediations. The network administrators also get access to rich visual analytics which captures the baseline performance and anomalies of key metrics in the form of graphs and tables with multiple data filters.

2.1 Components

The RCA engine consists of three principal components:

Run-time network metrics and system configuration parameters:
CV-CUE captures and stores run-time metrics of both clients and access points at 15 minute resolution. For clients, this data includes RSSI, retry rate, average data rate, network events (viz., association, authentication, network connectivity, client steering), application usage, capabilities (2.4 GHz, 5 GHz, 6 GHz), traffic volume in both the uplink and downlink, associated SSID & AP, etc. In addition to run-time data, details of client device vendor, OS, physical location, etc., are also made available to the RCA engine for analysis. For the APs, the recorded parameters are channel utilization, traffic volume, network latencies, application performance, average data rate of connected clients, client association failures, retry rate, spectrum bands in use, Wi-Fi/non-Wi-Fi interference , etc. The baseline data is stored for up to a month for APs.

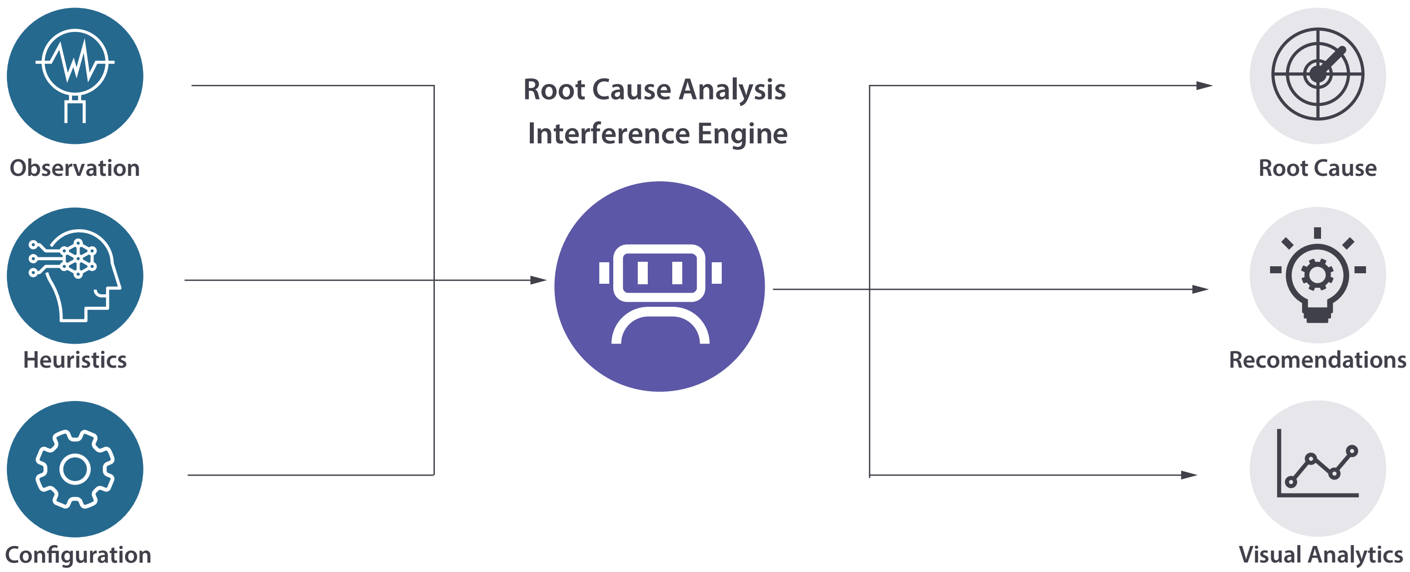

Figure 2: Components of RCA Interference Engine

ML based RCA engine:

Contextual root cause analysis is performed using an RCA algorithm designed from Arista's extensive Wi-Fi experience and heuristics that factor in system configuration parameters, location specific, client specific, AP specific, and time specific data. The most prominent symptoms experienced by the end user due to faults in the network are low throughput and/or poor application performance. The engine evaluates all the underlying root causes for the manifested symptoms and then associates one or more causes to the symptoms.

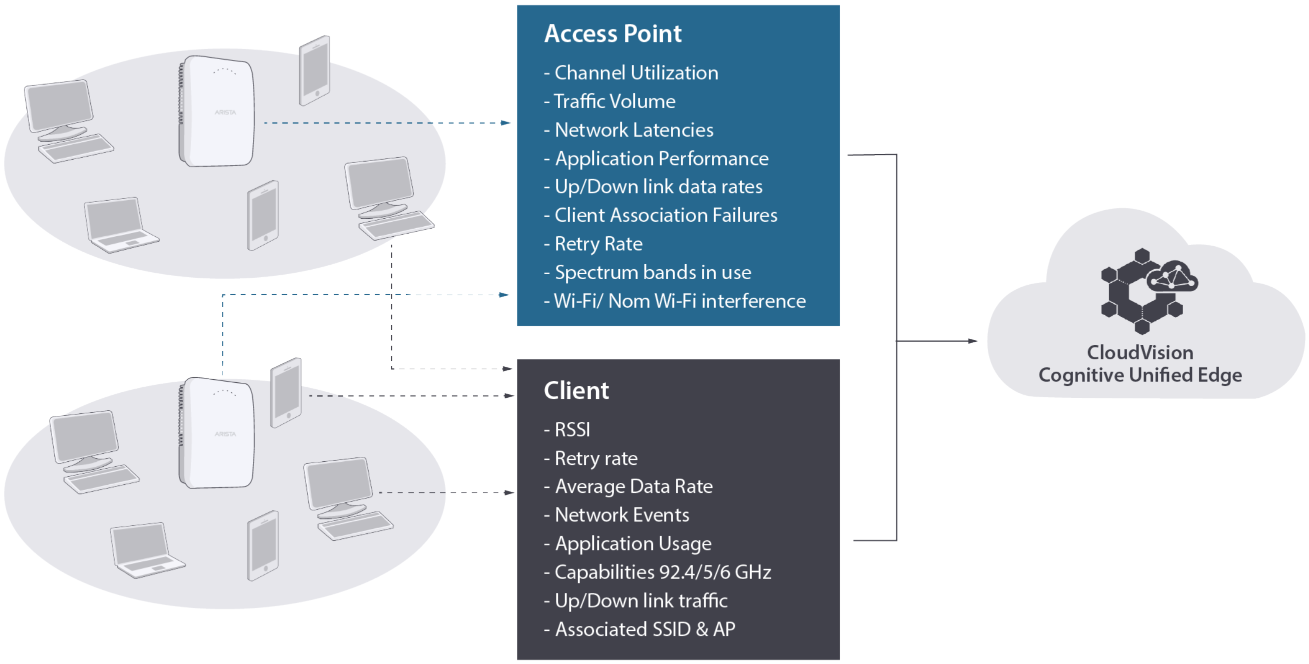

Figure 3: Run time metrics collected from APs and clients

Root causes, Recommendations & Visual analytics:

In situations where multiple root causes are identified for a single issue, the root causes are ranked in the order of importance. Suitable recommendations are listed against each root cause. The suggested recommendations guide the network administrators towards appropriate action to fix the respective root causes. CV-CUEprovides a rich visualization of network telemetry in the form of tables, charts and graphs. These visualizations offer a flexible way to gain insight into real-time as well as historical data and assist the network administrators in the heuristics of correlating the symptoms of poor network performance with root causes.

2.2 Types of Inferencing

Wi-Fi clients are subjected to a multitude of issues throughout their journey starting with associating with an AP until the application (audio/video/web-browsing/video streaming) completes exchange of data with the network. The RCA engine is capable of identifying the root causes for issues during connectivity, as well as when the client is actively exchanging data with the network. The CloudVision Wi-Fi dashboard highlights statistics of connectivity failures and performance issues on the Connectivity and Performance tabs respectively (see Figure 1.1 and Figure 1.2). The network administrator can then delve into corresponding root causes and recommendations by clicking on the displayed metrics. Depending on whether one is interested in analyzing a single client or a group of clients, two types of inferencing can be carried out by the RCA engine – single client and multi-client.

2.2.1 Single Client Inferencing

Wi-Fi clients are subjected to a multitude of issues throughout their journey starting with associating with an AP until the application (audio/video/web-browsing/video streaming) completes exchange of data with the network. The RCA engine is capable of identifying the root causes for issues during connectivity, as well as when the client is actively exchanging data with the network. The CloudVision Wi-Fi dashboard highlights statistics of connectivity failures and performance issues on the Connectivity

2.2.2 Multi Client Inferencing

In multi client mode, the engine provides analysis for a group of clients belonging to the same location. This type of analysis is helpful in identifying network wide or location specific issues. Since the wireless environment is highly localized and can vary drastically across different physical locations, the multi- client analysis is carried out separately for each leaf level location in the network. meaningful only at the AP level or leaf level in the network.

3. Use Cases

3.1 Resolving Connectivity Issues

The typical journey of a client from searching for available SSIDs to successfully connecting to the network involves the steps of association, authentication and network connectivity as shown in Figure 4. and rule mining techniques to arrive at the root causes for client/network issues accurately as well as recommend the appropriate remediations. The network administrators also get access to rich visual analytics which captures the baseline performance and anomalies of key metrics in the form of graphs and tables with multiple data filters.

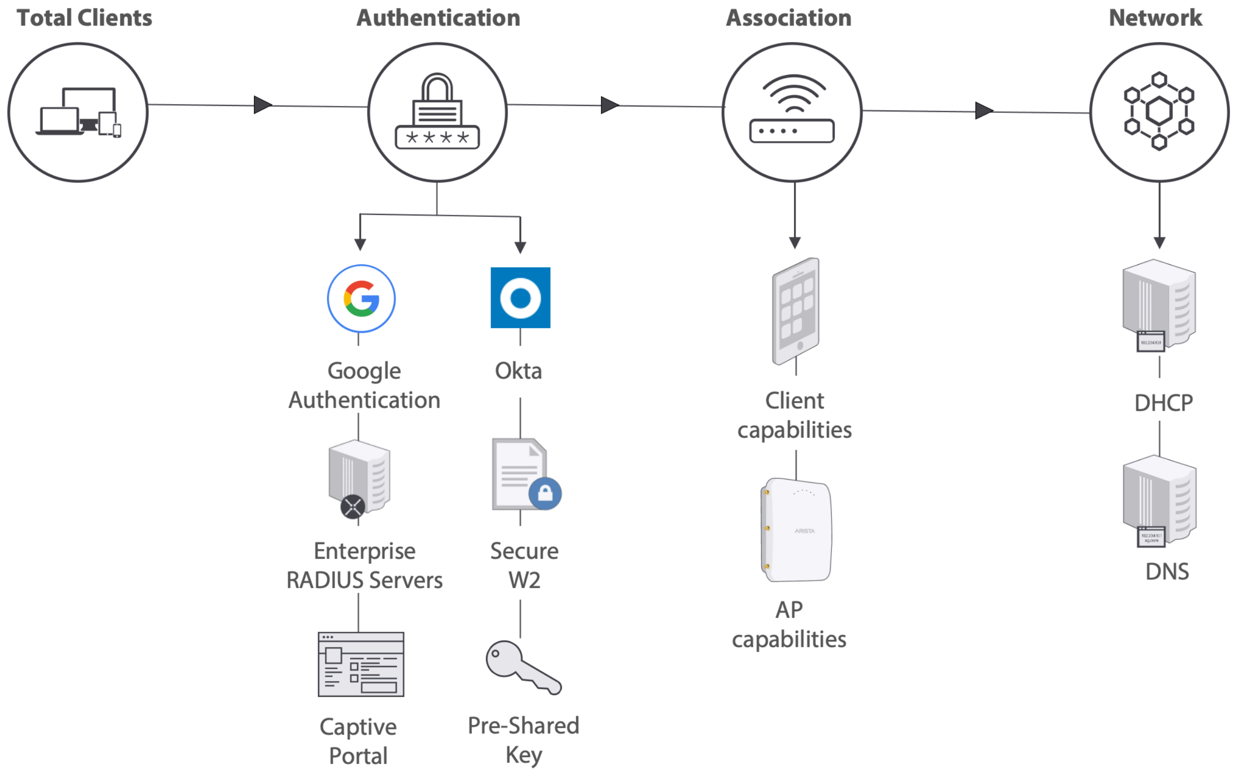

Figure 4: Stages in connectivity of a client with network

3.1.1 Connectivity Failures

Association - Association is the process of gaining access to the AP. Association may fail if the client has low RSSI, requests for capabilities not supported by the AP, or if the AP is already handling the maximum number of clients it can support. An example of association failure is depicted in Figure 5.1. From the Connectivity dashboard, one can access the list of all the clients that failed associating by clicking on the number of association failures (in this case, 10) highlighted in red color. The root cause analysis for association failure for any client in this list is carried out by the RCA engine upon clicking on the respective client. For instance, in the Figure 5.2 RCA engine identifies that the client requested capabilities not supported by the AP, resulting in a failed association.

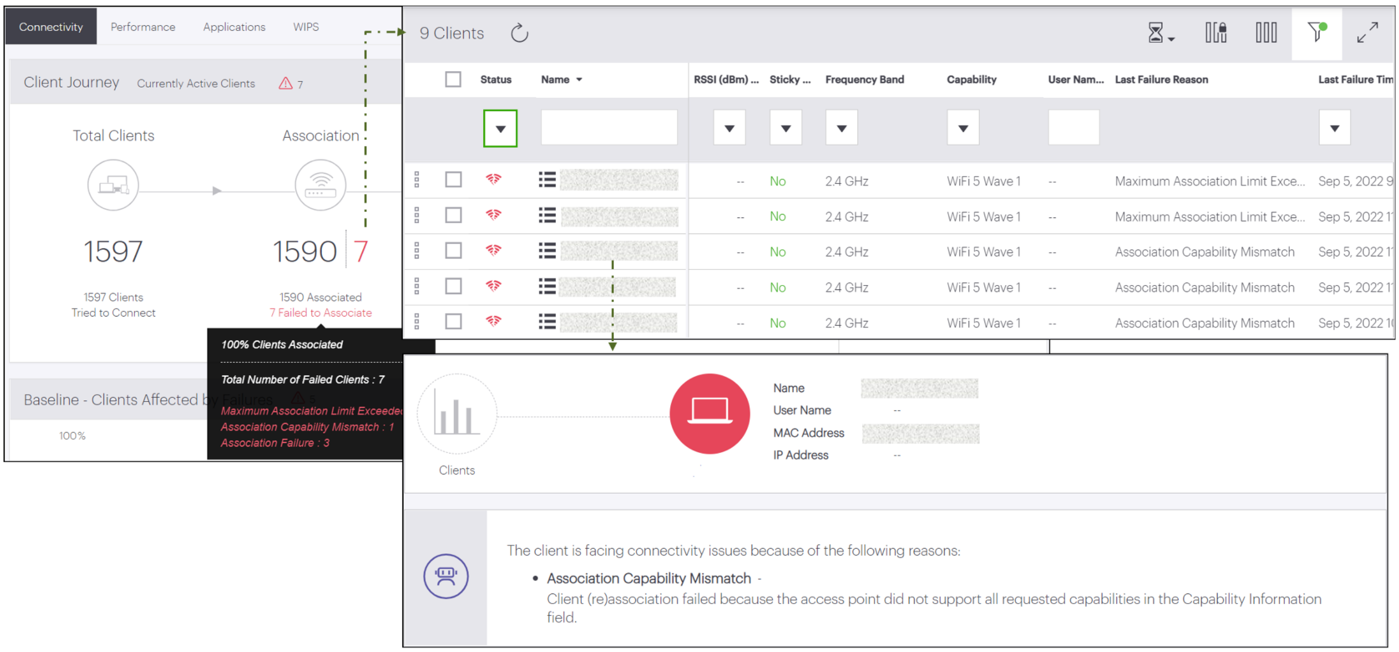

Figure 5.1: Connectivity - Association Failure

Authentication – A client may fail to authenticate when 802.1X/EAP key fails or the RADIUS server cannot be reached, or authentication with RADIUS server fails. The example illustrated in Figure 5.2 depicts the case of RADIUS authentication failure as identified by the RCA engine.

Network Connection - Once a client is successfully authenticated, it has to be assigned an IP address by the DHCP server and should be provided a DNS to access the internet. When the DHCP server fails to allocate an IP address to the client or the client is unable to connect to the DNS, connectivity to the network cannot be established. Figure 5.3 demonstrates how to drill down root causes for failures in network connectivity. The RCA engine identifies that the DHCP server failed to allocate an IPV4 address to the client due to which the client was unable to connect to the network.

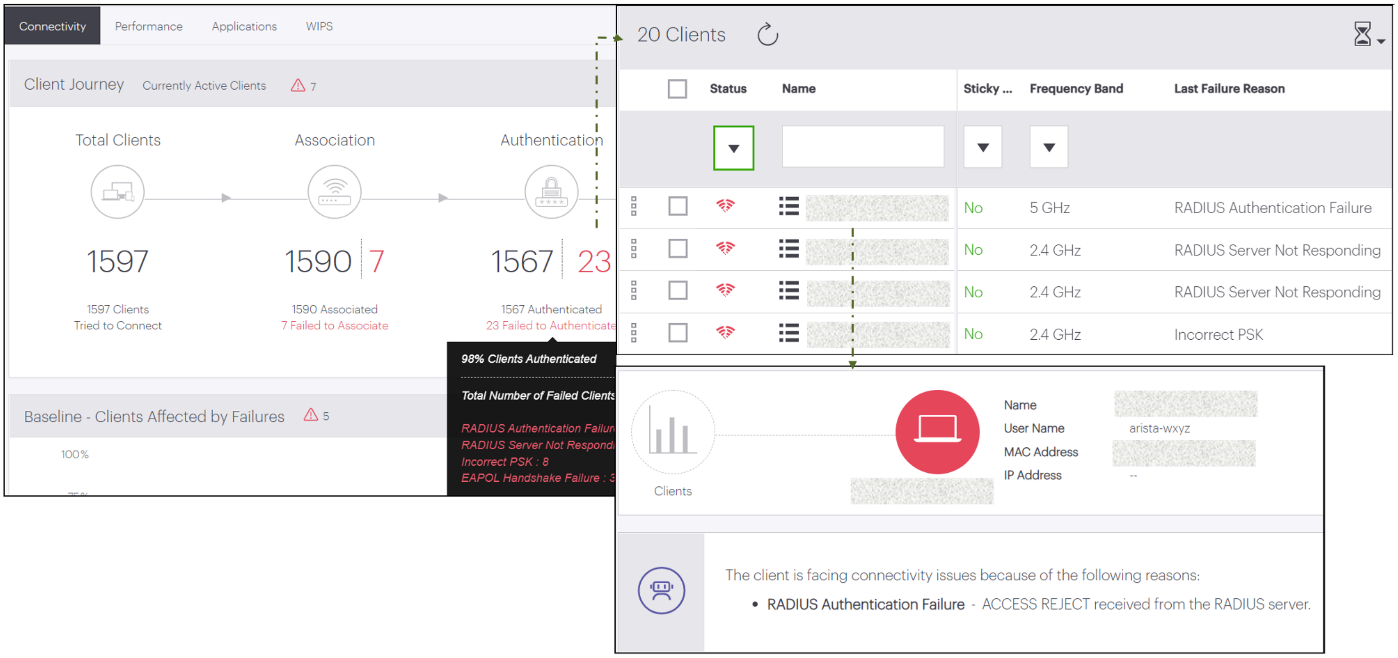

Figure 5.2: Connectivity - Authentication Failure

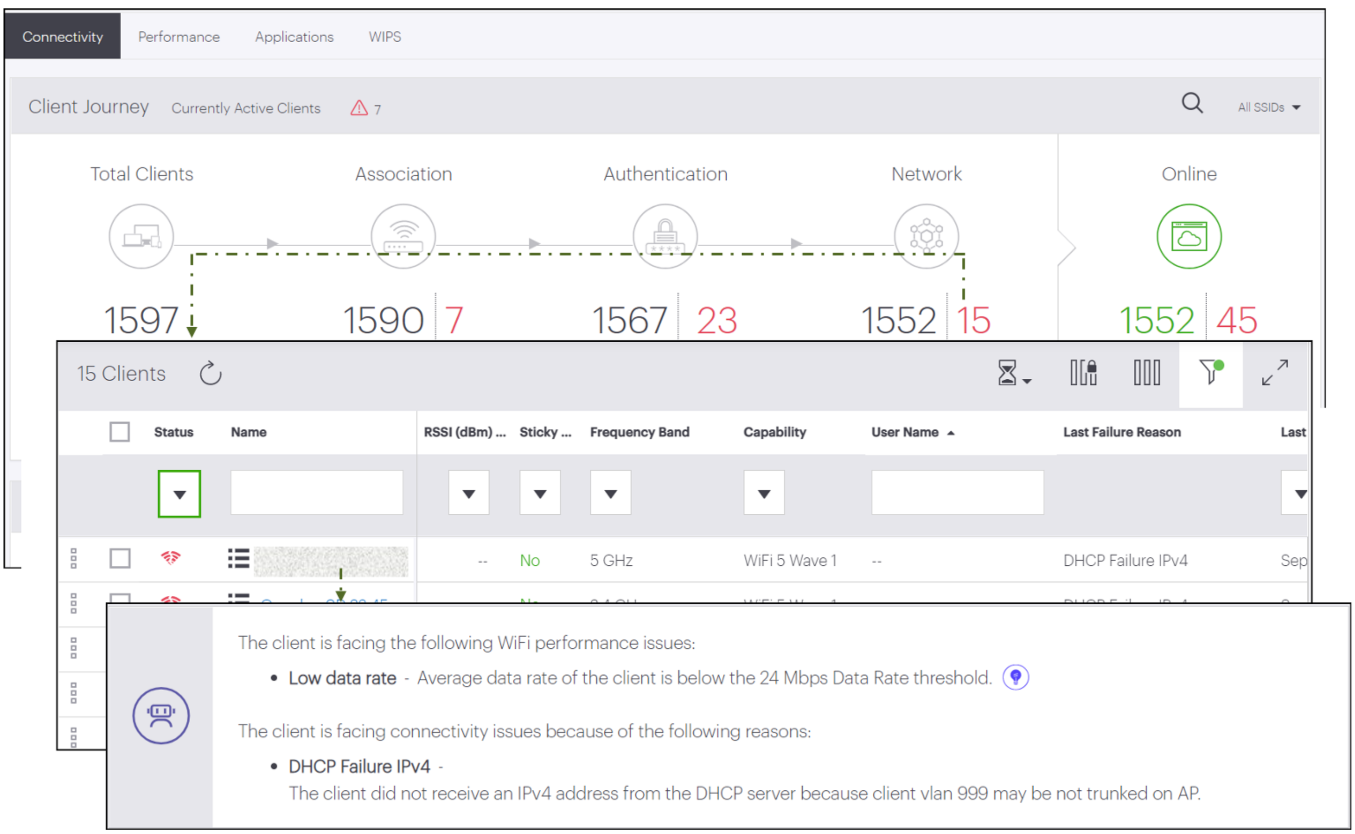

Figure 5.3: Connectivity - Network Failure

3.1.2 Aggressive Roaming

Time sensitive applications like voice and video require uninterrupted connectivity. To ensure this, Wi-Fi clients monitor the RSSI from all the APs in their vicinity and initiate probing an AP when they experience degradation in their current connection. The RSSI threshold at which a client moves from the current AP to another may be different for each client and is vendor specific. Some clients may have aggressive roaming settings whereby they move frequently across APs. This can result in increased contention in the network and consequently, longer delay for other clients in connecting or transmitting data. The single client drill down provides a detailed depiction of the association, authentication and network connectivity events from which aggressive roaming can be detected.

3.1.3 Frequent Fast Roaming Failures

Clients in motion use fast roaming to avoid frequent authentication when roaming across multiple APs. Fast roaming clients may face frequent connectivity failures due to repeated association and dissociation with APs. The root causes for fast roaming failures can be analyzed by the RCA engine as depicted below. The client is unable to reassociate with the AP in this case due to the AP reaching the limit on the maximum allowed number of clients. The timeline of failed association events and the respective root causes can be viewed on the Client Events tab.

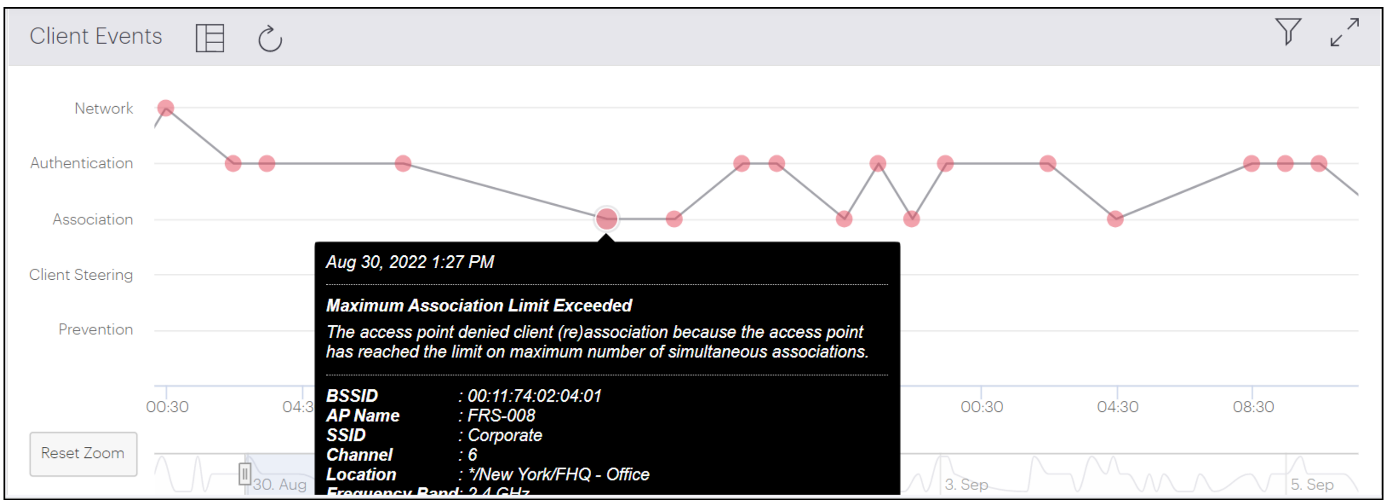

Figure 6: Client Journey - Association Failure - Client Events

3.1.4 DHCP/AAA/DNS Latency

Each of the association, authentication and network connectivity steps in Figure 7 adds some latency to the total time taken for successfully connecting a client to the network. The network wide average values of these latencies are captured by the RCA engine periodically and displayed on the Performance dashboard. Whenever the average latencies exceed respective set thresholds, CV-CUE automatically generates alerts.

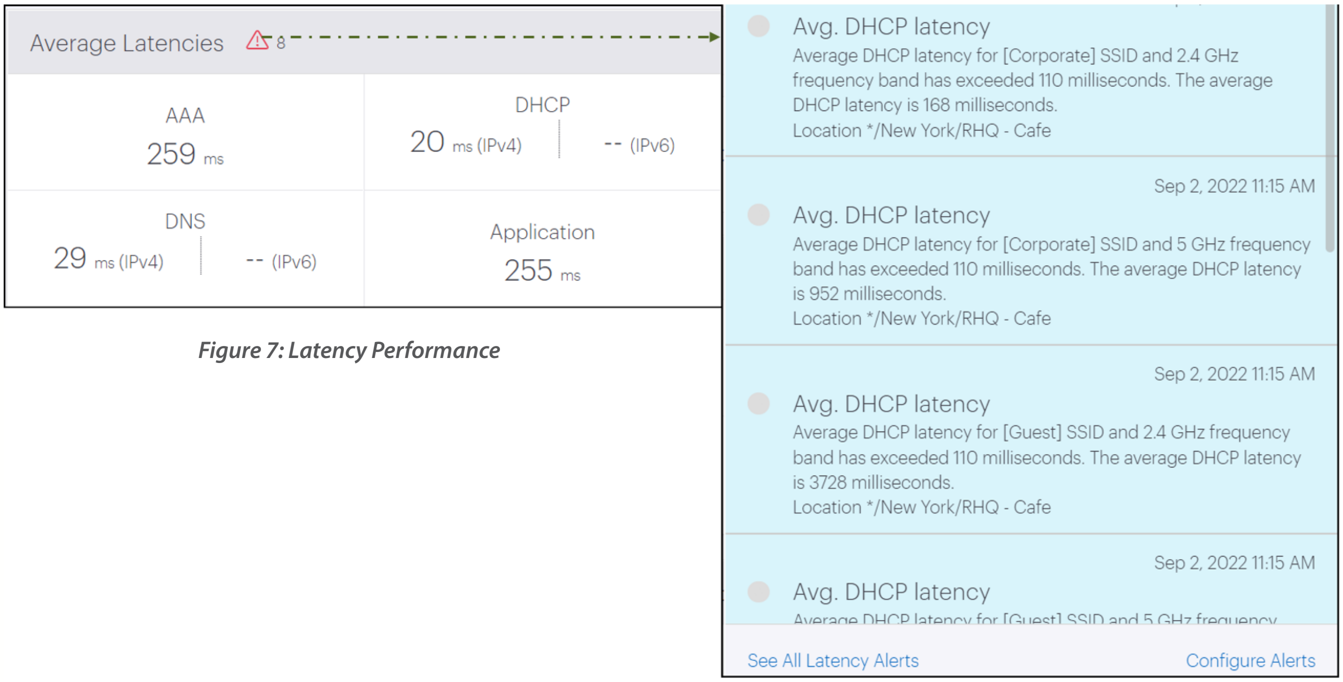

Figure 7: Latency Performance

3.2 Low Throughput Issues

A common problem that clients experience in the network is that of low throughput, as a result of low data rates on the wireless link. The multitude of reasons that can lead to a drop in data rate at the client demands a careful examination to resolve this problem. For example, in the below scenario, the client has a data rate of only 6.5 Mbps, much lower than the 24 Mbps threshold, despite having a good signal (-57 dBm RSSI).

The Single Client RCA engine drills down and identifies two potential reasons for this low speed.

High Contention/Interference: The first reason is that the retry rate of the client is very high at 48.24%. The high retry rate indicates that the client is unable to get a free channel as the associated AP is already handling a large number of clients. The high number of clients results in increased contention, forcing raspberrypi to retry for the channel several times. Another reason for channel unavailability could be high interference resulting in low SNR at the client. The best remediation in this case is to trigger Dynamic Channel Selection [2] at the AP which selects another channel with lower interference level.

Underutilization of client capabilities: The SCI engine detects that the client is multi-band capable i.e., it can support 2.4 GHz, 5 GHz/6 GHz. Arista's APs are capable of identifying a client's multi-band capabilities and can effectively steer the clients to less occupied bands so as to distribute the traffic load amongst all the available bands. Therefore, band steering will be automatically carried out by the AP and no action is required by the network administrator in this case.

3.3 Identifying Areas of Low Signal Strength

Due attention is paid during the planning and deployment stages of Wi-Fi networks to ensure that the areas to be served receive sufficient signal strength (RSSI) that is above the minimum threshold of -65dBm (set in the system) for successful connectivity. However, after deployment, the actual coverage area of an AP might not be what it was originally planned for, due to obstructions in the path of the AP's signal or misconfiguration of AP parameters. For clients positioned at the edge of the BSS, this shrinking of AP coverage means that they no longer meet the RSSI threshold required for successful association. Therefore, they start experiencing

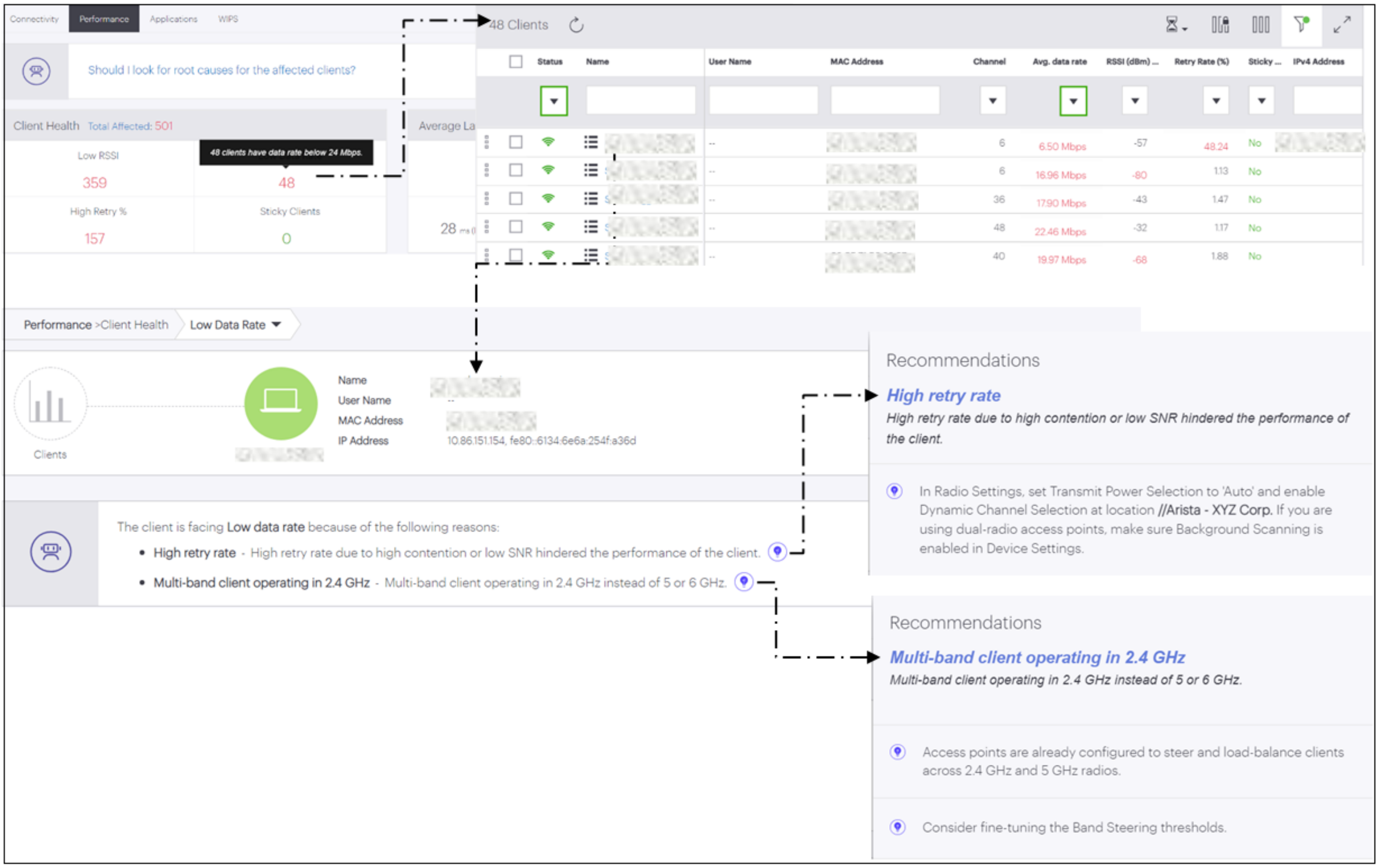

Figure 8: Performance-Low Data Rate-High Retry Rate-Masked

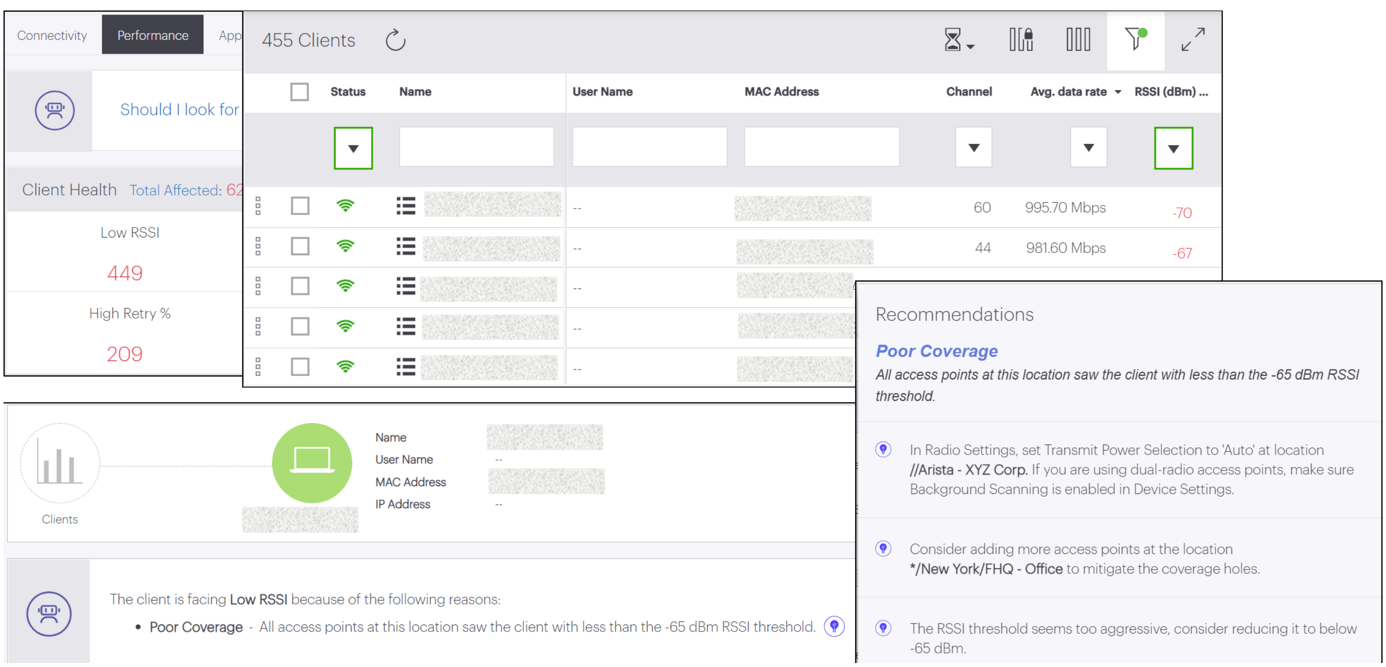

Figure 9: Single client RCA - Identification of poor coverage

low data rates, frequent disconnection, resulting in poor quality of experience. Coverage holes might affect a single client or multiple clients, depending on their physical locations with respect to the APs. Let us consider the scenario depicted in Figure 10. The planned coverage area of the AP meets the RSSI threshold of all the clients – Client1-Client8. The dotted line represents the actual AP coverage due to obstructions, where Client2, Client3 and Client8 might not meet the required RSSI threshold. Hence, these three clients start experiencing poor network quality.

The locations and clients affected by poor coverage can be identified by invoking RCA from the Performance tab. For example, in Figure 12, CV-CUE lists the locations affected by poor performance, out of which FHQ-Office in New York is identified as the top most location facing coverage issues. The RCA engine recommends setting the AP Transmit Power Selection to 'Auto' mode with background scanning enabled for dual-radio APs. Setting the coverage threshold too high might also result in restricting coverage area, hence RSSI threshold adjustment is also suggested. In case the poor coverage issue persists despite these remediations, RCA suggests deployment of additional APs to enhance coverage. RCA can also be carried out for a single client facing poor coverage, as depicted in Figure.

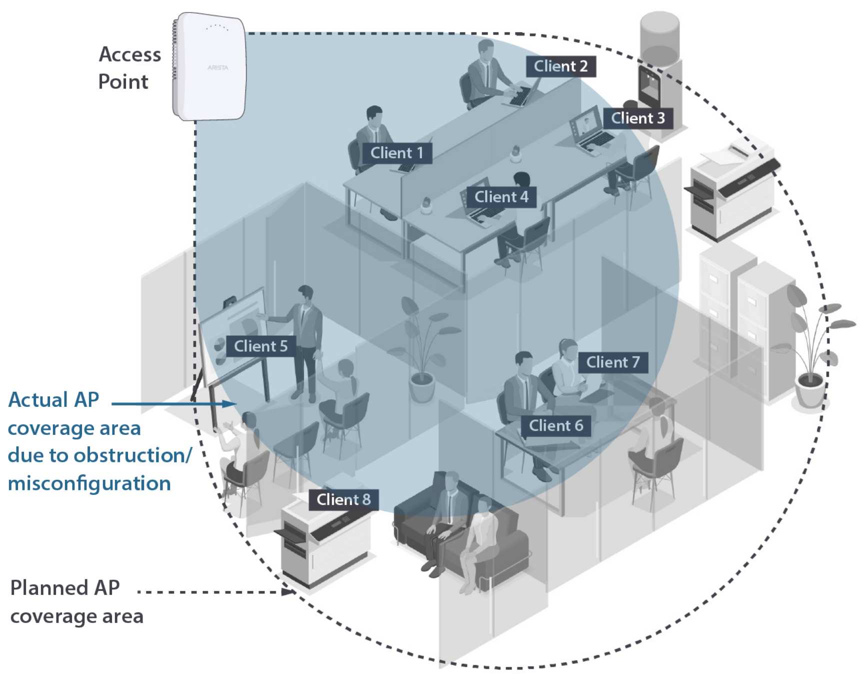

Figure 10: Effect of reduction of AP coverage area on clients

The Client Health dashboard on the Performance tab provides coverage insights in the form of RSSI distribution plot across all the clients in the network, as shown in Figure 11. The distribution indicates that most of the clients in the location have good RSSI (>-65 dBm), while a small fraction of them suffer from poor RSSI.

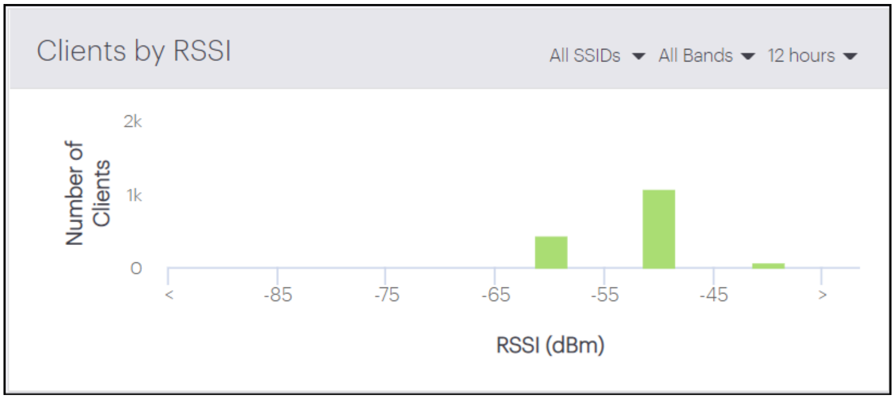

Figure 11: Multi client RCA - Client RSSI distribution

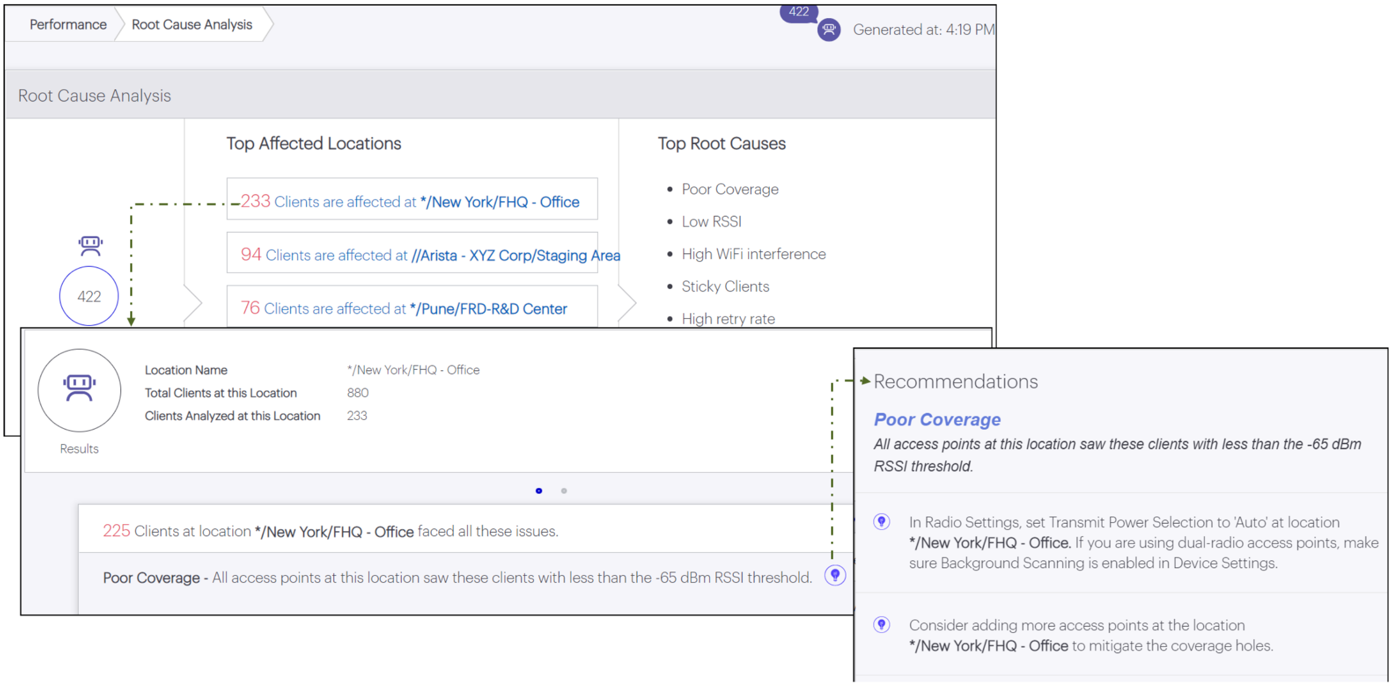

Figure 12: Multi client RCA - Identification of areas of low signal strength

3.4 Addressing Poor Application Performance

Enterprise clients use a wide range of audio-video communication (AVC) applications e.g., Google meet, Microsoft Teams, Zoom, Skype, YouTube, multiple e-commerce apps like Flipkart, Amazon and more. The AVC applications are sensitive to latency as any time lag in audio and video leaves a poor subjective experience on the end user. Similarly, delays in loading web pages of e-commerce applications, time-outs in transactional applications like mobile banking, net banking or UPI payments are perceived as poor network experience by the end user. Arista's unique solution for application performance monitoring equips APs with the necessary capabilities to capture application traffic metrics like bitrate, latency and jitter in real time. The metrics are further fed to the QoE engine [3] in CV-CUE which uses Machine Learning algorithms to analyze application performance accurately (see Figure 13). The results of the analysis are published on the Application Experience dashboard.

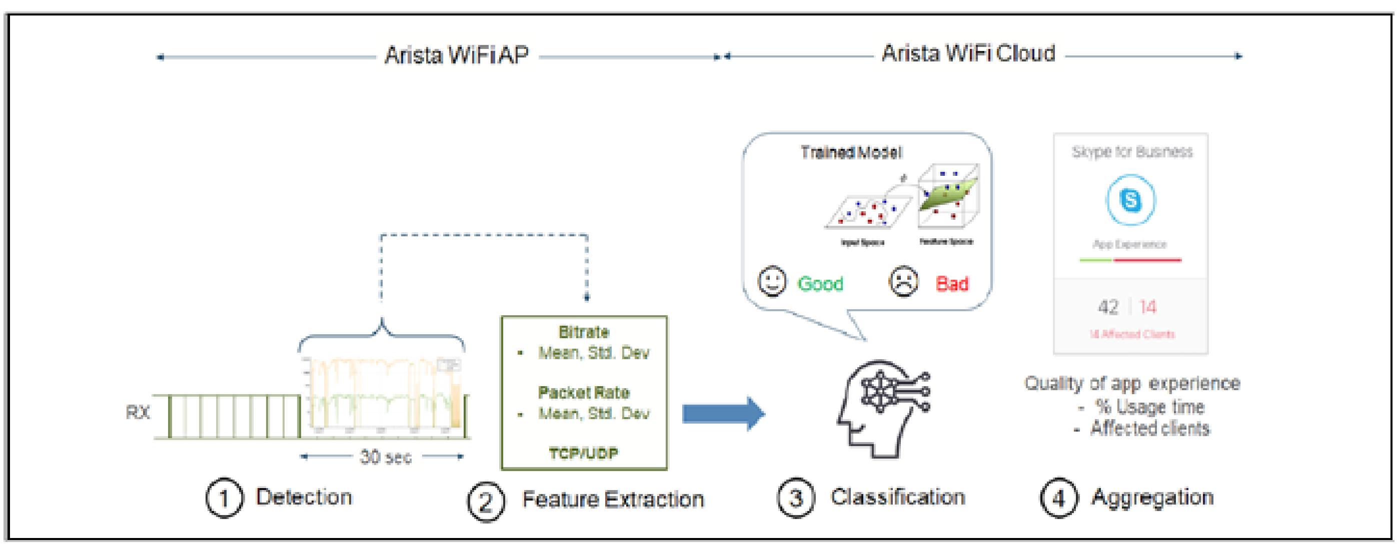

Figure 13: Arista's ML based Application QoE Engine Solution

3.4.1 Performance of AVC Applications

The traffic generated by AVC applications is two-way, i.e., the uplink and downlink traffic are comparable in volume. The AP identifies the AVC applications from the traffic flows and computes average bitrate, bit rate variance, average packet rate and packet rate variance for each of the applications separately. These metrics are fed to specially trained ML classification models in the CV-CUE server that classify the application's performance as 'good or 'bad'. The metrics computation and application performance classification are completed in under 3 seconds, so monitoring the applications in real time does not pose any significant overhead on the APs and CV-CUE.

The underlying root cause(s) for poor application performance might differ from client to client due to differences in their radio environments as well as the configurations of the APs to which they are connected to. For example, let us consider the case shown in Figure 14. The Applications dashboard depicts that the clients are experiencing poor performance while using GoToMeeting application 22% of the time, which is of concern. When we examine the GoToMeeting application, the list of clients affected by poor performance can be accessed. The fourth client on the client list seems to be affected for a longer period of time which needs a further drill down by the RCA engine. The engine ascertains poor coverage and high Wi-Fi interference as the reasons for this client experiencing poor application performance. The suggested remedial actions can be viewed upon clicking the bulbs next to the root causes.

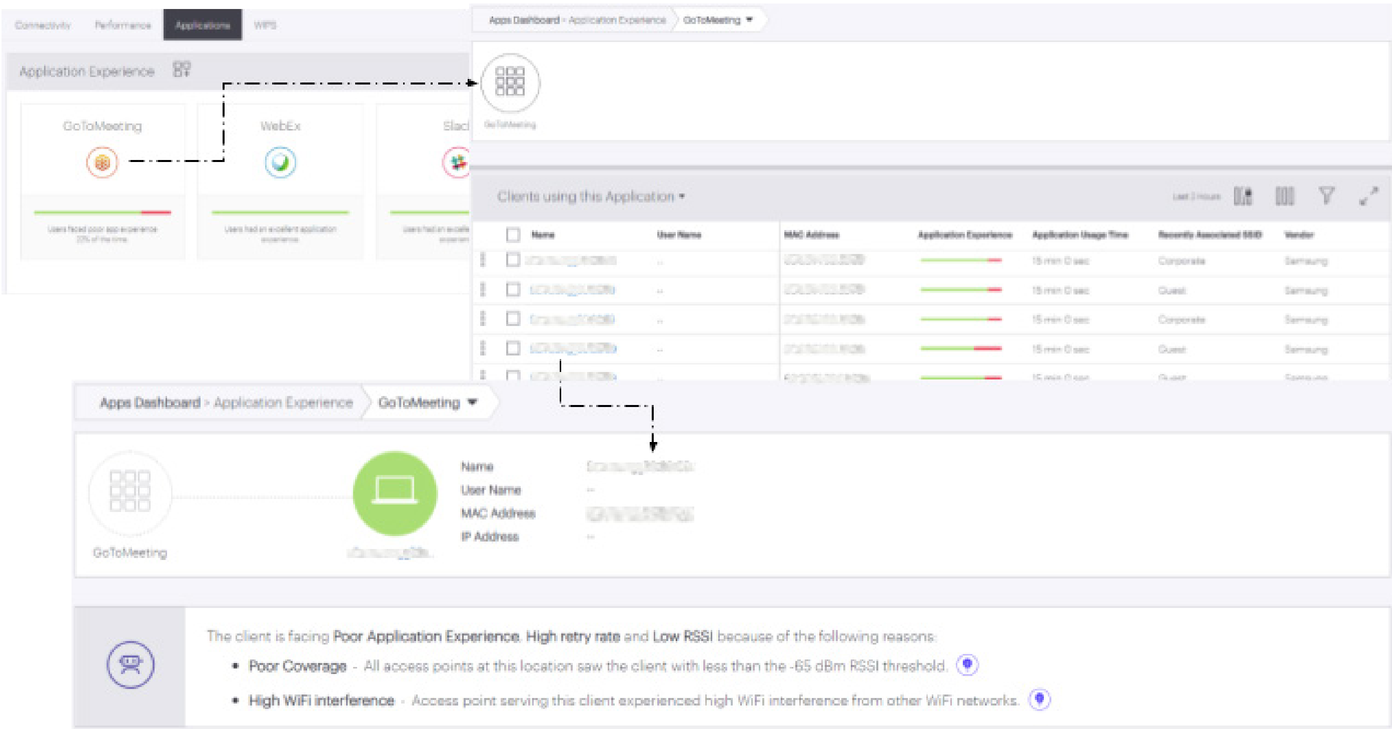

Figure 14: Application Performance - GoToMeeting

3.4.2 Performance of non-AVC Applications

A majority of non-AVC applications like web browsing, e-commerce, streaming video etc., use TCP for data transfer. Arista's Application QoE solution examines the end user QoE for such applications at the TCP packet level to measure the performance accurately.

3.5 Resolving Location Specific Issues

Often network issues might be localized, say, to a particular floor or room in an office or enterprise. Such problems are encountered when the APs placement or configuration is not optimal, the coverage area is laden with materials like glass, metal or brick that obstruct Wi-Fi signals, or the floor/room has a dense client distribution. The RCA engine can be invoked to troubleshoot location specific problems via the Floor Plans dashboard. Consider the case of the FHQ-Office in New York shown in the Figure 15. All the clients that failed to connect to the network can be seen on the floor plan, highlighted by red semi-circles. A right click on any client performs RCA on that client to show the root cause(s) for connectivity failure. For example, the client on the bottom right corner of the floor is unable to authenticate due to incorrect PSK. The client on the top left corner of the floor failed to associate with the AP as the AP is already handling the maximum allowed number of clients. Too many or too frequent association failures due to this root cause suggest that an additional AP is needed to ensure good service quality.

3.5 Identifying Vendor/OS/AP/SSID specific issues

Apart from run-time metrics, the Client Health dashboard provides filters which assist the network administrator in associating performance issues with a specific vendor, operating system, and associated AP/SSID.

Figure 15: Location specific analysis

3. Future Directions

The current capabilities of the RCA engine are limited to instantaneous root cause identification and displaying recommendations for fixing the root causes on the CV-CUE . The capabilities of the RCA engine can be extended in the future to carrying out analysis on historical data and automating remediation of the recommendations. This vision will pave the way towards building proactive, self-managed networks that are easy to manage.

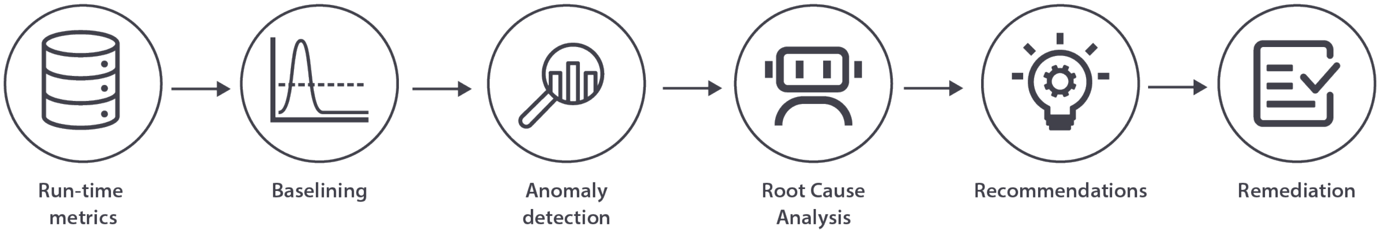

Figure 16: Proposed workflow of fully automated RCA engine

References

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2. Arista Networks, Wi-Fi Help - "Automatic and Dynamic Channel Selection"
3. Arista Networks White paper - "Application QoE - Monitoring end user experience of enterprise applications"

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

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

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

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

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

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

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

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

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