WHITE PAPER

CARRIER GRADE RF PERFORMANCE

aruba
a Hewlett Packard Enterprise company

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INTRODUCTION

Both 802.11ac Wi-Fi and 4G LTE represent substantial enhancements to legacy wireless broadband technologies. By utilizing Orthogonal Frequency Division Multiplexing (OFDM), enhanced coding and modulation, and multiple antenna technologies, both technologies have further enhanced the spectral efficiency of the airlink in the endeavor to approach Shannon's channel capacity limit. In addition, support for wider channels has enabled high data rates for the user.

Wi-Fi in recent years – through industry standards and vendor driven optimizations – has made progress on several fronts to become "carrier grade." Inclusion of Multiple Input Multiple Output (MIMO), higher order QAM and interference management technologies has further enhanced the RF performance. Support for Hotspot 2.0 has made authenticating and connecting to Wi-Fi as simple as connecting to the cellular network, while also enabling roaming onto other provider networks. Introduction of Self Organizing and Self Optimizing Network (SON) principles has made deploying and managing Wi-Fi easier, reducing OPEX. Integration of Wi-Fi with the operator's packet core network enables unified authentication, policy enforcement and feature parity with the cellular network. Support for state-of-the-art authentication, encryption and other security techniques has made communication over Wi-Fi as safe as the cellular network.

Thus, it is no wonder that Wi-Fi is increasingly being viewed as an extension of the cellular network, both by the service providers and the consumers. Service providers are increasingly leveraging Wi-Fi to keep up with mobile data demand, from additional indoor coverage and also by improving the overall subscriber experience in areas of heavy traffic like large public venues. Several tier-1 mobile network operators (MNOs) have implemented Wi-Fi calling not only to leverage Wi-Fi for data, but for voice as well. The mass consumer on the other hand, is just looking for reliable data connectivity – irrespective of whether it is on a cellular or Wi-Fi network.

In addition to deploying Wi-Fi to enhance capacity and coverage, service providers are looking to capitalize on a fast growing market – managed Wi-Fi services. There is a significant opportunity for service providers to leverage their scale and expertise to deliver innovative mobility solutions and value-added services to enterprises and businesses.

Aruba, a Hewlett Packard Enterprise company, provides solutions built on foundational elements critical to service provider deployments – whether for large scale Wi-Fi offload networks or for delivering managed services to a spectrum of enterprise customers. Aruba's solutions are designed to address the most critical requirements for service providers – RF reliability, scalability, security, reduced operational costs, contextual policy based controls, visibility, and integration with the cellular core network.

Of particular interest to service providers is the RF reliability and robust performance of Wi-Fi. Wi-Fi is deployed in the unlicensed spectrum without the benefits offered by licensed spectrum to cellular systems. The sophisticated mechanisms of Aruba's industry leading 802.11ac Wave 2 bring RF reliability and the robustness of Wi-Fi on par with 4G networks. The unique and sophisticated features built into Aruba Wi-Fi solutions ensure that users are always connected and therefore able to enjoy the best quality of experience possible.

Based on a holistic view of the entire Wi-Fi network and the surrounding environment, Aruba Wi-Fi ensures that each user is connected to the best access point at any point in time. In addition, the spectrum band, channel and power settings selected are optimal not just for a user but for the entire network. The airtime fairness algorithms ensure equal access for all subscribers, while airtime performance protection prevents slower clients from monopolizing available bandwidth. The self-healing property of Aruba Wi-Fi ensures that any coverage holes formed due to an access point (AP) failure are quickly filled by the surrounding APs adaptively adjusting their power levels. Together these capabilities maximize the quality of experienced for all subscribers, all of the time.

In this paper, we will explore how Aruba Wi-Fi enables carrier-grade RF reliability and robust performance for all the users connected to the network.

CLIENTMATCH

RF propagation characteristics are fundamentally statistical in nature, and consequently introduce a number of unique challenges – signal fading, shadowing, interference, noise, and relative motion – particularly in high-demand, dense environments. Aruba advocates RF management geared towards delivering high capacity and maximum performance to the service provider. Aruba's architecture is designed to squeeze maximum efficiency and performance out of all available RF spectrum, and it does so without compromising interference resistance, scalability, or interoperability. From a network design and continuous RF optimization perspective, overall WLAN network capacity and performance is dynamically increased through the use of Aruba's ClientMatch technology.

Ensuring that all wireless network clients get the service levels they need is a major challenge—especially when smartphones, tablets, and other clients make their own connectivity and roaming decisions. ClientMatch is a patented, standards-based RF management technology that puts the service provider's WLAN infrastructure in control of client connectivity and roaming. Leveraging a system-level view of the network, ClientMatch monitors clients and automatically matches them to the right radio on the right access point, boosting overall WLAN performance and delivering consistent, predictable performance to every user and client while eliminating the sticky client problem for good.

ClientMatch technology works with all clients – including new 802.11ac clients – across all operating systems, without the need for any client software. ClientMatch monitors each client's capabilities and connection on a WLAN, matching every client to the best radio on the best AP. By consistently monitoring each client, ClientMatch can react to client behavior at the time of connection and as client and network conditions change. For example, if a client moves into another AP's coverage area or interference causes performance to drop, ClientMatch will automatically move the client to an AP or channel that can deliver better performance. When a client attempts to connect to an AP that provides sub-optimal performance, ClientMatch uses client steering to direct that client to a better AP. Another example would be if a client connects to an AP with a weak signal, ClientMatch will steer that client to an AP with a stronger signal.

Likewise, if a user begins to roam, ClientMatch will move that client to another AP to maintain optimal performance. ClientMatch also focuses on optimizing the lowest performing clients; for example, only unhealthy clients are moved, such as a user experiencing interruptions on a call due to dropped packets.

ClientMatch leverages supported industry standards to accomplish its monitoring and control functions, including the 802.11k and the 802.11v standards. As a result, the service provider is assured of interoperability with no additional overhead. All standards-based clients work with ClientMatch; no proprietary client software is required. For legacy clients that do not yet support newer standards, Aruba provides a proprietary network-based solution that works with legacy clients, ensuring ClientMatch covers all clients on a WLAN.

By taking a system-level approach to client connectivity, ClientMatch can:

- Create a holistic view of each client by leveraging all of the APs on a network to dynamically gather information on a client's capabilities and behavior, such as signal strength and channel utilization
- Aggregate and share client information across APs
- Coordinate across APs to consistently connect each client to the AP that best meets their need

Many WLAN vendors offer limited client control, in which APs that are overloaded, for example, can actively discourage clients from attaching. In contrast, ClientMatch is aware of every client connected to every AP and directs each one to a specific AP based on its connection needs. To illustrate, a client may not know that it is connected to an AP that's very busy while a lightly loaded AP is only 15 feet away, or that a nearby AP has a stronger signal. ClientMatch is aware of all these characteristics and automatically moves a client to the optimal AP, adjusting dynamically to deliver consistent, predictable performance to everyone on the network.

As service providers look to leverage the multi-user MIMO (MU-MIMO) capabilities of 802.11ac Wave 2 APs, ClientMatch provides additional benefits. ClientMatch automatically groups MU-MIMO capable clients together on 802.11ac Wave 2 APs, so that the AP can realize the promise of MU-MIMO and transmit simultaneously to multiple clients. This unique Aruba technology is critical in the early days of Wave 2 when there are a limited number of MU-MIMO capable clients.

Figure 1 and Figure 2 below illustrate the cases of MU-MIMO operation without and with ClientMatch respectively. When there are multiple MU-MIMO capable APs or a mix of MU-MIMO and prior 802.11ac/802.11n APs, it will steer clients to group MU-MIMO clients together on Wave 2 APs, maximizing simultaneous data transmissions.

ClientMatch offers the following benefits to service providers:

- Delivers a faster network connection for individual clients
- Maximizes the overall throughput of the WLAN infrastructure
- Improves roaming performance for smartphones, tablets, laptops, and IoT devices
- Leverages a standards-based approach
- Operates automatically without requiring manual intervention
- Greatly reduces help desk calls by delivering a better user experience

ADAPTIVE RADIO MANAGEMENT

Aruba's Adaptive Radio Management (ARM) technology uses a dynamic channel planning algorithm in which each access point makes decisions independently by sensing its environment and optimizing its local situation. The algorithm is designed so that this iterative process converges quickly on the optimum channel plan for the entire network, without requiring a central coordinating function. Each access point periodically scans all channels for other access points, clients, rogue access points, background noise and interference. Note that during the scan the access point is not servicing its own associated clients, so scanning can be suspended for situations such as clients in power-save mode or active voice calls.

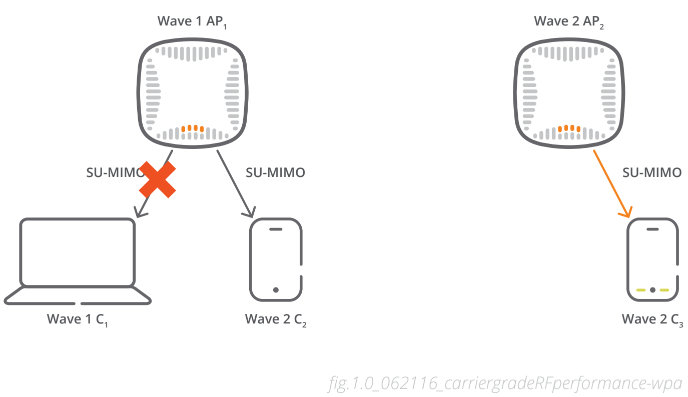

Figure 1: SU-MIMO operation without ClientMatch

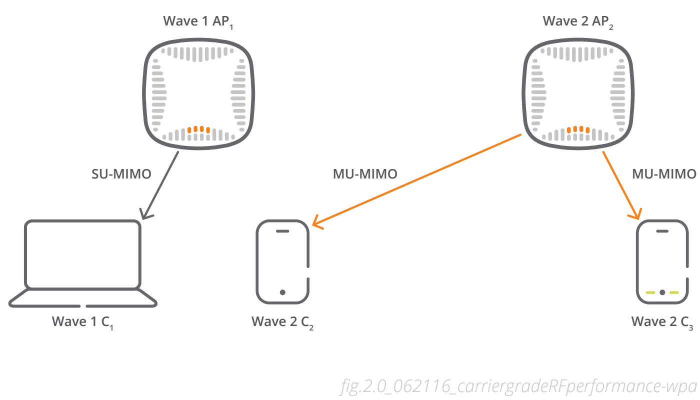

Figure 2: MU-MIMO operation with ClientMatch

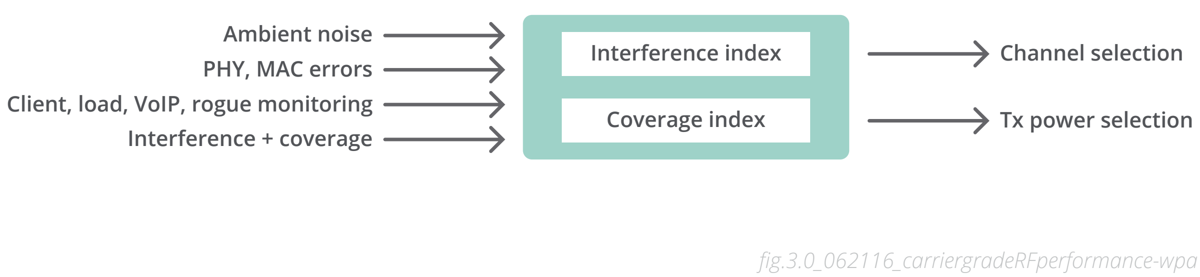

Figure 3: Inputs for selection of channel and transmission power

An ARM dynamic channel planning algorithm optimizes the RF plan by making the best use of the available spectrum, avoiding interference while also meeting the desired coverage parameters. Despite its simple objectives, the ARM channel and power assignment algorithm is extremely sophisticated. It allows configured boundaries to be set on the range of channels; minimum and maximum transmit power, error rates necessary to kick off a channel switch even without detected interference, and a number of timers to ensure stable, optimal solutions. ARM, thus, enables automatic selection of a channel optimal for the AP and the entire network, offering a crucial SON feature that the operators have come to expect.

Moreover, Aruba Wi-Fi has seal healing properties to further improve end-user experience and reduce OPEX. The system is able to automatically detect and remedy any coverage holes created due to an AP failure or general change in the RF environment. Upon detection of a coverage gap, the system will begin a configurable hold-down timer. At the expiration of the hold-down timer, the system will increase transmit power levels on surrounding APs to fill the coverage gaps and ensure ubiquitous coverage for all clients. The benefit is that even in the event of an AP failure, coverage gaps are immediately identified and corrected with AP power level adjustments. This scenario is not achievable in coverage-only deployments of other WLAN vendors who emphasize deploying APs at max power settings.

ARM offers the following additional benefits to the service providers.

- ARM dynamically increases overall network performance as the coverage increases, by utilizing high-capacity multi-channel network design – without requiring static channel overlays needed in legacy Fat AP WLAN solutions.
- With ARM, the network switch does not need any downtime for initial calibration.
- The AP response time to interference noise is quick and reliable.
- ARM algorithm is based on what the AP hears, which means that the system can compensate for scenarios like a broken antenna or blocked signal coverage on neighboring APs. Since channel decisions are based on the information that the AP receives from the RF environment, interference due to third party APs or other sources are accounted for.
- ARM technology uniquely enables APs to not only change channels or power one at a time but do both – change channel & power simultaneously – in order to enable faster convergence of the RF infrastructure when required.

Band Steering

The band steering functionality enables the service providers to move the user devices to the spectrum band that offers the best performance. If a dual-band capable client attempts to connect to a 2.4-GHz radio on an AP with a 20-MHz channel, the client will be steered to an available 5-GHz radio with a 40-MHz channel and good signal strength, taking advantage of the client's capabilities to double its throughput. Aruba WLAN addresses client density and stickiness problems by dynamically distributing clients across available APs and channels, ensuring that individual APs aren't overtaxed and client performance is continually maximized, even in dense environments.

Most enterprise WLANs use dual-radio access points, providing simultaneous coverage in the 2.4GHz and 5GHz bands. In Wi-Fi, clients are primarily responsible for association choices, and they should be able to pick the optimum access point and frequency band based on where they will achieve the best performance. However, a number of factors prevent this in practice:

- Some clients – including most Wi-Fi phones, older PCs, bar code readers and other special-purpose devices – are only capable of 2.4GHz operation. It is generally desirable for 5GHz-capable clients to use the additional number of channels available in the 5GHz band, distributing traffic and avoiding interference and contention with the plethora of 2.4GHz devices.
- While many devices and notebooks are capable of operating in either band, they typically have a preference for 2.4GHz because it is commonly available. Once a suitable 2.4GHz network is found, it is rarely vacated, even when 5GHz service is available.

The result is that dual-band networks find most clients connecting at 2.4GHz, even though it is the most crowded and interference-prone band. As a result, the 2.4GHz band becomes congested, despite plentiful capacity available at 5GHz, resulting in inefficient network usage. Given that 802.11 WLANs use a shared-access medium, channel utilization is always a concern. As channels become more heavily saturated, application performance suffers. This is especially true in the 2.4GHz band, where only three truly usable channels exist and contention from legacy and non-802.11 sources can be fierce.

The solution is for the WLAN to steer 5GHz-capable clients to that band, giving them clear conditions while clients limited to 2.4GHz gain access to more data capacity as that band becomes less crowded. The infrastructure-based steering mechanism used in ARM monitors probe requests from all clients, noting when they transmit on the 5GHz band. Association requests are refused at 2.4GHz with exceptions for persistent clients to avoid disruption, so the client only hears and connects to 5GHz access points. The algorithm is highly reliable by taking into account the signal strength of wireless clients in order to improve performance for WLAN deployments where 5GHz frequency coverage is sparse, and allows connection at 2.4GHz when it is beneficial.

To further provide flexibility to service providers, band steering supports multiple configuration modes. In preferred mode, band steering encourages dual-band clients to use the less congested 5-GHz band if available. In band balancing mode, the Aruba system allocates clients across the 2.4GHz and 5GHz radios on the same access point according to a preconfigured ratio. In force mode, band steering always assigns dual-band clients onto 5GHz channels.

Another major benefit offered to service providers by Aruba Wi-Fi is the capability to load balance between different channels with a band by steering the clients to the most appropriate channel. Given the limited spectrum available in Wi-Fi networks, it is important to optimize its use by distributing traffic loads uniformly across all clients. While traditional Wi-Fi load balancing schemes distribute clients across available APs, they do not account for two factors: multiple APs may occupy the same channel and static load-balancing thresholds cannot work for all use cases. Aruba's spectrum load balancing tackles this problem by using APs to identify load-balancing neighbors in real-time through periodic scans and then ensuring that APs are assigned to different channels, whereby the APs on one channel start load balancing by moving new clients to sparsely occupied channels. The load balancing algorithm works adaptively in real-time, without requiring pre-set thresholds, and works equally well for 10 users as it would for 200 users.

Airtime Fairness

The problems introduced in mixed-mode environments are manifold: legacy clients take too much air time; channels get saturated; noise on one channel spills over into others; clients get distributed unfairly across bands and channels.

These problems all produce the same result: degraded application performance in high-density environments. Aruba's ARM features aim to boost application performance for 802.11n/ac and legacy 802.11a/b/g clients, especially in high-density environments. The ARM feature introduce mechanisms for managing air time and, importantly, do so without requiring changes on the WLAN clients.

Air time fairness, a key part of Aruba's ARM feature set to help mediate access between speedy 802.11n/ac and slower legacy clients, gives service providers the final say over how clients gain access to the WLAN medium. Air time fairness grants access to clients using a token-based system, with preferred clients getting more tokens and thus more time to transmit data, thereby preventing starvation of client throughput in mixed mode. The token concept is useful in network management as it provides visibility to the service providers about clients that are the top data users on the network.

Air time fairness can be configured in fair and preferred access modes. Aruba's "Fair Access" option offers each client equal airtime regardless of client capability or capacity. The "Preferred Access" option gives more channel time to the faster clients but allocates time blocks for the slower clients. This ensures the slower clients are not starved from network access but allows faster client to benefit based on their PHY type.

In traditional WLAN installations, all clients are allocated access to the airwaves under the same set of conditions which is less than optimal for more capable clients. If a WLAN solution ignores the need for fair access this may either result in "starvation" of low-rate clients in the presence of high-rate clients or cause overall performance and scalability of the WLAN to be limited to the speed of the clients with the "weakest link".

In a recent performance review conducted by Network Test, Aruba's ARM technology was shown to deliver the following performance enhancements:

- Air time fairness delivered fourfold improvements in transfer rates for 802.11n/ac clients contending for bandwidth with legacy clients, while simultaneously reducing channel utilization.
- ARM's air time fairness feature nearly doubled transfer rates for a client to an access point without significantly reducing rates for a distant client on the same network.

CONCLUSION

The superior RF performance offered by Aruba Wi-Fi enable service providers to offer Wi-Fi as a natural extension of their mobile networks to augment total capacity and coverage. The self-organizing and self-optimizing properties of Aruba Wi-Fi meet and exceed the level of carrier-grade RF reliability that the operators have come to expect from their access networks. Aruba's unique ClientMatch technology ensures that each and every user on the Wi-Fi network is always best connected by optimizing across multiple dimensions including AP selection, band selection, channel selection, and transmit power selection. The optimizations take into account a holistic view of the network, the users and their surroundings to enable fairness across all users.

Aruba's Wi-Fi provides the robust performance needed to support carrier-grade services, allowing operators to adopt Wi-Fi as an alternate radio access technology while truly augmenting the access network to deliver enhanced services in a cost efficient manner. The self-healing properties of Aruba Wi-Fi to adaptively fill in any coverage gaps – along with distributed and redundant deployment architectures – allow service providers to exceed the five-nines reliability that they expect from their access networks.

Aruba's Wi-Fi solutions address service providers' key requirements including reliability, scalability, visibility, security, control, reduced OPEX and monetization opportunities. Aruba's controllerless Instant APs provide distributed control to support local data offload and selective tunneling of data traffic. Mobility controllers offer virtually limitless scalability in supporting tunnel aggregation. By integrating Wi-Fi into the mobile core network, service providers can enable automatic authentication, unified access policy management, seamless mobility and feature parity with cellular networks on Wi-Fi. AppRF technology provides comprehensive visibility into the application and web traffic in the network. The context aware Policy Enforcement Firewall provides the service providers granular control based on user, device, application and location. Aruba Activate enables zero touch provisioning capabilities to make deploying Wi-Fi a snap, while advanced management solutions, which include cloud-based Aruba Central as well as on-premise Aruba AirWave options, enable ease of management, diagnostics and reporting. This in turn lowers the overall cost of delivering and operating services. Aruba ClearPass enables network access control, secure device onboarding and advanced guest access solutions. The Analytics and Location Engine (ALE) provides a context aggregation function that drives third party analytics engines to offer advanced reporting. The service provider may drive additional value-added services including unified communications, mobile engagement and location-based advertisements to enable further monetization of Wi-Fi deployments.

Having worked closely with major mobile operators globally to deploy Wi-Fi services, Aruba understands the complexities and requirements of carrier Wi-Fi deployments. Aruba's service provider deployments support tens of terabytes of data on Wi-Fi on a daily basis. Aruba's carrier-grade solutions, best practices and support teams enable service providers to design effective network augmentation as well as managed services based on proven designs and effective monetization models to drive business.

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