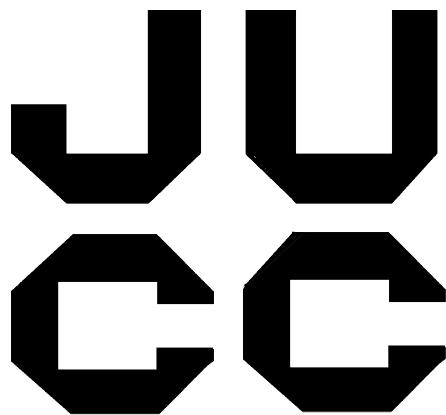


# *WLAN Scalability Test Report*

*Joint Universities Computer Centre*



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## Growing Demand for Scalable Classroom Connectivity

The demand for wireless connectivity in classrooms and throughout universities has grown significantly in recent years. The pervasive availability of wireless laptops and smart phones, coupled with the availability of e-learning tools and an expectation by faculty and students that they will have access to the university network from any location, at any time, has fueled Wi-Fi deployments at institutions worldwide. But not just any Wi-Fi network will suffice, because interactive multimedia-based curricula, computer-based training, wireless projectors, and real-time exam delivery systems require a Wi-Fi network with superior capacity, client density, and airtime access. Requirements include:

- Reliable wireless access in densely populated classrooms and lecture halls;
- Fair access across a mix of devices using standards-based methods and without requiring software clients on the users' computers;
- Real-time network optimization based on changing RF and client conditions to maximize reliability;
- Prioritization of learning-critical applications and latency sensitive traffic like voice and streaming video;
- Tiered, user-based security for separating student, faculty, administrative and guest traffic.

## *Testing Criteria: Validating the Latest Technology and Standards*

Aruba Networks, in association with the Joint Universities Computer Centres (JUCC), recently conducted a series of tests in a live campus environment to evaluate these performance and application delivery requirements. The tests assessed the performance benefits of both the latest high-speed Wi-Fi standard - 802.11n- and Aruba innovations for addressing densely populated, mixed-client deployments. Attention was focused on the delivery of interactive classroom applications and network reliability in challenging deployment scenarios. The tests were conducted on behalf of JUCC using the facilities of the Library of The Hong Kong Polytechnic University.

WLAN performance was measured in two challenging wireless environments: a classroom (confined area with fewer clients) and a library (large area with many clients);

Test Cases:

1. **802.11n Performance:** Performance comparison between legacy 802.11abg and the new 802.11n standard
2. **Impact of Adaptive Radio Management:** In-depth examination of Aruba's Adaptive Radio Management (ARM) technology and its impact in real world use cases.
  - 2.1. **Airtime Fairness** – Fair distribution of wireless network resources across clients
  - 2.2. **Traffic shaping for mixed client-types** – Maximize wireless performance with a mix of client types
  - 2.3. **Impact of legacy 802.11 b/g clients on 802.11n performance** – Maximize wireless performance when legacy b/g clients are introduced to a network
  - 2.4. **Band-Steering** – Move clients to optimal spectrum, for better performance and reliability
  - 2.5. **Co-channel interference management and channel reuse** – Avoid interfering wireless networks and maximize performance when overlapping channels are used.
  - 2.6. **Spectrum load balancing** – Improve scalability by spreading clients across available wireless spectrum

3. **High Density Stress Tests**

- 3.1. **Maximum clients per radio** – Over 100 clients connected simultaneously to a single radio, with 1 Mbps of service per client
- 3.2. **Interactive learning application performance:** Usability of University of Washington-developed interactive classroom learning application, Classroom Presenter, over Wi-Fi
- 4. **Video over WLAN:** Performance of streaming multicast video over WLAN for learning and entertainment applications
- 5. **Voice over WLAN:** Quality of voice over WLAN (VoWLAN) delivery in a shared environment using Polytechnic University’s existing VoWLAN infrastructure on an Aruba 802.11n network.

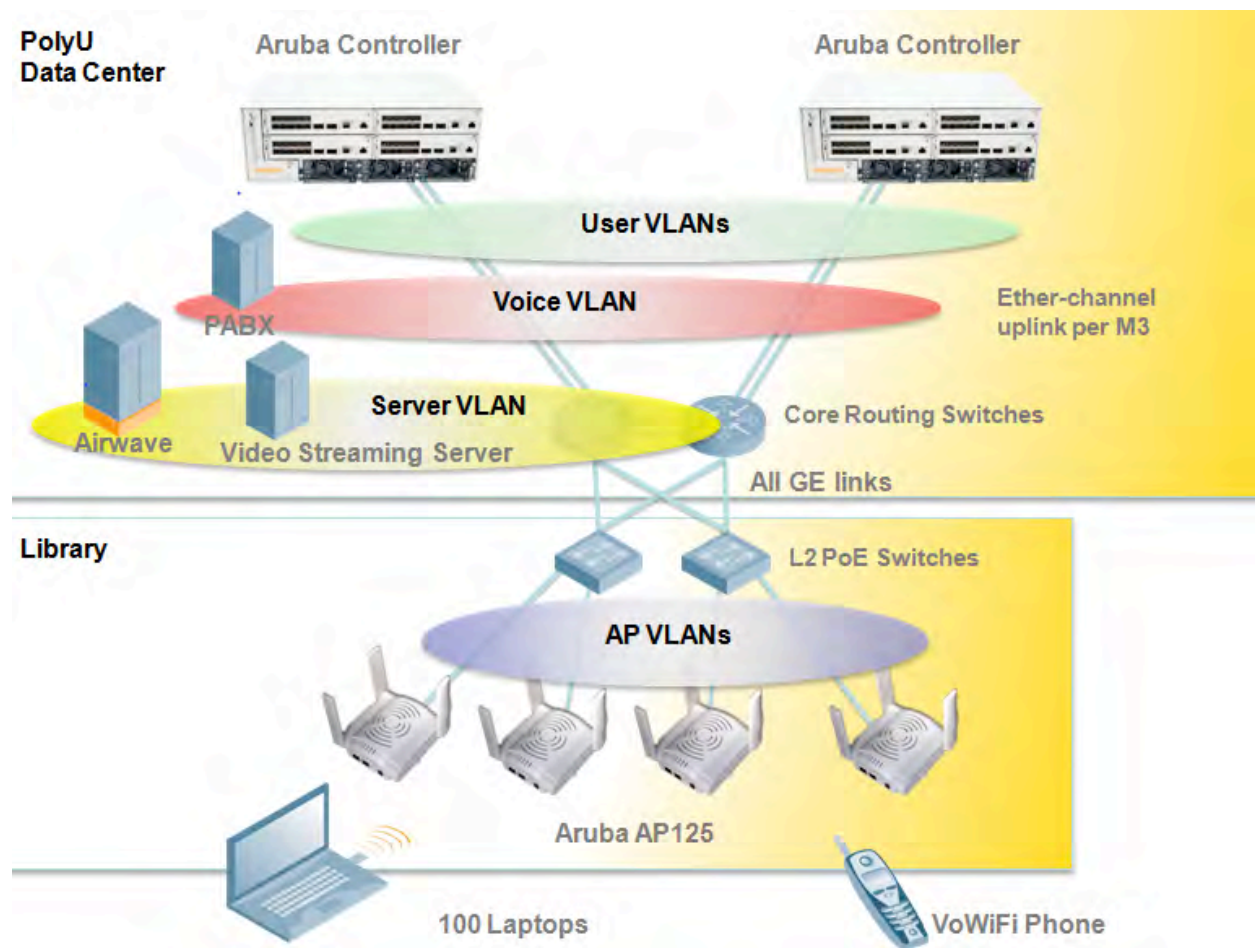
The JUCC identified several key criteria for a successful test as summarized in the table below.

Practical Goal	Key Enabler	Result
1) Support high bandwidth learning applications in a live classroom environment.	Aruba’s adaptive 802.11n provides <b>6x performance</b> vs. legacy 802.11abg networks.	TCP throughput >120 Mbps was consistently achieved across 802.11n clients using a wide range of RF chipsets, operating systems, and hardware configurations.
	Aruba’s ARM technology <b>doubles average throughput</b> per client for dual-band clients.	ARM band steering automatically shifts clients to the higher capacity 5GHz band. 60% of clients attained >10Mbps throughput compared to just 20% without band steering.
2) Maximize coverage and capacity in densely populated classrooms.	ARM technology <b>maximizes RF capacity</b> when channels are reused in close proximity.	Channel Reuse Management, in combination with ARM’s dynamic channel and power assignment increased channel throughput >10% in dense deployments.
	Aruba scales to > <b>100 clients per AP</b> with each simultaneously accessing a learning application.	Aruba achieved reliable CP performance while supporting >100 clients on a single AP .
3) Provide wire-like reliability resulting in fewer stalled clients.	ARM technology <b>improves the user experience and prevents stalled clients</b> by enforcing airtime sharing between clients.	ARM dropped the standard deviation of per-client throughput from 9.1 to 5.6, while the ratio of maximum per-client throughput to minimum per-client throughput dropped from 30 to 5.
4) Support video and IPTV over Wi-Fi.	Aruba’s video optimization enables over <b>40 simultaneous video clients per radio</b>	This was verified using Ixia Chariot to send simultaneous 1.1Mbps IPTV video simulation streams to multiple clients for 1 minute.
	Aruba’s Dynamic Multicast Optimization (DMO) enables <b>HD video over the air</b> with video streams ranging from 2.5 - 12.5Mbps.	Aruba is the first enterprise WLAN vendor to successfully deploy high-definition streaming video over WLAN. 15 clients were able to view high quality, jitter-free multicast video with video streams ranging from 2.5-12.5Mbps.
5) Support reliable voice over Wi-Fi, even when shared with a network that supports heavy data loads.	Aruba’s application awareness maintains <b>enterprise-grade quality voice</b> even with 100Mbps of data traffic on the AP.	Consistently able to attain a Mean Opinion Score of 4.0 or higher (on a scale of 5) indicating toll-quality with effective prioritization mechanisms both over-the-wire and over-the-air.

# Test Environment

## Network Topology

The Hong Kong Polytechnic University has a modern TCP/IP-based network consisting of tiered core and access layers. The routing switches in the core layer perform all routing and link-aggregation. In the access layer, L2 Power Over Ethernet (PoE) switches provide Gigabit Ethernet connectivity to APs as well as powering up Aruba 802.11n APs by standard 802.3af Power over Ethernet (PoE). Each L2 PoE switch has dual-homed uplinks achieving redundancy. The system diagram is presented below.



An Aruba 6000 Mobility Controller with M3 Supervisor Modules connects to core routing switches by Ether-channel enabled gigabit links. User VLANs and Voice VLAN are tagged between controllers and core switches. Wireless LAN user traffic is tunneled to the controller and then routed through core switches. VoWLAN traffic is placed in the Voice VLAN for communicating with the PABX and establishing voice calls.

Wireless network management is provided by Aruba's AirWave Wireless Management System (AWMS) located in the server VLAN. AWMS is a multi-vendor operations management platform that can monitor WLAN performance and security on a per-controller, per-AP, and per-user basis. AWMS can also configure and manage Aruba controllers. The VLC video streaming server is also in the server-VLAN and

broadcasts multiple video channels to wired and wireless clients using IP multicast. Multicast routing is performed by the wired switches.

The library was outfitted with Aruba's AP-125 802.11n Access Points connected to access PoE switches on non-user VLANs, which in turn are connected over layer-3 to the controller. The library deployment was used to execute all multi-AP, client scaling and classroom application tests. The clients were spread out over a range of 6-30 meters (20-100 feet) from the AP.

The 802.11n characterization, ARM, and multicast video tests were conducted in a 30-student classroom on the Hong Kong Polytechnic University campus. This set-up consisted of an Aruba 3200 Mobility Controller and an AP-125. The controller uplink connected to the campus wired network. DHCP, DNS, 802.1x authentication, and multicast video services were provided by the campus LAN. The clients were located a maximum distance of 7.5 meters (25 feet) from the AP.

### ***Test Clients***

All of the tests were conducted in a production setting in lieu of a controlled, pre-calibrated environment.

The more than 100 clients were sourced from different JUCC universities, rental agencies, and Aruba's testing inventory, and helped to simulate an actual mixed campus environment. Clients consisted of laptops running Windows and Mac operating systems, Intel and AMD processors and Intel, Broadcom, and Atheros Wi-Fi chipsets. The results demonstrated that Aruba's 802.11n solution has the technical superiority and robustness to support the diverse requirements of large, world-class universities such as those represented by the JUCC.

### ***Test Tools***

#### ***Ixia Chariot***

Ixia Chariot is a commonly used traffic generator application for wireless testing. IxChariot consists of a server component running on a wired terminal, and Ixia Performance Endpoints running on wireless clients. The application can generate TCP and UDP traffic flows in either direction from the wired server to multiple wireless clients.

#### ***University of Washington's Classroom Presenter***

Classroom Presenter is a Tablet PC-based interaction system that shares digital ink on slides between instructors and students. When used as a presentation tool, Classroom Presenter allows the integration of digital ink and electronic slides, combining the advantages of whiteboard style and slide-based presentations. The ability to link instructor and student devices, and to send information back and forth between the two, encourages active learning and creates new feedback channels. Additional information about Classroom Presenter is available at <http://classroompresenter.cs.washington.edu/>.

#### ***VideoLAN Project Media Player***

VLC media player is a highly portable multimedia player and multimedia framework capable of reading most audio and video formats including MPEG-2, MPEG-4, H.264, DivX, MPEG-1, mp3, ogg, and aac. VLC can also read DVDs, audio CDs VCDs, and various streaming protocols. It can also be used as a media

converter or a server to unicast or multicast stream in IPv4 or IPv6 networks. Additional information about VLC is available at <http://www.videolan.org/vlc/>.

## Test Cases

### *802.11n Performance: Comparing legacy 802.11 a/g vs. 802.11n*

#### **Motivation**

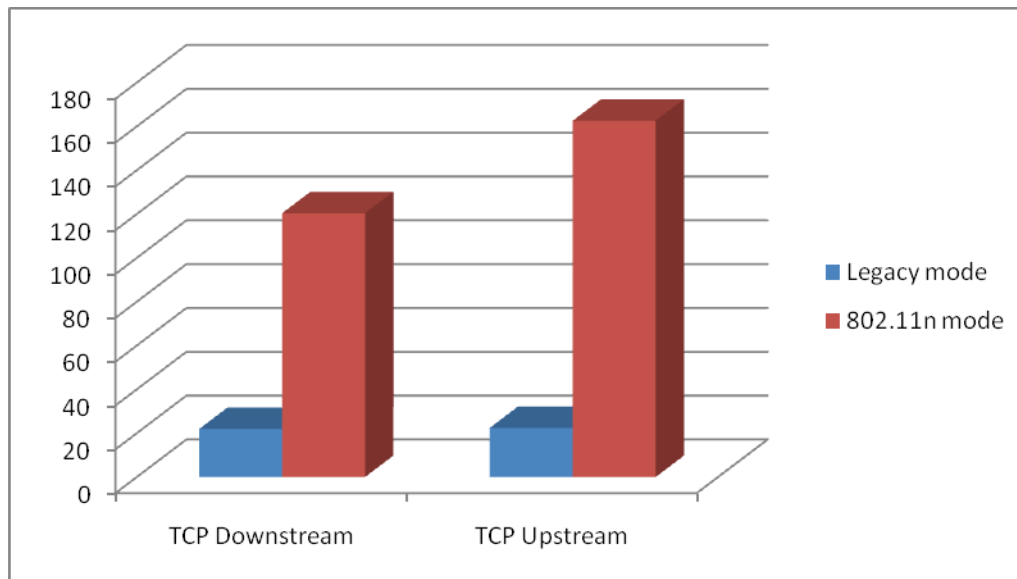
The first test case attempts to characterize a typical wireless client, operating in the same infrastructure, first in legacy 802.11abg mode and then in 802.11n mode. This test shows the incremental performance benefits of deploying an 802.11n solution. The client was associated to the 5 GHz radio on a 40 MHz channel.

#### **Procedure**

The test client used an Intel 4965 802.11agn chipset. TCP traffic was run using the Ixia Chariot tool between a wired server and the wireless client in operating in both legacy 802.11abg and 802.11n modes. This test used the Throughput.scr test script for TCP as the traffic type.

#### **Results**

	TCP Downstream	TCP Upstream
<b>Legacy mode</b>	21.9	22.4
<b>802.11n mode</b>	120.4	162.6



#### **Inference**

The use of 802.11n provides roughly a 6x improvement in downstream TCP throughput, and an 8x improvement in upstream TCP throughput. The bandwidth improvement demonstrates the improvements attainable from MAC aggregation, channel bonding, spatial diversity, and MIMO in Aruba's implementation of 802.11n.

## ***Impact of Adaptive Radio Management***

The next step was to assess the impact of 802.11n on a group of clients operating on the same access point. The 802.11 Medium Access Control mechanism, Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA), provides for contention resolution based on pseudo-random wait sequences. This allows different clients to behave with varying levels of aggression in medium access, and consequently can lead to large variance in data throughput, even when clients are operating on the same access point and have very similar capabilities.

ARM addresses this deficiency and greatly improves fairness in the allocation of network resources across a mix of clients. ARM can improve performance in dense deployments commonly found in schools and universities, and the intent of the following tests is to measure ARM's effectiveness.

## **Airtime Fairness**

### ***Motivation***

Aruba's airtime fairness algorithm uses infrastructure-based controls to dynamically manage and allocate airtime on a per-client basis. The algorithm takes into account the traffic type, client activity, and traffic volume before allocating airtime on a per-client basis for all downstream transmissions. This ensures that no clients are starved of airtime and all clients have acceptable performance with multiple clients associated to the same radio.

### ***Procedure***

Using a diverse mix of classroom clients – with a representative sample of Intel, Broadcom and Atheros chipsets – downstream TCP traffic was sent from a wired server to the wireless clients using Ixia Chariot's High-Throughput script. Results were recorded.

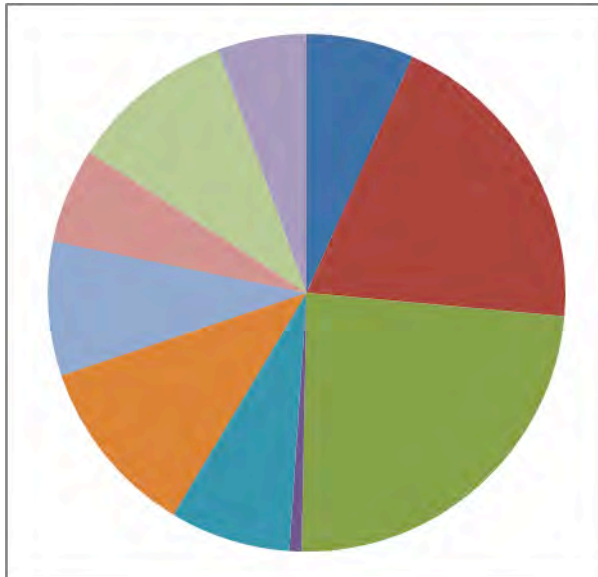
### ***Result***

The improvement in airtime sharing due to fair access is clearly evident by comparing the "Default Access" mode (airtime fairness disabled) and "Fair Access" mode (airtime fairness enabled). In the pie charts below an equal distribution – with each slice the same size – is ideal because it means no clients are receiving more airtime. Fair Access is much closer to an ideal distribution than Default Access.

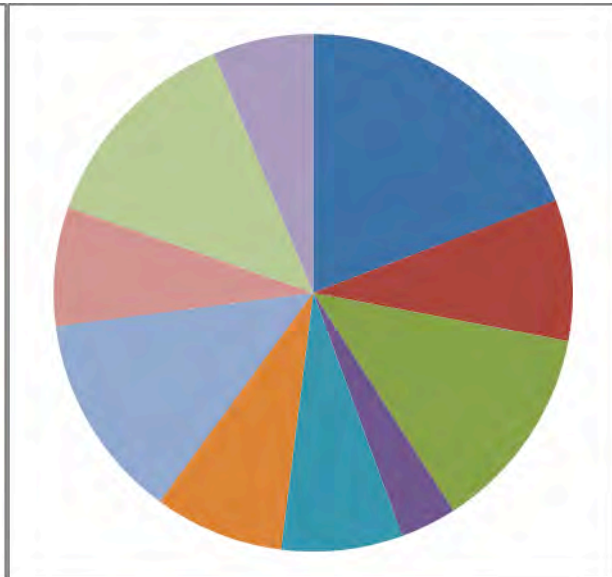
	<b>No Airtime Fairness</b>	<b>Fair Access</b>
Client 1	8.8	25.1
Client 2	25.9	11.5
Client 3	31.3	16.9
Client 4	1.0	4.6
Client 5	9.9	9.9
Client 6	14.7	10.6
Client 7	11.0	16.8
Client 8	7.8	9.7
Client 9	13.5	17.5
Client 10	7.3	8.2
<b>Total</b>	<b>131.2</b>	<b>130.8</b>

<b>Max</b>	<b>31.3</b>	<b>25.1</b>
<b>Min</b>	<b>1.0</b>	<b>4.6</b>
<b>Max / Min</b>	<b>31.3</b>	<b>5.5</b>
<b>STDEV</b>	<b>9.1</b>	<b>5.9</b>

**(a) Default Access**



**(b) Fair Access**



### ***Inference***

In the test, the standard deviation of per-client throughput dropped from 9.1 to 5.6, and the ratio of maximum per-client throughput to minimum per-client throughput dropped from 30 to 5 – both indicators of a decline in variance. The total throughput was not impacted and remained at 130 Mbps. Note that Aruba’s fairness mechanism provides for equal air-time, not equal throughput. This means that clients will have equal opportunities to access the air, but individual client performance will depend on the PHY transmit rates attainable by each client.

### **Traffic shaping for mixed client-types**

#### ***Motivation***

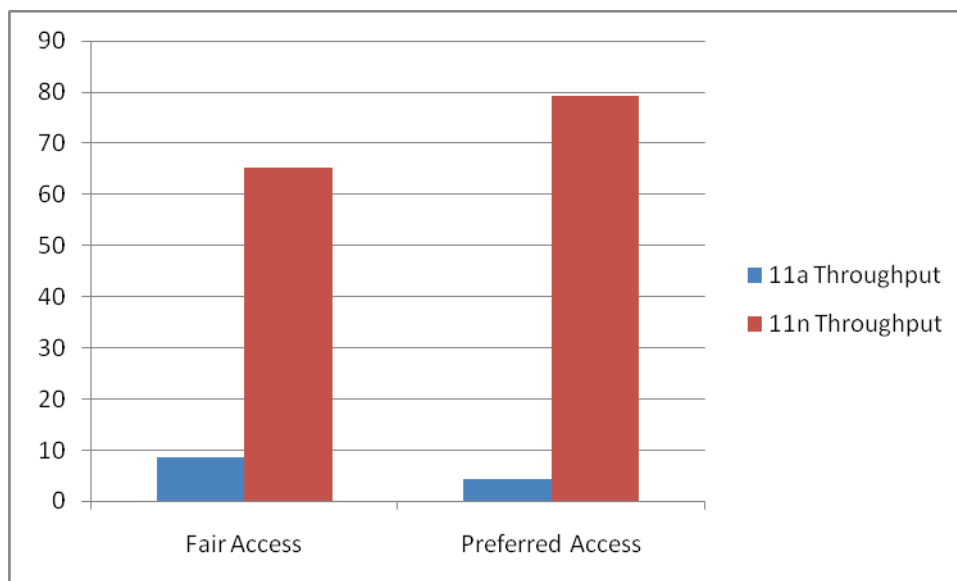
In real-life networks, legacy 802.11abg clients co-exist together with 802.11n clients. The 802.11 standard has a built-in mechanism for backwards compatibility, ensuring interoperability at the cost of performance by dropping higher speed devices to match the slower speed of legacy clients. Aruba’s airtime fairness algorithm includes a Preferred Access option. While Fair Access allows equal airtime for all active clients irrespective of their capabilities, Preferred Access allows the infrastructure to provide preferential access to faster 802.11n clients. This feature can be beneficial during accelerated migration of a wireless LAN to 802.11n.

#### ***Procedure***

This test included one 802.11n client and one client forced to function in 802.11a mode. Simultaneous traffic was run to both clients using the TCP high-throughput script. Fair Access was enabled in Run 1, and Preferred Access in Run 2. Results are shown below.

### Results

	Fair Access	Preferred Access
<b>802.11a Throughput</b>	8.6	4.4
<b>802.11n Throughput</b>	65.3	79.3
<b>Total</b>	73.9	83.7



### Inference

These results demonstrate how infrastructure control allows preferential airtime allocation to the 802.11n client. This allows a roughly 25% improvement in 802.11n throughput as well as an increase in total system throughput. The percentage improvement will vary depending on the number of active clients of each type associated to the AP. The network administrator has the option of modifying bandwidth preferences depending on the client mix, using Preferred Access if the majority of clients use 802.11n, and Fair Access if the majority are legacy clients.

### Impact of legacy 802.11 b/g clients on 802.11n performance

#### Motivation

Having tested different combinations of client counts and types on the 5 GHz radio, testing turned to analyzing performance of the 2.4 GHz band. The 2.4 GHz band presents multiple challenges for 802.11. The available spectrum on 2.4 GHz is very limited compared to 5 GHz, leading to increased interference between different 802.11 devices operating on the same channel. The 2.4 GHz spectrum is also shared with other, non-802.11 devices such as microwave ovens and cordless phones. Operation of 802.11b

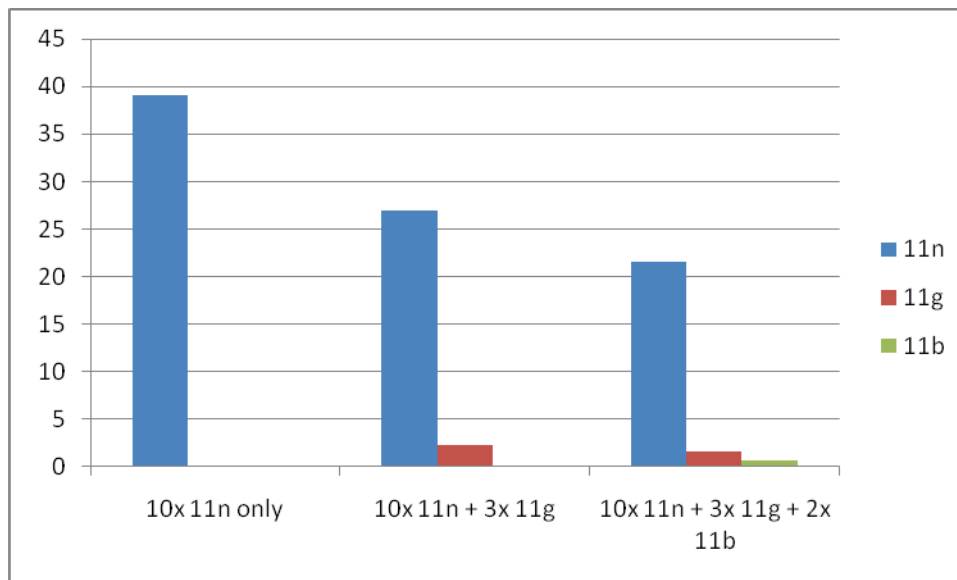
devices on the same channel adversely affects 802.11n performance as a result of 802.11 protection mechanisms such as RTS/CTS and CTS-to-self. The next test demonstrates and quantifies the impact of legacy devices on 802.11n performance.

### **Procedure**

Using the same 10 802.11n clients from the previous tests, a TCP downstream test was run on the 2.4 GHz band. Three additional clients, configured to operate in 802.11g mode, were associated and a throughput test was run to the complete set of clients. Finally, two 802.11b clients were added to the mix and the test was repeated. Results from the three runs are noted below.

### **Results**

	<b>11n</b>	<b>11g</b>	<b>11b</b>
<b>10x 11n only</b>	39.1	-	-
<b>10x 11n + 3x 11g</b>	27	2.3	-
<b>10x 11n + 3x 11g + 2x 11b</b>	21.5	1.6	0.6



### **Inference**

The results show a roughly 50% drop in 802.11n throughput as a result of legacy co-existence. This effect increases as the number of 802.11b clients rises. While Aruba's wireless LAN uses traffic shaping to optimize for different client mixes, the drop in throughput accentuates the need to minimize the number of 802.11b clients in any wireless LAN.

## **Band Steering**

### **Motivation**

To avoid the performance hit from an 802.11n client associating to a crowded 2.4 GHz channel, Aruba's band steering technique identifies clients capable of dual-band 2.4 GHz and 5 GHz operation. The AP then attempts to steer those clients to the less congested 5 GHz band, thereby boosting performance.

## ***Procedure***

Both radios on the single AP were enabled and the test SSID was advertised on both bands. At first clients were allowed to associate to any band as directed by their drivers. The distribution of clients was noted and a performance test was run. Next, band steering was turned on, clients re-associated, and the test was repeated. The results are presented in the table below.

## ***Results***

	<b>No Band Steering</b>	<b>Band Steering</b>
<b>Client 1</b>	9.4	27.1
<b>Client 2</b>	5.3	1.7
<b>Client 3</b>	0.2	25.5
<b>Client 4</b>	10.8	1.8
<b>Client 5</b>	9.5	19.3
<b>Client 6</b>	74.8	6.0
<b>Client 7</b>	8.0	8.7
<b>Client 8</b>	7.1	15.6
<b>Client 9</b>	8.6	13.7
<b>Client 10</b>	0.6	15.3

The numbers in red indicate 2.4 GHz association and green indicate 5 GHz association. With band steering disabled, just three clients associated to the 5 GHz band even though all ten clients were dual-band capable. These three clients accounted for 70% of the throughput. The remaining seven clients obtained just 30% of throughput sharing the 2.4 GHz band, at an average 5.7 Mbps. Only 20% of the clients obtained more than 10 Mbps of throughput.

When band steering was enabled, nine of the ten clients were steered to the 5 GHz band. The average throughput per client doubled to 13.5 Mbps. 60% of the clients obtained >10 Mbps throughput. This test clearly illustrates the benefit of band-steering in crowded 2.4 GHz environments.

## ***Inference***

In this test, same total bandwidth (1x 40 MHz channel and 1x 20 MHz channel) was available to users regardless of whether band steering was enabled or not - the total throughput on both radios remained the same (134 Mbps). The question key point is how the 134 Mbps was made available to multiple clients. Without band steering, most clients associated to the crowded, interference-prone 2.4 GHz band. As a result, all but the 5 GHz clients performed poorly. Recognizing that a client has dual-band capability and then automatically shifting them to the 5 GHz band eases congestion on the 2.4 GHz band while significantly enhancing the performance of band-steered clients.

## **Co-channel Interference Management and Channel Reuse**

### ***Motivation***

In a deployment with a high density of clients, it is quite likely that multiple APs will share the same channel, especially in the 2.4 GHz band. Since wireless traffic is predominantly downstream, it is very likely that multiple APs will need to transmit at the same time, on the same channel, in these dense

environments. In such cases, it is important to ensure that contention between APs does not degrade the overall channel throughput. Aruba protects co-channel performance using an intelligent rate control algorithm that distinguishes between failures due to poor link quality and those due to contention, and then reacts accordingly. This ensures that channel throughput is never adversely impacted regardless of the number of co-channel APs .

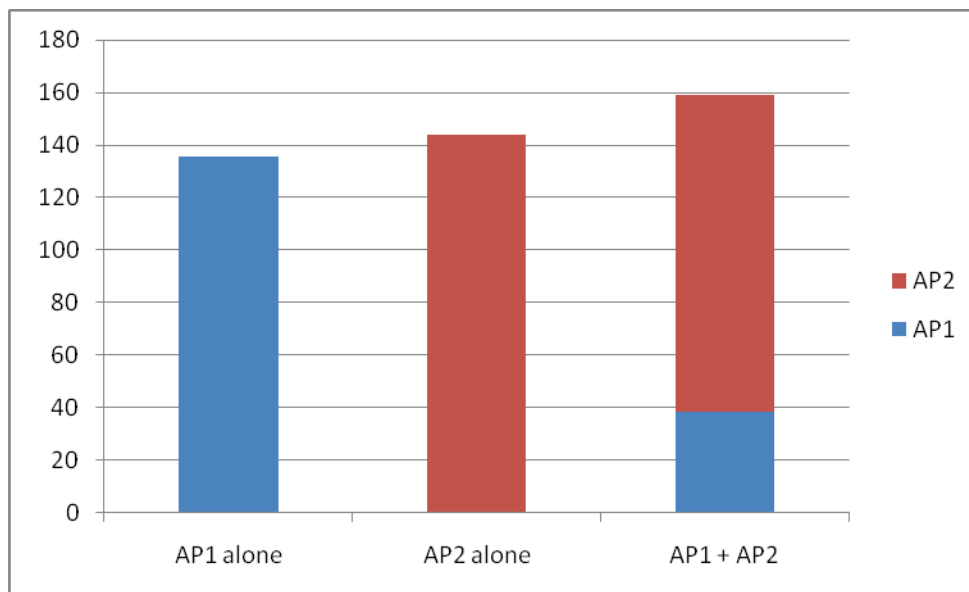
In addition, Aruba uses Channel Reuse Management to adjust AP receive sensitivity so that APs automatically reject interference from sources outside the coverage area and are thereby able to support distant clients. This feature enables the system to linearly scale the throughput for multiple APs operating in the same channel as the distance between same-channel APs increases.

**Procedure**

Two APs, spaced at about 27 meters (90 feet apart), were forced to advertise SSIDs on the same channel at the same time. In the radio-profile, Rx Sensitivity-based Channel Reuse in the dynamic mode was enabled. A client associated to each of the APs using different SSIDs to help ensure that the clients connect to the closest AP. A TCP throughput test was run on each client individually and the throughput numbers were noted. TCP throughput tests were then run on both clients simultaneously and the individual and total throughput numbers were noted.

**Result**

	AP1	AP2	Total
AP1	135.4	-	135.4
AP2	-	143.9	143.9
AP1 + AP2	38.3	120.8	159.1



**Inference**

Used in conjunction with ARM’s dynamic channel and power assignment, Channel Reuse Management ensures complete utilization of the available RF spectrum even in environments with high client densities. The observed improvement in channel throughput was in excess of 10%. The improvements

derived from Channel Reuse Management increase proportionally with distance between co-channel APs, and with typical greater than 30 meters (100 feet) the improvement is significant.

## **Spectrum Load Balancing**

### ***Motivation***

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 configurable 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. Once the number of associated clients on any one channel exceed those on another channel by  $\geq 20\%$ , the APs on that channel start load balancing by moving new clients to sparsely occupied channels. The load balancing algorithm works in real-time, without pre-set thresholds, and therefore works equally well for a classroom with ten students as it does for an auditorium with 200 students.

### ***Procedure***

Using two APs, clients are associated one-by-one to a common SSID broadcast by both APs. Client counts and the load balancing action flags are monitored using the "show ap active" command on the controller CLI.

### ***Results***

The two APs in the test were on channels 44+ and 149+. The first 2 clients that came up associated to channel 44+, which exceeded the 20% threshold. As a result the next two clients associated to 149+, balancing the load and disabling the load balancing algorithm so that new clients could associated to either AP. Thereafter clients alternately associated to the two different channels until all clients associated.

### ***Inference***

Spectrum load balancing is essential to maintaining peak throughput in dense deployments.

## ***High Density Stress Tests***

Having seen the performance benefits of Aruba's ARM technology and 802.11n access points, the next phase of demonstrations focused on testing the effects of high client density.

## **Maximum clients per radio**

### ***Motivation***

The first client density test involved finding the number of clients that could sustain a throughput of  $\geq 1$  Mbps on a single radio. This was done using Ixia Chariot to send simultaneous unicast IPTV video simulation streams to multiple clients for one minute. The video stream used was 1.1 Mbps wide and the goal was to see how many clients could be supported before the service level degraded.

### ***Procedure***

A downstream traffic test from a wired server to a wireless client was created using Ixia Chariot, the UDP traffic type, and the IPTVv.scr script. The script was edited to configure a load of 1.1 Mbps and then tested with five clients. Five additional clients were added sequentially until the average throughput dropped below 1 Mbps.

### ***Results***

The clients chosen for this test were the farthest from the AP in order to simulate worst-case conditions. A total of 42 clients associated before the 1 Mbps threshold was triggered. Each client saw an average of 1.01 Mbps and total throughput equaled 42.4 Mbps.

### ***Inference***

Aruba's ARM technology greatly improves scalability of bandwidth intensive applications such as video in high client density environments.

## **Interactive Learning Application Performance**

### ***Motivation***

The second client density test involved finding how many clients using the University of Washington Classroom Presenter (UW-CP) could be used on a single AP. UW-CP is a low bandwidth, delay-sensitive unicast TCP application.

### ***Procedure***

A PowerPoint presentation was loaded on a computer connected to the wired teaching station and advertised a classroom session. Wireless clients were registered as students to this shared session and were set up to view it. Slides were changed on the teaching station and the response time for the change to appear on the students' computers was monitored.

### ***Results***

A Microsoft PowerPoint presentation was advertised by a wired professor's station and could be viewed by 101 students using a single AP. This demonstrates that an Aruba 802.11n wireless LAN is capable of supporting very high client densities for common multi-media classroom applications.

### ***Inference***

With Aruba's ARM technology, delay-sensitive, interactive learning applications will now scale to large classrooms and lecture halls.



```

root@omp:~# show ip interface
158.132.37.151 00:1d:09:31:20:09 pu111 admin-role 00:00:47 802.1x APLL4D-w02 Associated PU
sest/00:1a:1e:53:a9:f0/a-HT PolyDWMAN-aaa admin-role 00:00:56 802.1x APLL4D-w02 Associated PU
158.132.37.144 00:03:7f:0f:bf:a7 pu144 admin-role 00:01:00 802.1x APLL4D-w02 Associated PU
sest/00:1a:1e:53:a9:f0/a-HT PolyDWMAN-aaa admin-role 00:00:56 802.1x APLL4D-w02 Associated PU
158.132.37.146 00:21:6a:7b:79:00 pu146 admin-role 00:00:54 802.1x APLL4D-w02 Associated PU
sest/00:1a:1e:53:a9:f0/a-HT PolyDWMAN-aaa admin-role 00:00:54 802.1x APLL4D-w02 Associated PU
158.132.37.147 00:21:6a:7b:dc:f8 pu147 admin-role 00:00:29 802.1x APLL4D-w02 Associated PU
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158.132.37.152 00:21:8d:e3:be:10 pu152 admin-role 00:00:49 802.1x APLL4D-w02 Associated PU
sest/00:1a:1e:53:a9:f0/a-HT PolyDWMAN-aaa admin-role 00:00:49 802.1x APLL4D-w02 Associated PU
158.132.37.151 00:21:8e:4d:f3:c6 pu031 admin-role 00:00:49 802.1x APLL4D-w02 Associated PU
sest/00:1a:1e:53:a9:f0/a-HT PolyDWMAN-aaa admin-role 00:00:49 802.1x APLL4D-w02 Associated PU
--More-- (q) quit (h) helpup (/) search (s) repeat
(MCIC) #
(MCIC) # show of ht-radio-profile default-a
High-throughput radio profile "default-a" (Pdefined (editable))
-----
Parameter Value
-----
40 MHz intolerance Disabled
Honor 40 MHz intolerance Enabled
Legacy station wstransport Disabled
(MCIC) #configure terminal of ht-radio-profile default-a single-chain-legacy
(MCIC) #
(MCIC) #write m
Saving Configuration...
Configuration Saved
(MCIC) #show ap active | include pu1est
APLL4D-100 pu1est-off 192.168.110.160 D AM 0 AM 128 E 4h:51m:44
w
APLL4D-104 pu1est-off 192.168.110.161 D AM 0 AM 128 E 2h:10m:20
w
RWT23-rpan pu1est 192.168.114.74 D 0 3D-168/21/36 70 E 8h:4h:59m
-c6
APLL4D-102 pu1est-off 192.168.110.89 D AM 0 AM 128 E 5h:45m:18
w
APLL4D-a11 pu1est-off 192.168.110.90 D AM 0 AM 128 E 2h:13m:24
APLL4D-101 pu1est-off 192.168.110.26 D AM 0 AM 128 E 8h:45m:11
w
APLL4D-w02 pu1est 192.168.110.27 D 104 AP-RT-366/20/14 128 E 2h:14m:20
w
(MCIC) #

```

## **Real-time Applications**

The two primary real-time applications currently used by Hong Kong Polytechnic are voice and multicast video. The tests below assess the capability of Aruba's 802.11n wireless LAN to handle VoWLAN and streaming video.

### ***Voice over WLAN***

#### ***Motivation***

Polytechnic University uses Cisco 7921 handsets and a Cisco Call Manager for voice over WLAN applications. Aruba's integrated stateful firewall capabilities on its Mobility Controller allows the WLAN to conduct a deep inspection of client traffic to identify call signaling. Once identified, the controller follows the voice traffic to the negotiated UDP ports (per the signaling exchange) and assigns required QoS properties to the voice flow for prioritization over-the-air (WMM) and over-the-wire (DSCP/802.1p). Aruba's mobility infrastructure is application-aware for most common voice protocols including SIP, SCCP, Polycom SVP, and Alcatel NOE. The objective of this test was to ensure that voice quality was maintained on the 802.11n APs in the presence of high data traffic loads.

#### ***Procedure***

An 802.11n AP was configured according to voice best-practice guidelines encompassing firewall ACLs, radio settings and SSID settings. A VoWLAN phone was associated to the SSID and a call to another phone on the same radio or different radio was initiated. A TCP throughput test was started to a data client associated to the same radio as the phone. The MOS / R-values as reported by the phone were monitored and verified for subjective voice quality.

#### ***Results***

The Polytechnic University assessed voice quality on the network under test and was consistently able to obtain a Mean Opinion Score of 4.0 or higher (on a scale of 5) indicating enterprise-grade voice quality. The score did not drop even in the presence of heavy data traffic in excess of 100 Mbps on the same AP, indicating effective prioritization mechanisms over-the-wire and over-the-air.

#### ***Inference***

The unique ability of the Aruba infrastructure to recognize application type has broad implications in delivering jitter-free, high quality voice over wireless LAN. Organizations can now consider Wi-Fi capable phones as an alternative to desk phones.

### ***Video over WLAN***

#### ***Motivation***

Polytechnic University's multicast video infrastructure consists of an open-source VLC server running on a Linux platform. This server live-encodes six different video streams of bandwidth ranging from 2.5 Mbps to 12 Mbps. To date, limitations on the bandwidth available for multicast delivery over WLAN have meant that video could not be made available to wireless users. Traditional multicast-over-WLAN implementations involve sending multicast frames over-the-air at base transmission rates of 1 or 6 Mbps for 802.11b and 802.11a/gn, respectively. This technique significantly reduces the WLAN's maximum transmission bandwidth. Furthermore, multicast transmissions are not ACKed in 802.11, thus multicast delivery is inherently unreliable.

Aruba's Dynamic Multicast Optimization (DMO) feature overcomes these limitations and delivers reliable, high-quality multicast transmissions over WLAN. DMO tackles the multicast reliability problem on multiple fronts including IGMP Proxy to ensure that the wired infrastructure sends video traffic to only those APs that have subscribers. DMO then has the ability to convert multicast traffic to unicast traffic which can be transmitted at much higher speeds and has an acknowledgement mechanism ensuring reliable multicast. Transmission automatically switches back to multicast when the client count increases high enough that the efficiency of unicast is lost.

### ***Procedure***

The VLC client was launched on wireless clients, which then subscribed to different video streams. The quality of the video was then inspected.

### ***Results***

During testing a single AP was able to sustain >20 Mbps of multicast traffic across multiple clients to multiple streams. Up to 15 clients streaming different video streams on a single AP was successfully tested.

### ***Inference***

Test results proved the efficacy of DMO for multicast transmissions over WLAN. The exercise also demonstrated that best results relied on the availability of an 802.11n capable network operating on the 5 GHz band.

## **Conclusion**

The JUCC tests challenged all aspects of Aruba's 802.11n wireless LAN infrastructure deemed essential in a high-density education application in which high capacity was essential. The results validated the superior performance of Aruba's wireless LAN and clearly showed that it is the solution of choice for the Hong Kong University System.

ARM is a unique and powerful technology that extends the performance, capacity, and coverage of an Aruba's standards-based 802.11n solution. RF optimization features include automatic channel planning, power assignments, load-aware scanning, and application-aware scanning. ARM also manages client access to the network with features like band steering that automatically moves clients away from the congested, lower capacity 2.4 GHz band. ARM also provides sophisticated Spectrum Load Balancing that provides a capacity-based method of client distribution. ARM's airtime fairness techniques deliver deterministic performance in dense client deployments, while Channel Reuse Management provides reassurance that a channel's capacity won't be compromised by increased AP density.

In addition to these leading RF and client optimization capabilities, Aruba's integrated stateful firewall and role-based identity management enhance mobility and simplify network design. Capabilities like Dynamic Multicast Optimization enhance the real-time application experience, while the Airwave Wireless Management Suite provides an operations management solution that encompasses multiple vendors across wired, wireless, and mobile devices.

The results described above demonstrate the technical merits and superior performance of Aruba's 802.11n solution, and highlight Aruba's ability to meet and exceed the diverse requirements of the members of the JUCC.