Dual-Band Wave 2 Access Points
Comparative Performance:
Cisco Aironet 2800 and 3800
Aruba AP-335

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1 – Executive Summary

Miercom was engaged to perform independent, hands-on, comparative testing of IEEE 802.11ac Wave 2-based Wi-Fi Access Points from Cisco Systems – the Aironet 2800 and 3800 – and the Aruba AP-335.

This report summarizes the comparative performance of these dual-band APs in the key areas of: throughput with up to 150 clients, maximum video-streaming clients, MU-MIMO support, auto radio-frequency-assignment abilities, and their ability to assess and adjust to interference.

Key Findings:

| **Cisco’s AP can dynamically change its 2.4-GHz radio to be a 5-GHz radio** | Only Cisco’s dual-band Cisco Aironet AP can dynamically reconfigure its 2.4-GHz radio to be a 5-GHz radio and run both simultaneously, significantly increasing channels and 5-GHz device throughput. |
| **Better throughput performance with Cisco** | In a typical dual-band environment, with both 2.4- and 5-GHz radios operating, Cisco achieved over 1 Gbps of AP throughput. Aruba posted a max AP throughput of just 714 Mbps under the same conditions. |
| **More clients can stream quality video with Cisco AP** | The Cisco Aironet 2800 can successfully stream cleanly watchable 5-Mbps video to more clients than the Aruba AP-335 can. |
| **Cisco’s RRM out-performs Aruba’s ARM in dynamic radio configuration** | Cisco’s Radio Resource Management (RRM) is better able to adapt to interference – both in detecting interference and reconfiguring radios to minimize it – than Aruba’s Adaptive Radio Management (ARM). |
| **Cisco AP’s are managed as a unit, improving coverage** | Cisco’s Wireless LAN Controller manages all connected APs as a unit and can adjust power levels to maximize available frequencies. |
| **Aruba MU-MIMO spatial-stream support offers no advantage over Cisco** | Testing found the Aruba AP-335s claimed support for four spatial streams can actually reduce aggregate throughput, offering no advantages over the Cisco 2800 APs support of three spatial streams. |

Miercom independently verified key performance differences between Cisco’s 2800 and 3800 Access Points and Aruba Networks’ comparable AP-335. With Cisco’s performance exceeding Aruba’s in the areas tested, we present the **Miercom Performance Verified** certification to the Cisco Aironet 2800 and 3800 Wi-Fi Access Points.

Robert Smithers
CEO
Miercom
2 – Congestion and Interference at 2.4 GHz

Most of the last decade, 2000 to 2010, saw an incredible proliferation of Wi-Fi and wireless devices, virtually all of which operated in the same 2.4 GHz frequency band. Since wireless devices using this ISM (industrial, scientific and medical) frequency band don’t need to be licensed, the same frequencies were also used in many other devices.

These include microwave ovens, cordless phones and Bluetooth devices, including cordless keyboards, all of which may be deployed alongside Wi-Fi smartphone and laptop users in the same area at the same time – and in the same 2.4 GHz band. The result is congestion and interference, which diminishes Wi-Fi-client throughput.

As a result, newer IEEE 802.11 specifications, starting with 802.11n in 2009, began extending Wi-Fi transmission into the 5 GHz band. 802.11n devices can work in either band. There are only three non-overlapping channels usable by Wi-Fi devices in the 2.4 GHz band, but 25 non-overlapping channels in the 5 GHz band. Subsequently, 5-GHz radio components came of age by 2010 and became economically competitive.

The table below shows that many Wi-Fi devices today still operate in the 2.4 GHz band. However, as new ones come to market and older ones are retired, more and more are operating at 5 GHz, a band featuring many more available non-overlapping channels, much less interference and, subsequently, significantly higher capacity.

**Frequency Use, by Wi-Fi Standard**

<table>
<thead>
<tr>
<th>IEEE 802.11 spec</th>
<th>Frequency</th>
<th>When supporting devices first delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11 “a”</td>
<td>5.1-5.8 GHz band</td>
<td>Largely supplanted by 802.11b and 802.11g products</td>
</tr>
<tr>
<td>802.11 “b”</td>
<td>2.4 GHz</td>
<td>2000</td>
</tr>
<tr>
<td>802.11 “g”</td>
<td>2.4 GHz</td>
<td>2003</td>
</tr>
<tr>
<td>802.11 “n”</td>
<td>2.4 and 5 GHz</td>
<td>2009</td>
</tr>
<tr>
<td>802.11 “ac”</td>
<td>5 GHz only</td>
<td>2013</td>
</tr>
</tbody>
</table>

Source: Miercom; chart is a compendium from various published sources, including IEEE and Wikipedia.

Invariably, APs today still need to support 2.4-GHz Wi-Fi devices to some extent, in addition to the growing number of 5-GHz devices. This has bred dual-band APs. The flexibility with which the AP can automatically detect and assign the appropriate frequency for the user environment is a key capability, one which we examined in this comparative testing.
3 – About the Products Tested

Most of this testing pitted the Cisco Aironet 2800 against Aruba Networks AP-335 – competitive, marketplace-leading, indoor, Wave 2 wireless Access Points (APs). Up to six of each vendor’s APs were deployed in identical indoor test environments with up to 150 wireless client devices.

As shown in the below table, the Aironet 2800 and 3800 are functionally the same in nearly all respects. Both support two Gigabit Ethernet (1000BASE-T), RJ-45-based copper uplinks, but only the Aironet 3800 model additionally supports Cisco’s Multigigabit Ethernet (mGig), which enables bi-directional transmission at up to 5 Gbps over widely installed Cat 5e copper cabling.

To test maximum throughput per AP, the Cisco Aironet 3800 model supporting Multigigabit Ethernet on the uplink was used. Aruba offers a similar capability with its AP-335, called a Smart Rate uplink port, and this capability was tested alongside the Multigigabit Ethernet support of the Cisco Aironet 3800.

The APs tested are described in more detail below.

Cisco

The Cisco Aironet 2800 model was used in all of the testing except one test case where the Multigigabit Ethernet uplink support of the 3800 model was employed. The features and capabilities of the 2800 and 3800 models are the same in all other respects.

Cisco says that its 5-GHz radio supports a theoretical maximum of 2.6 Gbps. And since both of the AP radios can operate at 5 GHz concurrently, the APs theoretical maximum throughput climbs to 5.2 Gbps. The AP supports all Wi-Fi channel widths from 20 to 160 MHz and can dynamically switch between channel widths as the client environment and conditions require.

Aruba AP-335
Contains internal antennas

Models support internal or external antennas
**Aruba**

The Aruba Access Point tested, the AP-335, represents one of the vendor’s top-of-the-line, dual-band APs as of the time of this testing. Aruba claims the AP-335 supports “an aggregate peak data rate of 2.5 Gbps.” That is based on a max 1,733-Mbps throughput on the 5-GHz radio and an 800-Mbps theoretical max on its 2.4-GHz radio. Unlike the Cisco 2800/3800, however, Aruba’s 2.4-GHz radio cannot alternately run as a 5-GHz radio.

The Aruba AP contains 12 internal omnidirectional, dual-band antennas. Like the Cisco AP, the Aruba AP-335 supports IEEE 802.11 a, b, g and n devices, as well as 802.11ac Wave 1 and 2.

The following table details the salient characteristics of the APs tested.

**Table 1: Dual-band Wave 2 Access Points Tested**

<table>
<thead>
<tr>
<th></th>
<th>Aruba AP-335</th>
<th>Cisco Aironet 2800 &amp; 3800</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processor, Memory</strong></td>
<td>1.4-GHz dual-core processor,</td>
<td>1.8-GHz dual-core processor,</td>
</tr>
<tr>
<td></td>
<td>256 MB RAM</td>
<td>1 GB RAM</td>
</tr>
<tr>
<td><strong>Wave 2 RF Support</strong></td>
<td>Single-User (SU) and Multi-User</td>
<td>Single-User (SU) and Multi-User</td>
</tr>
<tr>
<td></td>
<td>(MU) MIMO</td>
<td>(MU) MIMO</td>
</tr>
<tr>
<td><strong>Wi-Fi standards supported</strong></td>
<td>IEEE 802.11 a, b, g, n, ac</td>
<td>IEEE 802.11 a, b, g, n, ac</td>
</tr>
<tr>
<td><strong>Antennas</strong></td>
<td>12 internal, omnidirectional, dual-band antennas</td>
<td>i and e models support internal or external antennas</td>
</tr>
<tr>
<td><strong>Channel support</strong></td>
<td>20, 40, 80 and 160-MHz channels</td>
<td>20, 40, 80 and 160-MHz channels</td>
</tr>
<tr>
<td><strong>Dual-band radios</strong></td>
<td>2.4 GHz and 5 GHz</td>
<td>2.4/5 GHz and 5 GHz, both radios can run in 5 GHz concurrently</td>
</tr>
<tr>
<td><strong>Auto assignment of radios</strong></td>
<td>Adaptive Radio Management (ARM)</td>
<td>FRA (Flexible Radio Assignment)</td>
</tr>
<tr>
<td><strong>1000BASE-T interfaces</strong></td>
<td>Two; supports LAG (aggregation of both links)</td>
<td>Two; supports LAG (aggregation of both links)</td>
</tr>
<tr>
<td><strong>Higher-speed uplink over Cat 5e</strong></td>
<td>Supports a Smart Rate uplink port; can negotiate up to 2.5 Gbps</td>
<td>(Model 3800 only) Supports Multigigabit Ethernet (mGig), which can negotiate up to 5 Gbps</td>
</tr>
<tr>
<td><strong>Special features</strong></td>
<td>USB 2.0 port, Bluetooth Low Energy</td>
<td>Side-loading module port for future modules (i.e., security), USB 2.0 port</td>
</tr>
</tbody>
</table>
4 – Test Setup

Test Bed Set-up

The test bed included six wireless-Access-Point ceiling mounts positioned throughout the building, with associated Ethernet ports (Cat 6a cabling), for each vendor’s APs. The APs were mounted below the drop ceiling. Both vendors’ gear – six APs and the vendor’s WLC (wireless LAN controller) – were installed in the same locations, delivering the same coverage areas to the exact same deployment of client devices.

The APs were re-installed for each test using the same connecting cables for all the testing. When one vendor’s gear was tested the other vendor’s gear was shut down. Depending on test, up to six APs from each vendor were actively connected and enabled at any time.

*The primary Wi-Fi test room is pictured below. A total of 150 clients were used for the multi-client performance tests. The clients for all the tests were spread throughout the room; only the clients needed for a given test case were Wi-Fi-enabled.*
**Test Equipment**

Two test systems from Ixia ([www.ixiacom.com](http://www.ixiacom.com)), running IxChariot test software, were used for throughput testing. IxChariot scripts were written to conduct standard bi-directional throughput tests using real-world traffic for each configuration. Test traffic was sent for 60 seconds, and the throughputs from the two IxChariot runs were averaged. A preliminary run was used as a baseline: If a test runs yielded results below the baseline, that test was re-run.

Test traffic was sent through the vendor’s wireless LAN controller, to that vendor’s APs, out to client devices, and back again, as shown in the diagram. For the mGig tests, both 1-Gbps test-traffic streams were sent to just one AP to ascertain max per-AP throughput. The switch used to connect everything together was the Cisco Catalyst 3850 24 port mGig switch.

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**Cisco vs Aruba – Throughput Test Configuration**

<table>
<thead>
<tr>
<th>Ixia running IxChariot, 1 Gbps</th>
<th>Cisco WLC</th>
<th>Up to 6 x Cisco 2800 AP’s</th>
<th>Aruba WLC</th>
<th>Up to 6 x Aruba 335 AP’s</th>
<th>Up to 150 Clients</th>
</tr>
</thead>
</table>

---

**Clients**

The test configuration – number of APs, clients, channel bandwidths, and so on – varied depending on test objective. However, while the number of clients varied depending on the test, the distribution and mix of clients remained consistent.

The mix of clients used in this testing is shown below, along with the wireless standard they support. While 802.11ac is only supported in 5 GHz, the 802.11ac clients are backwards compatible with 802.11a/b/g/n, allowing them to connect in 2.4 GHz if they so choose.

<table>
<thead>
<tr>
<th>Clients</th>
<th>Protocol</th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
<th>t4</th>
<th>t5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macbook Pro</td>
<td>11ac</td>
<td>8</td>
<td>16</td>
<td>24</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>Macbook Air</td>
<td>1ac</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Macbook Pro</td>
<td>11n</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Windows w/ Intel 7260</td>
<td>11ac</td>
<td>6</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Windows w/ Broadcom</td>
<td>11ac</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>iPad Air 2</td>
<td>11n</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>iPhone 6</td>
<td>11ac</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Acer Aspire E 15 Laptop</td>
<td>11ac W2</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
</tbody>
</table>

**Total clients in each test**

| 30 | 60 | 90 | 120 | 150 |
Where the full complement of 150 clients was to be tested, an initial test applied just 30 clients – using the mix shown in column t1. The same relative distribution was then applied with 60 clients (t2) by doubling the number of each client type. Then 90 clients were tested, achieved by increasing clients in the same relative mix, and the same for 120 and 150 clients.

**Test Cases**

The test cases are detailed in the following sections. The test cases applied were:

1. Maximum mGig (multi-Gigabit) and Dual-5-GHz AP Throughput Performance
2. Multi-Client Performance
3. Video Streaming
4. Cisco Flexible Radio Assignment (FRA) vs Aruba Adaptive Radio Management (ARM)
5. Spectrum Analysis: Interference Detection
6. Multi-User, Multiple-Input, Multiple-Output (MU-MIMO)
7. Dual External Antennas
5 – Maximum mGig and Dual-5-GHz AP Throughput Performance

Test Objective
To measure the maximum throughput to Wi-Fi clients through the Cisco Aironet 3800 AP, with Cisco’s mGig in dual-band 2.4- and 5-GHz mode and dual-5-GHz radio mode, and the comparable maximum throughput of the Aruba dual-band AP-335.

How We Did It
As noted, the dual-band Aruba AP-335 supports one 2.4-GHz radio and one 5-GHz radio. The dual-band Cisco 2800/3800 AP also supports this configuration, but in addition can reconfigure its 2.4-GHz radio to be a second 5-GHz radio. This can be done manually by the administrator or dynamically by the system itself, depending on the Wi-Fi coverage environment.

In this testing, both Ixia traffic-load testers connect through the vendor’s Wireless LAN Controller to a single AP – an Aironet 3800 in the case of Cisco, and then an AP-335 in the case of Aruba. The Cisco AP’s input bandwidth was maximized by an mGig connection, supporting up to 5 Gbps over a single RJ-45 copper link. The AP-335 was similarly configured with an Aruba “Smart Rate” link, which supports a negotiated link speed up to 2.5 Gbps. The test used two Apple MacBook Pro’s as the wireless clients and a Cisco Catalyst 3850 24 port mGig switch.

Just two clients connect to the AP being tested – one on each radio – in three scenarios:

- **Aruba dual-band** AP-335: one client on the 2.4-GHz radio and a second on the 5-GHz radio.
- **Cisco 3800 in dual-band** mode: one client on the 2.4-GHz radio and a second on the 5-GHz radio.
- **Cisco 3800 in “dual-5-GHz”** mode: one client on each 5-GHz radio.

### Cisco 3800 Max mGig / Dual 5-Ghz Throughput Performance Configuration

- Ixia running IxChariot, 1 Gbps
- Cisco WLC
- Aruba WLC
- Cisco 3800 Dual Band
- **Cisco 3800 Dual 5-Ghz**
- Aruba AP-335 Dual Band
- Two clients: One on each radio

Results
As the chart shows, Aruba’s dual-band AP-335 achieved a maximum throughput in this environment of 717 Mbps. In the comparable dual-band mode, Cisco’s Aironet 3800 achieved 1,014 Mbps throughput.
Since the Cisco 3800s dual-band AP throughput exceeded 1 Gbps, a single 1-Gbps Cat 5e connection (1000BASE-T) would have been a bottleneck. However, because the mGig connection supports more than 1 Gbps (up to 5 Gbps over Cat 5e copper cabling), the full throughput of 1,014 Mbps could be achieved.

The Aruba AP-335 was configured with its “Smart Rate” link, the vendor’s comparable capability to Cisco’s Multigigabit Ethernet (mGig). A Smart Rate link likewise runs over Cat 5e cabling and operates at a negotiated speed up to 2.5 Gbps. However, this testing found that, with the Aruba AP-335’s maximum achievable throughput of 717 Mbps, none of the Smart Link bandwidth over 1 Gbps could have been used anyway.

With both radios supporting the 5-GHz band, the Cisco Aironet 3800 achieved an impressive 1,688 Mbps throughput with two 5-GHz clients (one on each 5-GHz radio).
6 – Multi-Client Performance

Test Objective

To determine how each AP performs as client load grows from 30 to 150 clients.

How We Did It

Ixia test systems delivered real-world traffic at a combined rate of up to 2 Gbps to the vendor’s Wireless LAN Controller, through three of the vendor’s APs and out to client devices. The aggregate throughput was carefully measured for seven different operational environments – first with 30 clients (see previous mix and distribution of client devices), then with 60 clients, 90 clients, 120 clients and finally all 150 clients.

Multi-Client Support - Test Configuration

| Ixia running IxChariot, 1 Gbps | 3 x Cisco 2800 AP’s | 150 Clients (in 30-client increments) |
| Aruba WLC | 3 x Aruba AP-335’s |

The dual-band Aruba AP-335 supports one 2.4-GHz radio and one 5-GHz radio. The dual-band Cisco 2800/3800 AP supports this configuration too, but can also run both radios at 5 GHz. Dual 5-GHz operation may be set as a configuration parameter, or the Cisco AP can switch it dynamically itself to take advantage of the dozens of non-overlapping channels in the 5-GHz band, compared to the handful in the overcrowded 2.4-GHz band. All three of these environments were tested, with varied client density and channel bandwidths. The multi-client throughput tests were run with the following channel bandwidths:

<table>
<thead>
<tr>
<th>Channel Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aruba 335</strong></td>
</tr>
<tr>
<td><strong>Radio 0</strong></td>
</tr>
<tr>
<td>2.4 GHz</td>
</tr>
<tr>
<td>20 GHz</td>
</tr>
<tr>
<td>20 GHz</td>
</tr>
</tbody>
</table>

| **Cisco 2800**    |
| **Dual Band**     |
| **Radio 0**       | **Radio 1**       |
| 2.4 GHz           | 5 GHz             |
| 20 GHz            | 20 GHz            |
| 20 GHz            | 40 GHz            |

| **Cisco 2800**    |
| **Dual 5 GHz**    |
| **Radio 0**       | **Radio 1**       |
| 5 GHz             | 5 GHz             |
| 20 GHz            | 20 GHz            |
| 40 GHz            | 40 GHz            |
This is how the throughput performances of the Aruba AP-335 and the Cisco Aironet 2800 compare in the various configurations, and with a mix of 20- and 40-MHz channel bandwidths.
### Aggregate Throughput (Mbps)

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Radio Config</th>
<th>Channel Widths (MHz)</th>
<th>30 Clients</th>
<th>60 Clients</th>
<th>90 Clients</th>
<th>120 Clients</th>
<th>150 Clients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco</td>
<td>Dual 5 GHZ</td>
<td>40 / 40</td>
<td>1131.5</td>
<td>952</td>
<td>839.5</td>
<td>825.5</td>
<td>807.5</td>
</tr>
<tr>
<td>Cisco</td>
<td>Dual 2.4/5 GHz</td>
<td>20 / 40</td>
<td>720.5</td>
<td>666.5</td>
<td>580</td>
<td>570</td>
<td>558</td>
</tr>
<tr>
<td>Aruba</td>
<td>Dual 2.4/5 GHz</td>
<td>20 / 40</td>
<td>653.5</td>
<td>600.5</td>
<td>515</td>
<td>495.5</td>
<td>484.5</td>
</tr>
<tr>
<td>Cisco</td>
<td>Dual 5 GHz</td>
<td>20 / 20</td>
<td>560</td>
<td>518.5</td>
<td>451.5</td>
<td>436.5</td>
<td>430.5</td>
</tr>
<tr>
<td>Cisco</td>
<td>Dual 2.4/5 GHz</td>
<td>20 / 20</td>
<td>435.5</td>
<td>396</td>
<td>382.5</td>
<td>353.5</td>
<td>347</td>
</tr>
<tr>
<td>Aruba</td>
<td>Dual 2.4/5 GHz</td>
<td>20 / 20</td>
<td>340</td>
<td>306</td>
<td>257</td>
<td>249</td>
<td>247</td>
</tr>
</tbody>
</table>

The results show that overall performance, for the same mix and number of clients, can vary widely depending on AP configuration. The best throughput performance was achieved with the Cisco Aironet 2800, with all clients operating at 5 GHz with 40-MHz channels. In this environment aggregate throughput ranged from an impressive high of 1,131 Mbps for 30 clients, to 807 Mbps for 150 clients.

The second and third best aggregate throughputs were also achieved with the Cisco 2800 – in second place with all clients running at 5 GHz and 20-MHz channel widths.

The best dual-band performance was also achieved with the Cisco 2800 AP, with 2.4-GHz clients using 20-MHz channels and 5-GHz clients using 40-MHz channels. The Aruba AP-335’s dual-band throughput performance in the exact same environment was 10+ percent less than with the Cisco 2800.
7 – Video Streaming

Test Objective

To compare the real-time application performance of the Cisco and Aruba APs, in this case a streaming 5-Mbps video.

How We Did It

This testing was conducted with a single Access Point, around which were deployed from 20 to 50 clients – a mix of MacBook Pros and Windows clients. The exact same AP position and client deployment was used for both APs – tested one at a time.

We used an open source multimedia player called VLC, from VideoLAN (http://www.videolan.org/vlc/index.html) to stream a movie trailer (Independence Day – Resurgence) at 5 Mbps per client. Each client was set to stream the video and then automatically repeat on completion.

We started testing each AP with from 35 to 50 clients (again, a mix of MacBook Pros and Windows clients). Each test run lasted from five to ten minutes, during which time three testers walked the room to see where there were problems with the video display.

We noted two recurring issues with some of the clients’ displays:

1. “Frozen screens:” Cases where the video would pause for more than 5 seconds
2. Pixelation: Cases where the video picture would decompose into pixelated squares.

The testers counted the number of clients that exhibited these problems during each test run. Afterwards, some clients would be shut down and the test would be re-run. This continued until all the remaining clients could display the trailer with neither problem occurring. The resulting maximum number of clients supporting “watchable” video was recorded.

Results

Aruba. Testing was first conducted with the Aruba AP-335. We expected that 35 clients would be able to stream the 5-Mbps repeating movie trailer without problems, so we conducted the first test run with 35 clients.

The testers found that five of the 35 clients streaming through the Aruba AP exhibited pixelation issues, and nine others exhibited “frozen screens” – pauses lasting longer than 5 seconds. Six clients were turned off and the test was re-run with 29 clients. There were a few brief screen pauses of less than 5 seconds – mostly just “stutters.” We turned off four more clients and re-ran the test. There were no problems with the remaining 25.

It was decided that the brief stutters with the last four Aruba clients were not severe enough to consider the resulting video “unwatchable.” So the testers agreed that a maximum of 29 clients could stream “watchable” video with the Aruba AP-335.
**Cisco.** Tests with the Cisco Aironet 2800 began with 50 clients. During the first test run a single client was observed exhibiting pixelation issues, and four clients exhibited “frozen screen” pauses of more than five seconds.

Four clients were turned off and the test was re-run of the remaining 46. One client still exhibited “frozen screen” issues. So one additional client was turned off and the test was re-run of the remaining 45. All 45 streamed “watchable” video with no display issues.

The chart below compares the max number of clients concurrently displaying “watchable” video with each of the Access Points tested.

![Max Clients Streaming Watchable Video](chart.png)

Source: Miercom August 2016
8 – Cisco FRA vs Aruba ARM

Test Objective
To compare the effectiveness of the AP vendors’ built-in capabilities to appropriately adjust their APs’ radio role and operating frequencies in a multi-AP environment.

How We Did It
Six of each vendor’s Access Points were deployed in the test area as shown in the diagram below. The APs were mounted from drop ceiling mountings and the two vendors’ APs were mounted in the same positions. Four APs covered the same open office area, as shown, with some coverage overlap. A fifth AP (AP6) was positioned down the hall and a sixth AP (AP3) was positioned down the hall and around a corner.

Once the APs were mounted and hooked up (six Cisco 2800 APs and six Aruba AP-335s), the network was activated – one vendor at a time – and the channel, frequency and role activity was carefully monitored using the vendor’s monitoring tool. The client disposition was the same for both vendor tests.

As another measure of the vendors’ AP coverage, we conducted a site survey of the radio coverage using Ekahau Site Survey (http://www.ekahau.com/wifidesign/ekahau-site-survey). This application provides a clear picture of the coverage associated with each AP.
Results

Aruba’s AP auto-adjustment capability is called Adaptive Radio Management, or ARM. According to Aruba documentation, ARM “automatically assigns channel and power settings, provides airtime fairness and ensures APs stay clear of all sources of RF interference.” Mode Aware ARM was configured to allow an automatic reduction in co-channel contention.

Cisco’s similar capability is called Flexible Radio Assignment, or FRA, which is a component part of Cisco’s Radio Resource Management, or RRM.

Observation #1: Aruba’s distributed ARM produced inconsistent results. Some Aruba APs would switch their 2.4-GHz radio to Air Monitor Mode. In this mode the AP doesn’t transmit, but rather just monitors the radio coverage for the particular AP, looking for a better non-contested channel. We observed that, in a few minutes, the AP would then switch back to an active 2.4-GHz channel.

Using FRA, two Cisco 2800 APs (AP2 & AP5) found additional channels by switching their 2.4-GHz radio (with just three non-overlapping channel choices) to 5 GHz (which offers 25 non-overlapping channel choices).

Observation #2: Aruba’s ARM coverage decisions are made by each AP independently. Cisco’s RRM coverage decisions are made at the Wireless LAN Controller. It monitors the coverage information for all the APs and sets the coverage power accordingly for each AP. As a result, RRM produces a more stable set of channel choices across all six cooperating APs.
**Observation #3:** There are major coverage differences between a Cisco 2800 AP and the corresponding Aruba AP-335. Shown below are survey maps of AP5 for both vendors.

The Cisco AP5’s radio coverage is more confined and overlaps less with the other Cisco APs. The other APs are all in the dark zone, outside the primary coverage zone of AP5. This gives the other Cisco AP’s channel bandwidth that interferes less with AP5s coverage, resulting in more uniform and cooperative coverage between the Cisco APs.

The coverage pattern for the corresponding Aruba AP-335 (AP5) spreads over the whole building, increasing AP-to-AP interference, and decreasing client roaming causing “sticky clients”. With ARM, each Aruba AP sets its own power. Aruba’s six-AP radio and power coverage never stabilized in our test bed. ARM kept changing power levels, and two of Aruba’s APs would continually put their 2.4-GHz radio into AP Monitor Mode (non-sending) and then back into normal sending mode.
Observation #4: Channel strengths are adjusted by Cisco FRA in a coordinated manner, taking all six APs into account. We ran tests using 40-MHz channels for the 5-GHz radios and 20-MHz channels for 2.4-GHz. Signal strengths are adjusted and frequencies assigned to minimize AP-to-AP interference. The below charts shows the power levels measured for each AP's radios.

Two of the Cisco AP's had their 2.4/5-GHz radio set to 5 GHz, in order to produce less interference on the 2.4-GHz set of channels. Cisco APs use less power and have more consistent power levels than Aruba's. This provides more concise coverage areas for each AP, and so reduces interference.
9 – Spectrum Analysis: Interference Detection

Test Objective

To compare the effectiveness of the vendors’ integral tools for spectrum analysis and ability to correctly detect and report sources of interference.

How We Did It

This test employed just one Access Point and the vendor’s respective spectrum-analysis tool, which displayed on a nearby monitor. Various interference-generating sources were introduced and turned on, individually and collectively, to ascertain whether:

a) The vendor’s AP and spectrum analysis could detect the presence of the interference
b) The device generating the interference could be identified
c) The AP could make channel changes as a result, to avoid interference.

Four interference-generating sources used:

1. A Bluetooth speaker
2. A microwave oven
3. A video camera, and
4. An illegal AP jammer.

Results

Aruba: There are several displays included in Aruba’s interference-detection and spectrum-analysis software. Below is part of a screenshot of an Aruba AP’s log file showing the results of its interference detection.

```
--- Interference Test ---
(Aruba7210) #show ap spectrum device-list ap-name 335-2 1
Non-WiFi Device List: 2GHz
     Type     ID    Freq(KHz)  Bandwidth(KHz) Channels-affected  Signal(dBm)  Duty-cycle
Cordless Network FH 1 2444000 80000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -75 0
Microwave 1 2450000 92000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -64 50
Cordless Network FH 1 2444000 80000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -75 0
Bluetooth 1 2444000 78000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -53 18
Cordless Base FH 1 2444000 80000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -73 3
Microwave 1 2412000 20000 1 -52 6
Microwave 2 2450000 92000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -41 2
Cordless Base FH 2 2444000 70000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -74 4
Cordless Base FH 2 2444000 80000 1 2 3 4 5 6 7 8 9 10 11 12 13 14 -73 2
```

Aruba detected interference from and identified two of the four sources: a Bluetooth device (the speaker) and the microwave oven. We saw no evidence that either the video camera or the illegal jammer were detected, though “cordless network” and “cordless network base” were listed.
Looking more closely for any sign of interference by the illegal jammer, the Aruba AP-335 detected 3 percent interference before the jammer test was run. The source was not identified, although it might have been due to ambient Bluetooth interference. The below Aruba displays show interference on this channel before and after the illegal jammer test.

*Before the illegal jammer was run*

![Channel Utilization before jammer](image1)

*After the illegal jammer was running*

![Channel Utilization after jammer](image2)

During the illegal jammer test Aruba detected 8 percent interference, but did not identify the source. As shown in the following display, the Aruba AP-335 did show a drop in the available bandwidth of this channel, due to the illegal jammer. It did not, however, identify the source and did not change its channel configuration to avoid the bandwidth loss due to the interference.
**Aruba display showing reduced channel bandwidth from illegal jammer interference.**

![Aruba Display](image)

**Cisco:** We observed that Cisco interference detection via the 2800 AP provided more accurate detection and identification of interference sources. What's more, channel configurations would frequently change in response to the detected interference. The Cisco 2800 correctly identified all four of the interference-generating sources we introduced, as shown in the following displays.

**Cisco detection of Bluetooth interference**

![Cisco Detection of Bluetooth Interference](image)

**Cisco detection of video camera interference**

![Cisco Detection of Video Camera Interference](image)
Cisco detection of microwave oven interference (including ambient Bluetooth interference)

We observed that the Cisco package will react to detected interference by changing channels. The below screenshot excerpt is a notification of such a channel change resulting from detection of the illegal jammer interference.
Cisco’s package also provides clear graphical displays of individual sources of interference that are detected. Below are the before and after views of the Cisco system’s detection of the illegal jammer interference.

**Cisco 2800 AP before the illegal jammer was turned on**

**Cisco 2800 AP after the illegal jammer was turned on**
10 – Multi-User MIMO (MU-MIMO)

Test Objective

Multi-User MIMO (Multi-Input, Multi-Output) is a new feature with 802.11ac Wave 2. A MU-MIMO AP can simultaneously transmit to multiple clients, increasing client density – the number of simultaneously supported clients. MU-MIMO support is required on both the AP and the client device to work, although MU-MIMO works on just downstream data delivery, AP to client.

The test objective was to validate the throughput benefits of using three and four spatial streams (3ss and 4ss) on the Aruba AP-335 and the Cisco Aironet 2800 AP.

How We Did It

Aruba data sheets claim the Aruba AP-335 features support for four spatial streams. Cisco’s 2800 and 3800 APs claim support for three spatial streams, using four radio transmitters. The additional transmitter is used to better adjust MU-MIMO ‘beamforming’ parameters. Beamforming adjustment is done to keep the three spatial streams from interfering with each other.

An Ixia test system running the IxChariot application generated test traffic, which was sent through each AP (the Cisco 2800 and the Aruba AP-335), as shown in the below test-configuration diagram. Throughout was measured in two tests:

1. The **three spatial-stream (3ss) test**, which used two clients: the 2ss Dell E5450 and a 1ss Acer Aspire E 15.
2. The **four spatial-stream (4ss) test**, which used three clients: the 2ss Dell E5450 and two 1ss Acer Aspire E 15’s.

The Ixia IxChariot captured the aggregate throughput for all clients in each test. Each test ran for one minute. We took the top two measured throughputs and averaged those to obtain the best-case throughput numbers. This average throughput (in Mbps) was recorded.

The Cisco AP software version used (8.2.121.8) was the latest software version available to customers, now on the Cisco Web site. This version will ship a future Cisco major release. The Aruba software was the currently shipping software at the time of testing (6.5.0.0).
Results

The results of this test show that adding a client using a fourth spatial stream actually decreases aggregate throughput. A fourth stream can indeed be supported, but at the expense of overall throughput. Our conclusion: Aruba’s claim for 4ss support offers no real advantage over Cisco’s MU-MIMO support on this point.

![MultiUser MIMO - Three and Four Spatial Streams Aggregate Throughput (Mbps)](chart.png)

| MultiUser MIMO - Three and Four Spatial Streams Aggregate Throughput (Mbps) |
|---|---|
| **Cisco 2800 AP** | **Aruba AP-335** |
| 2ss+1ss | 514 | 445 |
| 2ss+1ss+1ss | 459 | 392 |

Source: Miercom August 2016
11 – Dual External Antennas

Test Objective
To find out how the throughput of a Wi-Fi Access Point with external, directional antennas, covering two separate areas, compares with the same AP operating both radios simultaneously.

How We Did It
The Cisco Aironet 2802e AP ("e" for external antennas) has ports to connect external directional antennas. These are designed to provide directional coverage and not interfere with each other, as antennas operating in the same frequency band often do. This can result in greater throughput because, with directional antennas, when properly deployed there is less overlapping coverage compared to omnidirectional antennas.

In this test, two sets of five clients were set up in cubicles, as they would be in an office setting.
As shown in the floorplan diagram, one set of five clients (all were MacBook Pros) were positioned to the north of the 2802e AP; the other set was situated to the west of the AP. Two external antennas were configured – one pointing north and the other pointing west – allowing little overlap of the coverage areas allocated to each 5-GHz radio.

Throughput was then measured – first to the north set of clients, and then to the west set of clients. Then the throughput was measured to both set of clients at the same time, with both 5-GHz radios running. The results are shown in the chart below.

![Dual 5-GHz Radios with Two External Directional Antennas](chart.png)

**Results**

The throughput when running both radios simultaneously, 899 Mbps, is very close to the total of the two individual tests, 912 Mbps. This means that the dual directional antennas did indeed keep the two 5-GHz-band radio channels separated and so minimized their interference.

Note that the west client throughput is a bit higher than the north set, primarily due to the west set being slightly closer to the AP than the north set.
12 – Independent Evaluation

This report was sponsored by Cisco Systems, Inc. The data was obtained completely and independently as part of Miercom’s competitive analysis.

13 – About Miercom

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14 – Use of This Report

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