Tech Brief |

802.11n Client Throughput Performance

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EXECUTIVE SUMMARY

The objective of this paper was to determine the performance of different client types as well as the impact of using multiple clients in an 802.11n WLAN infrastructure. Since enterprises are likely to deploy a variety of class 802.11n Draft 2.0 client types, this testing was intended to reveal performance differences and compatibility among clients. In actuality, and to our surprise, the test also highlighted critical performance differences in the performance of enterprise WLAN infrastructure equipment when operated in an ideal environment with these clients.

We tested the TCP downstream throughput capability of Aruba's 802.11n AP against three: other enterprise-class Access Points (AP): Cisco's autonomous AP (IOS), Cisco's lightweight AP (LWAPP), and Meru's thin AP. Five wireless laptop clients using representative 802.11n chipsets from Atheros, Broadcom, and Intel were tested individually and in groups. At the time of testing, all APs under test and all clients were Wi-Fi Alliance® Draft-802.11n v2.0 certified.

The same test network topology, RF environment, and Gigabit Ethernet connectivity were used for all vendors. A TCP throughput script generated traffic from the wired Ixia's IxChariot Console to wireless clients running the IxChariot Performance Endpoint application.

SUMMARY OF RESULTS

The test results are summarized in Table 1. Among the highlights:

- Only Aruba infrastructure consistently yielded greater than 100 Mbps throughput, roughly 5 times the performance of earlier generation 802.11a/b/g compatible wireless systems, in single and multiple client tests using both PC and Apple Macintosh laptop clients.
- Aruba's AP-125 802.11n Access Point delivered the highest performance - >160 Mbps for a single client and >150 Mbps for multiple clients – and equitably shared the channel with multiple clients.
- Cisco's lightweight AP-1252 was capable of >125 Mbps but not with all clients. The mixed-client testing showed remarkable uniformity among clients but with lower aggregate throughput.
- Meru's AP-320 delivered poor performance with all but one of the clients, and exhibited inequitable channel sharing when used with multiple clients.

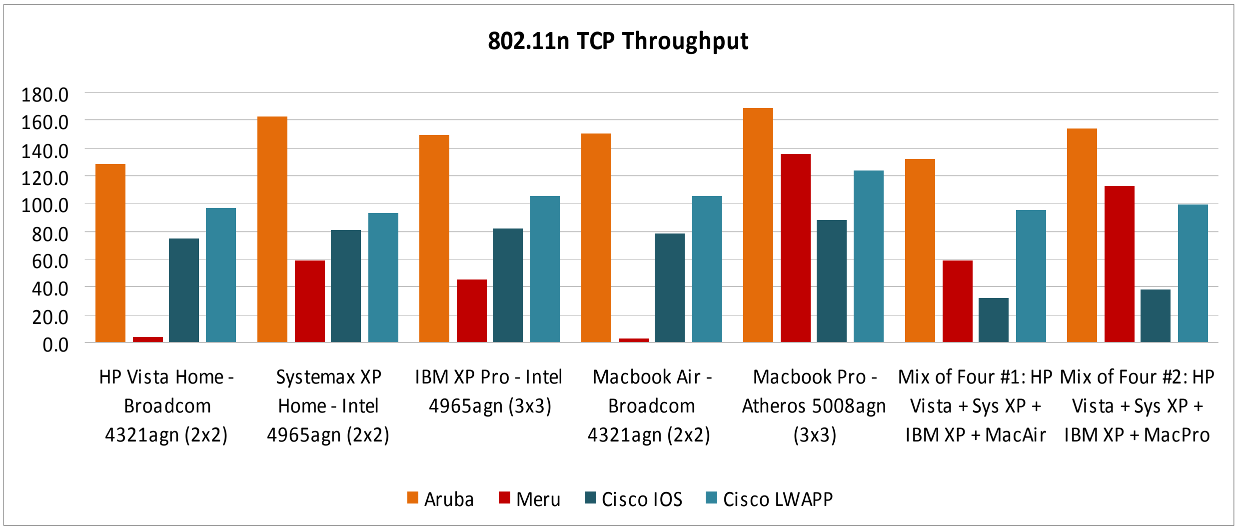

Figure 1

Aggregate Throughput

Table 1

Aggregate Throughput

802.11n TCP Throughput	**Aruba**	**Meru**	**Cisco IOS**	**Cisco LWAPP**
HP Vista Home - Broadcom 4321agn (2x2)	128.0	3.1	74.2	96.2
Systemax XP Home - Intel 4965agn (2x2)	163.3	58.2	80.8	92.5
IBM XP Pro - Intel 4965agn (3x3)	149.2	44.8	81.7	105.7
Macbook Air - Broadcom 4321agn (2x2)	151.0	2.0	78.9	105.4
Macbook Pro - Atheros 5008agn (3x3)	169.2	135.8	87.9	124.3
Mix of Four #1: HP Vista + Sys XP + IBM XP + MacAir	131.9	58.7	31.7	96.0
Mix of Four #2: HP Vista + Sys XP + IBM XP + MacPro	154.0	113.2	38.2	99.3

THE OBJECTIVE

One of the greatest attractions of 802.11n Draft 2.0 is its five-fold increase in data throughput compared with previous 802.11 WLANs. This throughput enhancement is the result of a new Multiple In-Multiple Out (MIMO) radio architecture coupled enhancements to the physical and media access control layers of the TCP/IP stack. .

Table 2

802.11n Speed Enhancements

Enhancement	**Effect**	**Layer**
Packet Aggregation	Multiple TCP Packets are clubbed into fewer MAC frames to reduce header and other overheads	MAC
Block Acknowledgment	Fewer Block ACKs cover multiple frames - this reduces the airtime used for low speed ACKs	MAC
Channel Bonding & Coding schemes	Use of 40 MHz channels and higher bits/symbol OFDM techniques increase the max PHY rate from 54 for 802.11 a/g to 300 Mbps for 802.11n.	PHY
Spatial Multiplexing	Multiple antenna chains transmit and receive simultaneously to improve radio channel utilization	RF
Improved Receive Sensitivity	Multiple receive antennas ensure better data integrity and fewer retransmissions.	RF

The efficiency of a specific 802.11n solution depends on how well these features have been implemented both on the client and the WLAN infrastructure. It is in these two areas that one finds variations among manufacturers, with good designs achieving >150 Mbps throughput and others considerably less so.

TEST NETWORK

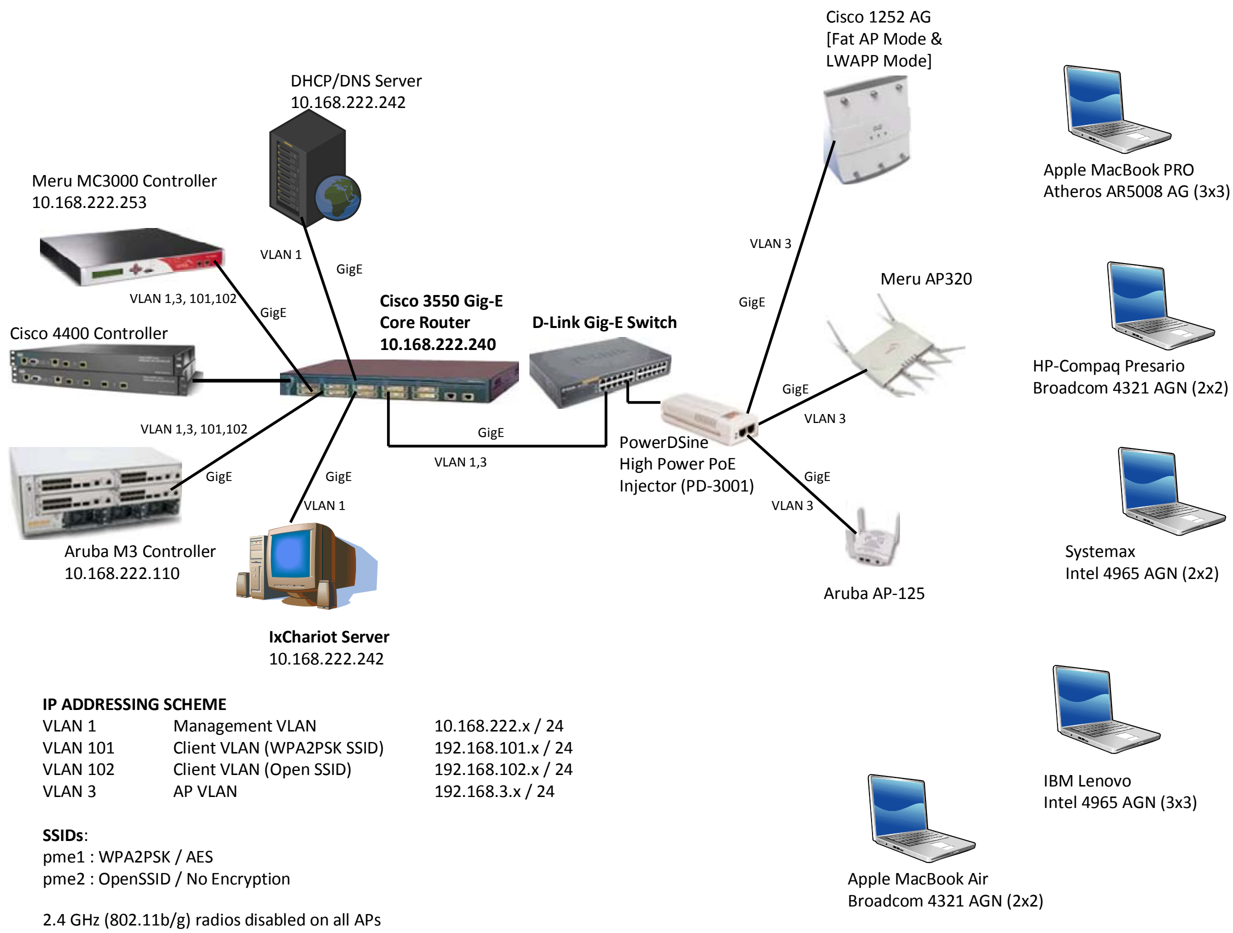

Figure 2

Network Topology

The WLAN infrastructure from all four vendors was deployed in accordance with published specifications. The latest released software/firmware was loaded on all equipment, antennas were oriented vertically for optimum transmission /reception, and all clients were located on a 1 meter high table. All testing was conducted indoors on a clean channel with no other nearby interfering APs.

The network was designed following a typical WLAN deployment. A Cisco 3550 device at the core of the network provided routing and connectivity between the various WLAN controllers and the APs. DHCP/DNS/RADIUS services were provided by a wired Microsoft Windows® 2003 Server connected to the router. The APs connected to the router through a D-Link Layer 2 switch and a high power midspan Power-over-Ethernet (PoE) injector. This common power source offered more than adequate power for all of the APs based on published specifications. All APs were configured to allow access to clients on the employee SSID, and used WPA2/AES authentication/encryption as would be typical of an enterprise deployment.

Although all of the APs were dual-band 2.4/5 GHz devices, the 5 GHz mode was used for the purpose of these tests in order to realize the maximum benefits of 802.11n. All of the APs used a 3x3 MIMO antenna configuration. Additional pertinent set-up details are shown below.

Table 3

Test Infrastructure Specifications

Aruba
ArubaOS (MODEL: Aruba6000-US), Version 3.3.1.4
AP Model: AP125
Mobility Controller Model: MMC-6000 w/ M3
Built-in antennas

Cisco IOS
Product/Model Number: AIR-AP1252AG-A-K9
System Software Version: 12.4(10b)JA
AP Model: AP1252AG
External patch antenna - AIR-ANT-5140V-R

Cisco LWAPP
System Software Filename: 5.0.148.0
AP Model: AIR-LAP-1252AG
WLAN Controller Model: WLC4402-12
External patch antenna - AIR-ANT-5140V-R

Meru
System Software Filename: 3.4SR3-112
AP Model: AP320
WLAN Controller Model: MC3100
External antennas

All WLAN controllers were set to their default configuration except with regard to authentication and RF level configuration options that required a manual setting. MPDU support was enabled on Cisco's WLAN controller to ensure the best interoperability with all clients.

TEST CLIENTS

The test included four major brand 802.11n-capable laptop clients that used WiFi chipsets from three different WLAN chipset vendors: Apple MacBook Pro based on an Atheros chipset; HP-Compaq and MacBook Air laptops based on a Broadcom chipset; Systemax laptop based on an Intel chipset; and a Lenovo laptop based on the same Intel chipset but equipped with additional MIMO antennas. The net result was a pool of 802.11n Draft 2.0 certified test clients using different Wi-Fi chipsets, processors (Intel / AMD), processor speeds, memory capacities, and operating systems (XP / Vista / MacOS).

Two changes were made to the settings of the clients: power save mode was disabled to prevent the radios from turning off during performance testing; and roaming aggressiveness was set to minimum wherever possible to ensure that clients did not scan off-channel during the throughput tests. These changes should have uniformly affected all of the WLAN systems under test. Table 4 summarizes the client specifications.

Table 4

Test Client Specifications

	HP-Compaq Presario V6000	**Systemax**	**IBM Lenovo**	**MacBook Pro**	**MacBook Air**
Processor Speed	2.0 GHz	1.73 GHz	2.2 GHz	2.2 GHz	1.6GHz
Processor	AMD Turion	Intel Core Duo	Intel Core 2 Duo	Intel Core 2 Duo	Intel Core 2 Duo
Memory	1 GB	1 GB	1 GB	2 GB	2GB
OS	Vista Home	XP Home	XP Pro	Mac OS X	MacOS X
Wireless NIC	Bcom 4321	Intel 4965	Intel 4965	Atheros 5008	Bcom 4321
Firmware Version	4.102.15.56	11.5.0.32	11.5.0.32	1.2.2	4.102.15.56
Radio	2x2	2x2	3x3	3x3	2x2

TEST TOOL

IxChariot Version 6.50 was used as the test tool, and was configured as follows:

- Script used: Throughput.scr (with all default parameters)
- Traffic type: TCP
- Run Options: Batch mode; No Polling.
- 8 parallel streams per client.

The Ixia Performance Endpoint application ran on each wireless client as well as wired console server. Sample test results are presented in Figure 3.

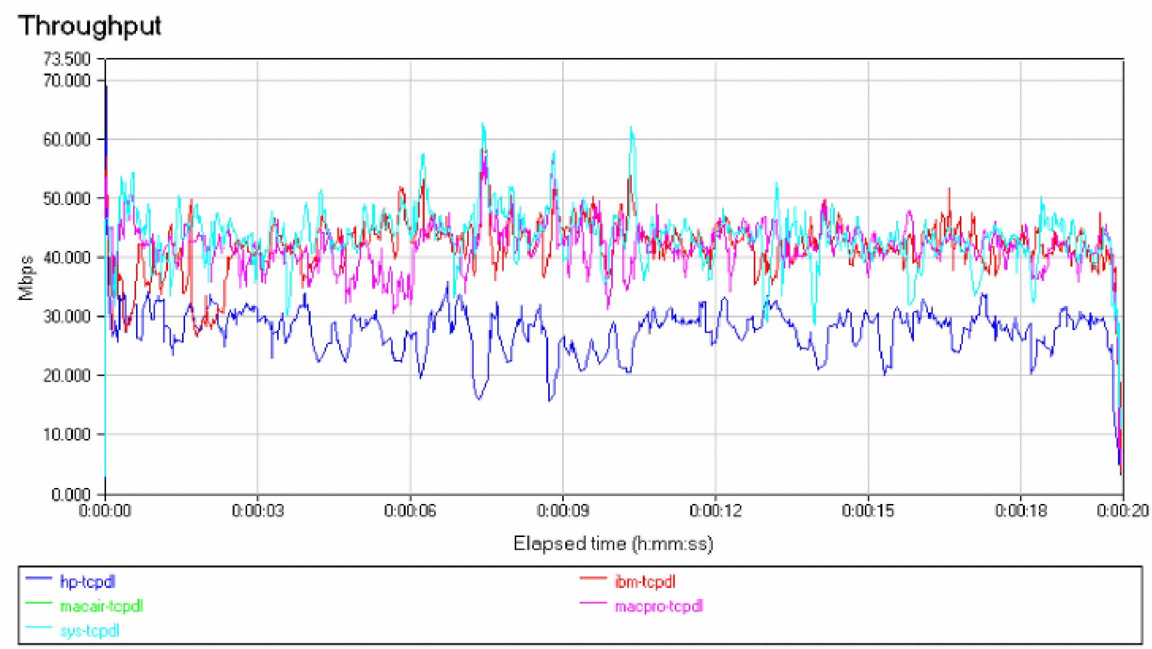

Figure 3

Sample Throughput Results From the IxChariot test.

TEST RESULTS:

The test results are summarized in Figure 4 and Table 5 below (repeats of Figure 1 and Table 1, respectively).

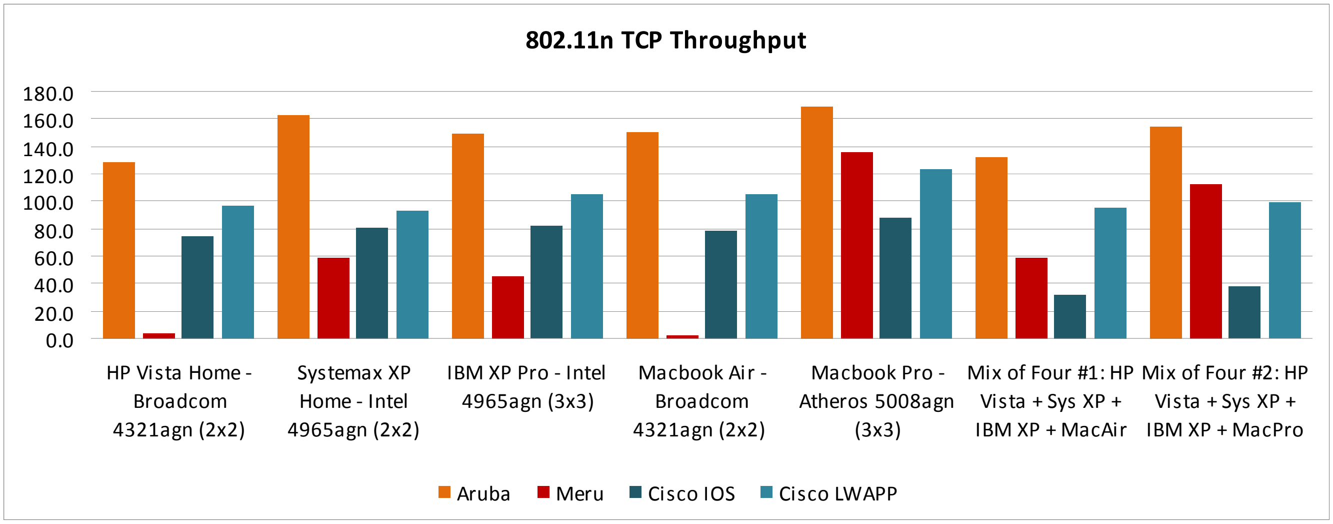

Figure 4

Aggregate Throughput

Table 5

Single Client and Mixed Client Aggregate Tesults

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KEY FINDINGS – SINGLE CLIENT TESTS

The primary purpose of the single client throughput tests was to determine which client laptop had the highest amount of performance/data throughput for each of the 3 WLAN infrastructure vendors.

Aruba:

- Throughput for the single-client tests was consistently >125 Mbps for all client-types.
- Top performance of 169 Mbps was observed with the MacBook Pro (Atheros chipset).
- Mac OS clients exhibited higher throughput than Windows XP / Vista clients regardless of vendor.

Cisco IOS:

- Demonstrated good compatibility with all clients during single client tests, but with lower than expected throughput of 85 Mbps for all client types.

Cisco LWAPP:

- Observed throughput was greater than the Cisco IOS AP.
- Single client throughput >100 Mbps for both MacBooks and 3x3 Intel clients.
- Best performance observed with MacBook Atheros client.

Meru:

- Very poor throughput with HP/Compaq (3.1 Mbps) and Apple Macbook Air (2.0 Mbps) clients using Broadcom chipsets.
- Best performance with Atheros (>135 Mbps), lower throughput with Intel chipsets.

TEST RESULTS - PER CLIENT THROUGHPUT IN MIXED CLIENT TESTS

The primary purpose of the mixed client throughput tests was to measure the amount of fairness in access to the channel (as a percentage – total of 100%) that was granted to each tested laptop client by the WLAN infrastructure vendor. This is an important test result to measure. Ideally, each client should get an equitable share of the channel. Test results defined below where certain clients had over 40% access of the total channel are not good. This implies that specific laptops essentially “took over the air” and starved other clients. For customers/prospects evaluating 802.11n infrastructure vendors, this means that one could expect trouble tickets or calls from wireless users complaining about wireless access or poor performance simply because of the type of laptop that they used.

Table 6

Mix #1 Test - 2 Intel 4965 + 2 Broadcom 4321 Clients – Total of 100%

Mix Client Throughput Share	**Aruba**	**Meru**	**Cisco IOS**	**Cisco LWAPP**
HP Vista Home - Broadcom 4321agn (2x2)	15%	5%	76%	22%
Systemax XP Home - Intel 4965agn (2x2)	31%	43%	6%	26%
IBM XP Pro - Intel 4965agn (3x3)	32%	49%	14%	28%
Macbook Air - Broadcom 4321agn (2x2)	22%	3%	4%	24%

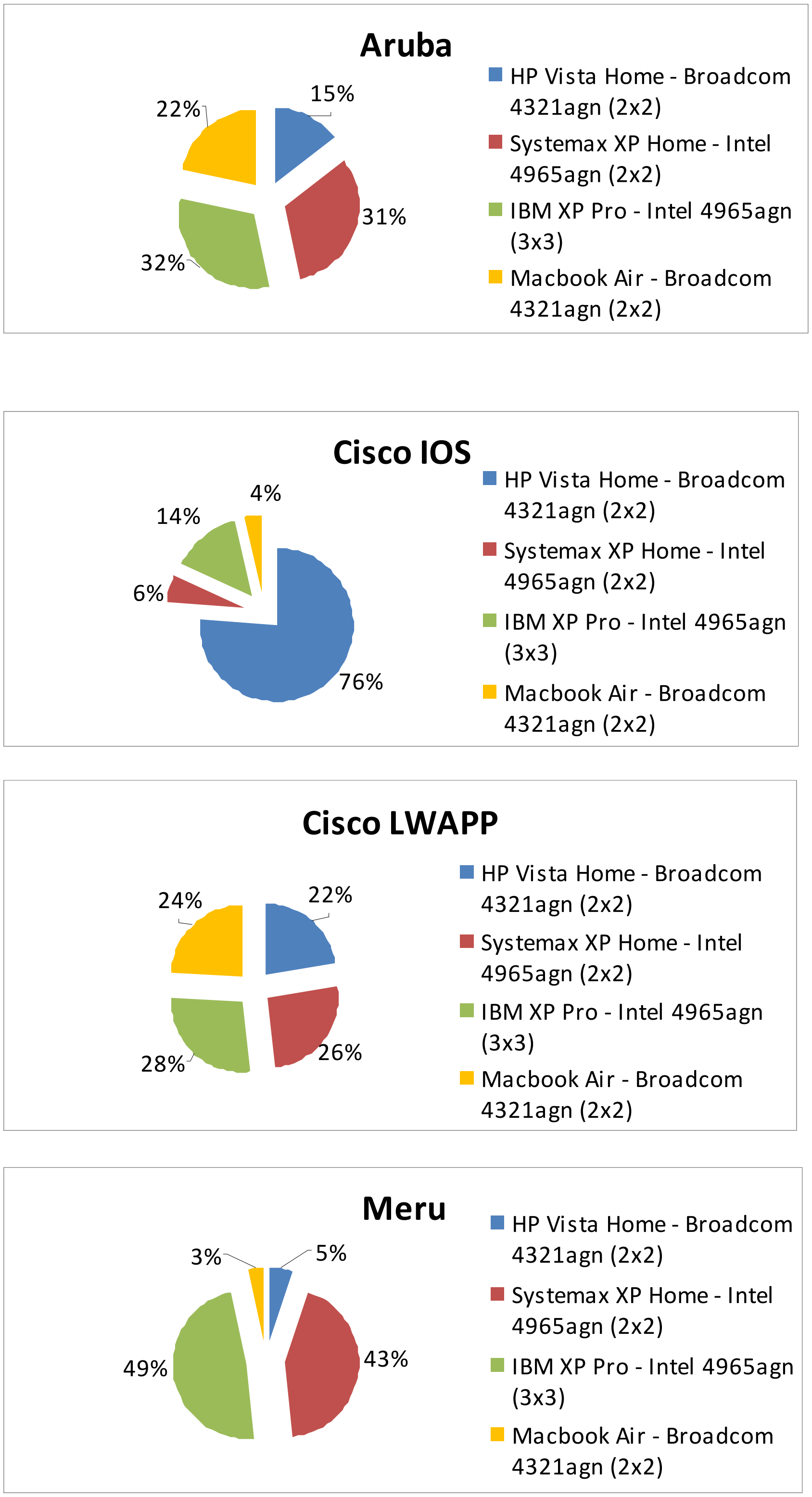


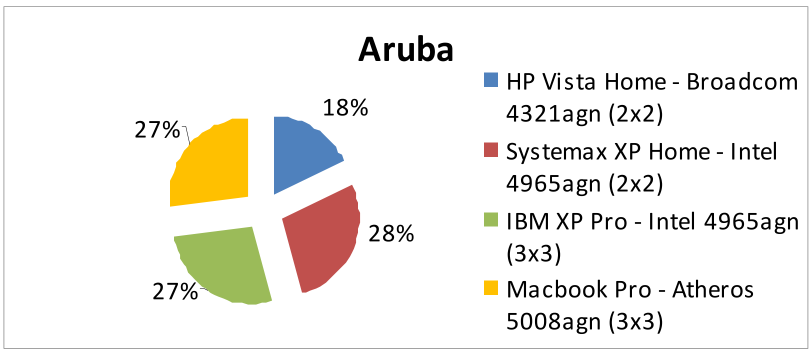
Figure 5

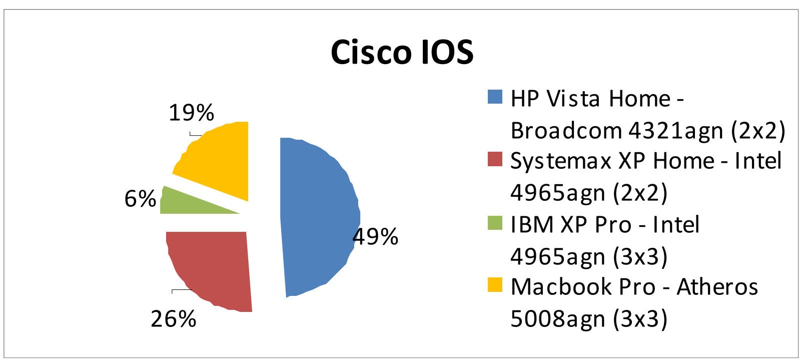
Per Client Throughput Distribution for Mix #1 Test

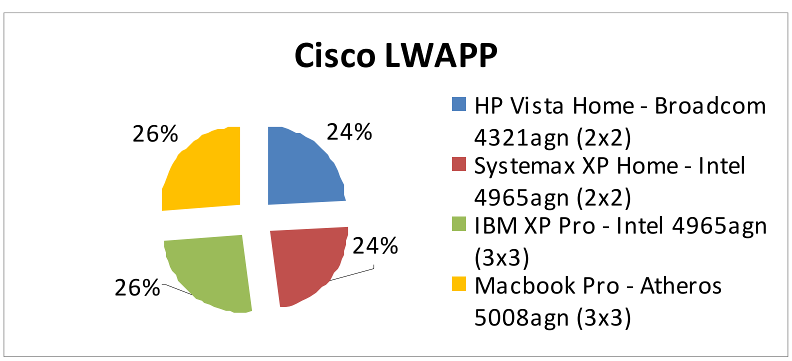
Table 7

Mix #2 Test - 2 Intel 4965 + 1 Broadcom 4321 + 1 Atheros AR5008- Total of 100%

Mix Client Throughput Share	**Aruba**	**Meru**	**Cisco IOS**	**Cisco LWAPP**
HP Vista Home - Broadcom 4321agn (2x2)	18%	3%	49%	24%
Systemax XP Home - Intel 4965agn (2x2)	28%	9%	26%	24%
IBM XP Pro - Intel 4965agn (3x3)	27%	6%	6%	26%
Macbook Pro - Atheros 5008agn (3x3)	27%	82%	19%	26%







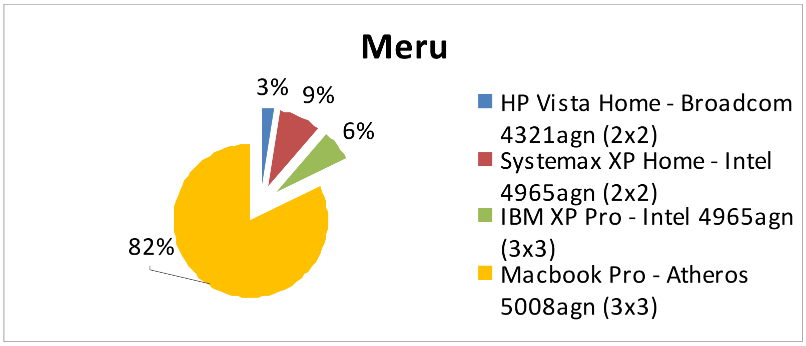


Figure 6

Per Client Throughput Distribution For Mix #2 Test

KEY FINDINGS – MIXED CLIENT TESTS

Aruba:

- Good ability to scale as demonstrated by aggregate throughput in the mixed-client tests almost equaling the average throughput of individual clients.
- Fair distribution of air-time and throughput across all clients and client combinations in the mixed-client tests.

Cisco IOS:

- Poor performance in mix-client tests that include clients with Broadcom chipsets.
- Total throughput for mixed-client tests was half of the individual client numbers.

Cisco LWAPP:

- Multiple-client split was relatively uniform but total throughput was lower than expected.

Meru:

- Aggregate throughput for mixed-client tests was about half of the individual client tests, suggesting scalability problems in mixed client environments.
- One or two clients dominate airtime and thereby starve other clients.

CONCLUSIONS

The type of Wi-Fi Alliance 802.11n Draft 2.0 certified client used in a network should not affect network performance, and indeed that was the case for Aruba's 802.11n infrastructure. In stark contrast, however, client type and client mix profoundly affected the throughput performance for other WLAN infrastructure vendors. The issue is not the clients, since they exhibited high throughput on the Aruba WLAN, but instead a design or implementation problem in the other WLAN infrastructure.

The Aruba WLAN exhibited aggregate, multiple client throughput that approached the maximum throughput observed for any individual client. The Aruba WLAN also demonstrated airtime fairness across all clients which resulted in very even throughput distribution across all clients.

Neither Cisco nor Meru delivered consistently high throughput or universal airtime fairness. The Cisco APs exhibited poor throughput performance that was typically <100 Mbps. Meru delivered high throughput only with the Apple/Atheros client, and caused client starvation and/or poor throughput for all other clients.

There is every reason to believe that end users will experience similar client performance, or lack thereof, in actual WLAN deployments. The best means to avoid trouble is for integrators and/or end users to run tests with a representative set of clients that are expected to be used in the final deployment. Only in so doing are they likely to observe potential client starvation and throughput problems.

The tests demonstrate that Aruba's 802.11n solution has much to offer enterprise WLAN users in terms of 802.11n AP throughput, scalability, multi-client environment performance, and client airtime fairness across a diverse range of clients – all key criteria for a successful 802.11n WLAN deployment.

ABOUT ARUBA NETWORKS

People move. Networks must follow. Aruba securely delivers networks to users, wherever they work or roam. Our unified mobility solutions include Wi-Fi networks, identity-based security, remote access and cellular services, and centralized network management to enable the Follow-Me Enterprise that moves in lock-step with users:

- Follow-Me Connectivity: 802.11a/b/g/n Wi-Fi networks ensure that users are always within reach of mission-critical information;
- Follow-Me Security: Identity-based security assigns access policies to users, enforcing those policies whenever and wherever a network is accessed;
- Follow-Me Applications: Remote access solutions and cellular network integration ensure uninterrupted access to applications as users move.

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