Enterprise Wireless Competitive Performance Test Results

Quantifying Improvements in Throughput, Coverage, and Capacity

Overview

Today's enterprises face a choice when selecting a vendor of wireless LAN infrastructure for their organization. While there are many vendors to choose from, not all possess the expertise in both radio frequency (RF) design and computer networking to build true, enterprise-class infrastructure. This disparity in competency manifests itself in disparities in performance—specifically, in throughput, wireless LAN coverage, and capacity.

This white paper examines testing conducted to characterize the capabilities of wireless LAN infrastructure from Cisco, Aruba, Motorola, and Hewlett Packard (HP). We'll describe the methodology for testing as well as test results.

Test Goals and Setup

In developing a plan to test the capabilities of wireless LAN infrastructure from different vendors, it is important to simulate a real-world computing environment, with usage scenarios that mimic key concerns of enterprise IT organizations. These concerns include:

- **Throughput:** What level of speed can I expect from my wireless LAN? Will my wireless LAN provide the bandwidth necessary to support my applications?
- **Coverage:** How consistent is the coverage provided by the wireless access point? Will my applications run the same way on the wireless LAN as they do one the wired LAN, or will the user's experience be variable?
- **Capacity:** How many clients can I support? How does the wireless LAN behave as more clients are added to the network?

To answer these questions, testing was conducted in a 40,000 square foot carpeted office environment with a mix of walled offices and cubicles. The facility was physically separated from other buildings to ensure that no other wireless network or source of RF interference affected the results of the test and to ensure that the results were reliable. Wireless LAN equipment was installed according to the documentation provided by each vendor, and both the wireless LAN infrastructure and clients ran the latest software available from each vendor.

Multipath

One feature of the test plan that requires special comment is multipath. **Multipath** is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. The causes of multipath include reflection from objects including walls, furniture, and metal.

The level of multipath propagation in the test facility was representative of most enterprise installations. Facilities such as warehouses where more multipath may be present are likely to experience incremental performance gains with 802.11n from the effects of multiple-input multiple-output (MIMO) technology. The results obtained in this test, while indicative of real-world performance, may vary depending on the physical environment that the WLAN is installed in, the level of multipath and/or RF absorption from the environment, surrounding sources of interference, and other factors.

Test Equipment

Tests were conducted using wireless LAN infrastructure from Cisco, Aruba Networks, Motorola, and Hewlett Packard. Specific pieces of wireless LAN infrastructure included:

- Cisco® 5508 Wireless LAN Controller
- Cisco Aironet® 1252 802.11n Wireless Access Point
- Aruba 6000 Controller with M3 Module
- Aruba AP-125 802.11n Wireless Access Point
- Motorola RFS6000 Wireless LAN Switch
- Motorola AP-7131 802.11n Wireless Access Point
- HP ProCurve MSM750 MultiService Controller
- HP ProCurve MSM422 802.11n Wireless Access Point
- Trapeze MX-200R Mobility Exchange
- Trapeze MP-82 Wireless Access Point

Each vendor's wireless controller was interconnected to a Cisco Catalyst® 3750-E Gigabit Ethernet switch. Access points were connected via Gigabit Ethernet to the same Cisco Catalyst 3750-E switch and powered via Power over Ethernet (PoE). Setup for each vendor's wireless LAN equipment was handled according to the vendor's published configuration and deployment guides. All wireless LAN infrastructure equipment ran with the latest software available from the vendor.

A variety of clients with Intel 5300 and 4965 802.11a/b/g/n wireless adapters were used as clients to test on the wireless network. The latest software drivers available from Intel were loaded on each client. Traffic generation for rate vs. range throughput testing was handled by a server connected over Gigabit Ethernet running Windows Server 2003, and Ixia's IxChariot software. Traffic generation for client density tests was handled by a Veriwave WT-90 chassis with a 4-port Gigabit Ethernet blade. Wireless clients were loaded with both the Ixia IxChariot and Veriwave WaveAgent endpoint software.

Performance Metrics

As discussed, the benefits of 802.11n fall into three primary areas: throughput, reliability, and predictability. A more detailed explanation of the testing and subsequent results is presented next.

Performance Metrics: Throughput vs. Distance

The Throughput vs. Distance test is designed to measure the speed of downstream, TCP traffic between the access point and client (Figure 1). In simple terms, think of this as how quickly a wireless client can download data from a server on the enterprise network, such as an FTP server. With wireless, clients can theoretically be anywhere within a facility, so it is important to measure throughput not just when a client is next to an access point but when other obstacles, such as distance and intervening walls, are introduced as well. Doing so challenges the design of a vendor's access point including optimization of the radio and antennas.

Figure 1. Testing Locations for Throughput vs. Distance Test

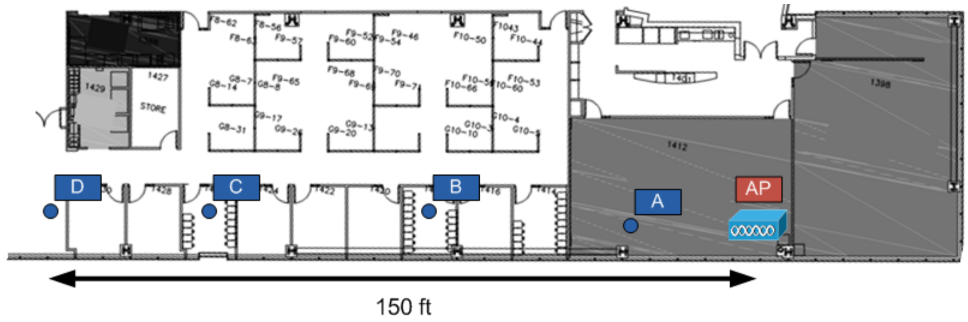


Table 1 lists the results of this test, and Figure 2 shows the results as a graphs. In every test location, Cisco's access point (represented by the blue line in Figure 2) outperformed the competition. When the testing results for each location were averaged, Cisco outperformed the competition by as much as 169 percent in the 2.4-GHz spectrum and by 64 percent in the 5-GHz spectrum.

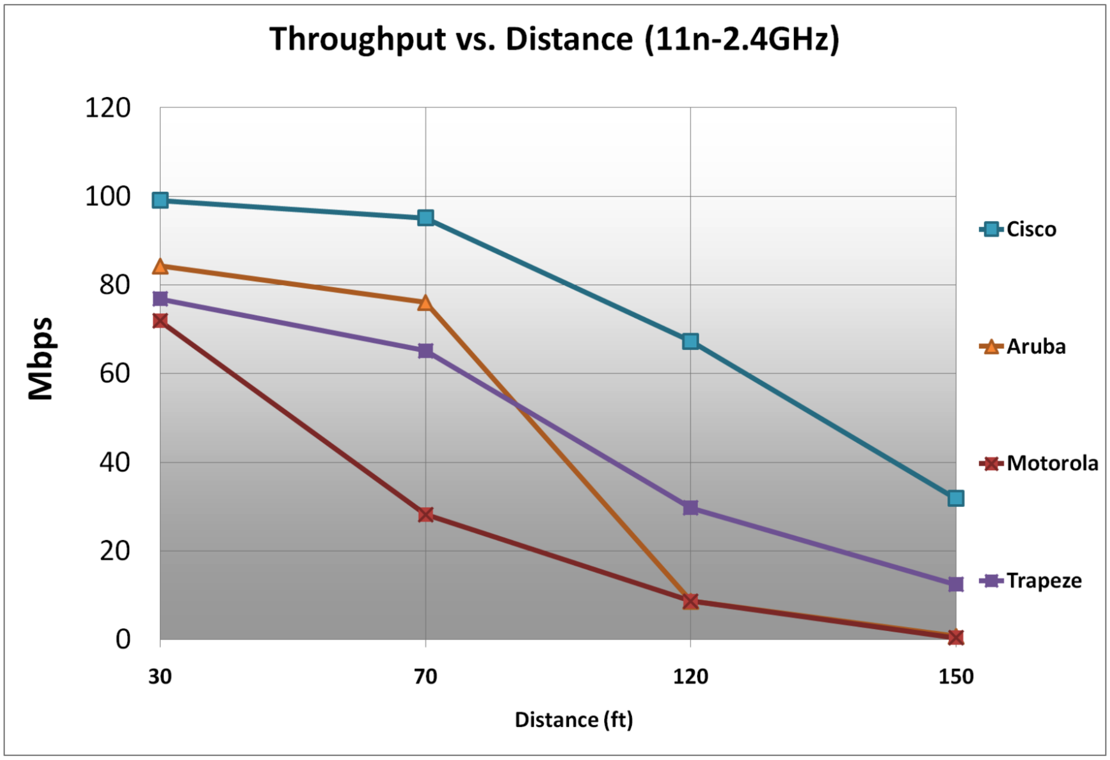
Note: HP was not tested in the 2.4-GHz spectrum for 802.11n as the MSM422 does not support simultaneous, dual-band 802.11n operation. Because 5 GHz is the recommended spectrum for 802.11n deployment, we chose to test the MSM422 in that spectrum.

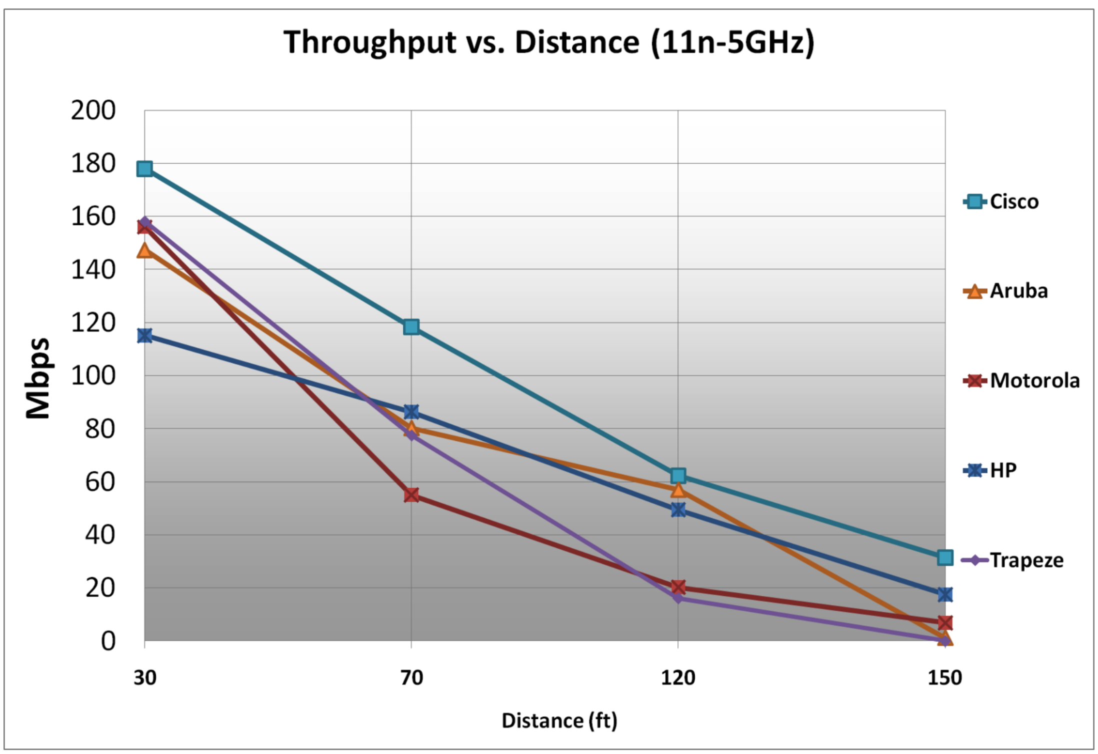
Table 1. Throughput vs. Distance Test Results

Throughput vs. Distance - 2.4GHz (Mbps)					
Location	Distance (ft)	Cisco	Trapeze	Aruba	Motorola
A	30	99.1	76.8	84.3	71.9
B	70	95.1	65.2	76.1	28.2
C	120	67.3	29.7	8.7	8.7
D	150	31.8	12.4	0.7	0.4
Average		**73.3**	**46.0**	**42.4**	**27.3**
Cisco Exceeds by		N/A	59%	73%	169%

Throughput vs. Distance - 5GHz (Mbps)						
Location	Distance (ft)	Cisco	Aruba	HP	Trapeze	Motorola
A	30	178.0	147.4	115.1	158.2	156.0
B	70	118.3	80.3	86.3	77.5	55.0
C	120	62.3	57.0	49.4	16.2	20.2
D	150	31.5	1.2	17.5	0.0	6.9
Average		**97.5**	**71.5**	**67.1**	**63.0**	**59.5**
Cisco Exceeds by		N/A	36%	45%	55%	64%

Figure 2. Graph of Throughput vs. Distance Results



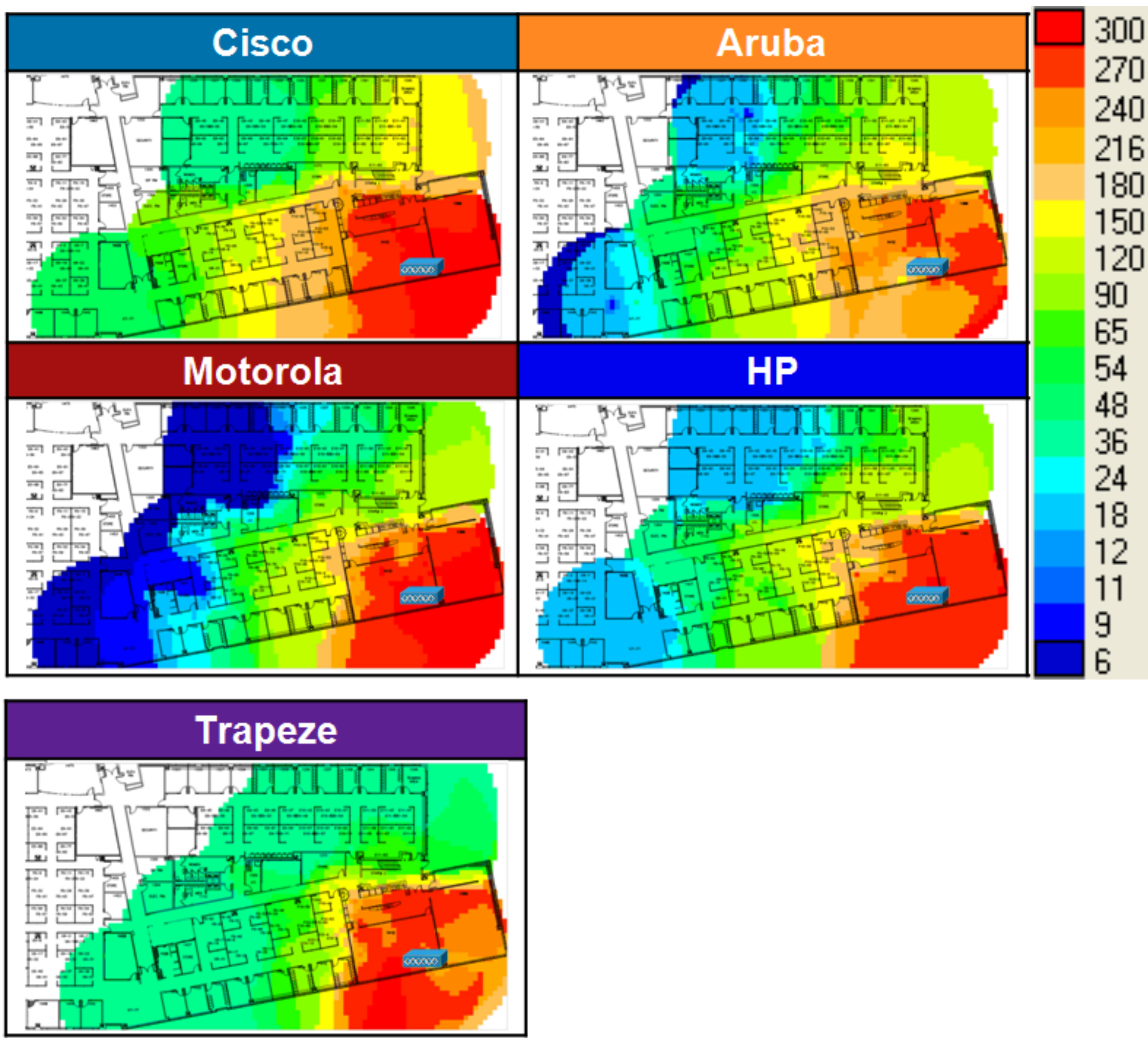


Performance Metrics: Coverage

While throughput may be the focus of many product comparisons, an equally important metric to consider is coverage. The objective of the Access Point Coverage test was to measure the consistency of RF coverage by an access point and the data rate at which clients connect. The quality of RF coverage is especially pertinent to voice and video applications as predictable and reliable coverage are essential to providing a wired-network-like user experience.

The Coverage test shows that Cisco's superior radio and antenna design provides better coverage across the test facility. In the visual depiction shown in Figure 3, "hotter" colors—red, yellow, and green—indicate higher data rates and thus, superior signal and coverage than "colder" colors (blue and teal).

Figure 3. 5-GHz Coverage Maps Gathered from Testing across the Entire Test Facility

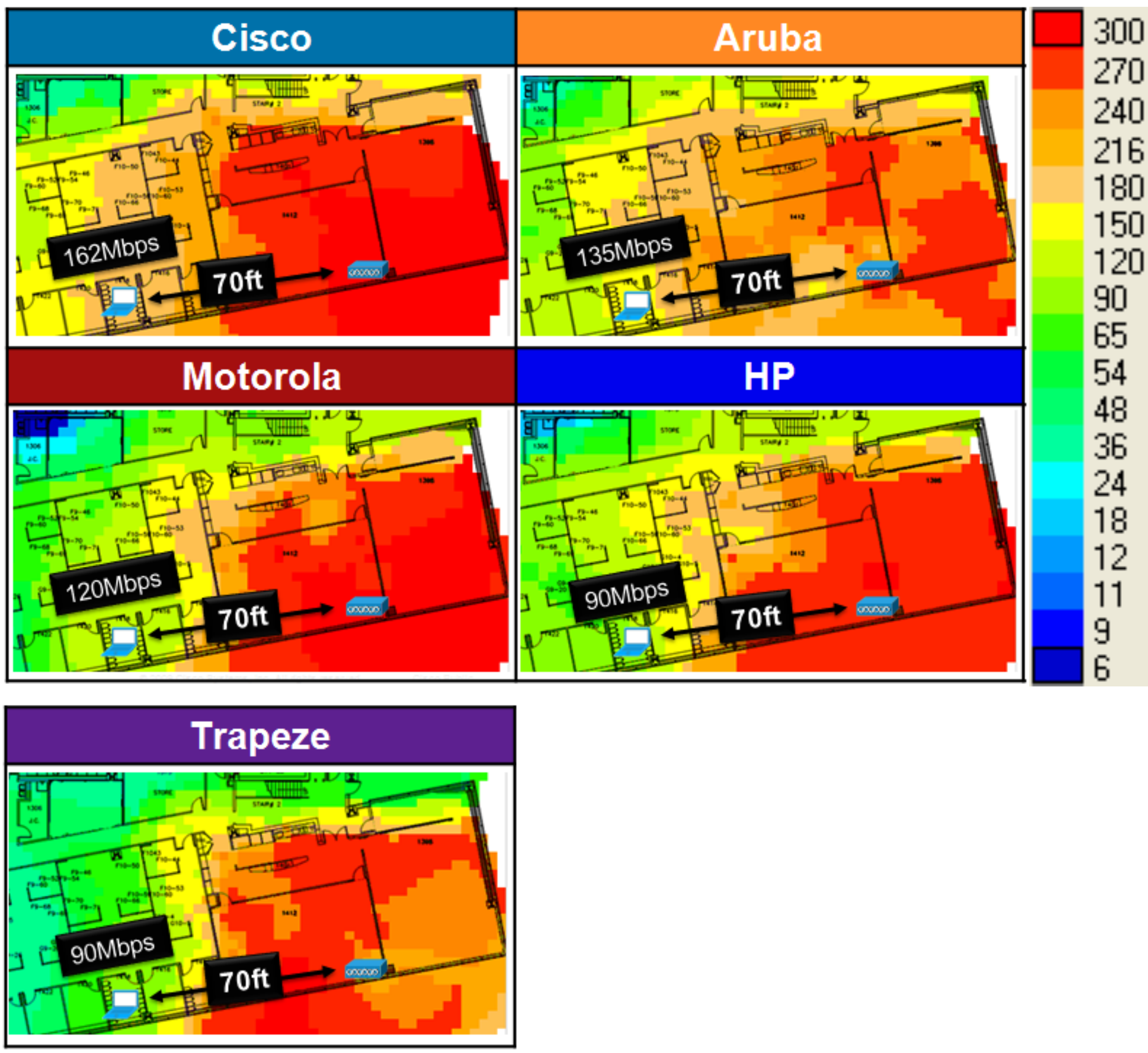


Critics may contend that the raw coverage provided by an access point is irrelevant as coverage can be easily improved by adding in additional access points. It is true that, to meet performance demands as more wireless clients join the network over time, organizations should deploy for capacity—many access points serving clients—rather than for coverage—that is, fewer access points serving clients. Cisco, for instance, recommends that access points be deployed at a distance where a client "hears" the access point at a signal strength of -65 to -70 dBm. Conventional

wisdom equates this guideline to deploying one access point for every 5000 square feet for data-only deployments, and one access point for every 3000 square feet to support voice and location. Essentially, this amounts to one access point every 50 to 70 linear feet, depending on the physical environment.

Even with this deployment recommendation in mind, Cisco still provides superior coverage compared to the competition. As shown in Figure 4, within a typical enterprise cell size, Cisco provides greater areas of higher data rates (marked in red, orange and yellow) than other vendors, which means application throughput will more often be higher with Cisco. Coverage provided by Cisco is also more even, allowing for real-time applications to achieve much more predictable performance as the client does not continually receive varying levels of performance from the access point. We can see also that even at the edge of a data cell (70 feet), a client will operate at a higher data rate when connected to a Cisco access point compared to the competition, resulting in higher individual client performance and increased capacity overall.

Figure 4. 5-GHz Coverage Map of a Typical Enterprise Cell Boundary

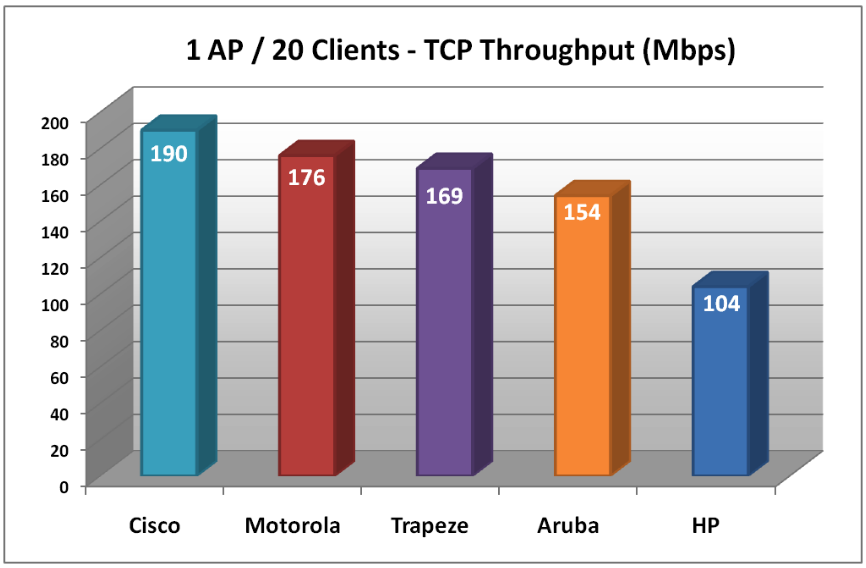


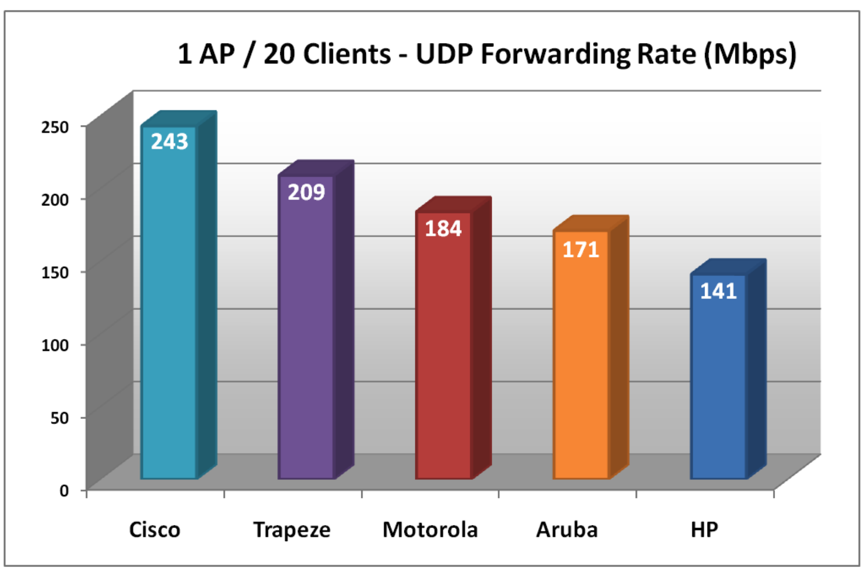
Performance Metrics: Capacity

The Capacity test is designed to determine how well an access point handles areas of high client density. Such areas include classrooms, cafes, and conference rooms where large numbers of people tend to congregate and use wireless. In this particular test, 20 clients were deployed in an area of cubicles and split between the 2.4-GHz and 5-GHz frequencies. Both UDP traffic, which simulates applications such as video, and TCP traffic, which simulates traffic such as email, web browsing, and business applications, was used to simulate how various applications (real-time and not real-time) would behave.

As Figure 5 shows, Cisco outperformed every competitor in capacity testing using both TCP and UDP traffic tests. With TCP tests, Cisco outperformed Motorola by 7.4 percent, Trapeze by 11 percent, Aruba by 19 percent, and HP by 45.3 percent. With UDP tests, the performance differences were even more substantial. Cisco outperformed Trapeze by 14 percent, Motorola by 24.3 percent, Aruba by 29.6 percent, and HP by nearly 42 percent. This testing indicates that Cisco is ideal for applications where there are large numbers of wireless clients on the network, particularly in enterprise offices, healthcare, and education.

Figure 5. Capacity Testing Results using TCP and UDP Traffic Types





Conclusion

Cisco's exhaustive testing of wireless performance provides clear, demonstrable differences between enterprise wireless LAN vendors. Cisco is the only vendor in the industry to develop and optimize its own wireless silicon and antenna designs. Cisco's expertise in RF design and in enterprise network engineering results in superior performance in the areas that matter most.

Cisco delivers industry-leading throughput over a variety of distances. Wireless clients can be located anywhere within an organization and with Cisco, they consistently achieve the high-speed performance needed to power enterprise applications. Cisco also delivers predominant coverage. This results in more consistent application performance, particularly in real-time applications such as video that are increasingly prevalent in the enterprise. Finally, Cisco provides superior capacity. This means that more devices can be supported over the wireless network and still achieve the performance necessary to drive enterprise applications.

Appendix

How We Tested Throughput vs. Distance

For this test, four locations were chosen with increasing linear distance from the access points and increasing obstacles in between the client and the access point. Each vendor's access point was mounted in the same physical location, and each client was tested in the same place and orientation to the access point at each testing location.

- Location A marked the best-case scenario for this test, with each client 30 feet from the access point and also within the same room so that there were no obstacles for the wireless signal between the access point and client to overcome.
- Location B was a bit more challenging, with the distance between the client and access point increased to 70 feet and with three walls in between the access point and the client.
- Location C was 120 feet away from the access point and included seven walls between the access point and the client.
- Location D was the most extreme test location, with a distance of 150 feet and 10 walls in between the client and the access point. At this particular test location, a client would have likely roamed to another access point in an enterprise deployment; however, the test location designed to test the limits in performance of each vendor's particular access point.

Traffic was generated using Ixia's Chariot application. A Dell Precision M2300, with an integrated Intel 5300 802.11n network interface card, was placed at each location. Traffic originated from a Windows 2003 server connected via Gigabit Ethernet.

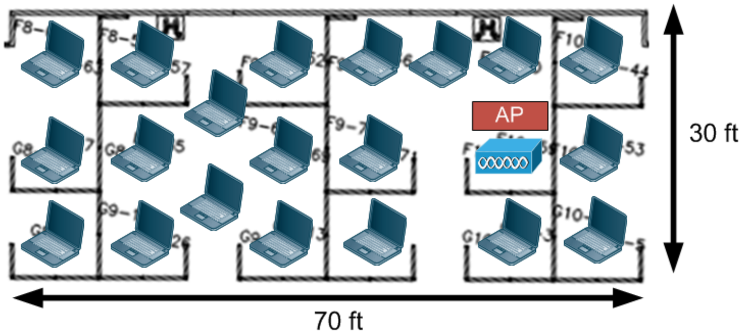
How We Tested Coverage

Coverage maps were gathered using AirMagnet Surveyor. Testing was conducted in "Iperf" mode, which continually sends data over the wireless network while recording the signal strength and data rate. The test laptop was mounted on a table with the table top 30 inches from the floor, a standard height for desks and other work spaces. Data from test points across the entire testing facility was gathered in both the 2.4- and 5-GHz ranges.

How We Tested Capacity

Capacity testing was conducted using 20 laptops with a mix of Intel 5300 and Intel 4965 802.11n wireless adapters. These clients were placed within cubicles in a 70-ft by 30-ft area (Figure 6).

Figure 6. Graphical Depiction of High Client Density Test Setup



A Veriwave WT-90 test chassis was connected via 4-port Gigabit channel (four 1-Gb Ethernet interfaces) to the Ethernet switch. Each wireless client was loaded with Veriwave WaveAgent, a lightweight executable that measures forwarding rate, throughput, and packet loss. Traffic between the wireless clients and the wired infrastructure was generated using the WT-90 chassis. Both TCP and UDP traffic types were used to simulate various types of applications, including large file transfers and video. Clients were split between the 2.4-GHz and 5-GHz frequencies; 12 clients operated in 5 GHz and 8 on 2.4 GHz. This split is indicative of the types of distribution seen in Cisco's own production wireless networks.

Each vendor's access point was mounted according to the vendor's own instructions and tested independently from one another.

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Printed in USA C11-558406-01 03/10