THE TOLLY GROUP

No. 207214 SEPTEMBER 2007

Test Summary

Meru Networks

Meru WLAN System vs. Cisco Systems WLAN Solution for Converged Voice and Data Wireless Networks

Premise: As VoIP over wireless LANs (WLANs) becomes more commonplace, enterprise network architects need to understand the impact on voice quality of running dozens of users across a single access point (AP). In order for VoIP over WLAN to be viable, voice quality has to remain acceptable even as loads increase and traditional data clients share the same WLAN.

Meru Networks commissioned The Tolly Group to evaluate the Meru Wireless LAN system which consists of a WLAN controller and one or more APs. For this test, engineers paired Meru's midsize enterprise-class controller, the MC3000, with its dual radio, 802.11g WLAN AP208 Access Point.

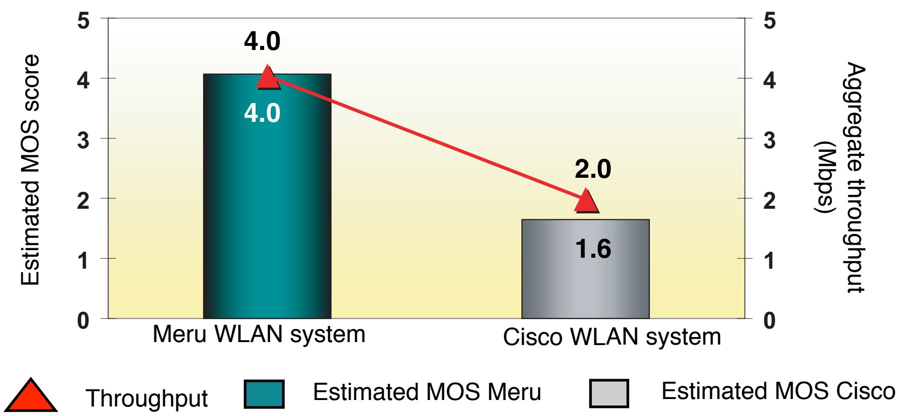
Engineers measured the voice quality and aggregate throughput in a single AP environment handling several dozen simultaneous live and simulated VoIP-over-WLAN sessions along with simulated traditional data applications. Tests focused on showing the benefits of Meru's over-the-air voice Quality-of-Service versus a Cisco Systems, Inc. 4402 WLAN controller and AP1242AG in high-density scenarios. Tests were conducted in July 2007.

Test Highlights

- Delivers toll quality (4.0 MOS) voice when handling 28 voice streams and 8 data streams simultaneously while Cisco solution delivers poor voice quality (1.6 MOS)
- Exhibits one-way latency of 17 ms for VoIP streams vs Cisco's 813 ms of latency for the network configuration described above
- Demonstrates fairness for balanced upstream and downstream data traffic, while Cisco supports 40% fewer transactions with unbalanced upstream and downstream traffic
- Achieves up to 4X greater bidirectional data throughput than Cisco WLAN solution when handling 30 data clients with 20 phones active

VoIP Call Quality and Aggregate Throughput of WLAN Systems over a Single Access Point (Bidirectional traffic)

as reported by Ixia IxChariot 4.2



Note: Offered load consisted of three VoIP conversations, 22 simulated VoIP sessions and eight data clients. Estimated MOS scores range from 1 to 4.5. The aggregate throughput counted the bandwidth usage by simulated VoIP and data, but did not include bandwidth consumed by six live phones.

Source: The Tolly Group, July 2007

Figure 1

Executive Summary

The Meru WLAN system demonstrated that it can deliver toll-quality VoIP even when handling 28 VoIP users and 8 data users communicating simultaneously across a single AP.

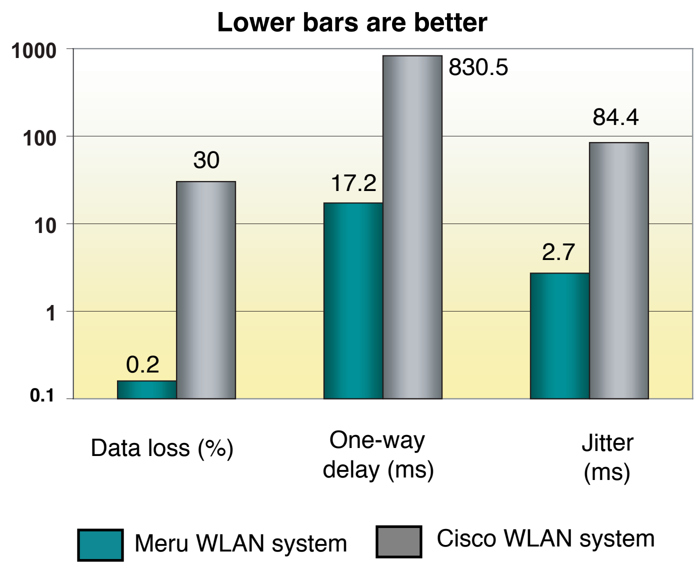
Like the first wired Ethernet networks, WLANs are shared environments — the available bandwidth must be spread across all users. And, like early Ethernet, performance can degrade when multiple users attempt to communicate simultaneously.

Such congestion situations can have a particularly negative impact on applications like VoIP that are sensitive to both delay and packet loss.

A shared access environment performs best with both fewer users and fewer large packets — as this reduces the frequency that users have to contend for the bandwidth. Unfortunately, VoIP traffic consists of many smaller packets. Thus, bandwidth efficiency can plummet in a WLAN with even just a modest number of users, when the overall number of users increases.

These tests illustrate that Meru's over-the-air QoS can manage VoIP and data traffic in such a way as to deliver toll-quality voice in a multi-user environment, where Cisco's solution fails to deliver acceptable quality for any of the VoIP users.

Data Loss, One-Way Delay, and Jitter of WLAN System over a Single Access Point
as reported by Ixia IxChariot 4.2



Note: The WLAN supported 22 VoIP clients and eight data clients per AP with six additional phones running in background using 1.15 Mbps of bandwidth,theoretically. Each VoIP stream used 192 Kbps bandwidth under normal conditions.

Source: The Tolly Group, August 2007

Figure 2

Single AP Converged Voice and Data

With 28 VoIP users and eight data users across the Meru solution, the simulated VoIP sessions achieved an estimated toll-quality MOS score of 4.07, while Cisco's MOS of 1.65 represents a level that would barely be understandable and is not recommended for business usage (See Figure 1. See Figure 5 for detail quality ratings of estimated MOS scores.)

In the same test, engineers also initiated live conversations using Ascom Wi-Fi phones and made a subjective evaluation of the call quality. Engineers noted that all six Ascom phone calls across the Meru system exhibited good sound quality, but with Cisco, the phone call qualities were all unacceptable. When engineers added two more Ascom phones to the test bed, engineers did not experience noticeable call quality degradation on the Meru system, but with Cisco, phone calls had unacceptable quality.

With VoIP traffic requiring low delay, Meru's measurement of 17 ms is well within the acceptable range. Cisco's latency of 830 ms, though, means almost one second of end-to-end delay for each voice packet considering voice packet processing delay and is more than two times the acceptable level. According to ITU-T Recommendation G.114, an end-to-end delay of 0 to 150 ms is acceptable for most applications but any delay above 400 ms is unacceptable for general network planning purposes.

The results are also reflected in the throughput numbers. A system handling all the offered voice and data traffic would show aggregate throughput of some 4 Mbps. (This throughput does not count the bandwidth used by the

Ascom Wi-Fi phones.) Meru's throughput measurement reflects the fact that it is handling all the VoIP traffic properly. With Cisco, however, the aggregate through-put of only 2 Mbps illustrates that it is dropping a significant amount of traffic — some 30%. (See Figure 2.)

The test also proves that the Meru system provides traffic fairness for upstream and downstream data traffic by recording 17 transactions for both directions, while the Cisco solution supported 40 % less traffic for upstream by recording 15 and 9 transactions for downstream and upstream, respectively.

LARGE-SCALE VOICE AND DATA

This test measured application data throughput for 30 simultaneous data streams using IxChariot. Throughput results were similar to the single AP converged voice/data scenario results when the data client load was increased to 30 and 20 Wi-Fi phones. Results show that the Meru system handled 4.1 Mbps of data traffic with 20 live VoIP streams active over an 802.11g channel simultaneously, but Cisco served only 1.1 Mbps of data in the same scenario.

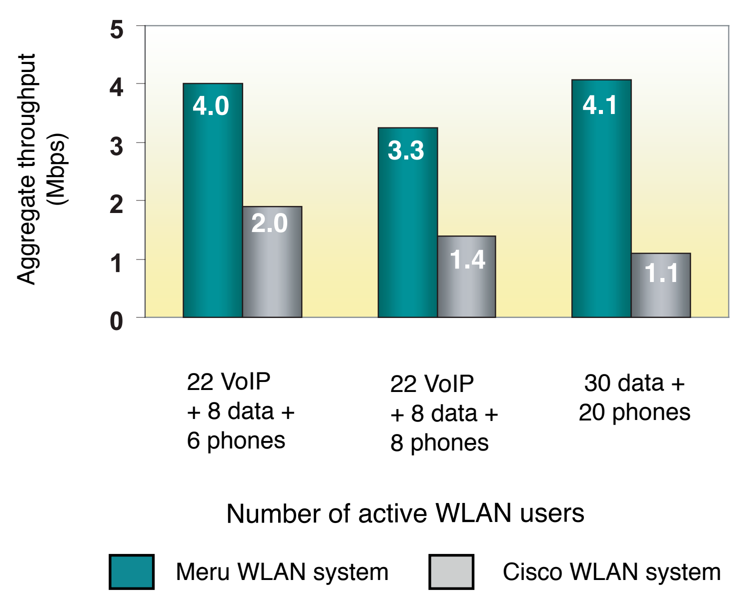
While VoIP call-quality measurements in this test were subjective, engineers experienced good voice quality for all 20 Ascom Wi-Fi phones for Meru's test, but for Cisco's test, the voice quality was unacceptable.

(Note: Upstream means traffic directed from the WLAN client across the AP to the controller; downstream means traffic directed from controller to the WLAN client.)

TEST SETUP & METHODOLOGY

Aggregate Application Throughput across WLAN System with Different Number of WLAN Users

as reported by Ixia IxChariot 4.2



Source: The Tolly Group, August 2007

Figure 3

Meru Networks

Meru Wireless LAN system

Voice Quality over MC3000 WLAN Controller and AP208 Access Point

Product Specifications

Vendor-supplied information not necessarily verified by The Tolly Group

MC 3000

- Centralized control for easy management and configuration
- Effortless AP deployment with no need for channel planning or complex site surveys
- Toll quality voice even in dense client environments
- Seamless client mobility across subnets
- Multi layered security including standard WPA and 802.11i security
- Dimensions - 1.7-in (H) * 17 in (W) *16.2 in (D)
- Power - 110VAC/220 VAC Auto ranging - 300 w
- Interfaces - Dual 10/100/1000s
- APs supported max MTU - Up to 150.

AP 200

- Zero configuration setup using plug and play architecture
- Best 802.11g performance in mixed 802.11b/g environment
- Exceptional wireless VoIP performance using Air Traffic Control technology
- Higher user density environment support
- Multi layered security including standard WPA and 802.11i security
- Dimensions: 1.5 in (H) *6.25 in (W) *8.25 in (D)
- Interfaces - Dual radios support any combination of 802.11a, 802.11b, 802.11g
- Wireless Media Access - Wi-Fi compliant 802.11 MAC standard.

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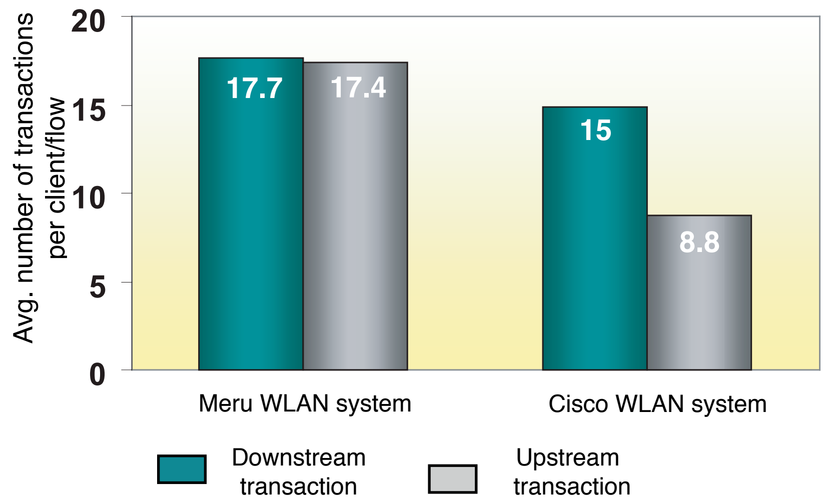
Tolly Group engineers tested the Meru Networks WLAN solution against the Cisco WLAN solution. The Meru solution included an MC3000 WLAN controller and AP208 running software version 3.3 GA (3.3-146). The Cisco solution included a Cisco 4402 WLAN controller and Cisco Aironet 1242AG (LWAPP) AP running software version 4.0.217.0. Both solutions were configured to run in 802.11g-only mode. Throughout the testing, the Meru and Cisco solutions used the same configurations except that the Cisco used Wi-Fi Multi-media (WMM) while Meru used its Air Traffic Control™ technology. The Cisco user guide recommends that the WLAN is configured for WMM and the Platinum QoS level for voice. Engineers configured the Silver QoS level for data.

All tests were conducted in an RF chamber on channel 6 and WildPackets AiroPeek NX WLAN analyzer was used to check the air prior to and during the test. Engineers tuned the transmit power levels to optimize it for the RF chamber.

Engineers used Ixia IxChariot 4.2 to generate multiple simulated data/VoIP streams over WLAN and to measure the performance metrics such as estimated MOS, throughput, one-way network latency and jitter. Engineers used IxChariot's "Throughput" script with one modification (send_buffer_size = 1416 bytes) for data-oriented application simulation and engineers used its VoIP module to generate and analyze the simulated VoIP streams. All the data and VoIP streams were generated for both directions.

Traffic Fairness as a Factor of Transactions Processed over Upstream and Downstream Links

as reported by Ixia IxChariot



Note: A single transaction represents the successful transfer of a 100 kb file over TCP. The WLAN system supported 22 VoIP clients and eight data clients per AP with six additional phones running in background.

Source: The Tolly Group, August 2007

Figure 4

In the test bed, the AP was connected via a Fast Ethernet connection to the Layer 2 Gigabit Ethernet switch, which in turn was connected to the WLAN controller via a Gigabit Ethernet connection. The IxChariot console and a wired backend IxChariot endpoint were connected to the Layer 2 switch. A DHCP server and Brekeke OnDo SIP server version 1.5.3.0/172 were available via the Layer 2 switch to set up the VoIP calls from Ascom i75 Wi-Fi phones (Ver 1.2.19). All VoIP streams including the simulated VoIP streams from IxChariot used a G.711 codec with 30 ms voice payload size and 60 ms of jitter buffer size.

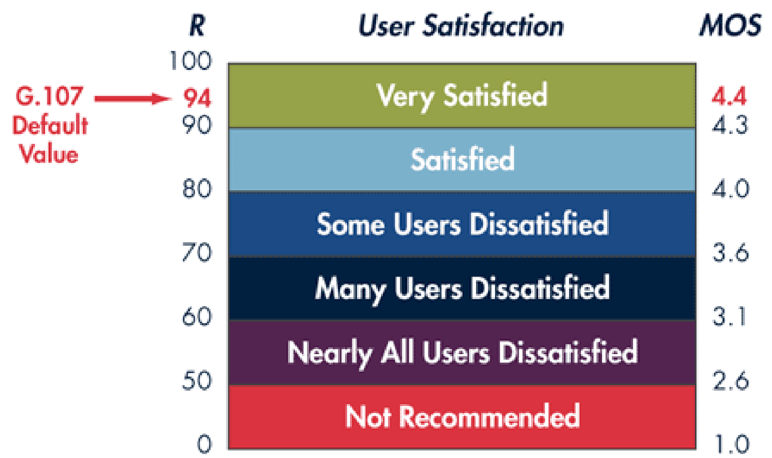
In total, 30 laptops running IxChariot endpoint software were connected to the AP wirelessly via 802.11g with WPA2-PSK security. The 30 laptops were equipped with Cisco 802.11a/b/g CardBus Adapters (CB21AG) running driver version 3.6.0.61 and Aironet Device Utility version 3.6.0.122 with CCXv5.

All tests were run for 60 seconds three times and the results were averaged to obtain the results.

For eight simulated data clients + 22 simulated VoIP clients + six phones tested, engineers used six Ascom Wi-Fi phones to establish three active VoWLAN connections. Engineers used the IxChariot to simulate eight data and 22 VoIP connections to the wired backend server. A total of eight upstream/eight downstream data flows and 22 upstream/22 downstream VoIP flows were created for this test. Engineers measured estimated MOS score, throughput, delay, jitter and data loss. Engineers also calculated the number of data transactions for both upstream and downstream to analyze the traffic fairness for upstream and downstream. During the test, engineers talked continuously to consume bandwidth and to ensure silence suppression features were not enabled, if available.

For 30 simulated data clients + 20 phones test, engineers used 20 Ascom Wi-Fi phones to establish 10 active VoWLAN connections. Engineers used the IxChariot to simulate 30 data connections to the wired backend server. A total of 30 upstream/30 downstream data flows were created to measure the application throughput. Engineers kept talking over the 20 Wi-Fi phones to maintain the connections active during the test.

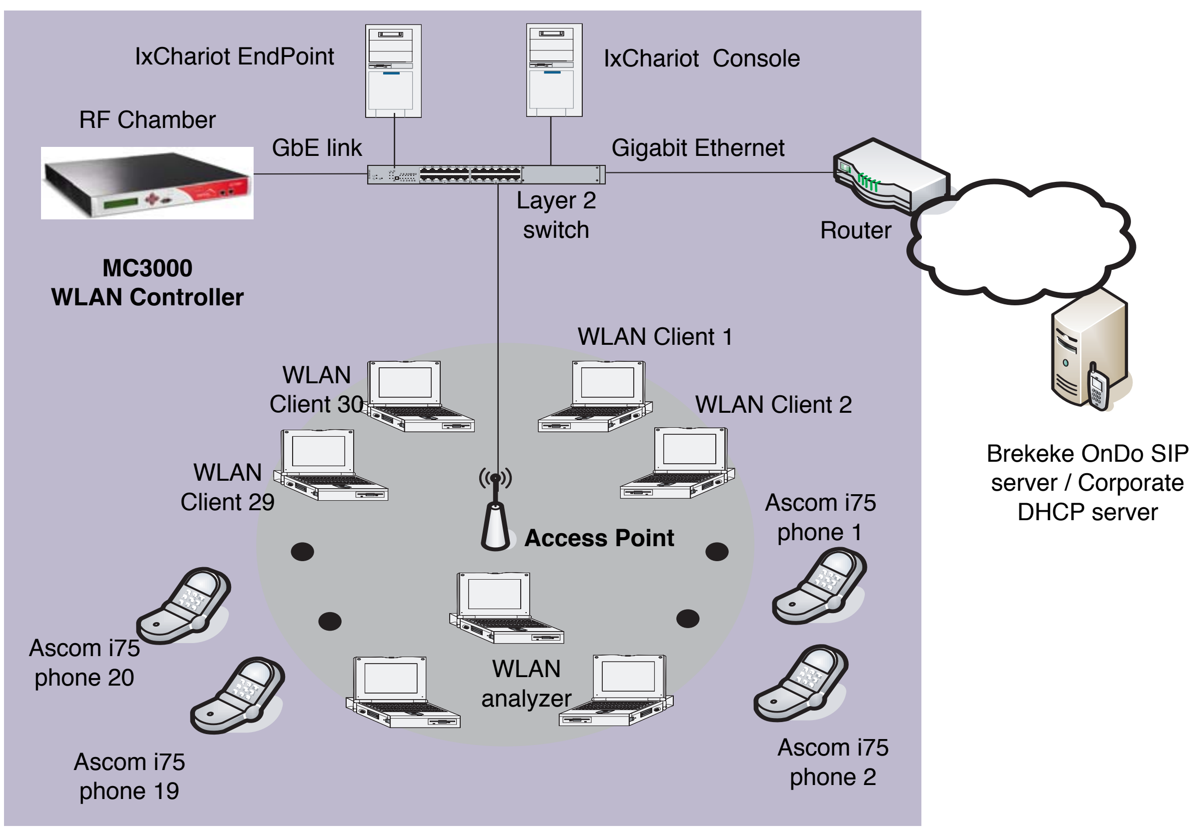
Voice Quality Rating of Estimated MOS Scores



Source: Ixia, 2004

Figure 5

Test Bed Diagram



Source: The Tolly Group, August 2007

Figure 6

Fair Testing Charter ™ and Interaction with Competitors

In accordance with The Tolly Group's process, competitors were contacted and invited to participate in the test — to review the test plans, the product levels and configurations of their products and to review and comment on their results. For more information on this process, see: http://www.Tolly.com/FTC.aspx.

Cisco Systems, Inc. was contacted on June 19, 2007 and invited to offer a higher level of technical support for this project. Representatives from Cisco did not respond to the invitation.

The Tolly Group is a leading global provider of third-party validation services for vendors of IT products, components and services.

The company is based in Boca Raton, FL and can be reached by phone at (561) 391-5610, or via the Internet at:
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Test Tool Acknowledgment

Vendor	Product	Web URL:
Ixia	Ixia IxChariot Ver 4.2	http://www.ixiacom.com
WildPackets, Inc.	AiroPeek NX	http://www.wildpackets.com

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