THE TOLLY GROUP

No. 203141 November 2003

Intel Corp.

Intel® IXP425/IXP420 Network Processors

Performance Analysis of 802.11 Broadband Routers and Access Points

Test Summary

Premise: *The market for small office/home office (SOHO) and small/medium business (SMB) is inundated with a range of broadband wireless gateway products at highly competitive prices. These devices are equipped with features that utilize the advantages of present-day wireless technology and state-of-the-art network processor capabilities. It is important for consumers to know the performance characteristics of these SOHO routers/access points in order to better understand these products' value propositions and to aid in making informed purchasing decisions.*

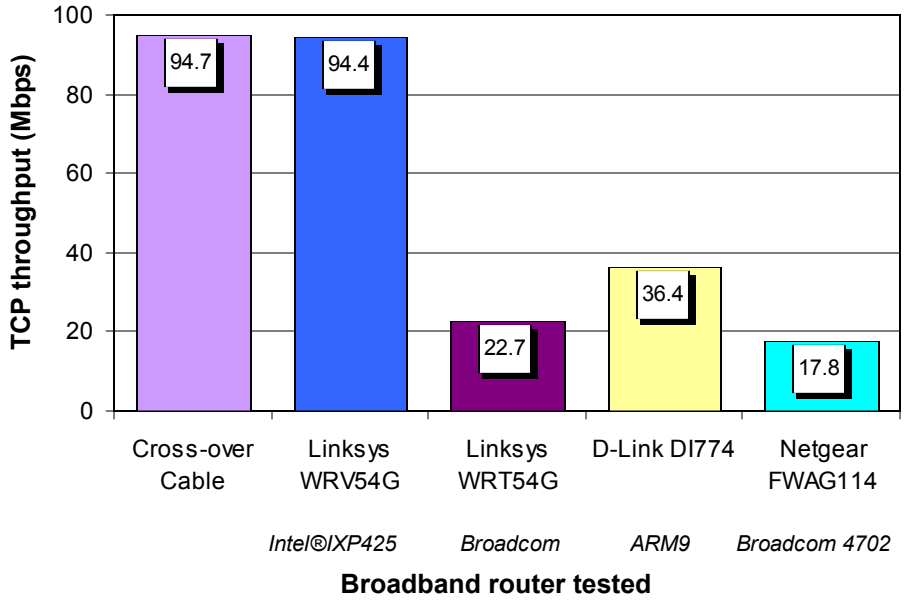
Intel Corp. commissioned The Tolly Group to benchmark the performance of several commercially available 802.11 wireless gateways (wireless broadband routers and access points) that utilize the Intel IXP425 and the Intel IXP420 network processors, and compare the performance of those devices against other generally available products based upon rival chipsets.

Tolly Group engineers used the industry-accepted NetIQ Chariot's "throughput.scr" script to determine the aggregate throughput of the devices under test. Throughput was

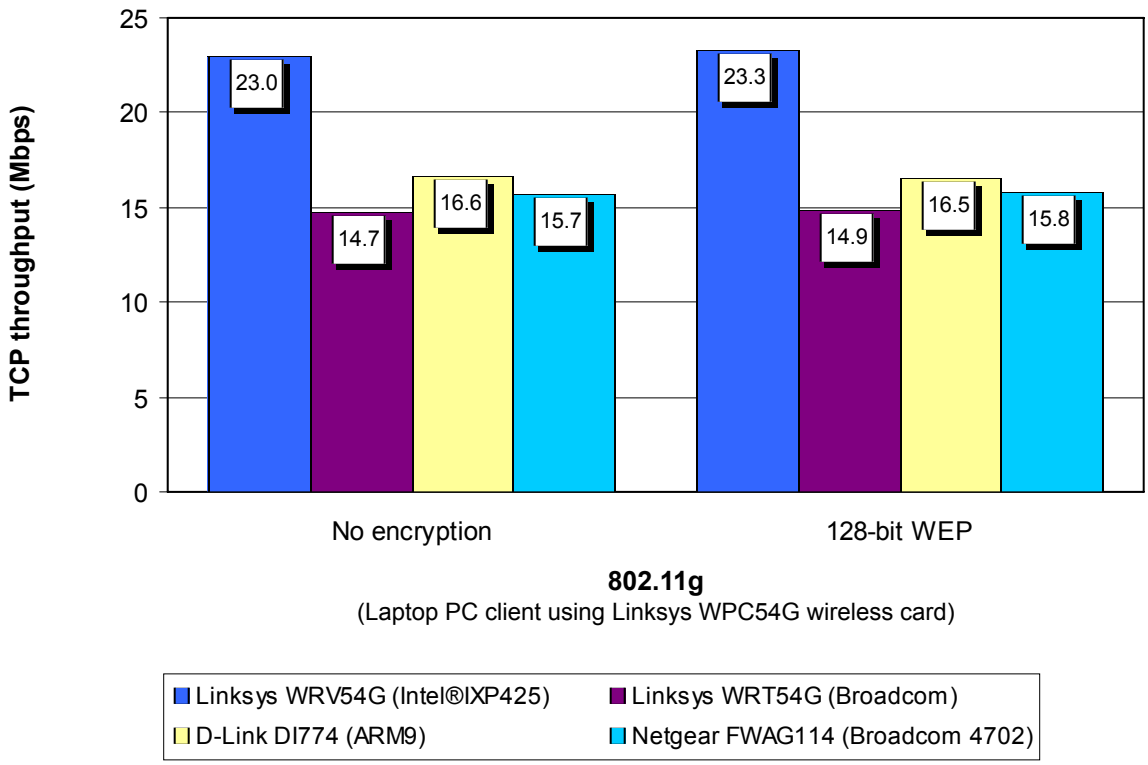
Test Highlights

- Intel IXP425-based Linksys WRV54G in most cases delivers more than four times the wired throughput of other broadband routers tested in unidirectional LAN-to-WAN TCP throughput tests
- Intel IXP425-based Linksys WRV54G achieves from 41% to 55% greater throughput than the other devices tested in unidirectional WLAN-to-WAN test
- Intel IXP425-based Linksys WRV54G performs almost 21% better than the Broadcom-based Linksys WRT54G router while delivering WEP-encrypted data in WLAN-to-WLAN testing
- Intel IXP420-based D-Link DWL 7000AP outperforms other APs tested in 128-bit WEP bidirectional WLAN-to-LAN TCP tests

Unidirectional LAN-to-WAN Wired TCP Throughput of Wireless Broadband Routers
As reported by NetIQ Chariot



Source: The Tolly Group, November 2003 *Figure 1*

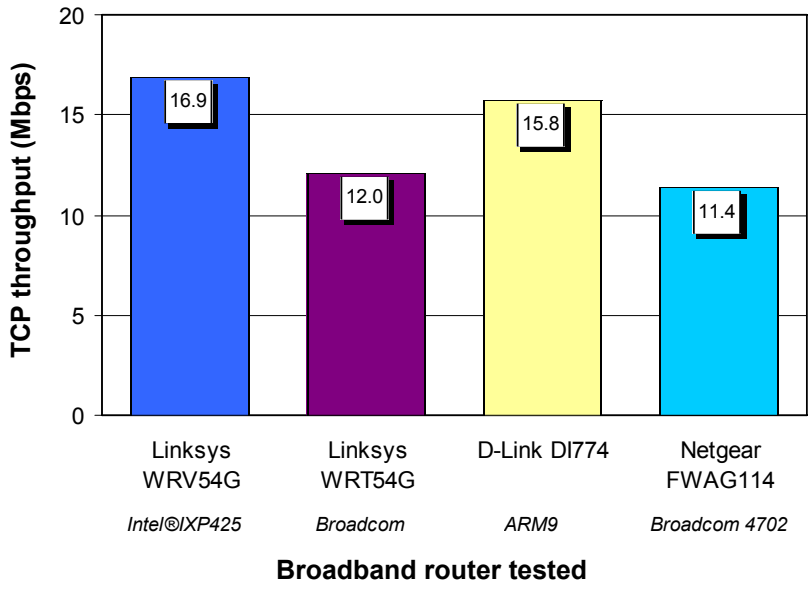


Source: The Tolly Group, November 2003

Figure 2

recorded in two different scenarios: (1) unidirectional WLAN-to-WAN traffic, where the Endpoint 1 (client) in the wireless network sends data to Endpoint 2 (client), which is wired to the WAN port in the tested device, and (2) bidirectional WLAN-to-WLAN traffic, where the data flows in both directions between Endpoint 1 and Endpoint 2 where both are wireless clients. Engineers measured throughput for devices supporting 802.11b, 802.11g and mixed mode (802.11b/g) wireless standards. Extensive testing was conducted between September 2003 and November 2003.

The test scenarios are indicative



Source: The Tolly Group, November 2003

Figure 3

of those encountered by wireless laptop PC users surfing the Web with a connection to a broadband wireless router connected to a wired infrastructure. Moreover, test scenarios also show how wired PCs connected to the router do not hit any bottlenecks when utilizing Web services.

Test results show that the wireless gateways based upon the Intel IXP425 and IXP420, respectively, either outperform competitive products in most scenarios, or provide performance on par with other devices.

Results

Broadband Router Throughput

On the broadband router side, The Tolly Group tested four products, starting with an Intel IXP425-based Linksys WRV54G. Other broadband routers tested were: D-Link DI774 (using an ARM9 chipset), a Linksys WRT54G (using an unknown Broadcom chipset) and a Netgear FWAG114 (using a Broadcom BCM 4702 chipset). All four devices were subjected to three TCP throughput tests:

- Unidirectional LAN-to-WAN (baseline between two computers connected via a crossover cable)
- Unidirectional WLAN-to-WAN (testing 802.11g with no encryption, 802.11g with 128-bit WEP, and 802.11g with WPA and a pre-shared key with TKIP)
- Bidirectional WLAN-to-WLAN (testing 802.11g with no encryption, 802.11g with 128-bit WEP, 802.11b/g with no encryption and 802.11b/g with 128-bit WEP)

For the baseline unidirectional LAN-to-WAN TCP throughput test, the Linksys WRV54G (with the embedded Intel IXP425) delivered 94.4 Mbps of throughput to a wired client over a traditional 100-Mbps Fast Ethernet link, more than five times the throughput of the Netgear FWAG114 and 2.5 times the throughput of the D-Link DI774, the closest competitive device. (See Figure 1.)

For the unidirectional 802.11g WLAN-to-WAN TCP throughput test, results tracked almost identically between the baseline performance test and the 128-bit WEP test. Here, again, the Intel IXP425-based Linksys WRV54G outperformed all other products. In the 128-bit WEP scenario, the WRV54G delivered 23.3 Mbps of aggregate TCP throughput, which represents anywhere from 41% to 56% greater throughput than the other devices tested. (See Figure 2.) It is also interesting to note that the similarity between the baseline test results and the 128-bit WEP results shows that the WEP encryption does not adversely impact bandwidth performance.

Engineers also tested the devices in the unidirectional 802.11g WLAN-to-WAN test scenario using the recently introduced Wi-Fi Protected

Intel Corp.

IXP425/IXP420 Network Processors

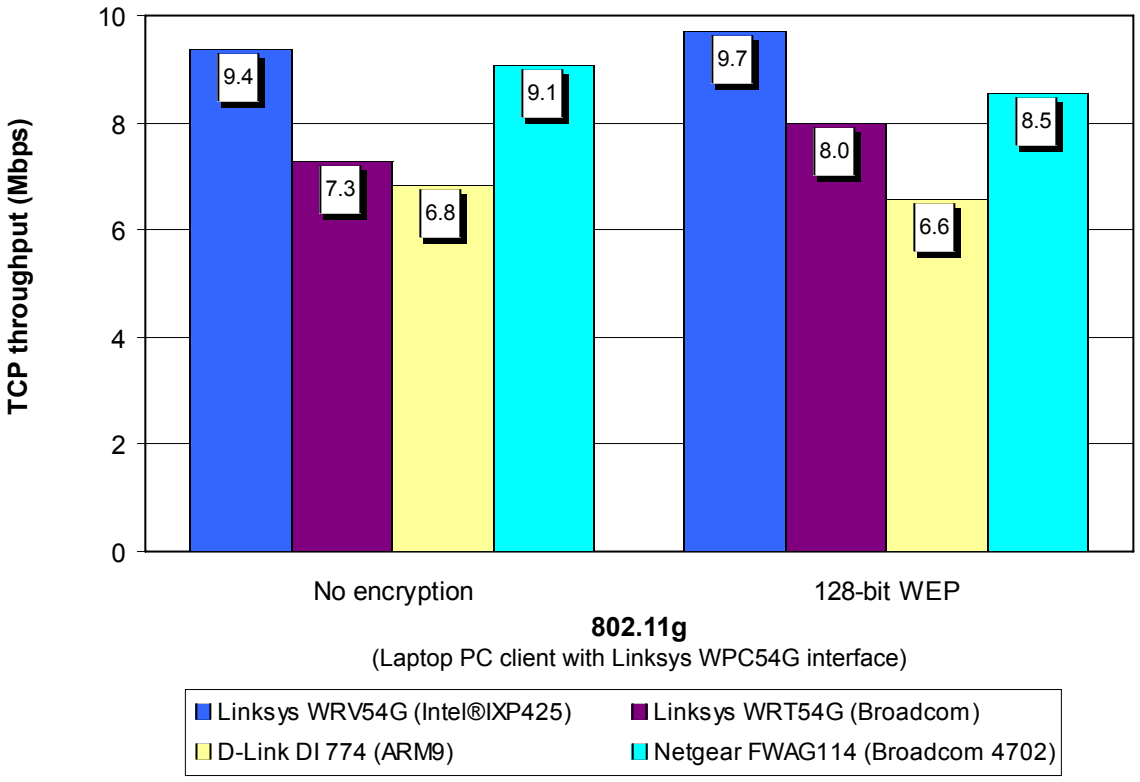
TCP Throughput

Intel Corp.
IXP425 Network Processor
Product Specifications*

- Member of the IXP4XX network processor product line for enterprise, small-to-medium enterprise (SME), residential and other networking applications
- Intel® XScale® RISC core at up to 533 MHz provides headroom for customer-defined applications
- Integrated hardware acceleration of popular cryptography algorithms (SHA-1, MD5, DES, 3DES, AES) for secure applications
- IPsec-enabled Network Processor Engine (NPE) to accelerate cryptography and authentication algorithms
- DSP software library on the Intel XScale core supports two to four voice channels and reduces system cost
- Two high-speed serial (HSS) ports for VoIP SLIC/CODEC or T1/E1
- Two integrated 10/100 Base-T Ethernet MACs with MII interface for design flexibility and cost-effective wire-speed performance
- UTOPIA 2 interface with multiple ADSL/G.SHDSL or VDSL support
- 33/66-MHz PCI v2.2 host and option interface for glueless connection of up to four devices
- Low system power consumption (1.0 to 1.5 watt typical)

For more information contact your Intel sales representative:
URL: http://intel.com/design/network/products/npfamily/ixp425.htm

**Vendor-supplied information not verified by The Tolly Group*



Source: The Tolly Group, November

Figure 4

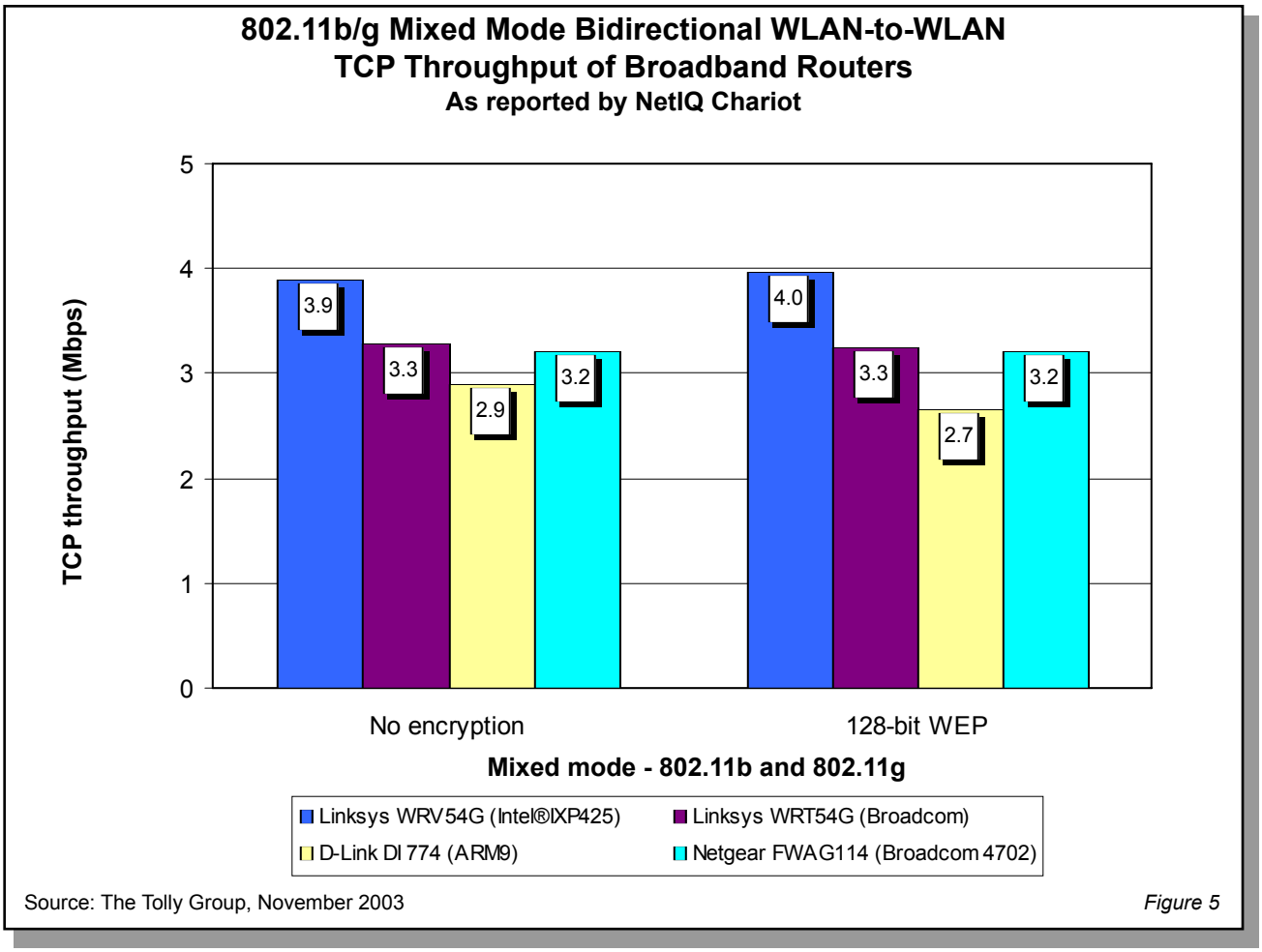
Access (WPA), a standards-based security mechanism that eliminates most 802.11 security issues. Maximum throughput for the Intel IXP425-based Linksys WRV54G was 16.9 Mbps, or about 7% higher than the D-Link DI774. Both Broadcom-based devices exhibited lower throughput values with the least value observed in the case of the Netgear FWAG114; the Intel IXP-based router delivered 48% greater throughput. (See Figure 3.)

In an 802.11g bidirectional WLAN-to-WLAN test, the Linksys WRV54G with the Intel® IXP425 performed about 18% better with a rate of 9.7 Mbps than the Broadcom-based Linksys WRT54G device while delivering WEP-encrypted data. (See Figure 4.) For non-encrypted throughput, the score difference was about 29% for these devices, with throughput of 9.4 Mbps and 7.3 Mbps respectively. Even in the mixed mode test (802.11b/g), the Linksys WRV54G offered anywhere from an 18% to 48% performance gain over other devices tested. (See Figure 5.)

Access Point Throughput

The Tolly Group tested four products, starting with an Intel IXP420-based D-Link DWL 7000AP access point. Other access points tested were: 3Com LAN AP8200, a Cisco Aironet 1220 (using an IBM Power PC 405) and a Broadcom-based Linksys WAP54G. All four devices were subjected to a bidirectional 802.11b WLAN-to-LAN TCP throughput test.

Here, the D-Link DWL 7000AP with the Intel® IXP420 performed on par with the Cisco Aironet 1200 series (1220) access point in delivering the 802.11b non-encrypted traffic to an 802.11b Centrino client with rates of 5.1 Mbps and 5.3 Mbps respectively. In the case of 128-bit WEP-encrypted traffic, Intel IXP420-based DWL 7000AP outperformed the others with a data rate of 5.4 Mbps. However, the performance observed for



Source: The Tolly Group, November 2003

Figure 5

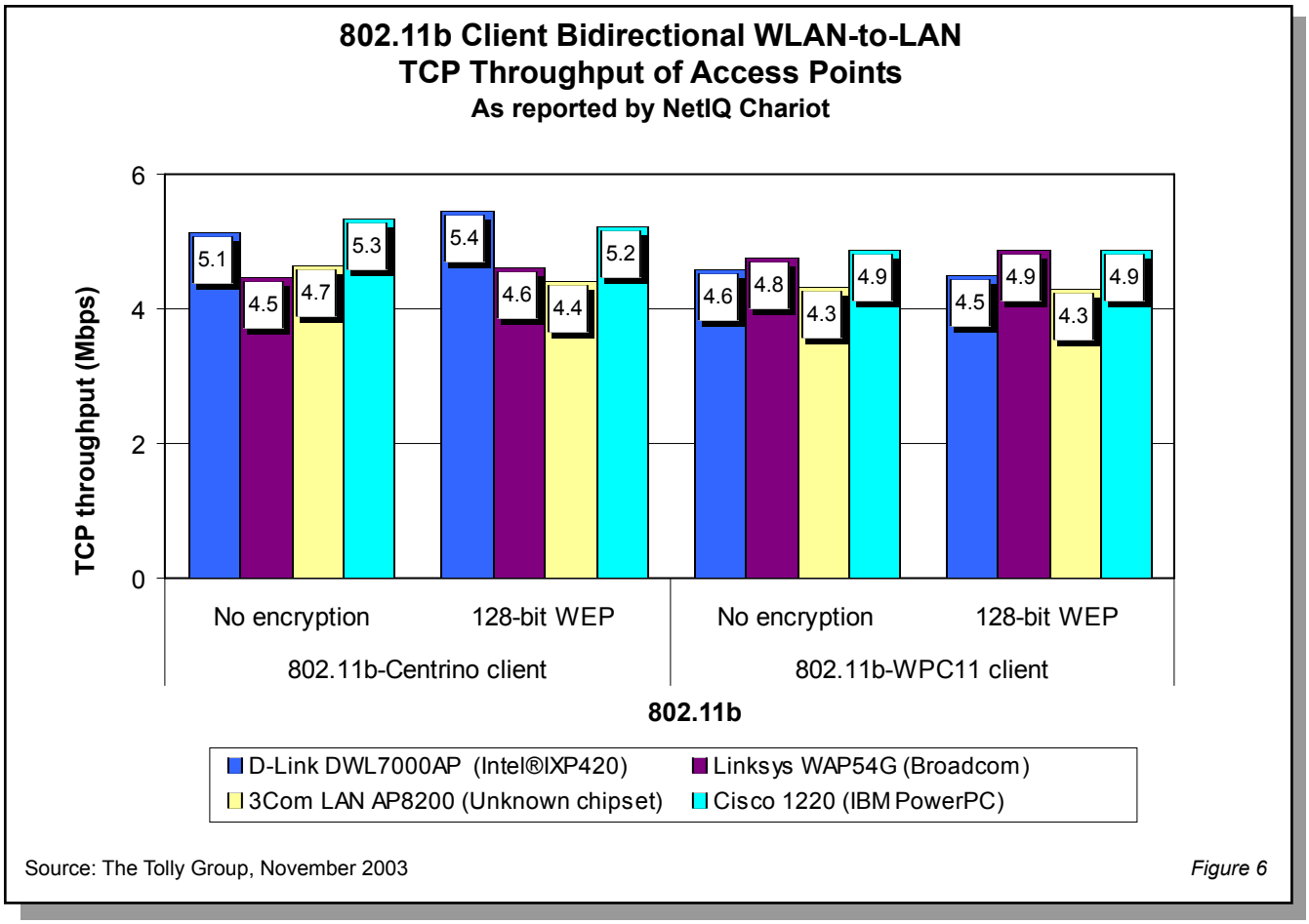
the D-Link device was not on par with that of the Cisco device with the 802.11b access through the Linksys WPC11 card. (See Figure 6.)

When the WPC11 client was used, the D-Link DWL 7000AP delivered competitive 802.11b throughput of 4.6 Mbps with no encryption and 4.5 Mbps with 128-bit WEP encryption, again proving there is no bandwidth tax paid for using WEP encryption. Moreover the D-Link DWL 7000AP is competitive with the other devices tested.

Analysis

TCP throughput is a measure of how fast the data moves between the clients using the TCP protocol. Under identical test conditions with no influence from any environmental variables, among other components (WLAN chipset and associated driver) the network processor has the greatest possibility of influencing the throughput performance of the wireless gateways.

The TCP throughput observed for two laptops connected through a crossover cable was 94.7 Mbps for unidirectional traffic over a 100-Mbps Fast Ethernet link. Inserting the router in between these laptops with a unidirectional LAN-to-WAN traffic configuration yielded maximum TCP throughput of 94.4 Mbps for the Intel® IXP425-based Linksys WRV54G. This is indicative of the bandwidth a wired client would experience. This illustrated that there was no performance degradation sourced from the Linksys WRV54G router, whereas the rest of the devices under test in this category compromised the data transfer capability significantly. The Linksys WRV54G in this scenario outperformed the ARM9-based D-Link DI774 by about 160%, the Broadcom-based Linksys WRT54G by 316% and Netgear FWAG114 by 430%. Test results show that vendors are implementing the same idea in different ways, and this is reflected with the Linksys



Source: The Tolly Group, November 2003

Figure 6

and Netgear routers with the Broadcom processor.

In the unidirectional WLAN-to-WAN throughput test, the Linksys WRV54G with the Intel network processor IXP425 clearly was able to transfer more encrypted and unencrypted data at rates of 23.3 and 23 Mbps respectively. This was 56% more throughput in both cases compared to the Linksys WRT54G with the Broadcom processor. (This scenario demonstrates the bandwidth available to a wireless user connected to the Internet or other wide area service.) The other Broadcom-based box by Netgear performed slightly better, but trailed behind the ARM9-based D-Link gear with a TCP throughput of 16.6 Mbps – with encryption disabled. One interesting observation from these test results is that there is no throughput degradation with 128-bit WEP encryption – in fact a slight increase was observed. Because WEP is a mature encryption technique, it is an efficient way to encrypt data.

The Intel IXP425-based broadband router demonstrated a performance edge even in the WPA test. Maximum throughput was observed with the Intel IXP-based device with a value of 16.9 Mbps, about 7% higher than that of the D-Link box. Both Broadcom-based devices showed lesser throughput values with the least value observed in the case of the Netgear box, since the Intel IXP-based router achieved 48% greater throughput. Because WPA is a highly processor-intensive encryption technique, network processors have a greater potential to facilitate higher performance.

Test Configuration and Methodology

For performance tests, The Tolly Group tested an Intel IXP425-based Linksys WRV54G broadband router. Other broadband routers tested were: D-Link DI774 (using an ARM9 chipset), a Linksys WRT54G (using a Broadcom chipset) and a

Netgear FWAG114 (using a Broadcom BCM 4702 chipset).

On the access point side, The Tolly Group tested an Intel IXP420-based D-Link DWL 7000AP access point. Other access points tested were: 3Com LAN AP8200, a Cisco Aironet 1220 (using an IBM Power PC 405) and a Broadcom-based Linksys WAP54G. During all tests, firewall functionality in the devices under test was disabled.

All results discussed in this section are averages derived from three iterations per test scenario. Results from each of the three test iterations were then averaged.

For the unidirectional LAN throughput tests, the test bed consisted of one laptop PC wired to the broadband router's LAN side and a second laptop PC wired to the WAN side of the router. Both the laptops had NetIQ's Chariot Endpoint software agent running, and one of the laptops also served as the Chariot console that managed the performance testing.

For the unidirectional WLAN-to-WAN TCP throughput test, the test bed consisted of one laptop PC wired to the WAN side of the broadband router and the other maintained an 802.11wireless session to the broadband router tested. Both the laptop PCs had NetIQ's Chariot Endpoint software running and a Dell Computer Corp. PC connected to the LAN side of the router served as the Chariot console that managed the performance testing.

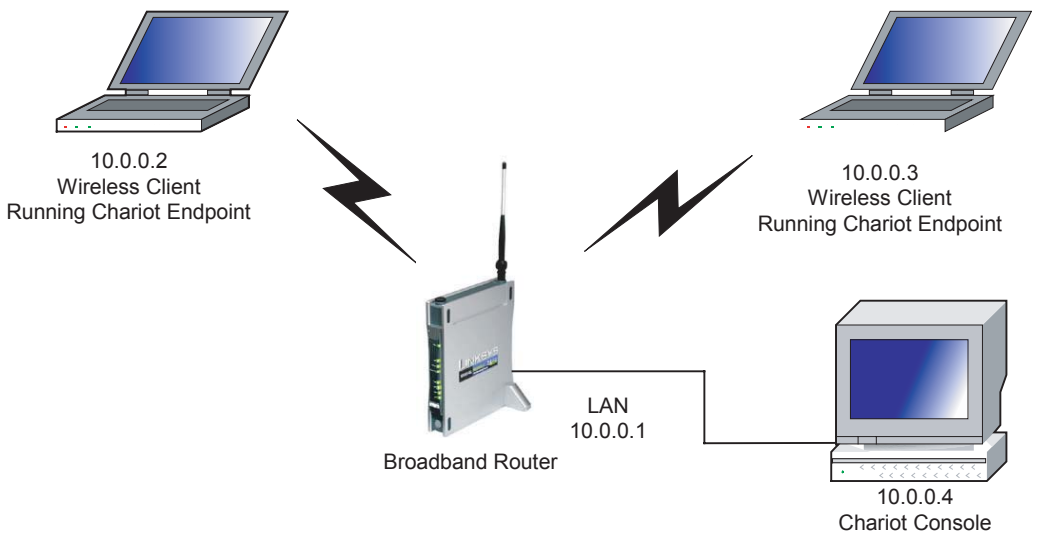
In the bidirectional WLAN-to-WLAN TCP throughput test, both laptop PCs connected to the broadband router through wireless sessions. Both the laptops had NetIQ's Endpoint software running, and a Dell Computer PC connected to the LAN side of the router served as the Chariot console that managed the performance testing.

In the bidirectional WLAN-to-LAN TCP throughput test was conducted with one laptop PC wired to the LAN side of the AP and the other connected through a wireless session. Both the laptops had NetIQ's Endpoint software running, and a Dell PC (connected to the LAN side of the access point via a generic Fast Ethernet switch) served as the Chariot console that managed the performance testing.

In the access point tests, data clearly shows that users obtained higher throughput in the scenario with a Centrino 802.11b client NIC (Intel PRO/Wireless LAN 2100 3B Mini PCI Adapter Driver version 1.1.5.0) than the alternative scenario with the Linksys WPC11 Version 3 (Driver version 5.131.0318.2003) 802.11b client NIC. Both NICs were each slotted into an IBM ThinkPad laptop PC with a 1.5-GHz Pentium M chipset, and 256 Mbytes of memory running Microsoft Windows XP Professional Version 2002/SP1. Tests also show there is no bandwidth tax paid for using 128-bit WEP encryption, as the D-Link DWL7000AP actually increased performance by 6% when in WEP mode.

All tests were conducted under identical test conditions with no other radio interference. The firmware/device driver software for each tested device was updated to the latest version available from the vendor's Web site prior to testing. All devices were set to the maximum power output mode, auto transmit rate with channel set to 1,6 or 11, RTS threshold set to the default value of 2346 and Fragmentation Threshold set to the default value of 2,347. The WEP key was created with 26 hex digits and the WPA key was created with 10 hex digits.

WLAN Test Bed



Test setup for bidirectional WLAN-to-WLAN traffic

Source: The Tolly Group, November 2003 *Figure 7*

The Tolly Group gratefully acknowledges the providers of test equipment used in this project.

Vendor	Product	Web address
NetIQ Corp.	Chariot Ver 4.5	http://www.netiq.com
NetIQ Corp.	Chariot Endpoint Ver 4.3	http://www.netiq.com

Tolly Group Services

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Project Profile

Sponsor: Intel Corp.
Document number: 203141
Product class: Network processor for wireless gateways
Broadband routers under test:

- D-Link DI 774 Ver 1.25 (Arm 9)
- Linksys WRV54G Ver 2.06 (Intel® IXP425)
- Linksys WRT54G Ver 1.42.2 (Broadcom chipset)
- Netgear FWAG114 Ver 1.0.19 (Broadcom BCM 4702)

Access Points under test:

- 3Com LAN AP8200 Ver 1.0.11
- D-Link DWL 7000AP Ver 1.04 (Intel® IXP420)
- Cisco Aironet 1220 Ver 5.02.12 (IBM Power PC 405)
- Linksys WAP54G Ver 1.08 (Broadcom)

Testing window: September to November 2003
Software status:

- Generally available

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