THE TOLLY GROUP

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Belkin Corp.

Wireless Pre-N Router (F5D8230-4) and Wireless Pre-N Notebook Network Card (F5D8010)

Competitive Wireless LAN Performance Evaluation

1989 - 2004 15 Years TOLLY

Test Summary

Premise: *Buyers of wireless network equipment understand that current products can sustain maximum throughput of 54 Mbps imposed by the IEEE's 802.11g standard. However, a new technology called MIMO will raise the ceiling on 802.11b/g throughput. MIMO stands for multiple input-multiple output and describes a technology that can boost the capacity and coverage area of wireless networks. The future IEEE 802.11n standard will be based on MIMO. Products based upon MIMO should offer significant throughput gains over traditional 802.11b/g offerings. Belkin markets these new MIMO products as Pre-11n, and while the final IEEE 802.11n standard is still undecided, buyers can take advantage of this core technology improvement now.*

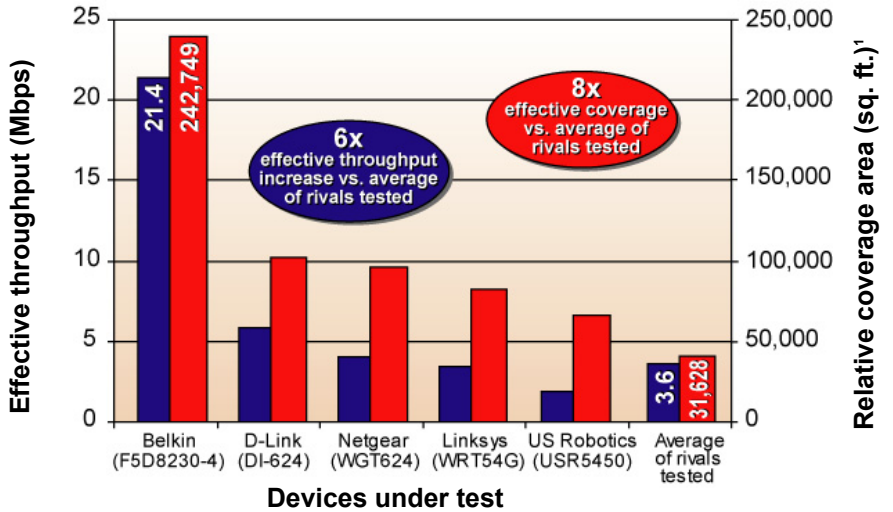
Belkin Corp. commissioned The Tolly Group to evaluate a wireless router and wireless client network interface card that are based on Airgo Networks' True MIMO™ antenna and chipset design. True MIMO (Multiple Input Multiple Output) is the most advanced form of smart radio technology that promises to increase speed, coverage, and reliability for wireless systems. The Belkin products tested represent a pre-standard implementation of MIMO technology. MIMO technology will drive the key performance improvements in the upcoming 802.11n standard.

Engineers measured the upstream and downstream effective throughput of the

Test Highlights

- Provides increased throughput and improved coverage area when compared with 802.11g broadband routers tested
- Demonstrates effective throughput six times greater than the average of competitive devices tested
- Support Ethernet-speed communications across an area that is eight times greater than the average of rival devices tested

Effective Throughput and Coverage Area of 802.11g Broadband Routers Tested
as Reported by IPERF ver. 1.7



[1]Effective coverage area results were based on the area of a circle (A = pi * r^2); "r" represents the distance (in feet) that each device was able to send 10-Mbps throughput. For example, for the Belkin product the 10-Mbps range was 278 ft., so [A = 3.141 (pi) * 2782] → 242,749 square feet.

Source: The Tolly Group, July 2004 *Figure 1*

Throughput Rates at Measured Ring Distances						
Downstream throughput						
	Ring distance 0	Ring distance 1	Ring distance 2	Ring distance 3	Ring distance 4	Ring distance 5
	30 ft	60 ft	100 ft	132 ft	206 ft	278 ft
Belkin (F58230-4)	39.2	38.8	36.2	27.4	20.3	12.8
D-Link (DI-624)	18.2	13.5	12.3	6.6	4.4	3.3
Netgear (WGT624)	15.8	14.6	12.2	3.3	2.8	2.4
Linksys (WRT54G)	14.1	14	10.9	3.4	2.2	1.9
US Robotics (USR5450)	18	10.8	6.3	1.3	0.3	0.8
Upstream throughput						
	Ring distance 0	Ring distance 1	Ring distance 2	Ring distance 3	Ring distance 4	Ring distance 5
	30 ft	60 ft	100 ft	132 ft	206 ft	278 ft
Belkin (F58230-4)	39.6	43.1	41.3	34	23.6	15.1
D-Link (DI-624)	21.8	13.9	13	7.9	5.7	4.3
Netgear (WGT624)	16.7	16.5	12.8	3.7	2.3	2.3
Linksys (WRT54G)	18.1	12.2	8.8	3.6	2.3	1.7
US Robotics (USR5450)	16	14.1	7.2	1.1	0.3	1.3

Source: The Tolly Group, July 2004

Figure 2

Belkin Wireless Pre-N Router (F5D8230-4) and Wireless Pre-N Notebook Network Card (F5D8010) – installed in a Dell Inspiron 8500 – and measured the range at which the pair could communicate at a minimum of 10 Mbps across variable distances from an access point in an effort to establish a credible effective coverage area metric. Effective throughput is a metric that combines throughput with coverage area.

Both the Belkin router and wireless client network interface were tested against a bevy of popular 802.11b/g products from D-Link Systems Inc., Linksys Corp., Netgear, Inc. and U.S. Robotics Corp. (*A complete list of the products tested and their software versions can be found on page 6 in the Project Profile section.*) Each of the rival product pairings tested consisted of a broadband wireless router, or access point, along with a client network interface on a downstream laptop. The rival product pairings were subjected to the same upstream/downstream throughput tests applied to the Belkin products.

Tests show that the Belkin Pre-N products tested deliver eight times greater effective network coverage and up to six times greater effective throughput, as calculated by a metric that factors in both performance and range, than standard 802.11g devices tested.

Results

WLAN Performance

The throughput of WLANs depends heavily on the nature of the environment, including the distance between the client and the access point. Throughput generally falls off as distance increases, but factors such as obstructions (*like furniture, people, or walls*) also have a significant effect. Throughput does not depend upon distance alone. Moreover, the peak data rate measured at short distances may or may not be the most important factor in the user's experience. Rather, the rate the user experiences at a variety of distances and locations is also likely a very important factor. Therefore, it is critical to measure WLAN throughput at a variety of locations, including some far from the access point.

Tolly Group engineers measured the average downstream and upstream throughput of the tested devices at various distances and then calculated a performance metric, developed in circa October 2003 by Atheros Communications, Inc., a chip manufacturer not directly involved in this test. This metric factors in both throughput and range to provide a single, composite effective throughput

number that seeks to characterize overall throughput across various distances.

"The performance metric is truly a function of both average throughput and range. At the far edges of coverage, extra range contributes greatly to the performance metric, due to the squared dependency. What the performance metric is truly quantifying is system capacity, that is, a system's ability to deliver high data rates across as wide an area as possible," according to the Atheros white paper, "Methodology for Testing Wireless LAN Performance with Chariot."

Multiple measurements were taken at distances of 30, 60, 100, 132, 206 and 278 feet from the access points/broadband routers under test. These measurements yielded raw throughput results which engineers used to compute a composite metric, or score, of throughput and coverage.

Purely from a raw throughput standpoint, the Belkin Wireless Pre-N Router (F5D8230-4) and associated client NIC achieved an average of 31 Mbps of upstream/downstream throughput. Competing products averaged raw throughput ranging from a low of 6.3 Mbps for a U.S. Robotics 802.11g Wireless Turbo Access Point (USR5450) to 10.4 Mbps for a D-Link AirPlus Xtreme G Router (DI-624). See Figure 2 for complete upstream/downstream throughput measurements.

Raw throughput, alone, though is not an accurate indicator of wireless performance since it does not take into account distance and other wireless variables. Tolly Group engineers utilized the Atheros metric to express "effective throughput" to express combined throughput and distance performance as a relative score to compare products. Details of the Atheros wireless performance metric can be found in the Test Methodology section below.

The Belkin Wireless Pre-N Router (F5D8230-4) and associated client NIC achieved an effective throughput of 21.4 Mbps, which was six times greater than the average of the rival products tested. Among the competitive products tested, effective throughput was 1.9 Mbps for the U.S. Robotics 802.11g Wireless Turbo Access Point (USR5450), 3.4 Mbps for a Linksys WRT54G, 4.0 Mbps for a Netgear WGT624 and 5.8 Mbps for the D-Link DI-624.

10-Mbps Ethernet Range

Engineers also measured the distance at which the tested devices can support Ethernet-speed (10 Mbps) transmissions. Again, the Belkin Wireless Pre-N Router (F5D8230-4) and associated client NIC outperformed other devices tested. The Belkin products were able to sustain 10-Mbps Ethernet transmission at a distance of 278 feet for both upstream and downstream traffic, which is more than twice the distance of the nearest competitor, the D-Link DI-624, with 118 feet for upstream traffic and 113 feet for downstream traffic. (See Figure 3.) The Belkin 10-Mbps range was as much as four times greater than the U.S. Robotics USR5450.

Coverage Area

Engineers measured the square-foot area supported by the devices tested to deliver 10-Mbps Ethernet coverage to wireless users. The Belkin Wireless Pre-N Router (F5D8230-4) and its related client NIC supported Ethernet-speed transmission across 242,749 square feet of building space. That represents an 8X advantage over the average of the rival devices tested (31,279 sq. ft.).

Among the rival product tested, the D-Link DI-624 achieved a 10-Mbps relative coverage area of 41,921 sq. ft., the Netgear WGT624 had a coverage area of 37,321 sq. ft., the Linksys WRT54G demonstrated a coverage area of 28,008 sq. ft.

Belkin Corp.

Wireless Pre-N Router (F5D8230-4) and Wireless Pre-N Notebook Network Card (F5D8010)

Functionality and Performance

Belkin Corp.
Wireless Pre-N Router (F5D8230-4) and Notebook Network Card (F5D8010)
Product Specifications*

Feature

- Based on MIMO antenna technology which improves the reliability, coverage, and robustness of the wireless connection
- 8X the coverage of standard 802.11g
- 6X the speed of standard 802.11g
- Improved resistance to interference from neighboring devices in the 2.4GHz frequency band
- Improves performance of connecting 802.11b and 802.11g client devices
- Does not drop to the lowest common networking speed in mixed-mode environments
- Seamless compatibility with 802.11b and 802.11g
- Features Wi-Fi Protected Access (WPA) as well as 64-bit and 128-bit WEP security
- Sets up in three minutes with Belkin Easy Install Wizard
- Offers six months free of 50 configurable Web Content/Parental Control Filters
- Offers six months of a free pop-up, adware, and spyware stopper
- Comes with a Belkin Lifetime Warranty and free, 24-hour technical support

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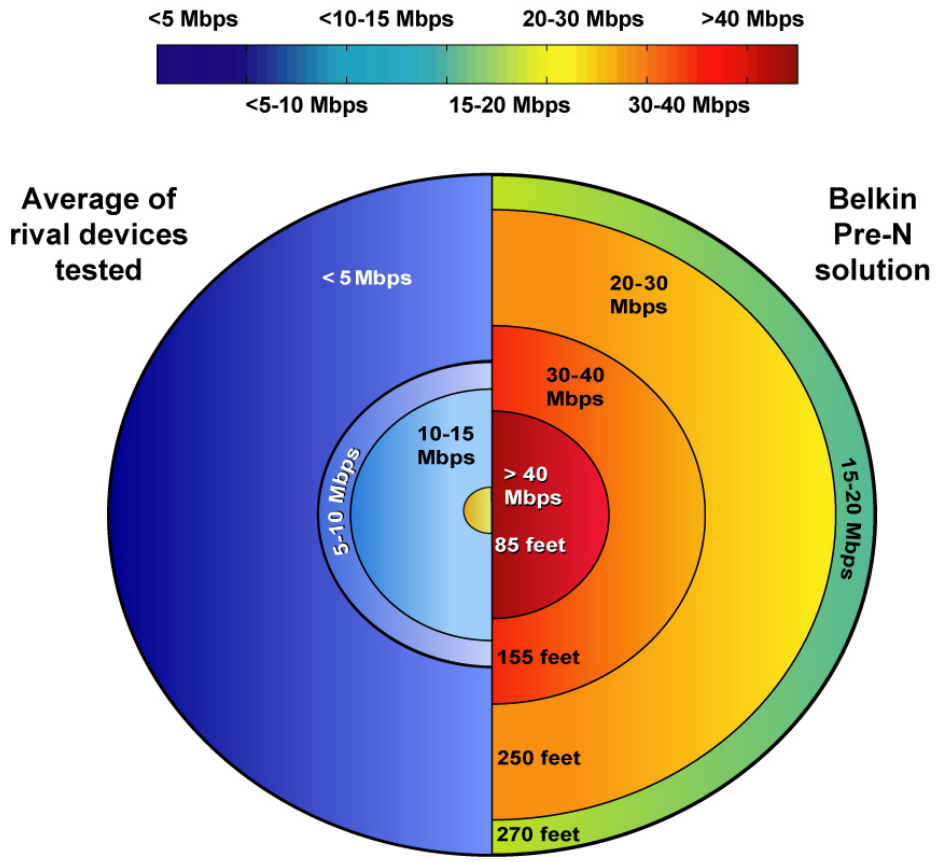
**Vendor-supplied information not verified by The Tolly Group*

Throughput Delivered Across Various Ranges from AP



Source: The Tolly Group, July 2004

Figure 3

Analysis

Being "first" into a nascent market often times can help companies build brand identity and a strong product following. Belkin appears to be hoping to capitalize on the push to 802.11n technology by bringing to market pre-standardized products – Belkin's Wireless Pre-N Router and Wireless Pre-N Notebook Network Card – that uses the MIMO orthogonal frequency division multiplexing (OFDM) technology that will be used in the upcoming 802.11n standard.

The 802.11n technology is currently an IEEE 802.11 task group focused on providing high-throughput over wireless. High-throughput is defined as more than 100 Mbps (Fast Ethernet-speed) of wireless performance. MIMO technology from Airgo Networks is at the heart of Belkin's "Pre-N" products; MIMO has emerged as the most likely way to boost WLAN throughput dramatically. It uses two or more antennas to transmit and to receive data that is sent over multiple pathways on a single channel, multiplying the channel's data capacity. Addition-ally, using multiple receivers results in greater receive sensitivity, giving user a higher wireless link budget, resulting in much larger coverage area.

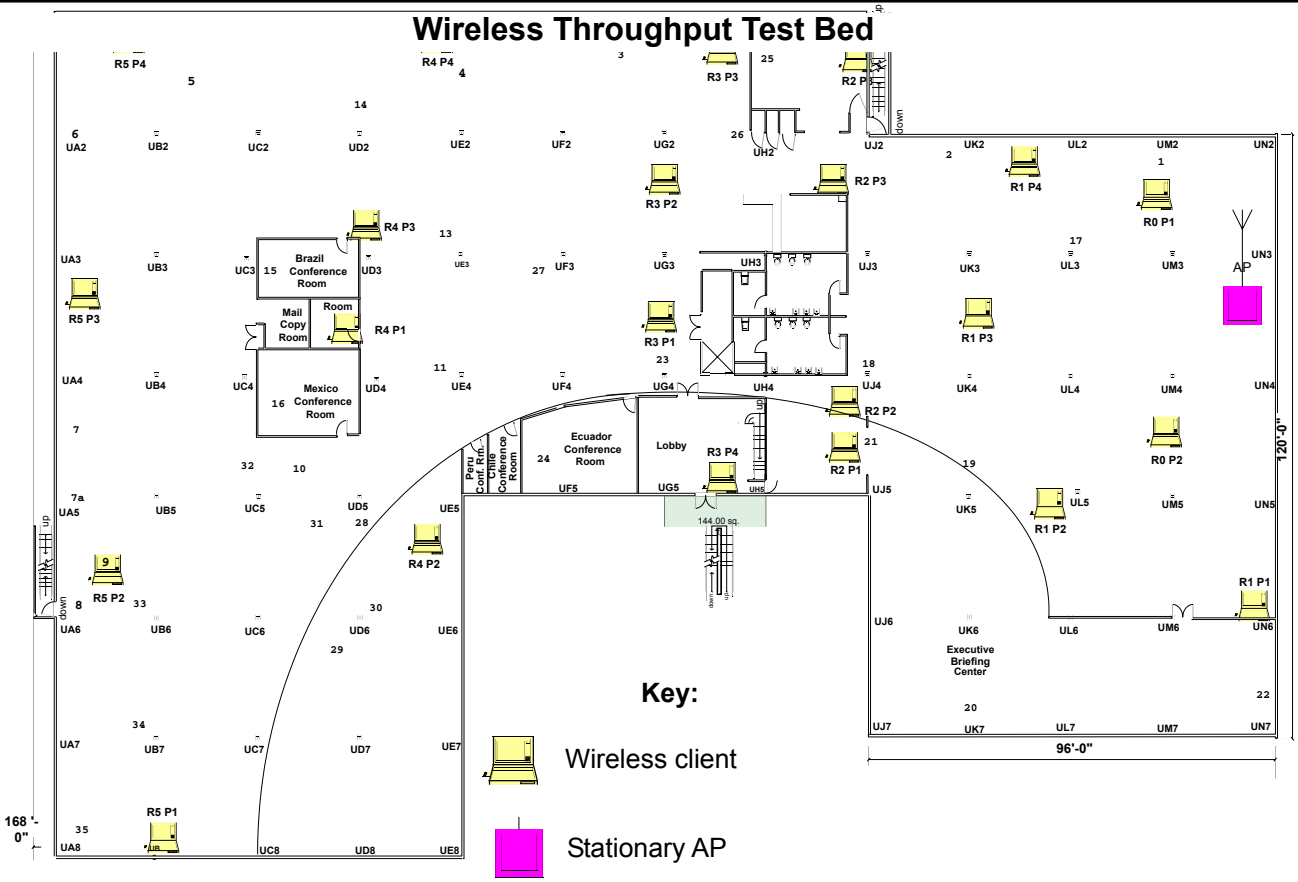
In this test, The Tolly Group compared Belkin's Pre-N offerings to four 802.11g product offerings that do not implement any "pre-N" throughput enhancing features. In every case, the Belkin products delivered greater performance and across a greater coverage area.

Not only did the Belkin/Airgo tandem demonstrate the highest effective throughput of any device tested, but it also achieved the greatest coverage area – more than eight times the coverage area when compared to the average of rival devices tested.

Test data shows that Belkin's Wireless Pre-N Router and Wireless Pre-N Notebook Network Card will attract performance-hungry consumers with a desire to set up an extremely fast WLAN in their home or small office.

Test Configuration and Methodology

For performance tests, The Tolly Group tested a Belkin Wireless Pre-N Router (F5D8230-4) Ver. 040624-040621-NOSDRAM-TD128 and a Belkin Pre-N Notebook Network Card (F5D8010) Ver. 1.2.0.46



Source: The Tolly Group, July 2004 *Figure 4*

designed for wireless clients. The Dell Inspiron 8500 laptop that housed the Belkin Pre-N Notebook Network Card was configured with 512 MBytes of memory and supported Windows XP Pro SP1. The client communicated with an upstream server – a Sony VAIO PCG configured with 256 MBytes of memory and supporting Windows XP Pro SP1. The Sony PC was attached to the Belkin Wireless Pre-N Router.

The Belkin products were tested against a variety of wireless router/network cards from D-Link Systems, Inc., Linksys Corp., Netgear Corp and U.S. Robotics Corp. (*For a complete listing of all the competitive products tested and their software versions, see the Project Profile on page 6.*)

Each of the product pairings was subjected to a downstream throughput and upstream throughput test.

Making meaningful measurements of throughput requires collecting a statistically significant number of samples. Making one measurement (*or even just three or four measurements*) of throughput at a particular location is not statistically significant. Such a methodology could be subject to reporting anomalies. Therefore, the test methodology used for this benchmark collects hundreds of throughput samples at each location and reports a throughput that represents a 90% confidence level (*i.e. a minimum throughput obtained in 90% of the measurements*).

For the downstream throughput tests, engineers measured the TCP flow from the server to the host computer (client) at different radius distances. The test was conducted across six different distance rings to determine throughput at various intervals from the broadband router. Measurements were taken at distances of 30, 60, 100, 132, 206 and 278 feet.

Engineers placed a host computer and an access point in a stationary position. They also placed a laptop with a client or notebook wireless interface on top of a turntable and moved it along through various radius distances. Tests were conducted in wireless 802.11g standard mode on Channel 11 with no encryption or firewall enabled. The turntable rotated approximately twice per minute.

During the test, engineers configured the laptop to launch Iperf server, a TCP throughput measurement tool. With Iperf active, engineers activated the turntable and started the throughput test on the host computer. Throughput measurements were recorded in Mbps.

For the upstream throughput test, engineers measured the unidirectional TCP flow between the laptop

(client) and host computer (server) throughout different radius distances. The test was conducted across the same six distance rings used in the downstream test and the test bed was set up identically to the downstream test.

During the test, engineers configured the laptop to launch Iperf server. With Iperf active, engineers activated the turntable and started the throughput test on the host computer. Throughput measurements were recorded in Mbps.

For the performance score, engineers collected upstream and downstream throughput measurements in order to apply the Atheros metric formula (below).(*Note: The metric formula is the sum over locations of the throughput achieved (average of upstream and downstream values in Mbps) multiplied by the ring area. A normalization factor (10^{-3} or 0.001) is used to make the scores more tractable. Belkin decided to replace this normalization factor to $1/R^2$ – big 'R' means the farthest distance achieved, 278 feet – to make the scores comparable to Ethernet speed values. Both high throughputs and large coverage areas are desirable to achieve a high score.*)

Atheros Metric Formula:

$$\text{Performance Metric} = 10^{-3} \times \sum_{i=1}^{n} \text{Mbps}(i) \left[r^2(i) - r^2(i-1) \right]$$

Finally, engineers determined relative coverage area based on the area of a circle ($A = \pi * r^2$) where 'r' represents the distance in feet that each device was able to send 10-Mbps throughput to wireless users.

Equipment Acquisition and Support

All of the competitive products tested were acquired through normal distribution channels since they represent off-the-shelf wireless gear that can be purchased in common retail outlets. Tolly Group engineers configured the devices according to normal information provided to buyers and standard technical support was utilized in the event assistance was required.

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

Vendor	Product	Web address
Open-source tool	Tool Command Language (TCL)	http://www.tcl.tk/
Public domain	Iperf v.1.7.0	http://dast.nlanr.net/Projects/Iperf/

Tolly Group Services

With more than 15 years of testing experience of leading-edge network technologies, The Tolly Group employs time-proven test methodologies and fair testing principles to benchmark products and services with the highest degree of accuracy. Plus, unlike narrowly focused testing shops, The Tolly Group combines its vast technology knowledge with focused marketing services to help clients better position product benchmarks for maximum exposure. The company offers an unparalleled array of reports and services including: Test Summaries, Tolly Verifieds, performance certification programs, educational Webcasts, white paper production, proof-of-concept testing, network planning, industry studies, end-user services, strategic consulting and integrated marketing services. Learn more about The Tolly Group services by calling (561) 391-5610, or send E-mail to sales@tolly.com.

For info on the Fair Testing Charter, visit: http://www.tolly.com/Corporate/FTC.aspx

Project Profile

Sponsor: Belkin Corp.
Document number: 204134
Product class: Wireless LAN router
Products under test:

- Belkin Corp. Wireless Pre-N Notebook Network Card (F5D8010) Ver. 1.2.0.46
- Belkin Corp. Wireless Pre-N Router (F5D8230-4) Ver. 040624-040621-NOSDRAM-TD128
- D-Link Systems, Inc. Airplus Xtreme G CardBus Adapter (DWL G650) Ver. 2.1.3.1
- D-Link Systems Airplus Xtreme G Router (DI-624) Ver 2.28
- Linksys Corp. Wireless G Notebook Adapter (WPC54G) Ver. 3.30.15.0
- Linksys Corp. Wireless G - Broadband Router (WRT54G) Ver. 2.02.7
- Netgear, Inc. 108 Mbps Wireless PC Card (WG 511T) Ver. 2.4.0.7181
- Netgear, Inc. 108Mbps Wireless Firewall Router (WGT 624) Ver. 4.0.4
- U.S. Robotics Corp. 802.11g Wireless Turbo PC Card (USR5410) Ver. 4.0.40.3
- U.S. Robotics Corp. 802.11g Wireless Turbo Access Point (USR5450) Ver. 1.31

Testing window: July 2004
Software status: Generally available

For more information on this document, or other services offered by The Tolly Group, visit our World Wide Web site at http://www.tolly.com, send E-mail to sales@tolly.com, call (561) 391-5610.

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