

NETGEAR: 802.11g MIMO Wireless Router Performance Study

Test report prepared under contract from NETGEAR Incorporated

Executive summary

NETGEAR Inc. commissioned VeriTest, a division of Lionbridge Technologies, Inc., to test the wireless network throughput performance and maximum range of their RangeMax Wireless Router and PC Card as compared to comparable Linksys and Belkin 802.11g MIMO wireless solutions.

Our tests measured the wireless network throughput performance and maximum range of each wireless notebook solution using the system configurations described below.

We performed two types of throughput tests: a transmit data and a combined transmit/receive data test. We used NetIQ's Chariot 4.3 performance tool (newer versions of the tool are now owned by Ixia) to generate "transmit" and "receive" network traffic between each wireless notebook solution and a notebook system connected through a wireless access point. We installed one Chariot endpoint on the test notebook system with each external wireless solution and a second endpoint on a notebook system connected through a wireless router. We tested for throughput performance using two environments: a line-of-sight environment and an indoor office environment with walls. We extended this environment outdoors for the maximum range tests.

We performed maximum range testing using the ping utility supplied by the Windows XP operating system, to determine the maximum distance at which a user could connect to the wireless router.

For this testing, NETGEAR supplied a ThinkPad T42 notebook system with a Pentium-M 1.7 GHz processor and 1GB RAM, running Microsoft Windows XP Professional SP2 operating system with the Chariot 4.3 console installed on it. NETGEAR also supplied wireless routers and PC Cards. The Linksys WRT54GX and Belkin wireless devices arrived for testing in retail, shrink-wrapped packaging. The NETGEAR devices did not, as they were pre-production products. NETGEAR also supplied an IBM ThinkPad T41 notebook system with a Pentium-M 1.4 GHz processor and 512MB RAM, running Microsoft Windows XP Professional SP1.

Figure 1 shows the wireless test configurations for the 802.11g throughput performance we tested.

Key findings

- ❑ The NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at all eight of the specific predetermined distances, as compared to the two other wireless configurations we tested.
- ❑ The NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination exhibited the longest maximum range, as compared to the two other wireless configurations we tested.

Wireless Router	Wireless PC Card	Wireless Router Mode
NETGEAR WPN824	NETGEAR WPN511	108-only Enabled for throughput, Auto-108 and XR Enabled for Max. Range
Linksys WRT54GX	Linksys WPC54GX	G-only Enabled for throughput, Mixed Mode Enabled for Max. Range
Belkin F5D8230-4	Belkin F5D8010	G-only Enabled for throughput, Mixed Mode Enabled for Max. Range

Figure 1. Wireless test configurations

Please refer to the Testing methodology section of this report for complete details on how we conducted the testing.

Receive Data Throughput Test Results

The receive data throughput testing consisted of using Chariot to generate an incoming stream of network traffic from the wired system through a wireless router to the client notebook system with each wireless station under test at distances of 1, 10, 40, 60, 75, 100, and 125 feet. Figure 2 shows the results of the testing for each wireless configuration we tested, measured in megabits per second, at each distance tested. For these tests, higher throughput numbers are better.

For these tests, Figure 2 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at all of the predetermined distances tested when compared to the other two participating wireless configurations.

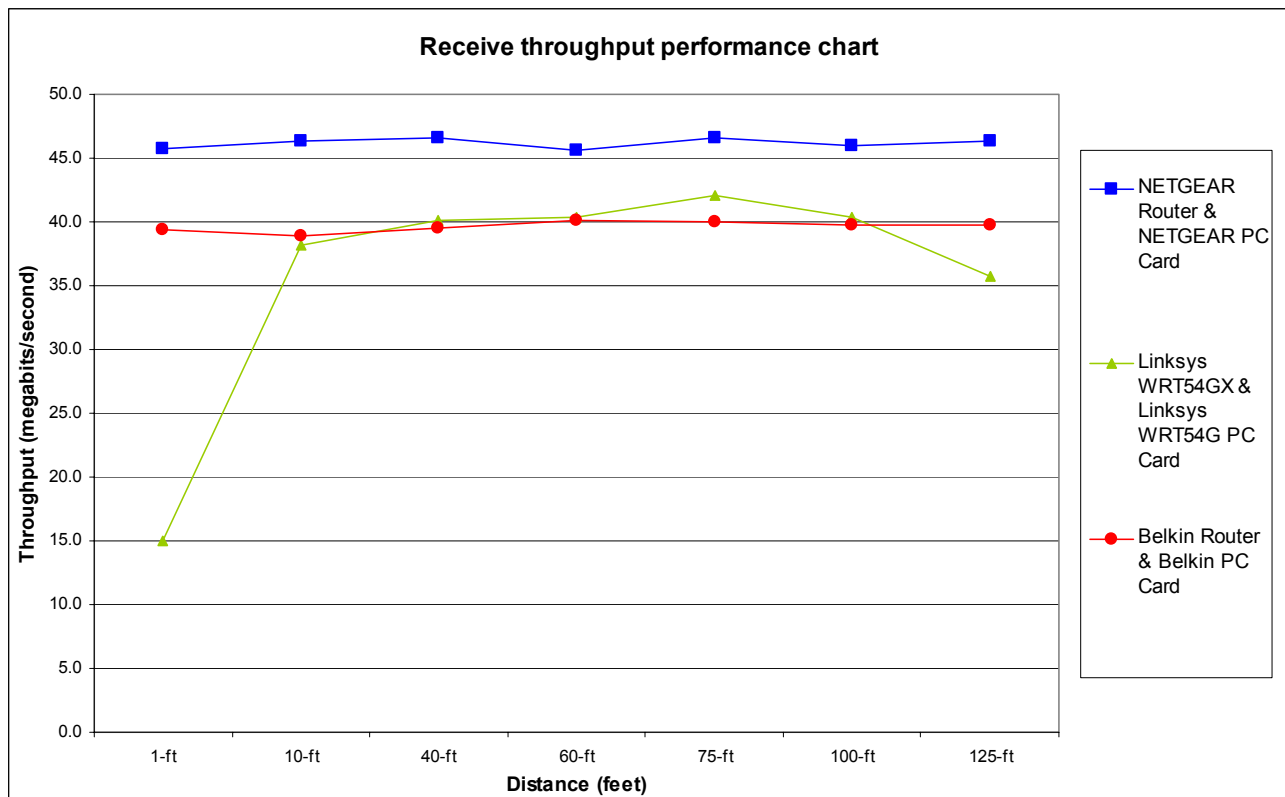


Figure 2. Wireless receive throughput performance chart, measured in megabits per second

We also tested in a typical office environment, including walls, at the 40-foot distance. Figure 3 shows the results of the testing for each wireless configuration we tested at the 40-foot distance in this environment. For these tests, higher throughput numbers are better.

For these tests, Figure 3 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at the 40-foot distance in a typical office environment, when compared to the other three participating wireless configurations.

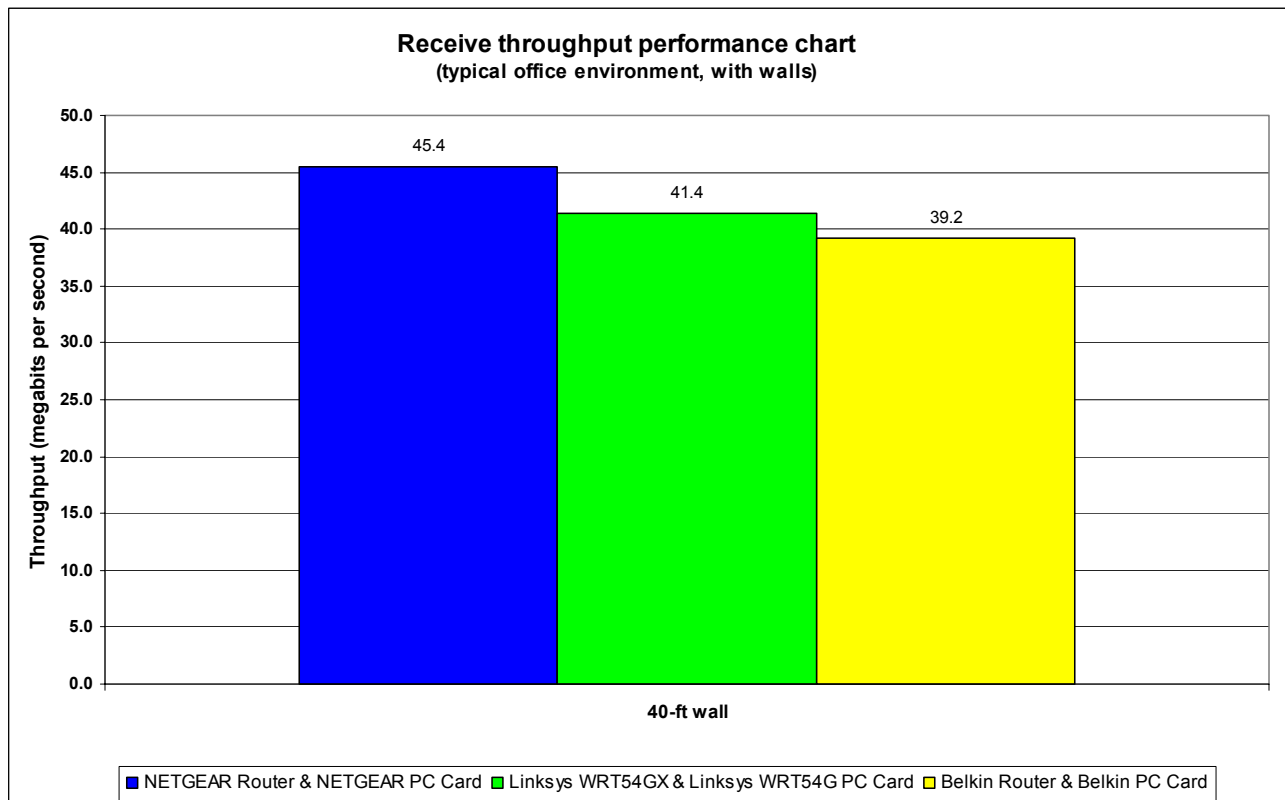


Figure 3. Wireless receive throughput performance chart, typical office environment, measured in megabits per second

Combined Receive/Send Data Throughput Test Results

The combined receive/send data throughput testing consisted of using Chariot to generate both an outgoing stream of network traffic from the client notebook system and an incoming stream of network traffic from the wired system at distances of 1, 10, 40, 60, 75, 100, and 125 feet. Figure 4 shows the results of the testing for each wireless configuration we tested, measured in megabits per second, at each distance tested. For these tests, higher throughput numbers are better.

For these tests, Figure 4 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at all of the predetermined distances tested as compared to the other two participating wireless configurations.

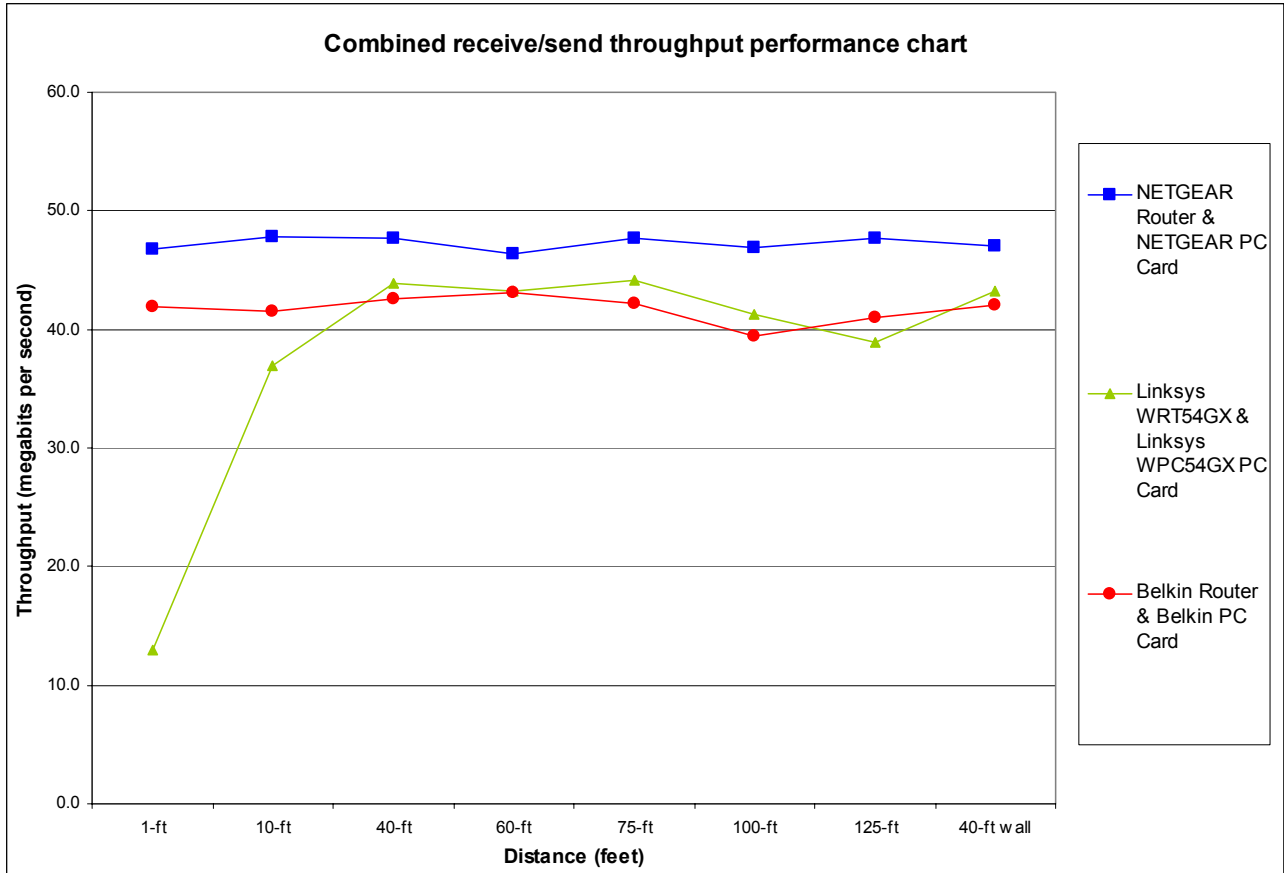


Figure 4. Wireless combined receive/send throughput performance chart, measured in megabits per second

We also tested in a typical office environment, including walls, at the 40-foot distance. Figure 5 shows the results of the testing for each wireless configuration we tested at the 40-foot distance in a typical office environment. For these tests, higher throughput numbers are better.

For these tests, Figure 5 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at the 40-foot distance in a typical office environment, when compared to the other two participating wireless configurations.

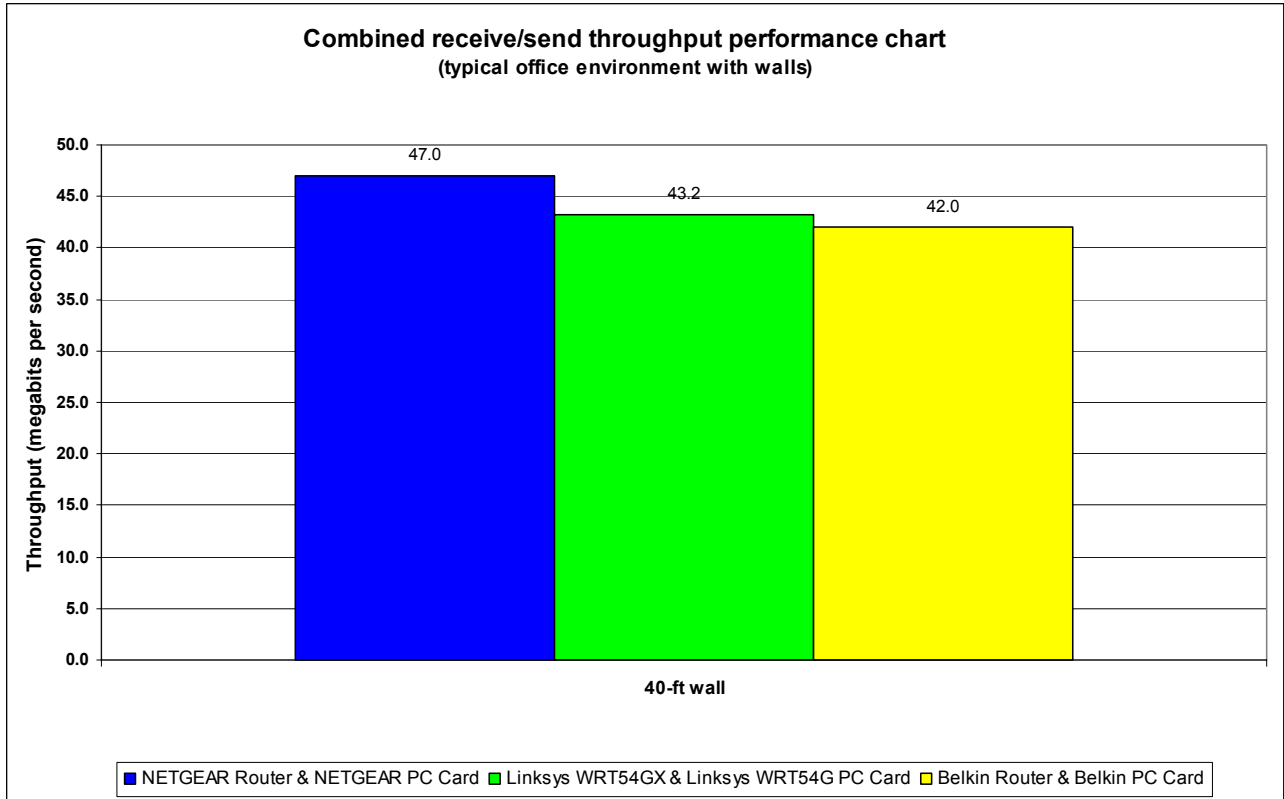


Figure 5. Wireless combined receive/send throughput performance chart, typical office environment, measured in megabits per second

Maximum Range Test Results

The maximum range testing consists of measuring the straight-line distance at which the wireless station under test can still connect to the wireless gateway. Figure 6 shows the results, in feet, of the testing for each wireless configuration we tested. For these tests, higher maximum range numbers are better.

Configuration	Distance (feet)
NETGEAR WPN824 Router (XR enabled) NETGEAR WPN511 Card	495
Linksys WRT54GX Router Linksys WPC54GX Card	342
Belkin F5D8230-4 Router Belkin F5D8010	341

Figure 6. Wireless Maximum Range results table

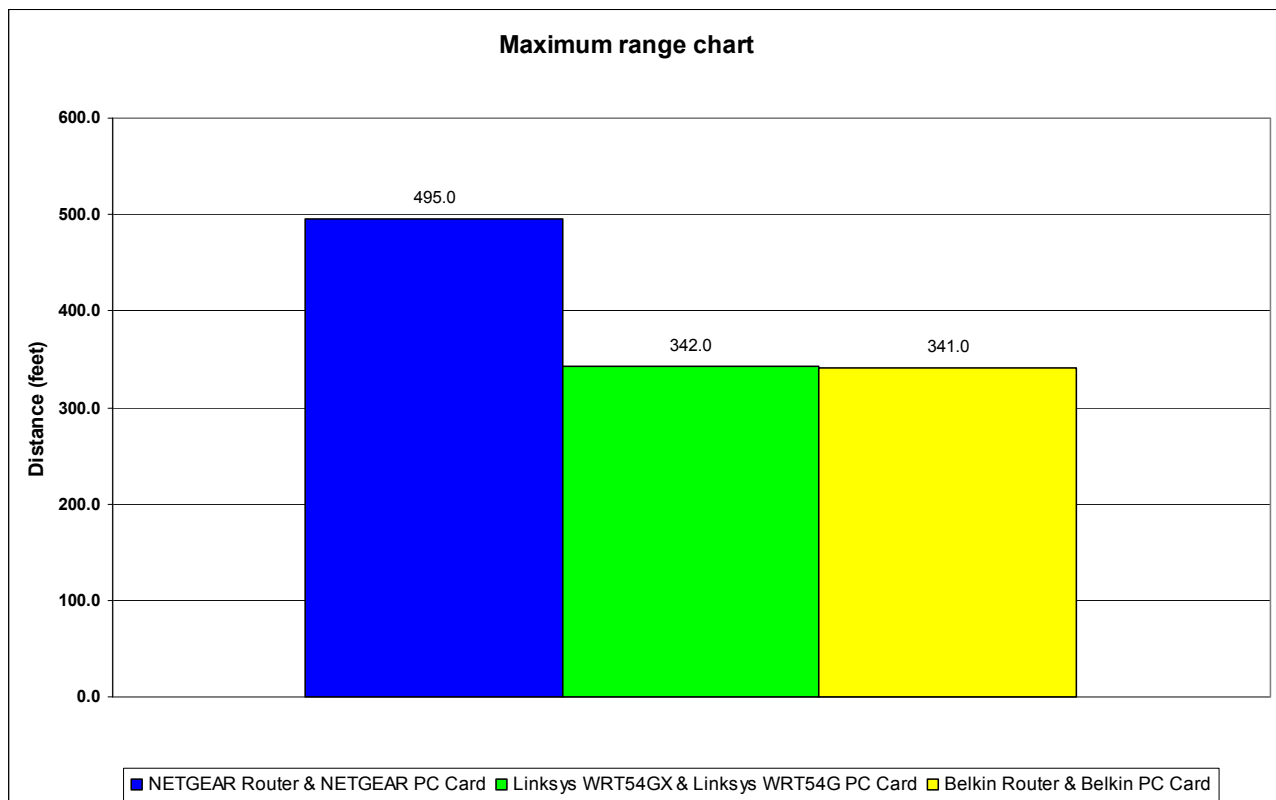


Figure 7. Wireless maximum range chart, measured in feet

Testing methodology

NETGEAR Inc. commissioned VeriTest, a division of Lionbridge Technologies, Inc., to test the wireless network throughput performance of their 802.11g router and PC Card as compared to comparable Linksys and Belkin 802.11g wireless solutions.

Testbed wireless configurations

Specifically, we tested the following wireless configurations listed in Figure 8 for throughput performance and maximum range.

Wireless Router	Wireless PC Card	Wireless Router Mode
NETGEAR WPN824	NETGEAR WPN511	108-only Enabled for throughput, Auto-108 and XR Enabled for Max. Range
Linksys WRT54GX	Linksys WPC54GX	G-only Enabled for throughput, Mixed Mode Enabled for Max. Range
Belkin F5D8230-4	Belkin F5D8010	G-only Enabled for throughput, Mixed Mode Enabled for Max. Range

Figure 8. Wireless Test configurations

Testbed configuration

The throughput testing consisted of two types of tests, namely a “receive data” test and a combined “receive/send data” test between a notebook system with a wireless station and a wired notebook system. We tested using a line-of-sight environment and a typical office environment, with walls. We used NetIQ’s Chariot 4.3 performance tool (newer versions are owned by Ixia), supplied by NETGEAR, to generate transmit and receive network traffic between the 802.11g wireless station and the wired Ethernet notebook endpoint system through each wireless router.

Chariot is a network traffic generation product commonly used to measure network throughput performance by sending a continuous stream of data between two endpoints. The Chariot controller system monitors and collects the reported information for each of the test iterations. The wired endpoint system, supplied by NETGEAR, was an IBM ThinkPad T41 notebook system running Windows XP Professional SP1, configured with a Intel Pentium-M 1.4GHz processor, 512MB RAM, and a single internal Intel Pro/1000 MT NIC.

We connected the wired endpoint system to the router via the built-in LAN 100Mbps full duplex switch. Each external wireless solution connected to the DSS (Distributed Service Set) using its wireless connection to the router. Figure 9 shows the basic components and network configuration we used for the tests in this report. Detailed information about each of the client notebook systems, Chariot controller system, wireless routers and wireless PC Cards are listed in the appendix.

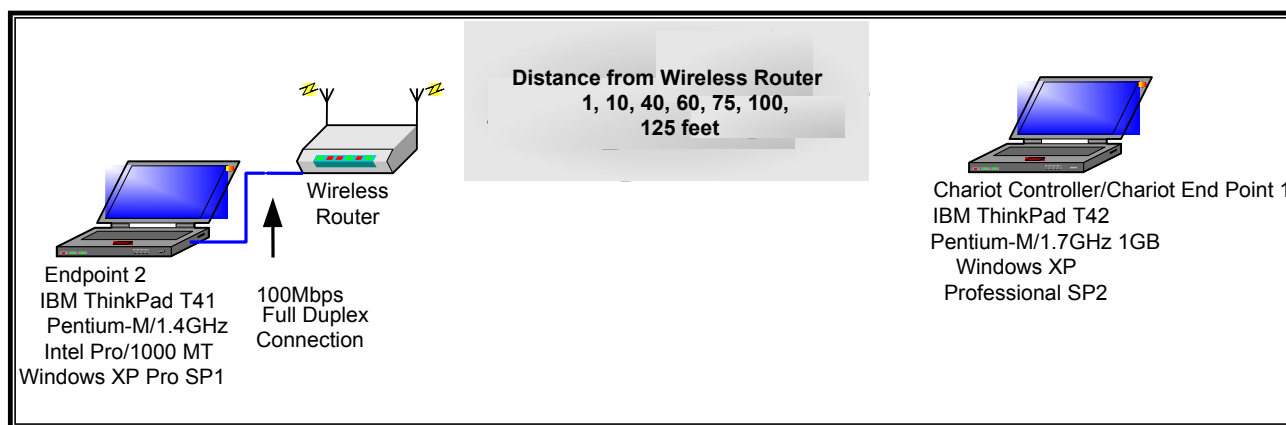


Figure 9. Wireless testbed setup

For the throughput performance tests, we did not use encryption. We configured fixed IP addresses for the Chariot controller system and for each wireless solution and wireless router. Figure 10 shows the settings we used for our tests.

Test System	Internet Protocol address
Wired endpoint system	192.168.0.50/24
Wireless solution/Chariot controller	192.168.0.3/24
Wireless Router	192.168.0.1/24
Wireless Network Settings	
SSID NETGEAR	WPN824VT
SSID Linksys WRT54GX	WRT54GXVT
SSID Belkin	BELKIN_Pre-N_141528

Figure 10. Distributed Service Set Network Settings

We tested for throughput performance using two environments: a line-of-sight environment and an indoor office environment with walls.

For the first suite of tests, we tested the wireless station at distances up to 125 feet from each wireless router. We measured the distances in a straight line from the router to each location where we tested each wireless station, down an unimpeded hallway. Figure 11 shows a diagram of the line-of-sight environment we used for testing. For these tests, we used the following fixed distances with the wireless station point towards the wireless router: (1ft, 10ft, 40ft, 60ft, 75ft, 100ft, and 125ft).

For the second suite of tests, we tested the products in a typical office environment, including walls. We placed the wireless station in a lab separated from the wireless router by two walls consisting of drywall and metal studs, at a distance of 40 feet from the router.

For maximum range testing, we placed the router in a separate room on the far side of the office building and measured range distance from that point.

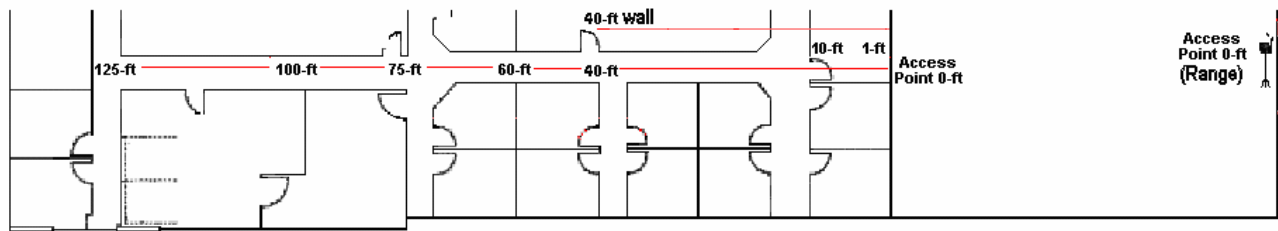


Figure 11. Indoor office environment

Throughput performance test configuration

For the wireless performance tests, we used a modified Chariot 4.3 script, the throughput (THROUGHPUT.SCR) script, to perform the throughput performance tests. This is the default script THROUGHPUT.SCR modified to change the transactions per record value from 1 to 10. Figure 12 shows the script parameters. This script emulates sending data from a laptop configured with the wireless station through a wireless router to a wired Ethernet system. To conduct the combined receive/send tests, we replicated the test and swapped the order of the Chariot endpoints on the replica, so that the data flowed both ways between the wired Ethernet system through the wireless router and the laptop configured with the wireless station.

Variable Name	File Send Long v.4.1	Description
initial_delay	0	Pause before the first transaction
number_of_timing_records	100	How many timing records to generate
transactions_per_record	10	Transactions per timing record
File_size	100000	How many bytes in the transferred file
send_buffer_size	Default value	How many bytes of data in each SEND
Receive_buffer_size	Default value	How many bytes of data in each RECEIVE
transaction_delay	0	Milliseconds to pause
send_datatype	NOCOMPRESS	What type of data to send
send_data_rate	UNLIMITED	How fast to send data
Destination_port	AUTO	What port to use for Endpoint 2
close_type	Reset	How connections are terminated
source_port	AUTO	What port to use for Endpoint 1

Figure 12. Modified THROUGHPUT script parameters

Chariot Controller configuration

The following were the Chariot configuration settings for each of the three iterations for each test script (receive/combined) at each distance:

- Run for a fixed duration: 1 min.
- Reporting type: Batch
- Automatically poll endpoints: No

We computed an average for three iterations and reported our results in megabits per second at each distance we tested.

Maximum range test configuration

To perform the maximum range tests we measured distance in a straight line from the router under test to the wireless station to determine the maximum distance at which a user could connect to the access point and ping it successfully. We used the ping utility provided by Windows XP, as well as the wireless client utilities provided with each wireless card, to determine that the card was connected to the access point. We specified a ping size of 1000 bytes for these tests.

Test results

This section provides details of our tests comparing the wireless network performance of NETGEAR, Linksys, and Belkin wireless products. Please refer to the Testing methodology section of this report for complete details on how we conducted the testing.

Receive Data Throughput Test Results

The receive data throughput testing consisted of using Chariot to generate an incoming stream of network traffic from the wired system through a wireless router to the client notebook system with each wireless station under test at distances of 1, 10, 40, 60, 75, 100, and 125 feet. Figure 13 shows the results of the testing for each wireless configuration we tested, measured in megabits per second, at each distance tested. For these tests, higher throughput numbers are better.

For these tests, Figure 13 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at all of the predetermined distances tested as compared to the other two participating wireless configurations.

Distance	NETGEAR Router NETGEAR PC Card	Linksys WRT54GX Router Linksys WPC54GX PC Card	Belkin Router Belkin PC Card
1-ft	45.7	15.0	39.4
10-ft	46.4	38.2	39.0
40-ft	46.6	40.2	39.5
60-ft	45.7	40.4	40.2
75-ft	46.6	42.1	40.0
100-ft	45.9	40.4	39.8
125-ft	46.4	35.7	39.8
40-ft (wall)	45.4	41.4	39.2

Figure 13. Wireless throughput receive results table, measured in megabits per second

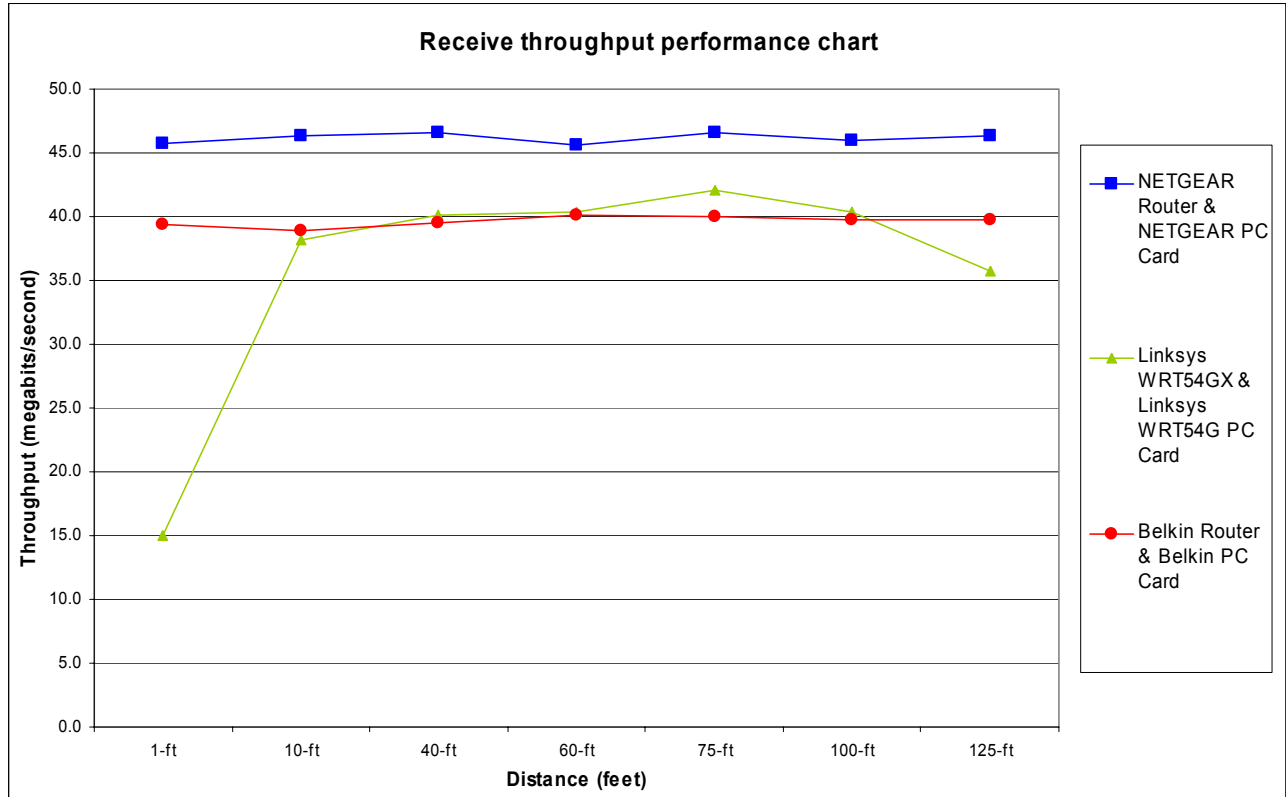


Figure 14. Wireless throughput receive chart, measured in megabits per second

We also tested in a typical office environment, including walls, at the 40-foot distance. Figure 15, below, shows the results of the testing for each wireless configuration we tested at the 40-foot distance in this configuration.. For these tests, higher throughput numbers are better.

For these tests, Figure 15 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at the 40-foot distance in a typical office environment, when compared to the other two participating wireless configurations.

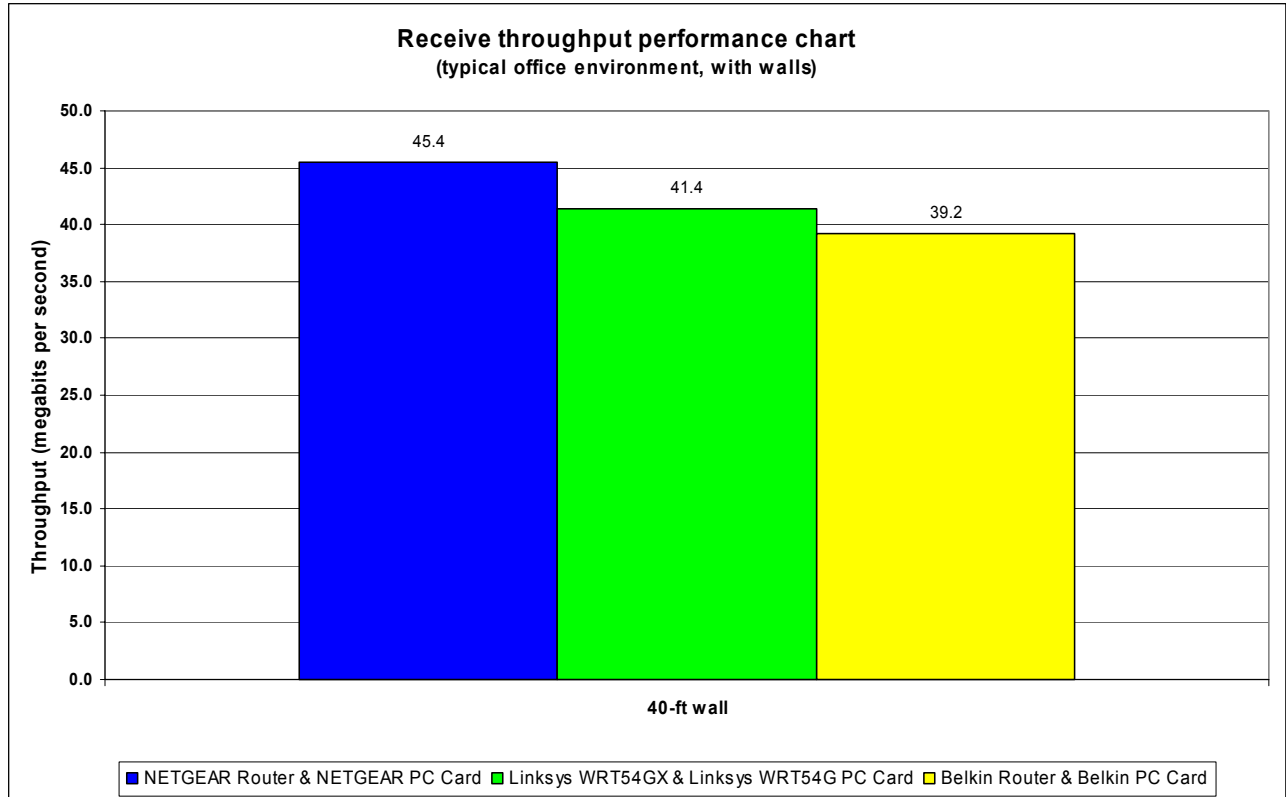


Figure 15. Wireless throughput receive chart, typical office environment, measured in megabits per second

Combined Receive/Send Data Throughput Test Results

The combined receive/send data throughput testing consisted of using Chariot to generate both an outgoing stream of network traffic from the client notebook system and an incoming stream of network traffic from the wired system at distances of 1, 10, 40, 60, 75, 100, and 125 feet. Figure 16, below, shows the results of the testing for each wireless configuration we tested, measured in megabits per second, at each distance tested. For these tests, higher throughput numbers are better.

For these tests, Figure 16 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at all of the predetermined distances tested, as compared to the other two participating wireless configurations.

Distance	NETGEAR Router NETGEAR PC Card	Linksys WRT54GX Router Linksys WPC54GX PC Card	Belkin Router Belkin PC Card
1-ft	46.8	13.0	41.9
10-ft	47.8	36.9	41.6
40-ft	47.7	43.9	42.6
60-ft	46.4	43.2	43.2
75-ft	47.7	44.2	42.2
100-ft	46.9	41.2	39.4
125-ft	47.7	38.9	41.1
40-ft (wall)	47.0	43.2	42.0

Figure 16. Wireless throughput combined receive/send results table, measured in megabits per second

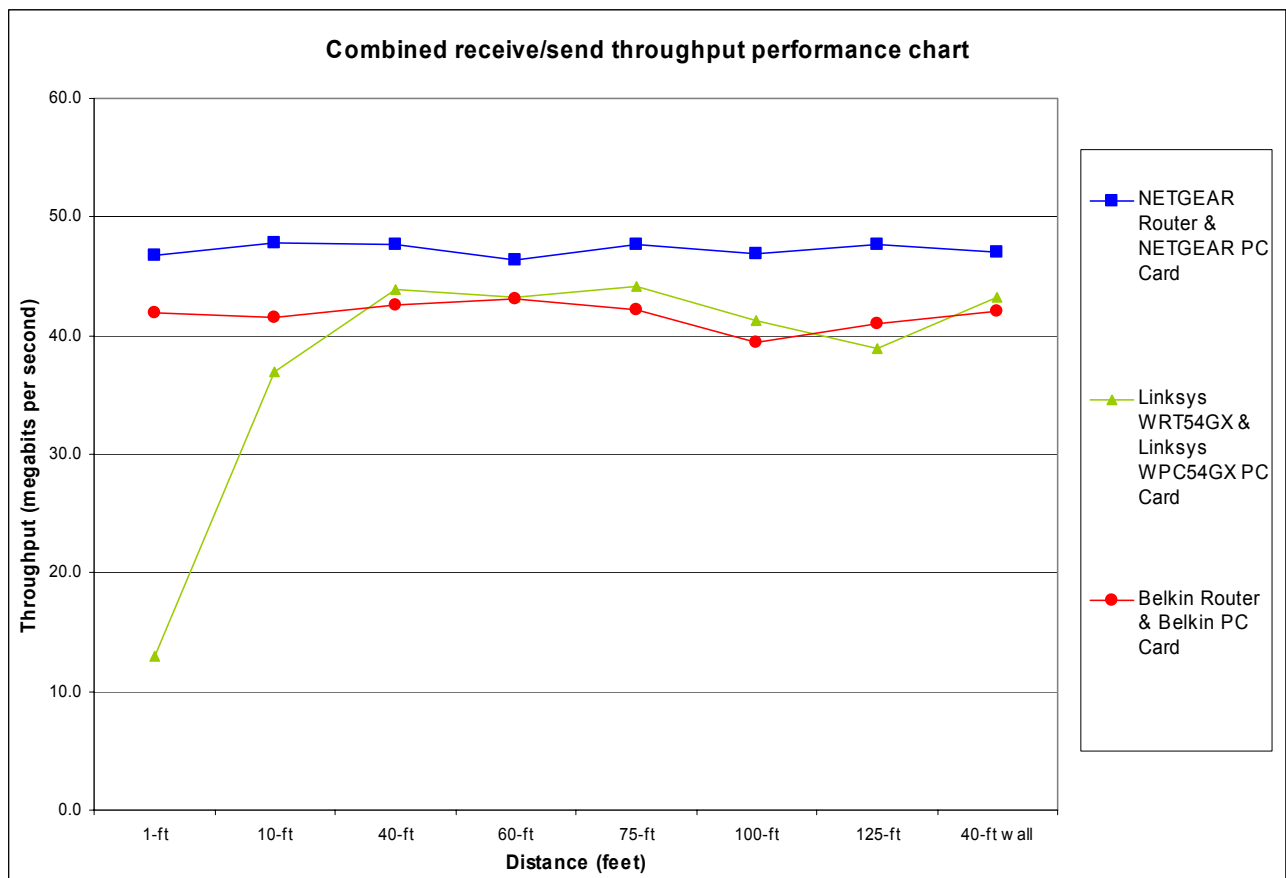


Figure 17. Wireless throughput combined receive/send chart, measured in megabits per second

We also tested in a typical office environment, including walls, at the 40-foot distance. Figure 18 shows the results of the testing for each wireless configuration we tested at the 40-foot distance in a typical office environment. For these tests, higher throughput numbers are better.

For these tests, Figure 18 shows that the NETGEAR Wireless Router WPN824 and NETGEAR Wireless PC Card WPN511 combination generated the highest throughput numbers at the 40-foot distance in a typical office environment, when compared to the other two participating wireless configurations.

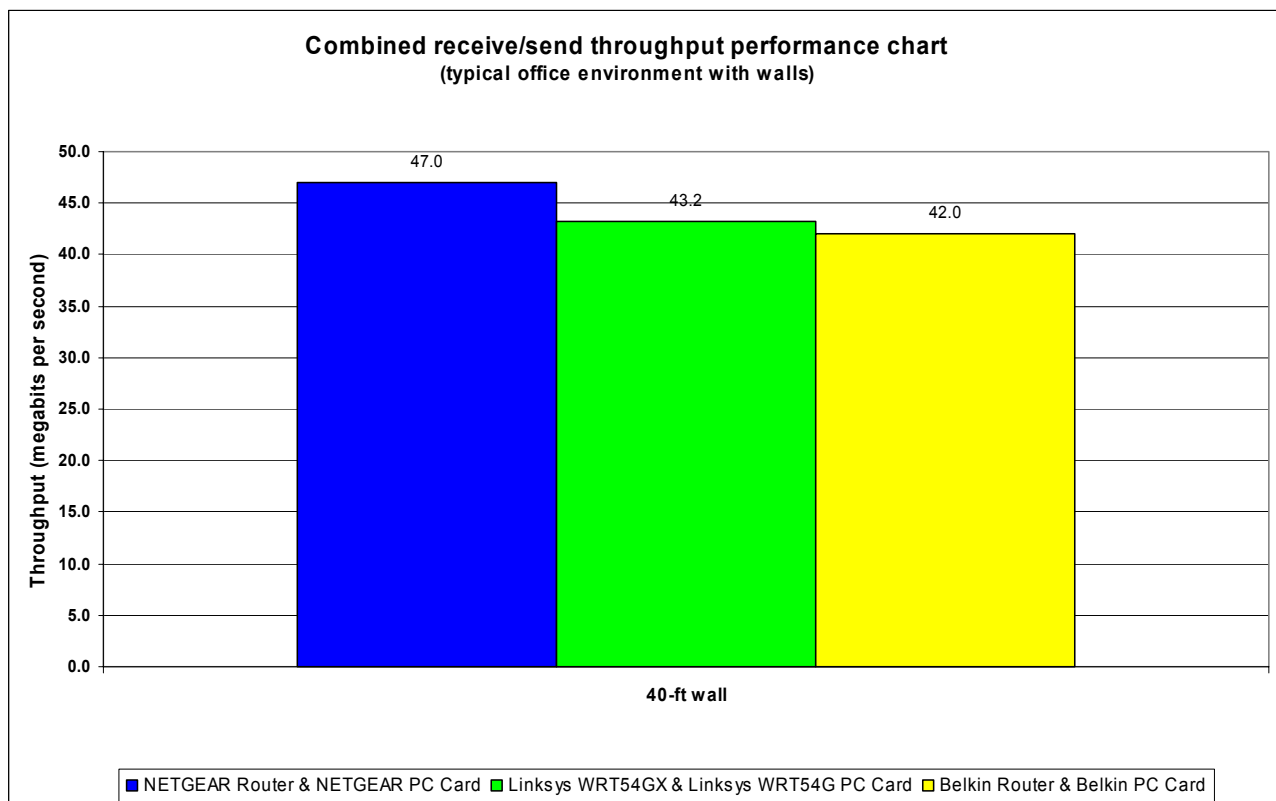


Figure 18. Wireless throughput combined receive/send chart, typical office environment, measured in megabits per second

Maximum Range Test Results

The maximum range testing consisted of measuring the straight-line distance at which the wireless station under test could still connect to the wireless router. Figure 19 shows the results of the testing for each wireless configuration we tested, measured in feet. For these tests, higher maximum range numbers are better.

Configuration	Distance (feet)
NETGEAR WPN824 Router (XR enabled) NETGEAR WPN511 Card	495
Linksys WRT54GX Router Linksys WPC54GX Card	342
Belkin F5D8230-4 Router Belkin F5D8010	341

Figure 19. Wireless maximum range results table, measured in feet

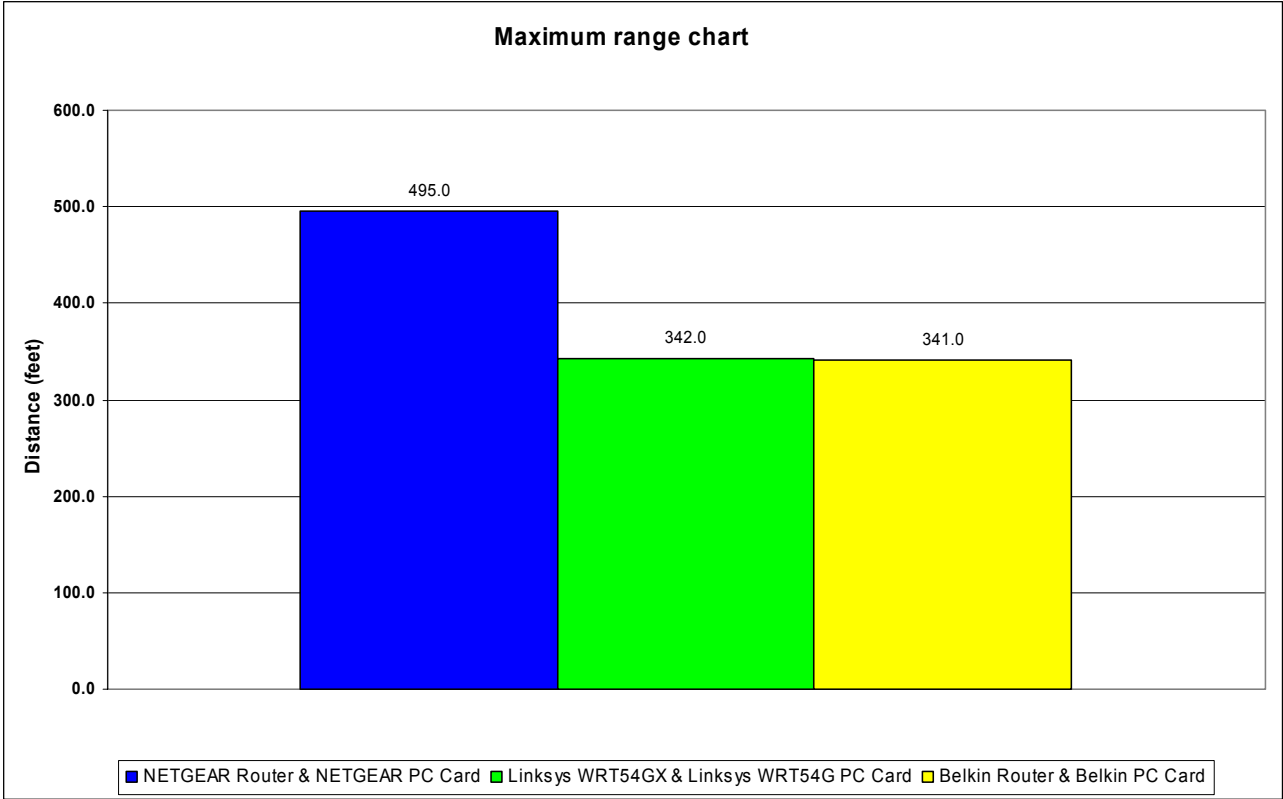


Figure 20. Wireless maximum range chart, measured in feet

Appendices

A. Wireless Driver and Utility Disclosures

Device	Driver/Firmware Rev.	Utility
NETGEAR Wireless Router WPN824	1.0.3_1.0.3	Web Interface
NETGEAR Wireless-G Notebook Adapter WPN511	Driver: wpn511.sys, 4.0.0.140; Firmware Rev. C	Smart Wizard 1.2.0.7
Linksys Wireless Router WRT54GX	1.00.13	Web Interface
Linksys Wireless-G Notebook Adapter WPC54GX	Driver: wnhdd51.sys, 1.4.0.97	Wireless G Notebook Adapter with SRX Utility 1.1
Belkin Wireless Router F5D8230-4	1.00.06	Web Interface
Belkin Wireless Pre-N Notebook Adapter FD8010	Driver: wnhdd51.sys, 1.2.0.68	Belkin WCU 1.2.0.68

B. System Disclosures

IBM ThinkPad T41 –End Point 2	
Processor / Speed / # of CPUs	Pentium-M / 1.4GHz / 1
System RAM	512MB
Ethernet Adapter	Wired: Intel Pro/1000 MT
Operating system	Windows XP Professional SP1

IBM ThinkPad T42 – Chariot Controller System (and End Point 1)	
Processor / Speed / # of CPUs	Pentium-M / 1.7GHz / 1
System RAM	1GB
Ethernet Adapter	Wired. Intel Pro/1000 MT – not used
Operating system	Windows XP Professional SP2

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