Benchmarking MIMO: Examining the Performance of "Draft N" Products

A Farpoint Group Technical Note

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Progress in WLAN systems continues at a pace that is truly remarkable. The next-generation 802.11n standard has proceeded to a first draft, and work continues on bringing this effort towards completion by the first half of 2007, and possibly even sooner. Given the highly-competitive nature of the WLAN market, we're now seeing a number of firms producing both chipsets and end-user products, still primarily aimed at the residential market, with claims of compliance with the initial .11n draft. While the IEEE explicitly frowns on the concept of draft compliance (each revision of the draft carries a stern disclaimer on the cover reminding all concerned not to claim compliance with the draft), the above-noted market conditions are leading in our opinion to highly-risky behavior on the part of some vendors in the form of claims of draft compliance and even software upgradeability to the full standard, clearly in the quest for short-term marketing gains. While we cannot at present evaluate any potential for or likelihood of upgradeability, we decided to look at several aspects of the performance of the latest crop of "Draft N Compliant" products, and compare them for reference against both an existing and established MIMO-based router and client as well as a popular 802.11g-compatible router and client PC Card. Fair questions are raised by the availability of these new products - are they really an improvement over current technologies, and exactly what degree of interoperability does "draft compliance" offer?

Considerations and Test Conditions

The evaluation was structured as a comparative benchmarking exercise, which we perform from time to time at Farpoint Group. While benchmarking is not an exact science, especially when freespace radio is involved, we took great pains in this test to provide as level a playing field as possible, controlling and holding variability in test conditions and especially the radio environment to an absolute minimum. For this test, we used a rented house in a residential area; a diagram of this residence can be seen in Figure 1. We carefully noted the RF environment using a spectrum analyzer (see Figure 2) and used otherwise unoccupied radio channels. We tested each wireless router/client pair for range vs. throughput, using the aver-

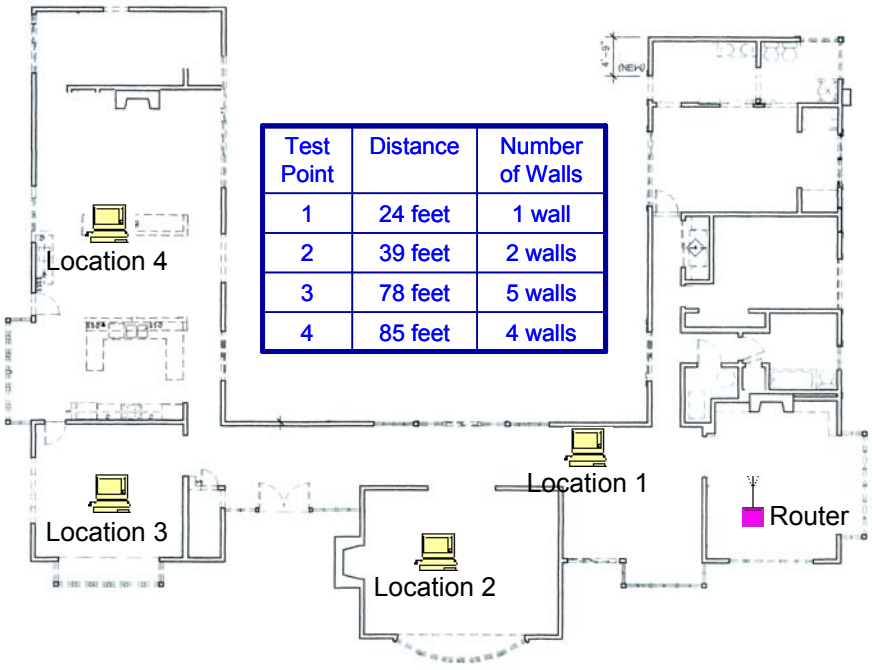

Figure 1 - A diagram of the residence hosting the tests performed. Four locations, Test Points 1-4, were used, with the range in each case indicated in the table embedded in the diagram. The number of walls is approximate and for guidance only, given the vagaries of radio propagation. However, we did see a degradation in performance, as expected, as we increased the distance between endpoints, the whole point of using multiple locations. *Source:* Farpoint Group

age of three different 180-second runs at four different client locations as are shown in Figure 1. Turntables (see Figure 3) revolving at a 45-second rate were used to minimize the effect of fading at each client location. We used the broadly-available (and free) Iperf benchmark [http://dast.nlanr.net/Projects/Iperf/] for our tests, specifying 1.5 minutes of upstream (client to router) and 1.5 minutes of downstream (router to client) traffic for each and thus four complete revolutions of the turntables for each test. This cycle was repeated and the results averaged. All products tested (see Table 1) were commercially obtained via retail channels and verified as being at the latest firmware and software revision levels. We did not contact any of the router/client equipment manufacturers as part of this test, even for tech support, so as to again maintain a high degree of fairness.

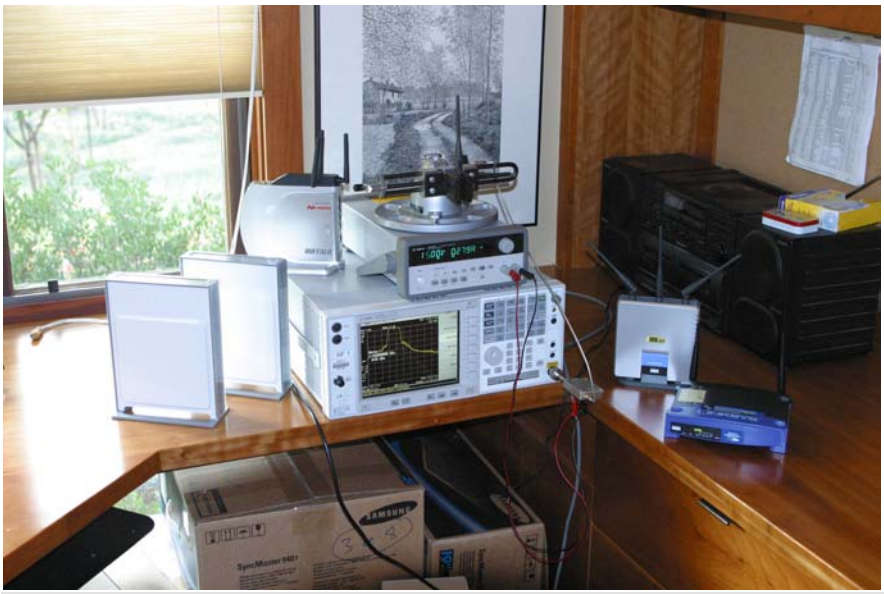

Figure 2 - The spectrum analyzer (an Agilent E4443A) used to monitor air conditions, as well as the five routers tested. *Source:* Farpoint Group.

Except where noted below, we used default configurations for all routers and client drivers. The only change made was to use WPA2/AES/PSK/TKIP security with a common security key ("myencryptionkey") for all runs and configurations. The assumption here was that a typical residential user would change no settings except security (or, at least, end-users *should* change security setting!), and would then use the best security available in a given product configuration. A notable exception was on the Netgear RangeMax *N*ext/Broadcom Intensi-fi router, which supports only AES encryption

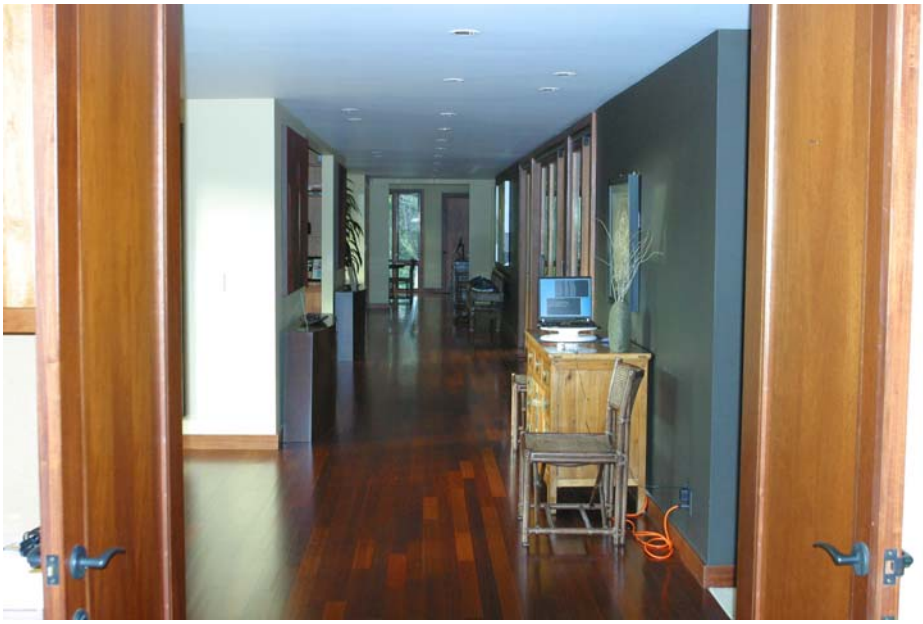

Figure 3 - Looking down the hallway from the location of the router towards Location 3 in the distance. Note the turntable with the ThinkPad. *Source:* Farpoint Group.

Brand	Radio	Router Model	Firmware Version	Client Model	Driver Version
Linksys SRX400	Airgo AGN300	WRT54GX4	1.00.09	WPC54GX4	2.0.1.19
Netgear RangeMAX *N*ext	Marvell TopDog	WNR854T	1.0.26NA	WN511T	2.1.0.0
Netgear RangeMax *N*ext	Broadcom Intensi-fi	WNR834B	V1.0.0.9	WN511B	4.80.5.0
Buffalo AirStation Nfiniti	Broadcom Intensi-fi	WZR-G300N	Ver. 1.42	WLI-CB-G300N	4.80.9.0
Linksys Wireless-G	Broadcom BCM94603MP	WRT54G ver.2	v4.20.7	WPC54G ver.2	6.0.0.18

Table 1: Products tested in this Tech Note. *Source:* Farpoint Group

but did so with unacceptably slow performance, and was thus tested with encryption disabled. We were also unable to enable WPA2 encryption on the Linksys WRT54G router, which we used only as a reference to non-MIMO products, and also left encryption disabled on this unit. All tests of MIMO-based products used 40 MHz. channels, centered at channel 6, again the default.

The Iperf (version 1.7.0) command lines for each stream were as follows:

Client (wired): iperf -c 192.168.1.100 -p <port> -w 128k -i .5 -r -t 90 ><log file>.txt
Server (wireless): iperf -s -w 128k -i .5 -p <port>

All IP addresses were static. No WAN connectivity was provisioned, so the routers were serving only as Layer-2 switches. All PCs used were IBM ThinkPad T42 models running Windows XP SP2, and based on 1.7 GHz. processors and 1 GB of RAM. Power settings on the PCs were left at the default; the server unit was running on batteries, but we do not believe that changing the power settings would result in any changes in outcome.

Because the data rates involved could easily swamp a single 100baseT connection, we used two client machines, each connected to a port on the router under test. An exception here was made in the case of the Netgear RangeMax *N*ext/Marvell TopDog router, which exhibited poor performance when using two 100baseT streams, but regardless supported gigabit Ethernet on all ports, and was thus tested with a single wired client. As an aside, we found Netgear's near identical names and packaging for its two RangeMax *N*ext routers confusing, and regardless (see below) found no MIMO-based "Draft N" compatibility between the two, although they were interoperable via .11g compatibility.

Results and Discussion

The results of the range-vs.-throughput tests are shown in Table 2. We were not surprised with the clear superiority of the Linksys SRX 400 implementation. It is, after all, based on the third generation of chipsets from Airgo Networks, the company that built the first MIMO-based WLAN components more than three years ago. And, given that the SRX 400 is not "draft compliant" (it was introduced before the draft, after all), we suspect Linksys was thus free to focus on absolute performance in this product line.

With respect to interoperability, we performed an additional set of simple limited-range (about 15 feet) tests designed to evaluate heterogeneous connections of the various products tested. In no case could we get any heterogeneous combination of the "draft compliant" cli-

		Location 1				Location 2				Location 3				Location 4			
Brand	Direction/Stream	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Linksys SRX400	Downstream 1	51.20	51.00	50.50	50.90	49.10	48.40	49.70	49.07	42.30	42.80	42.40	42.50	18.40	18.70	18.00	18.37
	Downstream 2	50.30	49.90	50.40	50.20	48.50	49.10	47.90	48.50	43.20	42.70	43.30	43.07	18.60	18.70	18.50	18.60
	Downstream Total	101.50	100.90	100.90	**101.10**	97.60	97.50	97.60	**97.57**	86.50	86.50	86.70	**85.57**	37.00	37.40	36.50	**36.97**
	Upstream 1	47.40	46.80	46.80	47.00	43.70	43.30	44.30	43.77	36.30	37.40	34.90	36.20	19.90	20.10	20.20	20.07
	Upstream 2	46.60	47.00	46.20	46.60	43.80	43.90	43.30	43.67	36.80	37.00	36.50	36.77	19.90	20.10	20.20	20.07
	Upstream Total	94.00	93.80	93.00	**93.60**	87.50	87.20	87.60	**87.43**	73.10	74.40	71.40	**72.97**	39.80	40.20	40.40	**40.13**
Netgear RangeMAX Next	Downstream	42.40	42.00	41.80	**42.07**	19.90	19.60	21.80	**20.43**	5.30	5.50	5.20	**5.33**	N/C	N/C	N/C	N/C
	Upstream	60.60	61.00	58.60	**60.07**	30.70	33.50	31.50	**31.90**	5.10	5.10	5.20	**5.13**	N/C	N/C	N/C	N/C
Netgear RangeMax Next	Downstream 1	37.30	38.70	38.20	38.07	24.20	23.50	23.50	23.73	13.30	14.00	13.70	13.67	N/C	N/C	N/C	N/C
	Downstream 2	37.40	38.60	36.90	37.63	24.00	23.70	22.90	23.53	13.60	13.60	13.80	13.67	N/C	N/C	N/C	N/C
	Downstream Total	74.70	77.30	75.10	**75.70**	48.20	47.20	46.40	**47.27**	26.90	27.60	27.50	**27.33**	N/C	N/C	N/C	N/C
	Upstream 1	37.80	36.40	37.50	37.23	20.40	21.10	21.30	20.93	10.60	8.70	10.30	9.87	N/C	N/C	N/C	N/C
	Upstream 2	38.00	37.90	38.40	38.10	18.50	18.80	20.80	19.37	9.00	9.80	9.90	9.57	N/C	N/C	N/C	N/C
	Upstream Total	75.80	74.30	75.90	**75.33**	38.90	39.90	42.10	**40.30**	19.60	18.50	20.20	**19.43**	N/C	N/C	N/C	N/C
Buffalo AirStation Nfiniti	Downstream 1	33.50	34.60	33.50	33.87	25.10	24.70	24.70	24.83	11.10	11.40	11.40	11.30	N/C	N/C	N/C	N/C
	Downstream 2	33.20	34.50	33.60	33.77	24.90	24.50	24.60	24.67	11.40	11.00	11.40	11.27	N/C	N/C	N/C	N/C
	Downstream Total	66.70	69.10	67.10	**67.63**	50.00	49.20	49.30	**49.50**	22.50	22.40	22.80	**22.57**	N/C	N/C	N/C	N/C
	Upstream 1	41.10	42.40	39.60	41.03	27.10	29.60	27.60	28.10	9.40	9.90	10.10	9.80	N/C	N/C	N/C	N/C
	Upstream 2	43.20	39.10	41.90	41.40	26.30	26.40	27.90	26.87	8.80	9.70	8.80	9.10	N/C	N/C	N/C	N/C
	Upstream Total	84.30	81.50	81.50	**82.43**	53.40	56.00	55.50	**54.97**	18.20	19.60	18.90	**18.90**	N/C	N/C	N/C	N/C
Linksys Wireless-G	Downstream	22.20	22.00	22.00	**22.07**	19.40	19.30	19.80	**19.50**	12.00	11.80	12.40	**12.07**	1.40	1.20	1.40	**1.33**
	Upstream	20.30	20.80	20.80	**20.63**	15.80	15.80	15.80	**15.80**	7.20	6.50	7.10	**6.93**	1.20	1.20	1.30	**1.23**

Table 2: Range-vs.-throughput benchmark test results. N/C = did not connect. *Source:* Farpoint Group.

ents and routers to connect at more than typical.11g (20-24 Mbps) rates. This seems to indicate that "draft compliance" is either poorly implemented or missing altogether, as products of different manufacture compliant with a standard should in fact interoperate to the degree specified in the standard. This is, of course, a problem to be expected with "draft compliance" in general. Without a third party, for example, the Wi-Fi Alliance, to specify interoperability criteria and verify compliance with an agreed specification, differences in interpretation and related issues often (usually?) result in a lack of compatibility as was seen in this test. And needless to say, the "draft compliant" products are not Wi-Fi certified.

Finally, we uniformly saw an improvement in performance using the Linksys SRX client or router in combination with the "draft compliant" as well as standard G products - mixed-vendor (and clearly .11g-based) throughput was always better at longer range with the Linksys SRX on one end than was available in homogeneous configurations. We were also quite surprised that our legacy Linksys G-only units were able to connect at the distant Location 4, while the "draft compliant" MIMO products were not, indicating that the range performance of the "draft compliant" products was even worse than our "plain old G" products - not a good sign at all and totally unexpected for any products based on MIMO.

While we were not surprised with the obvious immaturity of the "draft compliant" products, our expectations were frankly higher. Range-vs.-throughput performance was relatively poor, security implementations need work, and the interoperability implied by "draft compliant" seems to be missing. We suspect that these products were rushed to market to capitalize on 802.11n-draft hysteria, and grant that they could improve some via firmware and software upgrades over the next few weeks or months. The bottom line for now, however, is that the current crop of "draft compliant" products is difficult to recommend for those looking for solutions today. We might feel more comfortable with the "draft compliant" products if we believed that subsequent firmware and/or software upgrades would indeed result in significant improvement in either or both of performance or compatibility. But, again, we instead believe that fundamental improvements in radio, MIMO, and WLAN technologies over the next year will obviate any need for upgradeability and regardless suggest that users should today purchase the best tool for their particular job and not speculate as to what might happen in the future. And we continue to take issue with the entire concept of "draft compliance" and suggest that such is unnecessary at best and misleading at worst.

Conclusions and What's Next

We are planning an even more elaborate series of tests in the near future, this time using both multiple clients as well as benchmarks (subjective though they will be) of video performance as well. The methodology, however, will remain the same, and we expect the only additions to the tests will be updated firmware, software, a few more products, and possibly one or two enterprise-class MIMO-based APs. We'll also give the vendors an opportunity to assist where we suspect issues exist. Note that we've not made any attempt, nor could we, to evaluate conformance to or compliance with the draft standard, and believe that such is of no real value regardless. We'll leave any testing related to this item to the availability of the final, approved 802.11n standard. In the interim, the superiority of the Linksys SRX 400 was obvious, and we must conclude that "draft compliance" is not providing the implied benefits (higher performance and interoperability) that motivate users to purchase these products in the first place.

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