The Effects of Interference on General WLAN Traffic

A Farpoint Group Technical Note

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Farpoint Group

Executive Summary

- Previous Farpoint Group publications have discussed the increasing impact that we believe radio-frequency interference will have on wireless LANs. We have also defined a methodology for evaluating the effects of a variety of forms of interference on a number of types of wireless-LAN traffic.

- This document contains the results of a series of experiments using the above-mentioned methodology on general, non-time-bounded WLAN traffic. These experiments were performed in a typical office environment, with careful monitoring for interference other than that introduced as part of the experiment.

- We used the Iperf benchmark to establish a baseline for a given WLAN configuration, and then re-ran the same benchmark in the presence of different interferers, thus quantifying the effect of a given interference source and allowing careful measurement of any degradation resulting from a given interferer.

- We found that some common wireless devices could severely degrade the performance of a wireless LAN. For example, we saw throughput reductions of more than 62% caused by a microwave oven, 89% from another wireless LAN, and almost 20% from a Bluetooth headset. We also saw the complete obliteration (100% degradation) of a Wi-Fi link caused by a cordless phone. While not all of the devices tested resulted in reduced throughput, we verified that the threat from both Wi-Fi and non-Wi-Fi devices is real.

- Because it can be very hard to identify the specific reason for a reduction in throughput in a given case, we recommend the use of Spectrum Assurance (SA) tools to specifically identify a suspected source of interference.

- As wireless LANs proliferate and become the default connectivity for essentially all users in enterprise environments (and beyond), the interference issue will become more acute. Fortunately, it is likely that a combination of Spectrum Assurance tools, WLAN Assurance tools, and RF Spectrum Management tools will be very effective in dealing with this challenge.

As we discussed in our recent White Paper FPG 2006-321.1, *The Invisible Threat: Interference and Wireless LANs*, we expect radio-frequency (RF) interference to become an increasing concern for operators of enterprise-class and residential wireless LANs (WLANs) alike. Interference can result from traffic on other nearby WLANs, as well as non-Wi-Fi devices simultaneously using the unlicensed bands where WLANs operate. As we noted in the above document, interference is a fact of life in these bands and will only grow worse as usage of these bands continues to increase. Network managers have no choice but to develop a strategy for addressing the challenge of RF interference in order to maximize WLAN performance and reliability.

In our related Technical Note FPG 2006-307.1, *Evaluating Interference in Wireless LANs: Recommended Practice*, we discussed a methodology for evaluating the impact of interference on WLAN traffic via real-world experiments. This procedure enables network managers to see for themselves - in a simple but effective and, we believe, conclusive fashion - how interference might be affecting their WLAN operations. This methodology is, in fact, the result of many days of experimentation with many aspects of interference, including real-world tests which produced some occasionally surprising results.

This Tech Note, and two others in this series (FPG 2006-329.2, *The Effects of Interference on Video Over Wi-Fi*, and FPG 2006-330.2, *The Effects of Interference on VoFi*) present the results of those experiments. This document deals with the effects of a variety of interference sources on general WLAN traffic obtained via real-world testing. Our objective here is to show just how detrimental interference can be to WLANs, and to discuss some of the measures for dealing with what is certain to become an increasingly difficult challenge in the future.

Test Scenario

For this series of tests, we chose a typical open-architecture office consisting primarily of cubicles and a few closed offices and conference rooms. We operated within a single suite of a very large multi-tenant building, and our suite was occupied by typical office workers during the tests conducted. For all testing, we carefully monitored the radio channels we used with Cognio's *Spectrum Expert* [http://www.cognio.com/], a Spectrum Assurance (SA) tool which we have used in similar exercises before and which we highly recommend. Spectrum Expert is a spectrum analyzer designed for WLAN environments, and is capable of monitoring, identifying, and evaluating essentially all forms of interference in the 2.4 and 5 GHz. bands. We used Spectrum Expert both to measure the level of energy in the 2.4 GHz. Wi-Fi channels and to visually monitor the level of interference as the individual tests were run.

The test configuration and geometry can be seen in Figure 1. Following the general procedure outlined in FPG 2006-307.1, we set up a Proxim ORiNOCO AP-700 access point (AP) [http://www.proxim.com/products/ap_700/index.html] at Location 3, and connected it to a notebook computer running the Iperf 1.7 benchmark [http://dast.nlanr.net/Projects/Iperf/] as a server. We then set up two notebook computers at Location 4, approximately 25 feet away, and ran one copy of Iperf on each, using different port numbers so as to create multiple streams at the server end. The traffic generated TCP packets in both directions for three minutes, and was designed to simulate a heavy load of non-time-bounded traffic. The two command lines involved were (on the client) iperf –c 192.168.1.200 –p <port> –w 128k –i .5 –r –t 90 ><file>.txt and (on the server) iperf –s –w 128k –p <port>. The ports used were 5001 and 5002.

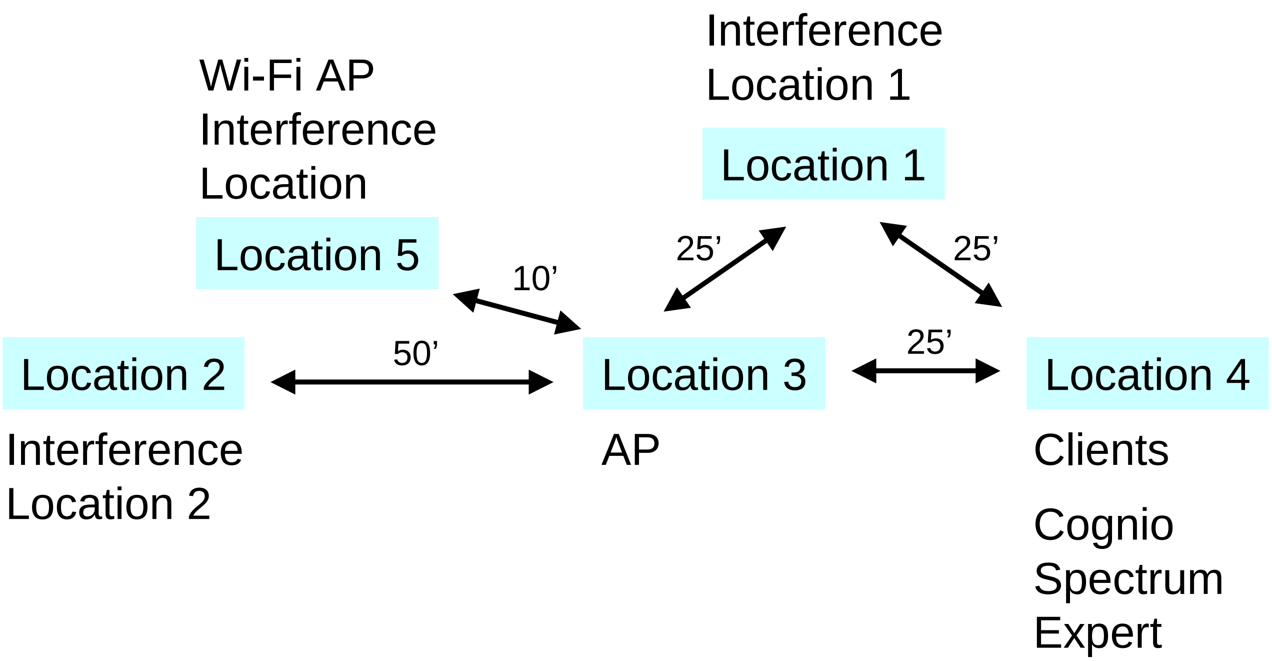

Figure 1 - Test geometry. Equipment was moved from Location 1 to Location 2 and the Iperf runs repeated. Location 5 was used only for the AP end of the interfering Wi-Fi system. *Source:* Farpoint Group.

Both notebooks were equipped with internal Intel PRO/Wireless 2915ABG radios [http://www.intel.com/network/connectivity/products/wireless/prowireless_mobile.htm], and we verified the use of the latest available drivers for all devices. We also set up Cognio's Spectrum Expert at Location 4, which we used to perform an initial RF sweep and as a monitor during benchmark runs. The key result of the former was the selection of Wi-Fi channel 7 for testing, as it appeared to be the best choice overall for minimal background traffic of any form (i.e., it was the "cleanest" of the 2.4 GHz. Channels at the time of testing). Again, we also monitored for any other interference during the test runs.

The general strategy was to test a number of potentially interfering devices at two different locations, one (Location 1) approximately 25 feet from both the AP and the clients ("short range"), and the other (Location 2) approximately 50 feet from the AP and 75 feet from the clients ("long range"). We obtained an initial baseline result in an interference-free environment by running the two Iperf streams for two iterations, obtaining four results. These were averaged to a single number which we used for comparison with exactly the same test run under conditions of varying forms of interference. We also averaged four results per interference test run as well for consistency.

Test Procedures

Interference sources were set up, in turn, at Locations 1 and 2. Each was operated with default settings during the execution of three-minute Iperf runs identical to those used to obtain the baseline. The interference sources tested included:

- *Microwave Oven* − An Emerson MW8987B oven was used because it was available and regularly used by workers in the office. The oven cavity was occupied by a glass of water. Microwave ovens operate at a 50% duty cycle, with energy centered at 2.45 GHz., the resonant frequency of water. The Emerson MW8987B operates at 900 Watts, much less than the 1200 now common. All microwave ovens are allowed a small amount of leakage, measured in milliWatts (mW) at a distance of a few centimeters, and this value is allowed to increase as the oven ages (see http://www.access.gpo.gov/nara/cfr/waisidx_03/21cfr1030_03.html for more information). Regardless, the leakage value is set very low for safety reasons, as the typical human body is approximately 70% water. It should be noted, then, that the presence of humans in the vicinity of the test might have had an effect on the outcome, but since approximately the same number of humans were present in each case, and, since these humans would absorb both WLAN traffic and the interference sources, we do not believe their presence materially affected the test results in this or any case covered by this report. Regardless, the specific amount of interference from microwave ovens varies widely with brand, model, and the age of the oven, but essentially all will interfere to some degree.

- *TDD Cordless Phone* − A Uniden TRU4465 was used in this case. The handset was placed off-hook with the base station, both in close proximity at the interference locations. This phone uses direct-sequence spread-spectrum (DSSS), which places a fairly low level of wideband RF across a portion of the 2.4 GHz. band. While we could have selected a non-interfering channel for the phone, our objective was after all to see how it might affect WLAN traffic. We therefore selected a channel overlapping Wi-Fi Channel 7, and expected severe interference with our Wi-Fi signal.

- *Interfering Wi-Fi System* − For this equipment, we selected a Netgear WG602 (Version 2) AP [http://www.netgear.com/Products/WirelessAccessPoints/WirelessAccessPoints/WG602.aspx], and placed it at Location 5. We then used a client PC, also equipped with the Intel PRO/Wireless 2915ABG radio, and tested this connection at the two interference locations. We operated only a single Iperf stream between the two, but traffic was otherwise identical to that used for our benchmark.

- *DECT Phone* − We used a Panasonic KX-TG2740 handset here. This phone is based on the Digital Enhanced Cordless Telecommunications (DECT) [http://www.dect.ch/] specification particularly popular in European products, but also seen in many cordless phones sold elsewhere in the world. DECT is based on frequency hopping, using narrowband channels across the entire 2.4 GHz. band (in the US).

- *Video Camera* − We chose a XC18A camera from X10, a popular manufacturer of residential home automation products. The camera's signal is analog, not digital, and designed for long-range (100+ feet operation) via a directional antenna. We expected severe interference from this device.

- *Bluetooth Headset* − We used a Jabra BT-200. Cordless headsets are by far the most popular (and common) application for Bluetooth. Bluetooth, however, typically operates at very low transmit power levels (about 1 mW), and we thus expected little interference from this device at the ranges tested.

While some of these devices are no longer current models, all were chosen because they display quantifiable interference characteristics and represent the types of interferers WLAN users are likely to encounter in an office setting. We did not worry very much about the detailed specifications for any of the above devices, nor did we calibrate or otherwise characterize them (although Spectrum Expert did in fact accomplish the latter, correctly identifying all sources of interference by type). Rather, it was our intent to simply gather data regarding the above devices interfering, in two locations, with our previously-baselined configuration, and then to evaluate the results. The process here was simple: we re-ran our baseline test with each of the above interferers running at both the "short" and "long" locations, and noted the Iperf results.

Test Results

The results of testing are shown in Table 1 and Figure 2. All results are in Mbps, except for percentage numbers, which show the percentage of the original throughput still available in the presence of each interferer. As expected, we saw greater interference when the interferers we placed closer (Location 1), and less at longer range.

		Location 1 - Short (Mbps)				**Location 2 - Long (Mbps)**			
					% of				**% of**
	Port	**Run 1**	**Run 2**	**Average**	**Baseline**	**Run 1**	**Run 2**	**Average**	**Baseline**
Baseline	5001	10.60	10.40						
	5002	10.30	10.40	10.43					
Microwave Oven	5001	3.88	3.68			4.67	4.77		
	5002	3.79	4.24	3.90	37.39%	5.09	5.21	4.94	47.34%
TDD Phone	5001	0.00	0.00			0.00	0.00		
	5002	0.00	0.00	0.00	0.00%	0.00	0.00	0.00	0.00%
Wi-Fi	5001	0.22	0.99			4.26	1.17		
	5002	2.15	1.00	1.09	10.44%	3.35	1.56	2.59	24.80%
DECT	5001	9.08	8.42			9.57	9.23		
	5002	8.16	8.39	8.51	81.65%	9.61	9.25	9.42	90.31%
Video Camera	5001	0.00	0.00			1.64	7.26		
	5002	0.00	0.00	0.00	0.00%	1.87	7.17	4.49	43.02%
BT Headset	5001	8.40	8.10			9.34	8.42		
	5002	9.00	8.07	8.39	80.50%	8.42	8.44	8.66	83.02%

Table 1 - The results of two bidirectional runs (four values in total) were averaged to obtain a figure of merit in each case. Of interest was the percentage of original baseline throughput available when the link was subjected to each interferer; this value is noted in the table for each location. *Source:* Farpoint Group.

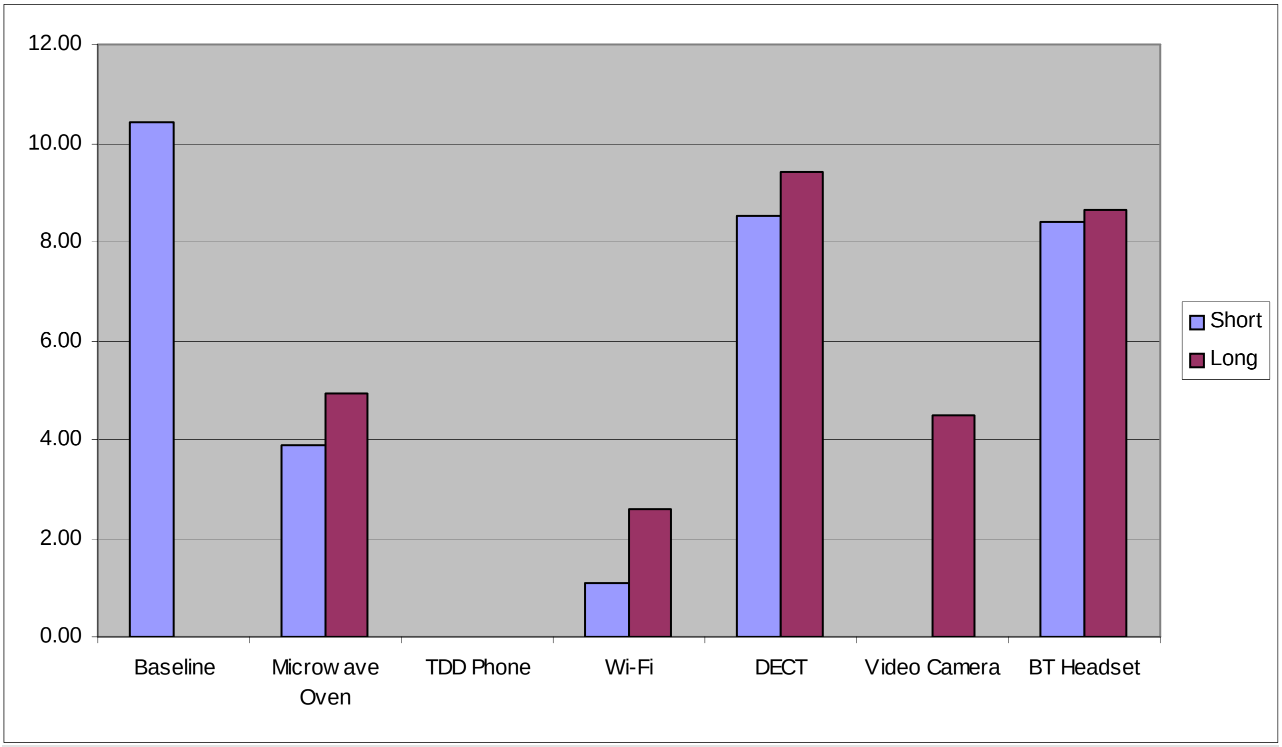

Figure 2 - A graphical version of Table 1. The value on the Y-axis is megabits per second. Note the complete obliteration of the Wi-Fi signal by the TDD phone and the video camera when operated in the "short" location (Location 1). *Source:* Farpoint Group.

We were surprised to see the *complete* obliteration of the Wi-Fi signal by the TDD phone, but not by the video camera, although this signal was less of a factor at longer range than we expected. Both the DECT and Bluetooth devices caused more degradation than we expected, especially in the case of Bluetooth, because its signal is so weak to begin with. Both reduced throughput at short range by about 20%, significant although still much less than the other sources. Also surprising was the degree of interference between the two Wi-Fi systems. One network reduced the throughput of the other by 75%, while its own throughput was reduced by 90%. Granted, both test networks were fully loaded, but it's very clear that Wi-Fi's listen-before-talk protocol was overwhelmed by this situation.

Overall, it was easy to see that common wireless devices could ruin the day of both users and network managers unless steps are taken to identify and mitigate their impact. And, of course, without proper SA tools, it could be very difficult indeed to determine exactly the cause of the problem in any given case.

Conclusions and Recommendations

It is quite obvious from this work that sources of interference can have a significant – and even *dramatic* − impact on the performance of WLANs carrying typical LAN data traffic. All applications, including Web access, e-mail, and access to shared data and other network resources, can be adversely affected. Our tests were designed to see how sources of interference might affect a heavily-loaded wireless LAN. While it can be argued that most WLANs today do not see such a high level of use, we believe that this will increasingly become a common situation as WLANs become more common in many enterprise settings. This situation is driven by the shared nature of a WLAN AP and, of course, the ever-increasing number of users and traffic requirements, with respect to both raw volume and time-boundedness. Since both the number of potential interferers and the volume of WLAN traffic itself will increase over time, we can conclude that interference will become a challenge in many, if not most, WLAN shops over the next few years.

Because interference from both Wi-Fi and non-Wi-Fi sources will manifest itself as a reduction in throughput, and because such can result from non-RF problems, such as congestion on the wired network, and because lower throughput will almost always impact user productivity, it therefore behooves any enterprise-class installation to have the tools necessary to recognize, characterize, localize, and monitor any potential sources of interference. Such functionality is today available in standalone Spectrum Assurance tools, and has also been integrated into some Wireless LAN Assurance (WLA) tools. We believe that this functionality will also be integrated into wireless LANs themselves over the next few years. And we believe that the eventual coupling of RF Spectrum Management (RFSM) capabilities (implemented to varying degrees in all enterprise-class products today) and SA tools will result in significant intelligence and automation being applied to the identification and remediation of radio interference.

Of course, such remediation may still require manual intervention, such as replacing an interfering device with non-interfering equivalent, reconfiguring elements of the WLAN, or even having a chat with a nearby operator of interfering wireless equipment. Regardless, we believe that interference will become as manageable as any other element of LAN operations, and that users and network managers alike should feel free to embrace wireless LANs as a primary and even default connection in enterprises of all sizes and types.

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