The Effects of Interference on VoFi Traffic

A Farpoint Group Technical Note

Document FPG 2006-330.2
January 2007

Executive Summary

- Farpoint Group believes that Voice over IP over Wi-Fi (VoFi) will become much more common and popular over the next few years. This trend is driven by the convenience of cordless phones, but also by the increasing availability of converged cellular/Wi-Fi subscriber units that will allow a single handset to serve a user's voice (and data) communications needs in the enterprise, the residence, and in the wide area.

- Our previous studies have shown that radio-frequency interference can have a major detrimental impact on general WLAN traffic and on video delivered over Wi-Fi. We thus set out to discover whether interference from common wireless devices operating at the same frequencies as wireless LANs could have a similar impact on VoFi.

- We set up a test environment in a typical office setting, using ZyXEL VoFi handsets, and instrumenting the environment with WildPackets' *OmniPeek* (configured to evaluate voice quality) and Cognio's *Spectrum Expert* to monitor both radio conditions and to evaluate external interference. A series of benchmark runs yielded results in terms of both Mean Opinion Score and the more quantitative R-Factors.

- We found that, with the exception of the DECT phone and the Bluetooth headset, all of the interfering devices tested caused a serious degree of interference to our VoFi traffic, enough so that voice quality was severely impacted. We do not believe that successful communication could occur in almost every case evaluated.

- As we usually recommend when interference is suspected, a Spectrum Assurance (SA) tool can be used to identify and classify a suspected source of interference. Some reconfiguration of the wireless network, most notably channel assignments, may be necessary to correct the problem. We expect that this capability will become very common in wireless-LAN system products in the near future, and consequently believe that the threat interference poses to Wi-Fi can be successfully addressed.

As we discussed in our White Paper FPG 2006-321.1, *The Invisible Threat: Interference and Wireless LANs*, radio interference is an increasing issue in the integrity and reliability of Wi-Fi-based WLANs. We further defined a methodology for testing and evaluating the effects of interference in our Technical Note FPG 307.1, *Evaluating Interference in Wireless LANs: Recommended Practice*, an approach to empirically evaluating the impact of various forms of interference in enterprise settings, and we applied these techniques and measured the results in our Technical Note FPG 2006-328.2, *The Effects of Interference on General WLAN Traffic*. What we discovered is that common wireless-equipped products, including other wireless LAN systems, can have a profoundly detrimental effect on typical IP-based WLAN traffic, up to and including the point of completely inhibiting throughput on a given link.

The purpose of this document is to report on a similar set of tests we performed to evaluate the impact of various sources of interference on Voice over IP over Wi-Fi (VoFi) traffic. The methodology we used was similar to that applied in the Tech Notes noted above, but involved a somewhat different WLAN configuration and the use of specialized analysis equipment to quantitatively determine voice quality over multiple simultaneous VoFi links subject to various forms of interference.

The evaluation of voice quality has progressed significantly over the years. Originally, a sampling of individuals was asked to provide their opinion on the sound quality of a given device and its corresponding connection. Ratings were made on a scale of 1 to 5, with integral increments corresponding to ratings of Bad, Poor, Fair, Good, and Excellent, respectively. A simple mathematical calculation thus produces the *Mean Opinion Score*, or *MOS*. A MOS in the high 3 range or above is considered acceptable voice quality.

Of course, the high degree of variability inherent in this method renders it less than desirable for absolute comparisons. Two more consistent approaches are thus more common today. The first of these is an analytical derivation of the MOS, called *Passive* (or sometimes *Pseudo*) *MOS (PMOS)*, and fairly approximate the MOS. The second is *R Factor* (or *R Value*), a mathematically-derived estimation of voice quality, and typically ranging from 0 to 100, although other scales are possible. R-Factors in the high 70s (out of 100) are generally noted as a minimum for acceptable voice quality. While other analytical measurements techniques exist, we used PMOS and R Factors for our work on evaluating the effects of interference on VoFi, the subject of this report.

Test Configuration and Procedures

We built upon the techniques defined in our Technical Note FPG 307.1, *Evaluating Interference in Wireless LANs: Recommended Practice*, and further developed in FPG 2006-328.2, *The Effects of Interference on General WLAN Traffic.* Testing was performed in a typical office environment with cubicles and some closed offices and conference rooms. Figure 1 shows the test geometry and the relative locations of the equipment used. We used four ZyXEL 2000 VoFi handsets [http://us.zyxel.com/web/product_family_detail.php?PC1indexflag=20040520161246&CategoryGroupNo=9F60EDCB-18CA-47EA-9ACE-FDD8CA02B1DC].

These handsets can establish direct IP-to-IP links, and that is how we configured them – as two pairs of off-hook handsets connecting directly to one another via a single Proxim ORiNOCO AP-700 AP [http://www.proxim.com/products/ap_700/index.html]. This AP was placed at Location 4, a cubicle, along with two other pieces of equipment. One of these was a PC running Wildpackets' *OmniPeek* analyzer configured with the Enterprise Enhanced Voice Option [http://www.wildpackets.com/products/omnianalysis_enterprise/omnipeek/voice]. This software allowed us to obtain both the PMOS and R Factors for all traffic flowing through the AP. We also used Cognio's *Spectrum Expert* [http://www.cognio.com/spectrum-expert-products/spectrum-expert-for-wifi/why-spectrum-expert-for-wifi.html] to perform and initial RF sweep, select the best Wi-Fi channel for the test (as it turned out, channel 7), and to monitor for extraneous interference during all test runs; none was noted. We established a baseline result with no interference by collecting data for two minutes. All results were averaged to a single figure of merit for the baseline and in each case of interference.

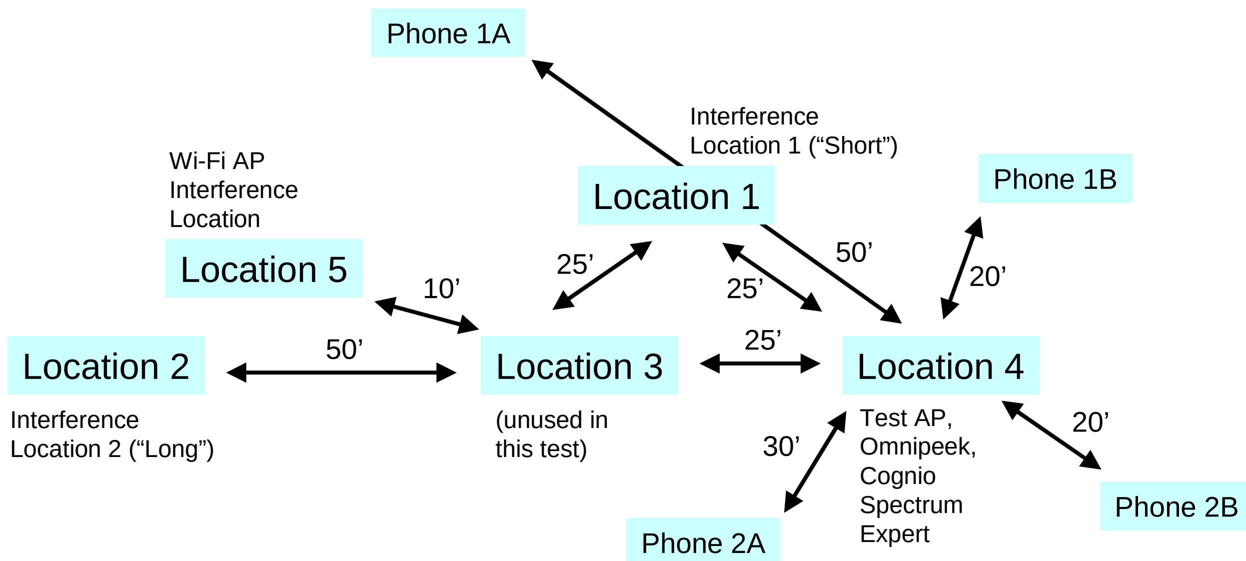

Figure 1 - The geometry of the test configuration. The ZyXEL VoFi handsets were configured in pairs, and all were associated with an access point at location 4. Interferers were placed at Locations 1 and 2 in turn, and the interfering AP was placed at Location 5. Location 3 was not used in this test, but was maintained for consistency with our other interference studies. *Source:* Farpoint Group.

Note that Location 3 in Figure 1 is unused in these tests. We located the client end of our baseline Wi-Fi connection here during our general (see FPG 2006-328.2) and video (see FPG 2006-329.2) tests, and decided to leave this location identified here for reasons of consistency in numbering the various locations.

Interference Sources

A number of interference sources were used in this test. All were operated with default configurations other than setting channels for maximum overlap where appropriate. These sources 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 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 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 selected a channel overlapping Wi-Fi Channel 7, and therefore 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 (1 and 2). We operated a single Iperf stream (IP traffic) between the two, moving packets as fast as possible and thus keeping the channel very busy.

- *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. As a hopper, we did not expect much interference from this device.

- *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 as a frequency-hopper at very low transmit power levels, 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 significant 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 compare the results of the above devices interfering, in two locations, with our previously-baselined configuration, and 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. We repeated the runs while using the VoFi handsets to obtain results via OmniPeek.

		Location 1 (Short)							
	Connection	**Jitter (ms)**	**Packet Loss %**	**PMOS**	**Average**	**% of Baseline**	**R-Factor**	**Average**	**% of Baseline**
Baseline	Call 1	1	0.0%	3.81			79		
	Call 2	2	0.0%	3.84	3.825	100.00%	80	79.5	100.00%
Microwave Oven	Call 1	6	0.0%	2.61			53		
	Call 2	6	0.0%	2.92	2.765	72.29%	59	56	70.44%
TDD Phone	Call 1	6	100.0%	0			0		
	Call 2	9	28.7%	1.75	0.875	22.88%	35	17.5	22.01%
Wi-Fi	Call 1	16	0.0%	2.61			53		
	Call 2	16	0.0%	2.67	2.640	69.02%	54	53.5	67.30%
DECT	Call 1	2	0.0%	3.84			82		
	Call 2	2	0.0%	3.77	3.805	99.48%	78	80	100.63%
Video Camera	Call 1	6	0.0%	1.39			26		
	Call 2	3	0.0%	3.44	2.415	63.14%	70	48	60.38%
BT Headset	Call 1	2	0.0%	3.84			80		
	Call 2	1	0.0%	3.84	3.840	100.39%	80	80	100.63%

		Location 2 (Long)							
	Connection	**Jitter (ms)**	**Packet Loss %**	**PMOS**	**Average**	**% of Baseline**	**R-Factor**	**Average**	**% of Baseline**
Baseline	Call 1	1	0.0%	3.81			79		
	Call 2	2	0.0%	3.84	3.825	100.00%	80	79.5	100.00%
Microwave Oven	Call 1	3	0.0%	3.61			74		
	Call 2	3	0.0%	3.84	3.725	97.39%	80	77	96.86%
TDD Phone	Call 1	34	31.2%	1.16			18		
	Call 2	59	0.0%	2.82	1.990	52.03%	57	37.5	47.17%
Wi-Fi	Call 1	28	0.0%	1.93			39		
	Call 2	30	0.0%	2.07	2.000	52.29%	42	40.5	50.94%
DECT	Call 1	1	0.0%	3.77			78		
	Call 2	2	0.0%	3.81	3.790	99.08%	79	78.5	98.74%
Video Camera	Call 1	5	0.0%	1.93			39		
	Call 2	4	0.0%	3.88	2.905	75.95%	81	60	75.47%
BT Headset	Call 1	1	0.0%	3.84			80		
	Call 2	2	0.0%	3.73	3.785	98.95%	77	78.5	98.74%

Table 1 - Results of the testing. The key metrics are PMOS and R-Factor scores. We saw essentially no degradation from the DECT phone or Bluetooth headset, but a severe impact from the others. The only exception was the microwave oven at longer range, which was less of a problem than we expected. *Source:* Farpoint Group.

Test Results

The results of our testing can be seen in Table 1 and Figure 2. As we had previously seen in our testing of general Wi-Fi traffic and streaming video in the presence of the interferers noted above, all but the DECT phone and the Bluetooth headset caused severe damage to voice quality in terms of both PMOS and R-Factor scores. The microwave oven was less of a factor at longer range than we expected, and probably would have caused only minor degradation of voice quality. There was good correlation between PMOS and R-Factor scores in all cases, giving us a high degree of confidence in the results.

We also recorded jitter and packet loss values in all test runs. Jitter is minor variations in timing that can affect overall throughput and, in this case, voice quality. Packet loss was only a factor in tests using the TDD phone and did not always correlate to high jitter values. Rather, we believe the packet loss was simply due to overwhelming high-amplitude interference. We also once again observed benchmark results in the case of the short-range DECT and Bluetooth interferers that net throughput was higher than the baseline. This is due to minor statistical variations inherent in the nature of radio and is not otherwise significant.

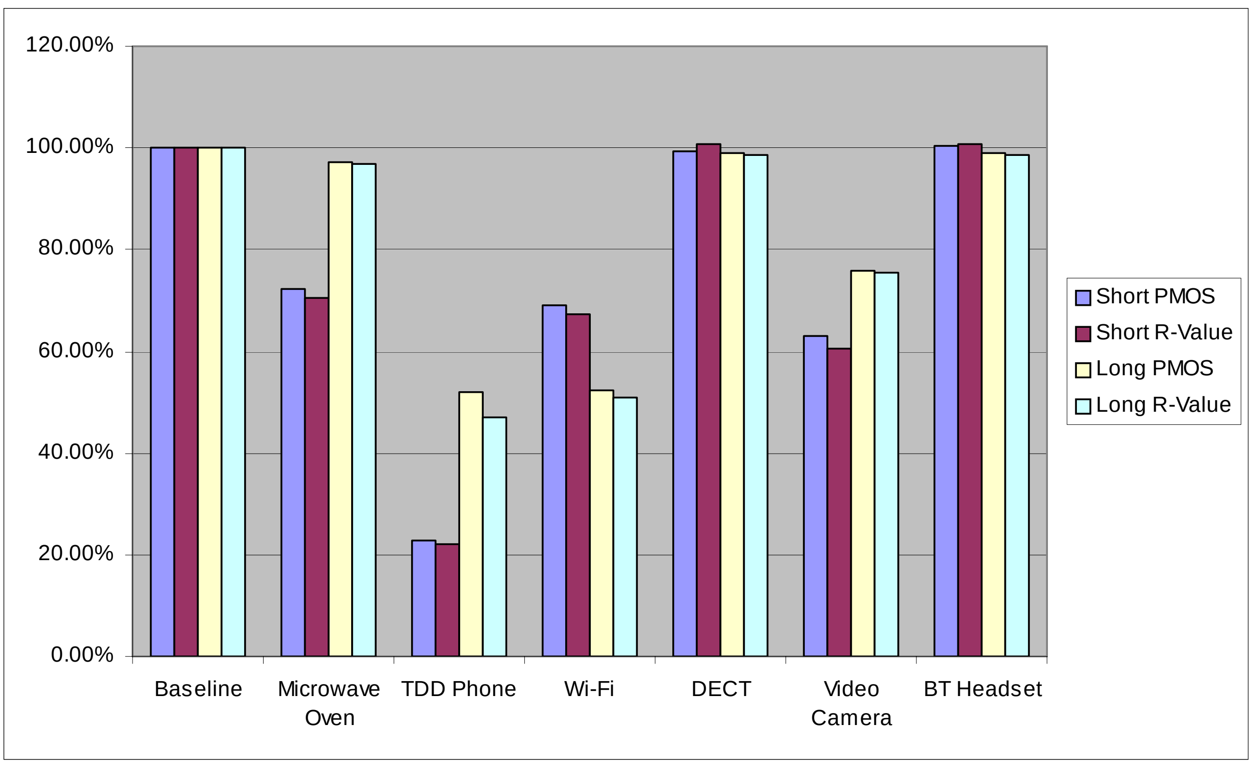

Figure 2 - A graphical representation of the key metrics (PMOS and R-Factor) from Table 1. This is expressed in all cases as a percentage of the original baseline, obtained in the absence of interference. Note the major impact of the TDD phone , the interfering Wi-Fi system, and the video camera, as well as the microwave oven at short range. *Source:* Farpoint Group.

Conclusions

As we previously saw with general WLAN and streaming-video traffic, interference can also have a devastating effect on the quality of VoFi connections. Farpoint Group believes that it is particularly important to address this challenge as soon as possible, and for two key reasons. First of all, we believe it is clear that VoFi will become a key driver of enterprise WLAN installations over the next few years, with the percentage of voice traffic on the LAN growing dramatically. User expectations for both service availability and connection quality continue to increase as the quality of that other popular voice technology, cellular, does similarly. And this leads to the second reason for the increasing popularity of VoFi, which also drives the first: the rapid advances that will be seen in converged cellular/Wi-Fi services over the next few years. Dual-mode cellular/Wi-Fi handsets are already widely available, as are a variety of enterprise- and carrier-centric convergence solutions. Convergence of this form means that end users will have a single-device/single-number/single-voice-mail telephony service essentially everywhere they roam. And convergence further gives the cellular operators the opportunity to displace enterprise wireline carriers and lock in enterprises for a significant period of time.

But enterprise users will, as always, have little tolerance for poor voice quality, service dropouts, and the other artifacts that, sadly, have been far too much a part of the wireless landscape throughput its history. As a consequence, enterprises will need to make use of the various approaches to Spectrum Assurance (SA) now on the market, including products from AirMagnet, Cognio, Fluke Networks, and WildPackets. We believe these tools will eventually become part of WLAN infrastructure equipment, and, thus armed, network managers can specify and control any required reconfiguration to minimize and even eliminate interference where and when it is identified.

Regardless, as we have shown in this report, VoFi interference will become a challenge that enterprise IT managers will need to address. We are very confident, however, that suitable tools, already available, will continue to evolve to aid in this task. We thus conclude that interference will not be a showstopper in the wide deployment of VoFi in the enterprise – and beyond.

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