

Effects of Radio Frequency Interference on an 802.11a Wireless Ad-Hoc Network

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Abstract— Consumer electronic devices that utilize wireless communication interfaces to share information on the go are becoming a part of everyday life. Many of these devices communicate on unlicensed channels in the Industrial Scientific and Medical (ISM) and Unlicensed National Information Infrastructure (U-NII) frequency bands. One common communication interface used by these devices is described by the IEEE 802.11a standard. A wireless router is a typical device that employs the 802.11a communication standard. Wireless routers are located in many places we frequent every day, such as coffee shops, libraries, and even fast food restaurants. The proliferation of these devices throughout our environment has increased the potential for loss of connectivity due to interference from other devices. This paper will explore the effects of radio frequency interference on an ad-hoc wireless network of consumer routers in a congested 802.11a channel. In this paper, the source of interference will be a radio frequency sine wave generator. Interference will be measured by recording metrics about the data link, such as throughput and latency, between the different router nodes. These metrics will be monitored as the amplitude of the sine wave is varied to determine the effect of its interference on the ad-hoc wireless network of consumer routers.

Radio frequency interference; wireless ad-hoc network; consumer 802.11a router

I. INTRODUCTION

In today's world, we are surrounded by wireless electronic devices. These devices help us interact with the world. We use cellular phones to communicate with one another, vehicle remotes to interact with our cars and trucks, and wireless routers to access information. In our daily lives, we have contact with a veritable cornucopia of wireless devices.

Many modern wireless devices occupy unlicensed frequency bands. Two common unlicensed frequency bands are the Unlicensed National Information Infrastructure (U-NII) bands [1] and the Industrial, Scientific, and Medical (ISM) bands [2]. The U-NII devices operate in one of three primary bands. Each of these three bands has a different transmission power limitation as shown in Table I below.

TABLE I. U-NII TRANSMISSION POWER PARAMETERS

Unlicensed National Information Infrastructure		
Band	Frequency	Power Limitation
U-NII Lower:	5.150-5.250 GHz	50 mW
U-NII Middle:	5.250-5.350 GHz 5.470-5.725 GHz	250mW
U-NII Upper:	5.725-5.825 GHz	1000mW

The ISM standards, on the other hand, permit devices to transmit at higher power across multiple frequency bands according to the specifications in Table II below.

TABLE II. ISM TRANSMISSION POWER PARAMETERS

Industrial, Scientific, and Medical	
Frequency	Power Limitation
902-928 MHz	1000mW
2400-2483 MHz	1000mW
5725-5825 MHz	1000mW

As more devices occupy these unlicensed frequency bands, the potential for unintentional interference from other devices increases. To understand the effect that interference has on reliable communication between devices in the unlicensed bands, testing needs to be conducted to collect data that can be used to develop a model. This model would be a valuable tool for device developers. Device developers could use such a model to simulate and hone their device designs to better handle different types of interference and reduce data transmission loss.

Interference can be attributed to different sources. Three common sources of interference are timing errors, coding symbol duplication, and channel noise. Each of these interference sources presents a unique challenge for device developers. High fidelity models for each of these interference sources would help foster improved designs leading to more robust devices to simplify our everyday lives.

II. APPROACH

To investigate the effect interference has on common wireless devices, an experiment was developed to simulate multiple wireless devices on a wireless channel was developed. The effect of multiple wireless devices transmitting simultaneously was emulated by artificially increasing the noise level on a particular wireless channel. A simple signal was generated to resemble noise on the channel centered in a common unlicensed communication frequency band. The signal was then broadcasted at a low power level, and then directed at a test system to observe its effects.

The test system used in this experiment is a common 802.11a wireless ad-hoc router. This device is commercially available from the Gateworks Corporation and Ubiquity Networks. The test system is comprised of two primary pieces, a controller and a wireless card. The controller used was the Avalia Network Platform [3]. The Avalia Network Platform runs an open source embedded router operating system called OpenWRT. For this test, OpenWRT¹ was configured to establish an ad-hoc mesh network using the Optimized Link State Routing (OLSR) protocol [4]. This system interacts with other wireless devices via an XtremeRange5 wireless card [5]. This card was configured to transmit on IEEE 802.11a [6] channel 52, which has a center frequency of 5.26GHz. This frequency is within the U-NII Middle band described above in Table II. The power output of the test system radio was configured to transmit at 250mW, the maximum power permitted by the U-NII standard. An image of the test system is show in Figure 1 below.

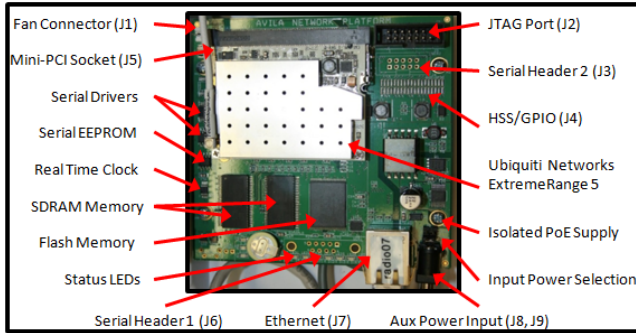


Figure 1: Test System

The IEEE 802.11a Standard outlines several communication specifications that were used in the design of this test system. This test system utilizes orthogonal frequency-division multiplexing (OFDM) to more effectively mitigate the effects of multipath interference. OFDM sends information across multiple subcarriers. There are 52 sub-carrier frequency bands within each of the channels specified in the IEEE 802.11a Standard. This system uses channel 52, which is centered at 5.26GHz with a 20MHz bandwidth. Across the 20MHz bandwidth, this system uses 48 subcarriers, each with a bandwidth of 312.5 KHz. The graphic in Figure 2 depicts the relationship between subcarrier frequencies that reside in each

of the 802.11a channels, as well as the 802.11a channels themselves.

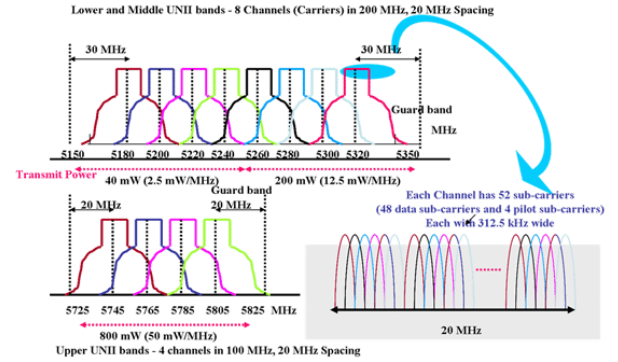


Figure 2: U-NII Channelization [5]

To explore the effect that radio frequency interference had on the test system, the signal generator was configured to create a signal centered at 5.26GHz with a transmission power of 10mW. The spectrum analyzer was configured to monitor a 30MHz bandwidth centered at 5.26GHz in real-time. The experiment procedure consisted of powering on the spectrum analyzer, followed by each of the two wireless routers. Traffic on each of the routers was monitored to determine when information was being exchanged between the two routers, at which time, the signal generator was activated. The physical configuration used for this experiment is represented in Figure 3 below.

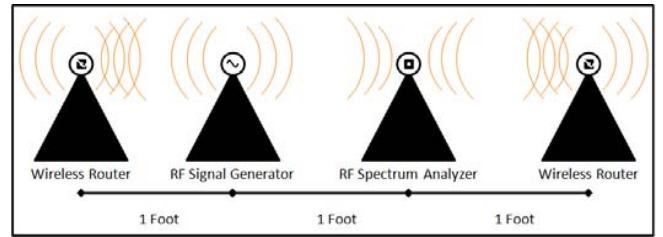


Figure 3: Test Configuration

III. RESULTS

A baseline of normal communication signal between the two wireless ad-hoc routers is shown in Figure 4 below.

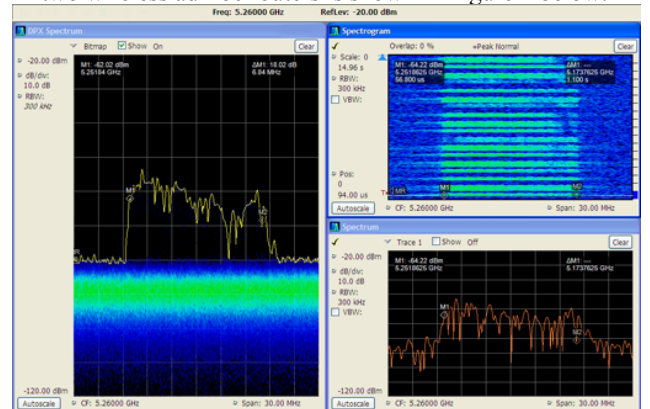


Figure 4: Normal Communication Channel

¹ More information about OpenWRT is available from the developer's website: <http://www.openwrt.org/>

During the baseline data collection, the OLSR protocol running on the routers was configured to exchange ‘hello’ packets at a rate of one per second. These packets provided sufficient traffic between the two routers to observe communication in the radio frequency environment with the spectrum analyzer. The baseline signal that was collected was consistent with the expected communication signal of an IEEE 802.11a device.

With the normal communication pattern between the two routers collected, the effects of an interference source in communication channel was able to be observed. The best metric available to determine reliable connectivity between the two routers was network latency. Network latency was tested by sending an echo request, using Internet Control Message Protocol (ICMP), from one router to the other. Figure 5 below shows the effect that the presence of the interference signal had on the network latency between the two routers.

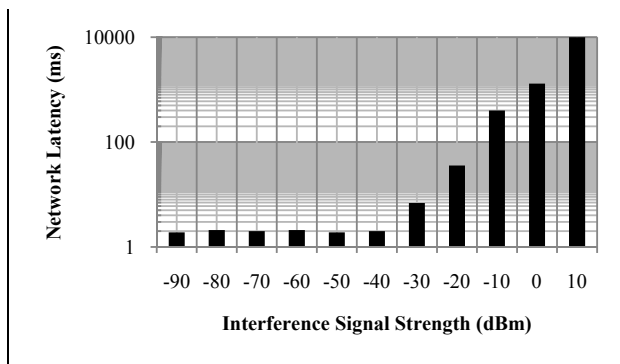


Figure 5: Interference Effect on Network Latency

The maximum network latency that the routers could tolerate was 1500 milliseconds (ms). If a response from one router to the next takes longer than 1500 ms, then the two routers view each other as unreachable. When a router enters the unreachable state, communication to other devices is not possible, resulting in effectively disrupting the flow of data from one router to the other. The results from this experiment indicated that when the power of the interference signal exceeded 10dBm, reliable communication between the routers was impossible.

To better understand this phenomenology, the spectrum analyzer was configured to record the real-time radio frequency environment within the bandwidth of the target system. The output of the spectrum analyzer with the presence of the interfering signal is shown in Figure 6. This capture from the spectrum analyzer shows the interfering signal occurring at 5.26GHz. The interfering signal power is much greater than that of the normal communication signal that the two wireless ad-hoc network nodes are exchanging.

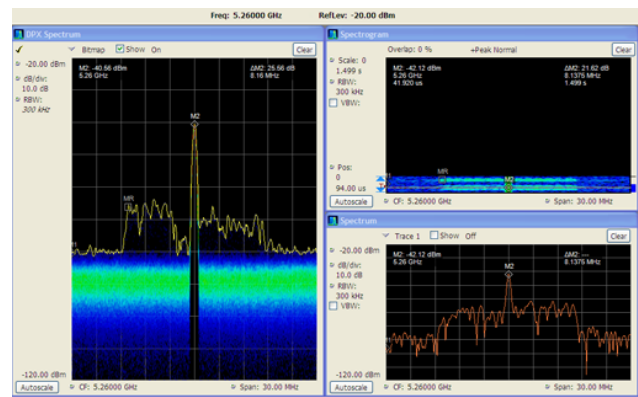


Figure 6: Interference Source Introduced into Communication Channel

The interfering signal had an adverse effect on the ability of the wireless routers to reliably exchange information. When the signal generator transmitted noise on the active wireless channel, the ad-hoc routers lost the ability to reliably exchange information for a minimum of five seconds.

IV. CONCLUSION

This experiment serves as a demonstration of how overloading an unlicensed wireless channel can have great consequences. The introduction of a noisy signal broadcast at a low power level (10dBm) into an active channel quickly had an adverse effect on the routers ability to exchange information. End users across the world would benefit from the development of high fidelity computer models and simulators for unlicensed devices. The main take away from this experiment is that when developers build devices that communicate in these bands, it is imperative to take the time to implement robust solutions that are able to handle interference from other devices on active channels. With no end to the proliferation of consumer electronic devices in sight, device developers will need to test the effect interference has on their devices ability to communicate. To achieve this goal, specialized modeling and simulation tools are needed to better estimate these effects.

REFERENCES

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