IEEE Mini Grant Project:
WiMAX Interference Testing Final Report

Senior Design II EECE 404 – April 20, 2010

WiMAX Senior Design Team

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Executive Summary

Intel Corporation, in order to promote education, foster healthy competition, and expose students to new technology, holds design challenges between universities. In the 2009-2010 academic year, Howard University and North Carolina A&T University were selected to participate. Howard University's design challenge entails WiMAX testing methodology, allowing students to be exposed to an emerging technology. The problem statement that Intel provided to Howard University requested for different testing methodologies for WiMAX, as well as promoting student knowledge on the IEEE 802.16 standard. In keeping with the problem statement, and under funding from the Institute of Electrical and Electronics Engineers, we as the senior design team have refined and focused our project on interference testing with respect to WiFi's affect on WiMAX performance, hypothesizing that WiMAX performance will degrade under dense WiFi deployments that are prevalent across the U.S., most notably around Howard University's campus. The following will detail our solution approach and outline our results.

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BACKGROUND

Intel Corporation [8] advocates the advancement of education and the provision of opportunities to students in varying fields of study. As a testament to their dedication, Intel Corporation sponsors design challenges to foster competition and student driven innovation. For the 2009-2010 academic year Howard University has been included in a competition with North Carolina A&T University. The design challenge that Intel posed to Howard University is the industry problem that our senior design team will address as a component of the design challenge team at-large.

The design challenge entails WiMAX testing methodology. Intel supports WiMAX as the up-and-coming standard in next generation wireless communications. With WiMAX disseminating across the nation and the world, it is imperative that Intel be able to best analyze a network's performance capabilities for optimization of the IEEE 802.16 standard [1], network optimization, coverage area tower placement, and consistency in their products that leverage WiMAX technology.

WHAT IS WiMAX?

WiMAX, or Worldwide Interoperability for Media Access, is a method for deploying metropolitan area networks with broadband comparable speed with minimal need for a complex, wired infrastructure, and currently using the 2.5, 3.5, and 5 GHz frequency bands in various locations around the world. The figure below gives an example of how WiMAX can be deployed in order to "blanket" an area with its signal and be used as a backbone or backhaul to local access points. The standards that characterize WiMAX are defined in the IEEE 802.16 standard [1].

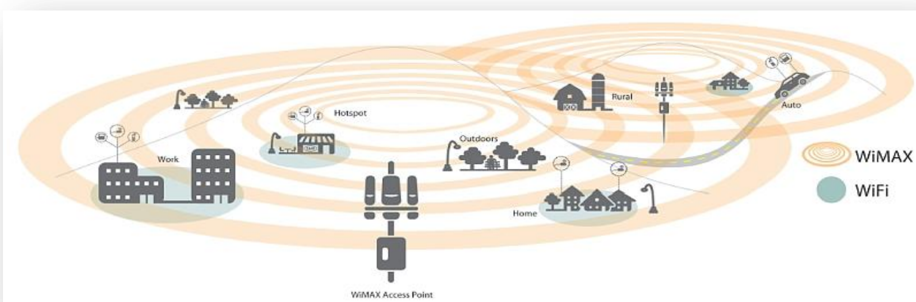

Figure 1: Metropolitan Area Network (MAN) Capable

PROBLEM DEFINITION

In considering Intel's need, and the current status of WiMAX technology, we have refined the problem definition to the following statement:

How to best formulate and deploy a test method to evaluate emerging WiMAX technology.

This problem definition was determined by establishing the set scope for our project that focuses solely on a testing methodology and/or system while bounding the team to a set date (i.e. ECE Day). Intel's need entailed comprehending the system and its characteristics, but not knowing how to predict its actions. We determined that the desired result was a test method that could be replicable and beneficial to Intel's ambitions with respect to WiMAX technology.

SOLUTION APPROACH

In evaluating Intel's problem statement, and deriving our problem definition, we came to the conclusion that experimental design with a focus on using Howard University's campus as the setting would be the best approach. Implementing an experimental design requires the establishment of a hypothesis based on theory and current, common ideas concerning the state of the subject to be tested.

Theory

In the United States, the 2.4GHz frequency band is an unlicensed frequency band utilized by commercial devices, most notably WiFi, which is defined to work in this range in the IEEE 802.11 standard [2]. Commercial WiMAX deployments in the U.S. currently leverage the 2.5GHz frequency band as a licensed band, which falls into the range defined in the IEEE 802.16 standard [1]. As shown in Figure 2, these bands are relatively close.

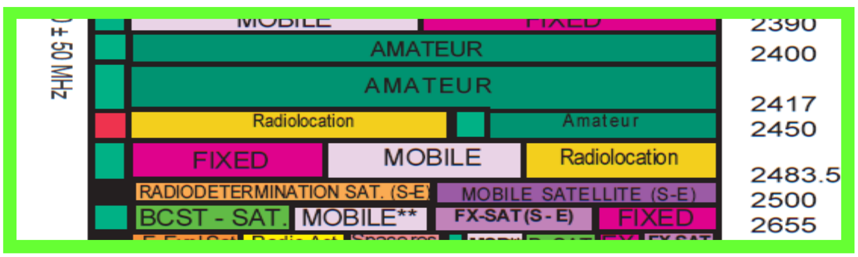

Figure 2: 2.4-2.6 GHz Frequency Band Usage in United States

Additionally, Intel's prescribed architecture for these devices leverages the same antennae for both IEEE 802.XX standards [8]. Taking into consideration the commercial frequency proximity of where these standards function, Intel's frugal design, and WiFi's heavy deployment across the nation (and our campus), we assumed that WiFi can impact WiMAX performance. Thus, our formal hypothesis is as follows:

Under real-world conditions, WiMAX signals will be subject to and degraded by interference created by Wi-Fi signals that propagate in various locations on Howard University's campus.

Experiment

Leveraging previous Intel testing methodologies, as well as the advice and expertise of Professors Kim and Trimble [10, 11], we designed an experiment leveraging Howard University's campus, as stated in our hypothesis. Firstly, the components of the experiment are as follows: Hardware, Software, System Setup, and Process. The hardware and software that was used throughout the experiment was provided, either by Intel, or Howard University, with the exception of the embedded system that we constructed. They are listed as follows:

Hardware

- 3 WiMAX enabled Laptops provided by Intel
- Embedded System: RF Detector (See Figure 3)
    - LMH2100 Evaluation Board [3]
    - DI-158U Data Acquisition Board [4]
    - Peak Follower Circuit with Voltage regulator and battery pack
    - Physical media connectors
- Wireless router - meant to be a secure point for WiFi-enabled computers to be used
- 2.4 GHz Antenna

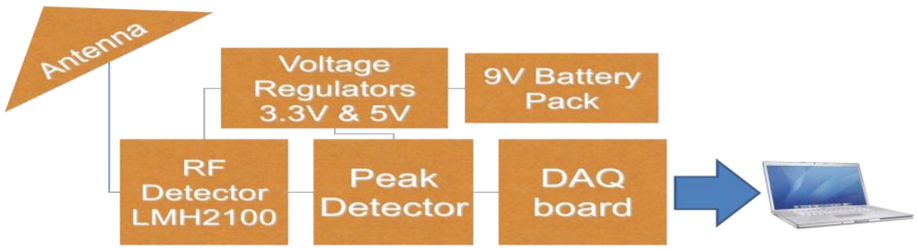

Figure 3: RF Detector Diagram

Software

- Microsoft Office Excel 2007
- WinDAQ – Windows Graphing tool association with Data Acquisition Board.
- Windows Performance Monitor
- FiDO – WiMAX analyzing software from Intel.
- inSSIDer – Wi-Fi network scanner for Windows Vista.
- Channelyzer – allows users to visualize wireless landscape.
- Speakeasy.net – online speed test that allows free testing of one's network connection. [5]

System Setup

The following describes the system setups we used during testing, highlighting how each piece of equipment was utilized.

WiFi Laptop

- Monitors Available WiFi Networks via inSSIDer & Channelyzer
- Creates WiFi Traffic by connecting to available network

WiMAX Laptop

- Records system values via WinDAQ software
- Tests Uplink/Downlink speeds
- Records values from Windows performance monitor

Process

To test for interference of WiMAX signals at the various locations we have developed the following process to test for the amount of interference present and its resulting affects.

Testing Method

- Time Period per test: 20 minutes
  - 10 minutes without WiFi activity
  - 10 minutes with WiFi activity

- RF Detector embedded system records data for the 20 minute duration, exporting this data to an excel spreadsheet.

- Microsoft Performance & Reliability Monitor records data for the 20 minute duration.

- Execute 15 replications of the online downlink/uplink speed test (speakeasy.net) for each 10 minute interval; Record downlink and uplink for each replication.

- One Laptop monitors the present Wi-Fi signals using inSSIDer and Chanalyzer while also monitoring the outputs from the overall system.

- Record the location, time, date, WiFi Networks present, signal strength of each, and signal channel of each.

- If Fido is functioning, record values using the process respective to the software. If not, skip this step.

Testing Locations

- Howard Towers Plaza
  - On campus, indoor student residential area with a high density of Wi-Fi signals and users. This was used as a control location, leveraging both time (7AM) and the wireless router to eliminate idle traffic from varying WiFi-enabled devices.
- College of Engineering Purple Room
  - Indoor computer lab and class simulation with a significant number of Wi-Fi signals with varying intensities and large number of users
- Upper Quadrangle Flagpole
  - Outdoor location with large student population but many Wi-Fi signals with low signal intensities and minimum users
- Undergraduate Library Study Area
  - Indoor student study location with numerous Wi-Fi signals with varying signal intensities and users
- Blackburn Meeting Rooms
  - Indoor rooms with no windows and minimum foot traffic and access to numerous Wi-Fi signals with varying intensities

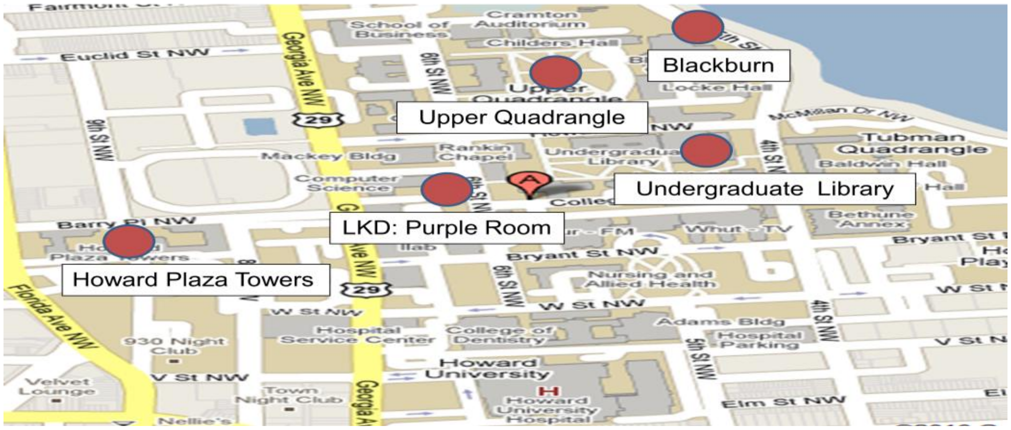

Figure 2: Test Locations

RESULTS

The testing took place from April 7th to April 13th. The following are the results from those tests.

Average Downlink/Uplink Per Site Location

	Control - East Towers		Purple Room Study		Upper Quadrangle - Flag Pole		Blackburn Rm 148-150		Undergraduate Library	
	Dwnlink	Uplink	Dwnlink	Uplink	Dwnlink	Uplink	Dwnlink	Uplink	Dwnlink	Uplink
WIMAX ONLY	4.712	2.56	7.97	1.256	3.29	1.08	1.29	0.03	2.29	0.49
	5.5	2.64	5.13	0.68	2.5	0.6	1.22	0.06	3.58	0.5
	7.23	2.69	7.468	1.49	2.53	1.11	0.92	0.04	2.69	0.34
	8.55	2.77	7.1	1.93						
	6.498	2.665	6.917	1.339	2.7733	0.93	1.1433	0.0433	2.8533	0.4433
WITH WIFI	5.29	2.61	7.31	1.35	3.27	1.02	1.24	0.03	3.93	0.73
	5.18	2.6	4.98	1.06	2.32	0.67	1.09	0.05	2.09	0.22
	6.88	2.74	3.65	1.81	2.31	1.1	0.89	0.05	2.11	0.25
	5.94	2.75	3.94	1.77						
	5.8225	2.675	4.97	1.4975	2.6333	0.93	1.0733	0.0433	2.71	0.4

Figure 3: Speed Test Results

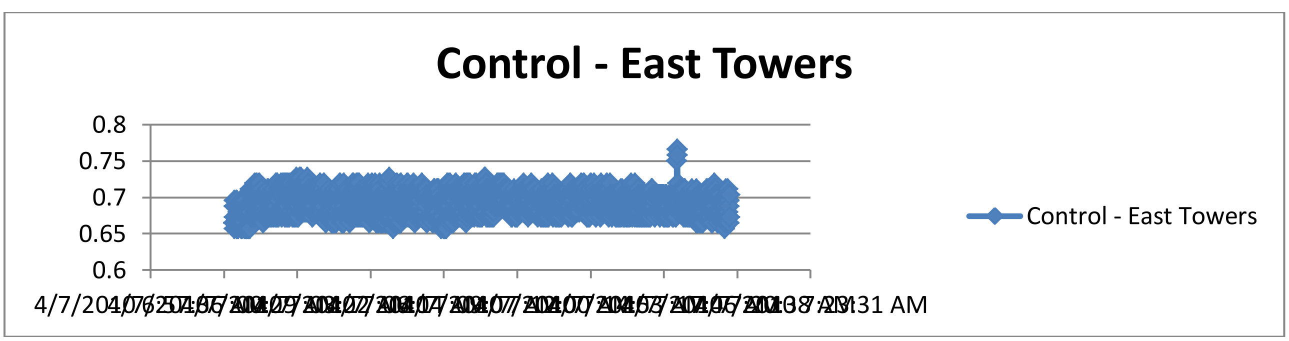

Figure 4: RF Detector Results (Control – East Towers)

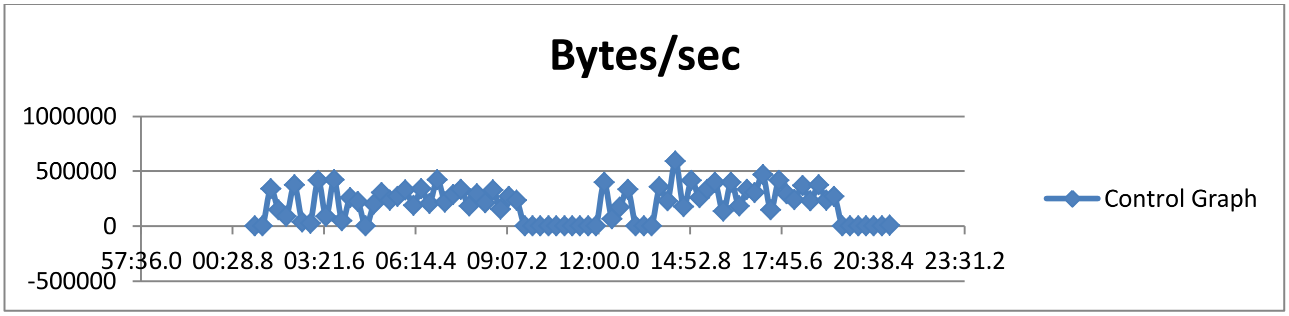

Figure 5: Performance Monitor Results (Control – East Towers, Bytes/sec)

OBSERVATION

The testing observations, both during testing and while reviewing the data, were interesting. Above are the results of a sample compilation of the raw data that we gathered. Figure 3 contains the average values of the downlink and uplink during the two parts of testing. The next set of data in Figure 4 illustrates the output of the RF detection embedded system. Lastly, Figure 5 shows the performance monitor data which represents the amount of bytes per second that were received/sent through the network device (in this case, the WiMAX device).

After analyzing the data, we found that downlink performance was impacted while uplink performance remained unchanged. We surmised that downlink performance is primarily impacted because of the issues that we theorized could cause such a phenomena (i.e. shared antennae, location in frequency spectrum, etc). Conversely, since uplink performance is a measure of data leaving the WiMAX-enabled system, the methods used to record the performance data would always maintain an average rate since the power to generate the signal allows the device to transmit at said rate.

An additional observation was that WiMAX and WiFi actually affect each other's performance. The tendency to degrade performance was not a one way street in WiFi's favor. WiMAX has just as much tendency to degrade WiFi performance as well. This was made obvious during tests where WiFi activity that was being conducted during testing would slow tremendously from time to time. For example, while executing an Ubuntu Linux download, what started as a 20 minute download quickly became grew to 9 hours, as WiMAX performance consistently reached its maximum for that test location. This can also be contributed to the same cited issues in out theory.

CONCLUSIONS & RECOMMEDATIONS

The data that we collected and analyzed effectively proved our hypothesis, as well as a promoted the interest in this field of study within our group. Considering the results from our testing process, we suggest the following:

- WiMAX should operate in a different set of frequency bands, considering that WiFi is currently used so heavily.
- Develop a method to check WiFi monopoly on the the frequency band and/or have WiMAX compensate
- Further venture into the interaction of WiMAX and WiFi in order to make them more mutually exclusive.
- Expansion of testing to determine if the hypothesis holds true with respect to uplink performance (i.e. data transferred from a WiMAX-enabled system to another being impacted in a similar manner as data entering said system).

The overall experience was interesting for the team at large. We appreciate the opportunity and and will take the lessons learned with us into our future endeavors.

ACKNOWLEDGEMENTS

We would like to formally thank IEEE for providing our team with the grant from their Mini Grant Project initiative. Having the funds to do what was necessary to execute this project was well appreciated by us, the senior design team who have graduated from our illustrious university, and the professors and mentors who deemed our work satisfactory. Additionally, we would like to thank our external mentor Chris Hansen of Intel Corporation for counseling us throughout the year, as well as all of Intel Corporation. Lastly, we want to thank the professors at Howard University who contributed. Dr. Charles Kim, the instructor for the Senior Design course, advised us on the presentation and focus of our project, and Dr. John Trimble, the lead professor on for the Design Challenge, We are grateful for the opportunity.

Best Regards,

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Brandon Montgomery

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